Alternative Approaches to Analyzing Greenhouse Gas Emissions and Global Climate Change in CEQA Documents

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Association of Environmental Professionals

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Executive Summary

Global climate change (GCC) is a change in the average weather of the earth that can be measured by wind patterns, storms, precipitation, and temperature. This paper is not a scientific analysis of the existence or potential causes of GCC. Further, this paper does not address National Environmental Policy Act (NEPA) requirements. Instead, the intent of this paper is to provide practical, interim information to California Environmental Quality Act (CEQA) practitioners to help Lead Agencies determine how to address GCC in CEQA documents prior to the development and adoption of guidance by appropriate government agencies.

A typical individual project does not generate enough greenhouse gas emissions to influence GCC significantly on its own; the issue of GCC is by definition a cumulative environmental impact. Therefore, if the Lead Agency chooses to address GCC effects in a CEQA document, it should be discussed in the context of a cumulative impact. A complicating factor, however, is that there are currently no published CEQA thresholds or approved methods for determining whether a project's potential contribution to a cumulative GCC impact is considerable.

This paper provides a summary of background information on GCC, the current regulatory environment surrounding greenhouse gas (GHG) emissions, and the various approaches that a Lead Agency may select in a CEQA document to address the potential impacts of GCC and a project's cumulative contribution to GHG. There are many potentially valid approaches, some of which may not be addressed in this paper; for this reason, this document does not recommend a single approach, but rather describes several alternative methodologies and factors that a Lead Agency can consider in selecting the most appropriate methodology for a particular project.

[1] Preparation of this paper was partially funded by Michael Brandman Associates

atmosphere regulates the earth's temperature. Without the natural heat trapping effect of GHG, the earth's surface would be about 34 degrees Centigrade (°C) cooler (CAT 2006). However, it is believed that emissions from human activities, such as electricity production and vehicle use, have elevated the concentration of these gases in the atmosphere beyond the level of naturally occurring concentrations.

Climate change is driven by forcings and feedbacks. A feedback is "an internal climate process that amplifies or dampens the climate response to a specific forcing" (NRC 2005). Radiative forcing is the difference between the incoming energy and outgoing energy in the climate system. The global warming potential (GWP) is the potential of a gas or aerosol to trap heat in the atmosphere; it is the "cumulative radiative forcing effects of a gas over a specified time horizon resulting from the emission of a unit mass of gas relative to a reference gas" (EPA 2006a).

Individual GHG species have varying GWP and atmospheric lifetimes. The carbon dioxide equivalent is a consistent methodology for comparing GHG emissions since it normalizes various GHG emissions to a consistent metric. The reference gas for GWP is carbon dioxide; carbon dioxide has a GWP of one. Compared to methane's GWP of 21, methane has a greater global warming effect than carbon dioxide on a molecule per molecule basis (EPA 2006b). One teragram (Tg) (equal to one million metric tons) of carbon dioxide equivalent (Tg CO_2 Eq.) is the mass emissions of an individual GHG multiplied by its GWP.

Of all greenhouse gases in the atmosphere, water vapor is the most abundant, important, and variable. It is not considered a pollutant; in the atmosphere, it maintains a climate necessary for life. The main source of water vapor is evaporation from the oceans (approximately 85 percent). Other sources include evaporation from other water bodies, sublimation (change from solid to gas) from ice and snow, and transpiration from plant leaves.

Ozone is a greenhouse gas; however, unlike other GHG, ozone in the troposphere is relatively short-lived and, therefore, is not global in nature. It is difficult to make an accurate determination of the contribution of ozone precursors (nitrogen oxides and volatile organic compounds) to GCC (CARB 2004b).

Aerosols are suspensions of particulate matter in a gas emitted into the air through burning biomass (plant material) and fossil fuels. Aerosols can warm the atmosphere by absorbing and emitting heat and can cool the atmosphere by reflecting light. Cloud formation can also be affected by aerosols. Sulfate aerosols are emitted when fuel containing sulfur is burned. Black carbon (or soot) is emitted during bio mass burning or incomplete combustion of fossil fuels. Particulate matter regulation has been lowering aerosol concentrations in the United States; however, global concentrations are likely increasing.

Carbon dioxide (CO_2) is an odorless, colorless gas, which has both natural and anthropogenic sources. Natural sources include the following: decomposition of dead organic matter; respiration of bacteria, plants, animals, and fungus; evaporation from oceans; and volcanic outgassing. Anthropogenic sources of carbon dioxide are from burning coal, oil, natural gas, and wood. Concentrations of carbon dioxide were 379 parts per million (ppm) in 2005, which is an increase of 1.4 ppm per year since 1960 (IPCC 2007).

Methane is a flammable gas and is the main component of natural gas. When one molecule of methane is burned in the presence of oxygen, one molecule of carbon dioxide and two molecules of water are released. There are no ill health effects from methane. A natural source of methane is from the anaerobic decay of organic matter. Geological deposits, known as natural gas fields, also contain methane, which is extracted for fuel. Other sources are from landfills, fermentation of manure, and cattle.

Nitrous oxide (N_2O), also known as laughing gas, is a colorless greenhouse gas. Higher concentrations can cause dizziness, euphoria, and sometimes slight hallucinations. Nitrous oxide is produced by microbial processes in soil and water, including those reactions that occur in fertilizer containing nitrogen. In addition to agricultural sources, some industrial processes (fossil fuel-fired power plants, nylon production, nitric acid production, and vehicle emissions) also contribute to its atmospheric load. It is used in rocket engines, racecars, and as an aerosol spray propellant.

Chlorofluorocarbons (CFCs) are gases formed synthetically by replacing all hydrogen atoms in methane or ethane with chlorine and/or fluorine atoms. CFCs are nontoxic, nonflammable, insoluble, and chemically unreactive in the troposphere (the level of air at the earth's surface). CFCs were first synthesized in 1928 for use as refrigerants, aerosol propellants, and cleaning solvents. They destroy stratospheric ozone; therefore, their production was stopped as required by the Montreal Protocol in 1987.

Hydrofluorocarbons (HFCs) are synthetic man-made chemicals that are used as a substitute for CFCs for automobile air conditioners and refrigerants.

Perfluorocarbons (PFCs) have stable molecular structures and do not break down though the chemical processes in the lower atmosphere. High-energy ultraviolet rays about 60 kilometers above the earth's surface are able to destroy the compounds. PFCs have very long lifetimes, between 10,000 and 50,000 years. Two common PFCs are tetrafluoromethane and hexafluoroethane. Concentrations of tetrafluoromethane in the atmosphere are over 70 parts per trillion (ppt) (EPA 2006d). The two main sources of PFCs are primary aluminum production and semiconductor manufacture.

Sulfur hexafluoride (SF_6) is an inorganic, odorless, colorless, nontoxic, nonflammable gas. It has the highest GWP of any gas evaluated, 23,900. Concentrations in the 1990s were about 4 ppt (EPA 2006d). Sulfur hexafluoride is used for insulation in electric power transmission and distribution equipment, in the magnesium industry, in semiconductor manufacturing, and as a tracer gas for leak detection.

International and Federal Legislation

International and Federal legislation has been enacted to deal with GCC issues. The Montreal Protocol was originally signed in 1987 and substantially amended in 1990 and 1992. The Montreal Protocol governs compounds that deplete ozone in the stratosphere—chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform. The Protocol provided that these compounds were to be phased out by 2000 (2005 for methyl chloroform).

In 1988, the United Nations and the World Meteorological Organization established the Intergovernmental Panel on Climate Change (IPCC) to assess "the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation" (IPCC 2004).

Homewood Mountain Resort Development Water, Gas, and Electric Energy Use Projection

For:
Homewood Mountain Resort
5145 West Lake Boulevard
Homewood, California 96143

BEAUDIN GANZE
Consulting Engineers, Inc.

By:
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11430 Deerfield Dr, Suite B5
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October 30, 2007

c) Mid Mountain Facility: 150 DFU, 80 GPM
d) Development Total: 6,900 DFU, 1,650 GPM

2. In addition to the sewage flow demand created by the building development, parking drainage and pool backwash may also create additional sanitary sewer flow. These additional flows are assumed to be negligible compared to the rest of the project.

B. Sanitary Sewage Discharge

1. The daily sanitary sewer flow will be near the daily building cold water usage as detailed above.
   a) North Base**:** 44,700 GPD
   b) South Base: 22,000 GPD
   c) Mid Mountain Facility: 3,750 GPD
   d) Development Total: 70,400 GPD

IV. Gas

A. Demand Estimation:

1. Likely sources of gas consumption will be appliances, space heating, water heating, Pool heating, Ventilation air, and snowmelt. To predict the project gas demand we considered each one of these items separately for each of the resort areas. Appendix D summarizes each of the expected demands. Gas demand analysis assumed the following:
   a) Gas appliance quantities are as shown in Appendix A. Appliance consumption rates are as recommended by the 2001 CPC.
   b) Space peak heating gas consumption rate is 18 Btuh/sq.ft.
   c) Water peak heating gas consumption rate is 12 Btuh/sq.ft.
   d) Pool Heating gas consumption is based on uncovered, winter-time use.
   e) Snowmelt areas were assumed to be 6,000 sq.ft. prorated by square footage to various parts of the development. Energy input rate to snowmelt systems is assumed to be 200 Btuh/sq.ft.
   f) Appliance and Altitude Combustion efficiencies of 80%.
   g) 10% safety factor

2. Our results for gas demand are as follows:
   a) North Base – 83,400 MBH
   b) South Base – 83,000 MBH

c) Mid Mountain Facility – 3,300 MBH
d) Development Total – 154,000 MBH

B. Usage Estimation

1. In order to estimate annual consumption of gas a month by month analysis was completed for each gas use in each part of the development (Appendix E). In this analysis the following was used:
   a) Annual heating degree data from the state of California for the town of Tahoe City, CA to determine monthly gas consumption for space heating.
   b) Hours of appliance operation per month as shown in Appendix E.
   c) 50% of the daily water usage was assumed to be hot water.
   d) The mid-mountain building will not be operated during the summer months.

2. The Annual gas consumption is summarized here:
   a) North Base: 632,000 therms.
   b) South Base: 402,000 therms.
   c) Mid Mountain Facility: 30,500 therms.
   d) Development Total: 1,064,000 therms.

V. Electricity

A. Demand Estimation

1. Industry standard data for watts/sq.ft. were applied to each area on the project to calculate the expected electrical demand. Appendix F shows the load in each respective area of the project. Our study has estimated the following electrical demand for each building area on the project:
   a) North Base – 9.02 Megawatts(MW)
   b) South Base – 6.8 MW
   c) Mid-mountain – 250 kW
   d) Development total – 16 MW

2. Existing electrical demand data for the past two years was obtained from the utility company. The maximum site demand over the past couple of years was 1.6 MW. Most of this demand was due to ski lift operation. This 1.6 MW will still occur in addition to the building demands mentioned above.

B. Electrical Usage

1. Industry standard data for annual kWh/sq.ft. were applied to each area on the project to calculate the expected electrical demand. Appendix G shows the load in each respective area of the project. Our study has estimated the following electrical usage for each building area on the project:
   a) North Base – 14,417,000 kWh
   b) South Base – 6,528,000 kWh
   c) Mid-mountain – 741,000 kWh
   d) Development total – 43,374,000 kWh

2. Existing electrical usage data for the past two years was obtained from the utility company. The average annual resort energy usage was 1,220,000kWh. Again, we attribute most of this usage to ski lift operation. This usage will occur in addition to the building usages mentioned above.

C. On-site generation study

1. BGCE, Inc. completed an alternative energy study for micro-hydro turbine power systems on the mountain streams. We estimated the Madden and Ellis Creek systems could generate 589,000 kWh during three months of operation. This amount of power is estimated to be 1.4% of the developed resort's annual energy usage. This may seem trivial, but the annual power requirements of the eleven, 5,000 sq.ft. single family homes is estimated to be 856,000kWh. Therefore, just by operating three months a year, the Madden and Ellis systems could provide 68% of the annual electrical energy consumption for the eleven new homes.

2. Other potential uses of energy include, but are not limited to, the following:

   a) Homewood's renovation plan, by 2017, will have chairlifts requiring approximately 1,850 kW when running at full capacity. It is estimated that Homewood Mountain Resort demands 11,100 kWh per day to run all the chairlifts at full capacity. That being said, the proposed micro-hydro turbine generation systems could generate enough energy in a year to power all chairlifts at Homewood Mountain Resort for 53 days.

Daily Water Use Based on 1997 UPC Recommended Values					
	Quantity	Approx area (sq.ft)	GPD/Unit	Quantity	Total GPD
North Base					
Hotel Building					
Standard King Guest Room	34	572	30		1020
Double Queen Guestroom	12	609	30		360
Executive Suite Guestroom	2	1144	30		60
Presidential Suite Guestroom	2	1716	30		60
One Bedroom Suites (Sold)	40	1144	30		1200
One Bedroom Lockoff (Sold)	40	572	30		1200
F&B (Bar and Restaurant)	1	4980	10/meal	200*	2000
Function Space	1	4487	25/person	100**	2500
Lobby Areas	1	2001	.1/sq.ft.		200.1
Retail Areas	1	2581	.1/sq.ft.		258
Fitness/Spa Area	1	12001	50/person	50**	2500
Food and Bev BOH	1	3930	25/person	20**	500
Function Support	1	755	25/person	20**	750
Employee Facilities	1	2765	10/person	50	500
Housekeeping/Laundry	1	4135	50/washing	150***	7500
Boh circulation	1	4376	25/person	10**	250
Condos					
One Bedroom Units	10	1100	30		300
Two Bedroom Units	36	1650	60		2160
Three Bedroom Units	20	2200	90		1800
Four Bedroom Units	6	2750	120		720
North Common Areas	1	32597	.1/ft^2		3259.7
North Base Skier Services	1	41596	0.1/sq.ft		4160
North Base Retail	1	25000	0.1/sq.ft.		2500
North Base Total:					**35758**
South Base					
South Base Residential					
One Bedroom Units	16	1100	30		480
Two Bedroom Units	48	1650	60		2880
Three Bedroom Units	38	2200	90		3420
Four Bedroom Units	18	2750	120		2160
Single Family Homes	11	5000	90		990
Managers housing	1	1500	42		42
Assisstant Manager housing	1	1200	42		42
Employee Apartments	20	850	42		840
South Base common area	1	57331	.1/ft^2		5733
South Base skier Services (incl 2000 kitchen)	1	4420	10/meal	100**	1000
South Base Total:					**17587**
Mid mountain Facility					
Maintenance Area	1	7830			0
Lodge Areas (incl 1800 kitchen)	1	7000	10/meal	300**	3000
Circulation	1	2886	0		0
Mechanical	1	200	0		0
Mid Mountain Total:					**3000**
25% Future/Safety					**14086**
Mountain Total:					**70431**

*Estimated number of meals per day
**Estimated Occupancy
***Usage based on estimated laundyr cycles daily

CAPCOA

CALIFORNIA AIR POLLUTION CONTROL OFFICERS ASSOCIATION

CEQA & Climate Change

Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act

January 2008

"average" treatment plant. Thus, research will need to be conducted on a case-by-case basis to determine the "Fraction Anaerobically Digested" which is a function of the type of treatment process. Indirect emissions from these facilities can be calculated using the CCAR energy use protocols and URBEMIS model for transportation emissions.

Solid Waste Disposal Facilities

Air districts will have emission estimate methodologies established for methane emissions at permitted landfills. In addition, EPA's Landfill Gas Emissions Model (LandGem) and the CCAR methodology could also be used to quantify GHG emissions from landfill off gassing; however, this model requires substantial detail be input. The model uses a decomposition rate equation, where the rate of decay is dependent on the quantity of waste in place and the rate of change over time. This modeling tool is free to the public, but substantial project detail about the operation of the landfill is needed to run the model. Indirect emissions from these facilities can be calculated using the CCAR energy use protocols and URBEMIS model for transportation emissions.

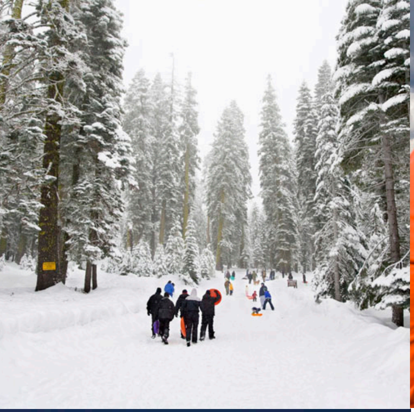
Construction Emissions

GHG emissions would occur during project construction, over a finite time. In addition, a project could result in the loss of GHG sequestration opportunity due primarily to the vegetation removed for construction. URBEMIS should be used to quantify the mass of CO_2 that would occur during the construction of a project for land development projects. Some construction projects would occur over an extended period (up to 20–30 years on a planning horizon for general plan buildout, or 5–10 years to construct a dam, for example). OFFROAD emission factors are contained in URBEMIS for CO_2 emissions from construction equipment. For other types of construction projects, such as roadway construction projects or levee improvement projects, SMAQMD's spreadsheet modeling tool, the Road Construction Emissions Model (RoadMod), should be used. This tool is currently being updated to include CO_2 emissions factors from OFFROAD.

The full life-cycle of GHG emissions from construction activities is not accounted for in the modeling tools available, and the information needed to characterize GHG emissions from manufacture, transport, and end-of-life of construction materials would be speculative at the CEQA analysis level. The emissions disclosed will be from construction equipment and worker commutes during the duration of construction activities. Thus, the mass emissions in units of metric tons CO_2e/year should be reported in the environmental document as new emissions.

General Plans

In the short-term, URBEMIS can be used as a calculation tool to model GHG emissions from proposed general plans, but only if data from the traffic study is incorporated into model input. The same methodology applied above in the specific plan example applies to general plans. The CCAR GRP can be used to approximate indirect emissions from



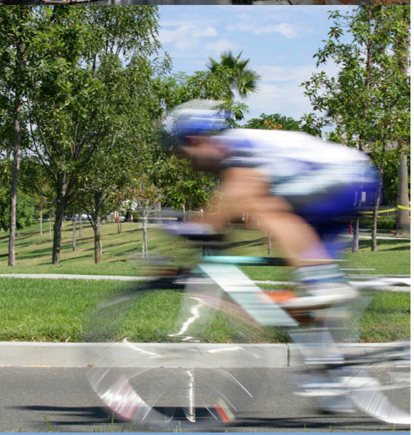

Climate Change Proposed Scoping Plan

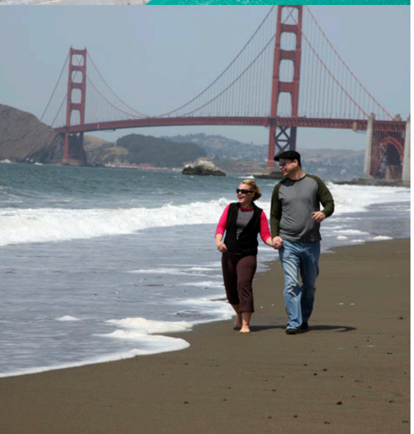
a framework for change

OCTOBER 2008

Pursuant to AB 32

The California Global Warming Solutions Act of 2006





Prepared by
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APPENDICES

EXECUTIVE SUMMARY

On September 27, 2006, Governor Schwarzenegger signed Assembly Bill 32, the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006). The event marked a watershed moment in California's history. By requiring in law a reduction of greenhouse gas (GHG) emissions to 1990 levels by 2020, California set the stage for its transition to a sustainable, clean energy future. This historic step also helped put climate change on the national agenda, and has spurred action by many other states.

The California Air Resources Board (ARB or Board) is the lead agency for implementing AB 32, which set the major milestones for establishing the program. ARB met the first milestones in 2007: developing a list of discrete early actions to begin reducing greenhouse gas emissions, assembling an inventory of historic emissions, establishing greenhouse gas emission reporting requirements, and setting the 2020 emissions limit.

ARB must develop a Scoping Plan outlining the State's strategy to achieve the 2020 greenhouse gas emissions limit. This Proposed Scoping Plan, developed by ARB in coordination with the Climate Action Team (CAT), proposes a comprehensive set of actions designed to reduce overall greenhouse gas emissions in California, improve our environment, reduce our dependence on oil, diversify our energy sources, save energy, create new jobs, and enhance public health. It will be presented to the Board for approval at its meeting in December 2008. The measures in the Scoping Plan approved by the Board will be developed over the next two years and be in place by 2012.

Reduction Goals

This plan calls for an ambitious but achievable reduction in California's carbon footprint. Reducing greenhouse gas emissions to 1990 levels means cutting approximately 30 percent from business-as-usual emission levels projected for 2020, or about 15 percent from today's levels. On a per-capita basis, that means reducing our annual emissions of 14 tons of carbon dioxide equivalent for every man, woman and child in California down to about 10 tons per person by 2020. This challenge also presents a magnificent opportunity to transform California's economy into one that runs on clean and sustainable technologies, so that all Californians are able to enjoy their rights in the future to clean air, clean water, and a healthy and safe environment.

Significant progress can be made toward the 2020 goal relying on existing technologies and improving the efficiency of energy use. A number of solutions are "off the shelf," and many – especially investments in energy conservation and efficiency – have proven economic benefits. Other solutions involve improving our state's infrastructure, transitioning to cleaner and more secure sources of energy, and adopting 21st century land use planning and development practices.

A Clean Energy Future

Getting to the 2020 goal is not the end of the State's effort. According to climate scientists, California and the rest of the developed world will have to cut emissions by 80 percent from today's levels to stabilize the amount of carbon dioxide in the atmosphere and prevent the most severe effects of global climate change. This long range goal is reflected in California Executive Order S-3-05 that requires an 80 percent reduction of greenhouse gases from 1990 levels by 2050.

Reducing our greenhouse gas emissions by 80 percent will require California to develop new technologies that dramatically reduce dependence on fossil fuels, and shift into a landscape of new ideas, clean energy, and green technology. The measures and approaches in this plan are designed to accelerate this necessary transition, promote the rapid development of a cleaner, low carbon economy, create vibrant livable communities, and improve the ways we travel and move goods throughout the state. This transition will require close coordination of California's climate change and energy policies, and represents a concerted and deliberate shift away from fossil fuels toward a more secure and sustainable future. This is the firm commitment that California is making to the world, to its children and to future generations.

Making the transition to a clean energy future brings with it great opportunities. With these opportunities, however, also come challenges. As the State moves ahead with the development and implementation of policies to spur this transition, it will be necessary to ensure that they are crafted to not just cut greenhouse gas emissions and move toward cleaner energy sources, but also to ensure that the economic and employment benefits that will accompany the transition are realized in California. This means that particular attention must be paid to fostering an economic environment that promotes and rewards California-based investment and development of new technologies and that adequate resources are devoted to building and maintaining a California-based workforce equipped to help make the transition.

A Public Process

Addressing climate change presents California with a challenge of unprecedented scale and scope. Success will require the support of Californians up and down the state. At every step of the way, we have endeavored to engage the public in the development of this plan and our efforts to turn the tide in the fight against global warming.

In preparing the Draft Scoping Plan, ARB and CAT subgroups held dozens of workshops, workgroups, and meetings on specific technical issues and policy measures. Since the release of the draft plan in late June, we have continued our extensive outreach with workshops and webcasts throughout the state. Hundreds of Californians showed up to share their thoughts about the draft plan, and gave us their suggestions for improving it. We've received thousands of postcards, form letters, emails, and over 1,000 unique comments posted to our website or sent by mail. All told, more than 42,000 people commented on the draft Plan.

ARB catalogued and publicly posted all the comments we received. In many instances, we engaged experts and staff at our partner agencies for additional evaluation of comments and suggestions.

This plan reflects the input of Californians at every level. Our partners at other State agencies, in the legislature, and at the local government level have provided key input. We've met with members of community groups to address environmental justice issues, with representatives of California's labor force to ensure that good jobs accompany our transition to a clean energy future, and with representatives of California's small businesses to ensure that this vital part of our state's economic engine flourishes under this plan. We've heeded the advice of public health and environmental experts throughout the state to design the plan so that it provides valuable co-benefits in addition to cutting greenhouse gases. We've also worked with representatives from many of California's leading businesses and industries to craft a plan that works in tandem with the State's efforts to continue strong economic growth.

In short, we've heard from virtually every sector of California's society and economy, reflecting the fact that the plan will touch the life of almost every Californian in some way.

Proposed Scoping Plan Recommendations

The recommendations in this plan were shaped by input and advice from ARB's partners on the Climate Action Team, as well as the Environmental Justice Advisory Committee (EJAC), the Economic and Technology Advancement Advisory Committee (ETAAC), and the Market Advisory Committee (MAC). Like the Draft Scoping Plan, the strength of this plan lies in the comprehensive array of emission reduction approaches and tools that it recommends.

Key elements of California's recommendations for reducing its greenhouse gas emissions to 1990 levels by 2020 include:

- **Expanding and strengthening existing energy efficiency programs as well as building and appliance standards;**
- **Achieving a statewide renewables energy mix of 33 percent;**
- **Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system;**
- **Establishing targets for transportation-related greenhouse gas emissions for regions throughout California, and pursuing policies and incentives to achieve those targets;**
- **Adopting and implementing measures pursuant to existing State laws and policies, including California's clean car standards, goods movement measures, and the Low Carbon Fuel Standard; and**

- **Creating targeted fees, including a public goods charge on water use, fees on high global warming potential gases, and a fee to fund the administrative costs of the State's long term commitment to AB 32 implementation.**

After Board approval of this plan, the measures in it will be developed and adopted through the normal rulemaking process, with public input.

Key Changes

This plan is built upon the same comprehensive approach to achieving reductions as the draft plan. However, as a result of the extensive public comment we received, this plan includes a number of general and measure-specific changes. The key changes and additions follow.

Additional Reports and Supplements

1. Economic and Public Health Evaluations: This plan incorporates an evaluation of the economic and public health benefits of the recommended measures. These analyses follow the same methodology used to evaluate the Draft Scoping Plan.[1]

2. CEQA Evaluation: This plan includes an evaluation of the potential environmental impacts of the Proposed Scoping Plan under the California Environmental Quality Act (CEQA).[2]

Programmatic Changes

1. Margin of Safety for Uncapped Sectors: The plan provides a 'margin of safety,' that is, additional reductions beyond those in the draft plan to account for measures in uncapped sectors that do not, or may not, achieve the estimated reduction of greenhouse gas emissions in this plan. Along with the certainty provided by the cap, this will ensure that the 2020 target is met.

2. Focus on Labor: The plan includes a discussion of issues directly related to California's labor interests and working families, including workforce development and career technical education. This additional element reflects ARB's existing activities and expanded efforts by State agencies, such as the Employment Development Department, to ensure that California will have a green technology workforce to address the challenges and opportunities presented by the transition to a clean energy future.

[1] Staff will provide an update to the Board to respond to comments received on these analyses.

[2] This evaluation is contained in Appendix J.

3. Long Term Trajectory: The plan includes an assessment of how well the recommended measures put California on the long-term reduction trajectory needed to do our part to stabilize the global climate.

4. Carbon Sequestration: The plan describes California's role in the West Coast Regional Carbon Sequestration Partnership (WESTCARB), a public-private collaboration to characterize regional carbon capture and sequestration opportunities. In addition, the plan expresses support for near-term development of sequestration technology. This plan also acknowledges the important role of terrestrial sequestration in our forests, rangelands, wetlands, and other land resources.

5. Cap-and-Trade Program: The plan provides additional detail on the proposed cap-and-trade program including a discussion regarding auction of allowances, a discussion of the proposed role for offsets, and additional detail on the mechanisms to be developed to encourage voluntary early action.

6. Implementation: The plan provides additional detail on implementation, tracking and enforcement of the recommended actions, including the important role of local air districts.

Changes to Specific Measures and Programs

1. Regional Targets: ARB re-evaluated the potential benefits from regional targets for transportation-related greenhouse gases in consultation with regional planning organizations and researchers at U.C. Berkeley. Based on this information, ARB increased the anticipated reduction of greenhouse gas emissions for Regional Transportation-Related Greenhouse Gas Targets from 2 to 5 million metric tons of CO_2 equivalent ($MMTCO_2E$).

2. Local Government Targets: In recognition of the critical role local governments will play in the successful implementation of AB 32, ARB added a section describing this role. In addition, ARB recommended a greenhouse gas reduction goal for local governments of 15 percent below today's levels by 2020 to ensure that their municipal and community-wide emissions match the State's reduction target.

3. Additional Industrial Source Measures: ARB added four additional measures to address emissions from industrial sources. These proposed measures would regulate fugitive emissions from oil and gas recovery and transmission activities, reduce refinery flaring, and require control of methane leaks at refineries. We anticipate that these measures will provide 1.5 $MMTCO_2E$ of greenhouse gas reductions.

4. Recycling and Waste Re-Assessment: In consultation with the California Integrated Waste Management Board, ARB re-assessed potential measures in the Recycling and Waste sector. As a result of this review, ARB increased the anticipated reduction of greenhouse gas emissions from the Recycling and Waste Sector from 1 to 10 $MMTCO_2E$, incorporating measures to move toward high recycling and zero-waste.[3]

5. Green Building Sector: This plan includes additional technical evaluations demonstrating that green building systems have the potential to reduce approximately 26 $MMTCO_2E$ of greenhouse gases. These tools will be helpful in reducing the carbon footprint for new and existing buildings. However, most of these greenhouse gas emissions reductions will already be counted in the Electricity, Commercial/Residential Energy, Water or Waste sectors and are not separately counted toward the AB 32 goal in this plan.

6. High Global Warming Potential (GWP) Mitigation Fee: Currently many of the chemicals with very high Global Warming Potential (GWP)—typically older refrigerants and constituents of some foam insulation products—are relatively inexpensive to purchase. ARB includes in this plan a Mitigation Fee measure to better reflect their impact on the climate. The fee is anticipated to promote the development of alternatives to these chemicals, and improve recycling and removal of these substances when older units containing them are dismantled.

7. Modified Vehicle Reductions: Based on current regulatory development, ARB modified the expected emissions reduction of greenhouse gases from the Heavy-Duty Vehicle Greenhouse Gas Emission Reduction (Aerodynamic Efficiency) measure and the Tire Inflation measure. The former measure is now expected to achieve 0.9 $MMTCO_2E$ while the latter is now expected to achieve 0.4 $MMTCO_2E$.

8. Discounting Low Carbon Fuel Standard Reductions: ARB modified the expected emission reductions from the Low Carbon Fuel Standard to reflect overlap in claimed benefits with California's clean car law (the Pavley greenhouse gas vehicle standards). This has the result of discounting expected reduction of greenhouse gas emissions from the Low Carbon Fuel Standard by approximately 10 percent.

A Balanced and Comprehensive Approach

Meeting the goals of AB 32 will require a coordinated set of strategies to reduce emissions throughout the economy. These strategies will fit within the comprehensive tracking,

[3] Research to help quantify these greenhouse gas emissions reductions is continuing, so only 1 $MMTCO_2E$ of these reductions are currently counted toward the AB 32 goal in this plan. Additional tons will be considered part of the safety margin.

reporting, and enforcement framework that is already being developed and implemented. By 2020, a hard and declining cap will cover 85 percent of California's greenhouse gas emissions, helping to ensure that we meet our reduction targets on time.

AB 32 lays out a number of important factors that have helped to guide the development of this plan and will continue to be considered as regulations are developed over the next few years. Some of the key criteria that have and will be further considered are: cost-effectiveness; overall societal benefits like energy diversification and public health improvements; minimization of leakage; and impacts on specific sectors like small business and disproportionately impacted communities. The comprehensive approach in the plan reflects a balance among these and other important factors and will help to ensure that California meets its greenhouse gas reduction targets in a way that promotes and rewards innovation, is consistent with and helps to foster economic growth, and delivers improvements to the environment and public health.

Many of the measures in this plan complement and reinforce one another. For instance, the Low Carbon Fuel Standard, which reduces the carbon intensity of transportation fuels sold in California, will work in tandem with technology-forcing regulations designed to reduce greenhouse gas emissions from cars and trucks. Improvements in land use and the ways we grow and build our communities will further reduce emissions from the transportation sector.

Many of the measures also build on highly successful long-standing practices in California—such as energy efficiency and the use of renewable energy resources—that can be accelerated and expanded. Increasing the amount of energy we get from renewable energy sources, including placing solar arrays and solar water heaters on houses throughout California, will be supported by an increase in building standards for energy efficiency. Other measures address the transport and treatment of water throughout the state, reduce greenhouse gas emissions that come from ships in California's ports, and promote changes to agricultural and forestry practices. There are also measures designed to safely reduce or recover a range of very potent greenhouse gases – refrigerants and other industrial gases – that contribute to global warming at a level many times greater per ton emitted than carbon dioxide.

Many of the measures in this plan are designed to take advantage of the economic and innovation-related benefits that market-based compliance strategies can provide. Particularly in light of current economic uncertainty, it is important to ensure that California's climate policies be designed to promote and take advantage of economic opportunities while also cutting greenhouse gas emissions. For instance, the cap-and-trade program creates an opportunity for firms to seek out cost-effective emission reduction strategies and provides an incentive for technological innovation. California's clean car standards, which require manufacturers to meet annual average levels of greenhouse gas emissions for all cars they sell in California, also offer flexibility to help ensure compliance. Under California's clean car standards, manufacturers who exceed compliance standards are permitted to bank credits for future use or sell them to other manufacturers. These types of compliance options will be key in ensuring that we are able to meet our reduction targets in a cost-effective manner.

Working with the Western Climate Initiative

California is working closely with six other states and four Canadian provinces in the Western Climate Initiative (WCI) to design a regional greenhouse gas emissions reduction program that includes a cap-and-trade approach. California's participation in WCI creates an opportunity to provide substantially greater reductions in greenhouse gas emissions from throughout the region than could be achieved by California alone. The larger scope of the program also expands the market for clean technologies and helps avoid leakage, that is, the shifting of emissions from sources within California to sources outside the state.

The WCI partners released the recommended design for a regional cap-and-trade program in September 2008.[4] ARB embraces the WCI effort, and will continue to work with WCI partners. The creation of a robust regional trading system can complement the other policies and measures included in this plan, and provide the means to achieve the reduction of greenhouse gas emissions needed from a wide range of sectors as cost-effectively as possible.

California's Economy, Environment, and Public Health

The approaches in this plan are designed to maximize the benefits that can accompany the transition to a clean energy economy. California has a long and successful track record of implementing environmental policies that also deliver economic benefits. This plan continues in that tradition.

AB 32: Evaluating the Economic Effects

The economic analysis of this plan indicates that implementation of the recommended strategies to address global warming will create jobs and save individual households money.[5] The analysis also indicates that measures in the plan will position California to move toward a more secure, sustainable future where we invest heavily in energy efficiency and clean technologies. The economic analysis indicates that implementation of that forward-looking approach also creates more jobs and saves individual households more money than if California stood by and pursued an unacceptable course of doing nothing at all to address our unbridled reliance on fossil fuels.

Specifically, analysis of the Proposed Scoping Plan indicates that projected economic benefits in 2020 compared to the business-as-usual scenario include:

- Increased economic production of $33 billion
- Increased overall gross state product of $7 billion
- Increased overall personal income by $16 billion
- Increased per capita income of $200

[4] Details of the WCI recommendation are provided in Appendix D.

[5] See Appendix G.

- Increased jobs by more than 100,000

Furthermore, the results of the economic analysis may underestimate the economic benefits of the plan since the models that were used do not account for savings that result from the flexibility provided under market-based programs.

AB 32: The Environmental and Public Health Costs of Inaction

A key factor that was not weighed in the overall economic analysis is the potential cost of doing nothing. When these costs are taken into account, the benefits associated with implementing a comprehensive plan to cut greenhouse gas emissions become even clearer. As a state, California is particularly vulnerable to the costs associated with unmitigated climate change.

A summary report from the California Climate Change Center notes that a warming California climate would generate more smoggy days by contributing to ozone formation while also fostering more large brush and forest fires. Continuing increases in global greenhouse gas emissions at business-as-usual rates would result, by late in the century, in California losing 90 percent of the Sierra snow pack, sea level rising by more than 20 inches, and a three to four times increase in heat wave days. These impacts will translate into real costs for California, including flood damage and flood control costs that could amount to several billion dollars in many regions such as the Central Valley, where urbanization and limited river channel capacity already exacerbate existing flood risks.[6] Water supply costs due to scarcity and increased operating costs would increase as much as $689 million per year by 2050.[7] ARB analysis shows that due to snow pack loss, California's snow sports sector would be reduced by $1.4 billion (2006 dollars) annually by 2050 and shed 14,500 jobs; many other sectors of California's economy would suffer as well.

Failing to address climate change also carries with it the risk of substantial public health costs, primarily as a result of rising temperatures. Sustained triple-digit heat waves increase the health risk for several segments of the population, especially the elderly. But higher average temperatures will also increase the interactions of smog-causing chemicals with sunlight and the atmosphere to produce higher volumes of toxic byproducts than would otherwise occur. In the 2006 report to the Governor from the California Climate Center, it was reported that global increases in temperature will lead to increased concentrations and emissions of harmful pollutants

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[6] A Summary Report from: California Climate Change Center. *Our Changing Climate: Assessing the Risks to California.* Document No. CEC-500-2006-077. July 2006. http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF (accessed October 12, 2008)

[7] A Report from: California Climate Change Center. *Climate Warming and Water Supply Management in California*. Document No. CEC-500-2005-195-SF. March 2006. pp.13-14 http://www.energy.ca.gov/2005publications/CEC-500-2005-195/CEC-500-2005-195-SF.PDF (accessed October 12, 2008).

in California.[8] Some cities in California are disproportionately susceptible to temperature increases since they already have elevated pollution levels and are subject to the heat-island effect that reduces nighttime cooling, allowing heat to build up and magnify the creation of additional harmful pollution. Low-income communities are disproportionately impacted by climate change, lacking the resources to avoid or adapt to these impacts. For example, low-income residents are less likely to have access to air conditioning to prevent heat stroke and death in heat waves. For California, then, taking action with other regions and nations to help mitigate the impacts of climate change will help slow temperature rise. This in turn will likely result in fewer premature deaths from respiratory and heat-related causes, and many thousands fewer hospital visits and days of illness.

California cannot avert the impacts of global climate change by acting alone. We can, however, take a national and international leadership role in this effort by demonstrating that taking firm and reasoned steps to address global warming can actually help spur economic growth.

AB 32: Providing Savings for Households and Businesses

This plan builds upon California's thirty-year track record of pioneering energy efficiency programs. Many of the measures in the plan will deliver significant gains in energy efficiency throughout the economy. These gains, even after increases in per unit energy costs are taken into account, will help deliver annual savings of between $400 and $500 on average by 2020 for households, including low-income households.

Businesses, both large and small, will benefit too. By 2020, the efficiency measures in the plan will decrease overall energy expenditures for businesses even after taking into account projected rises in per unit energy costs. Since small businesses spend a greater proportional share of revenue on energy-related costs, they are likely to benefit the most. Furthermore, businesses throughout the state will benefit from the overall economic growth that is projected to accompany implementation of AB 32 between now and 2020.

Similar savings are projected in the transportation sector. By reducing greenhouse gas pollution from more efficient and alternatively-fueled cars and trucks under California's Clean Car law (the Pavley greenhouse gas standards), consumers save on operating costs through reduced fuel use. Although cars will be marginally more expensive, owners will be paid back with savings over the lifetime of the car, and the average new car buyer will have an extra $30 each month for other expenditures. Current estimates indicate that consumer savings in 2020 for California's existing clean car standards will be over $12 billion. These savings give Californians the ability to invest their dollars in other sectors of the state's economy.

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[8] A Report from: California Climate Change Center. *Scenarios of Climate Change in California: An Overview*. Document No. CEC-500-2005-186-SF. February 2006. http://www.energy.ca.gov/2005publications/CEC-500-2005-186/CEC-500-2005-186-SF.PDF (accessed October 12, 2008)

AB 32: Driving Investment and Job Growth

Addressing climate change also provides a strong incentive for investment in California. Our leadership in environmental and energy efficiency policy has already helped attract a large and growing share of the nation's venture capital investment in green technologies. Since AB 32 was signed into law, venture capital investment in California has skyrocketed. In the second quarter of 2008 alone, California dominated world investment in clean technology venture capital, receiving $800 million of the global total of $2 billion.[9]

These investments in building a new clean tech sector also translate directly into job growth. A study by U.C. Berkeley's Energy and Resources Group and Goldman School of Public Policy found that investments in green technologies produce jobs at a higher rate than investments in comparable conventional technologies.[10] And the National Venture Capital Association estimates that each $100 million in venture capital funding helps create 2,700 jobs, $500 million in annual revenues for two decades and many indirect jobs.[11]

AB 32: Improving Public Health

The public health analysis conducted for this Plan indicates that cutting greenhouse gases will also provide a wide range of additional public health and environmental benefits. By 2020, the economic value alone of the additional air-quality related benefits is projected to be on the order of $2.2 billion. Our analysis indicates that implementing the Proposed Scoping Plan will result in a reduction of 15 tons per day of combustion-generated soot (PM 2.5) and 61 tons per day of oxides of nitrogen (precursors to smog). These reductions in harmful air pollution would provide the following estimated health benefits in 2020, above and beyond those projected to be achieved as a result of California's other existing public health protection and improvement efforts:

- An estimated 400 premature deaths statewide will be avoided
- Almost 11,000 incidences of asthma and lower respiratory symptoms will be avoided
- 67,000 work loss days will be avoided

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[9] Press Release from Cleantech Network LLC, *Cleantech Venture Investment Reaches Record of $2 Billion in 2008*. July 08, 2008. http://cleantech.com/about/pressreleases/011008.cfm (accessed October 12, 2008)

[10] Report of the Renewable and Appropriate Energy Laboratory. *Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?* Energy and Resources Group/Goldman School of Public Policy at University of California, Berkeley. April 13, 2004. http://rael.berkeley.edu/old-site/renewables.jobs.2006.pdf (accessed October 12, 2008)

[11] Report prepared for the National Venture Capital Association. *Venture Impact 2004: Venture Capital Benefits to the U.S. Economy*. Prepared by: Global Insight. June 2004. http://www.globalinsight.com/publicDownload/genericContent/07-20-04_fullstudy.pdf (accessed October 12, 2008)

In addition to the quantified health benefits, our analysis also indicates that implementation of the measures in the plan will deliver a range of other public health benefits. These include health benefits associated with local and regional transportation-related greenhouse gas targets that will facilitate greater use of alternative modes of transportation such as walking and bicycling. These types of moderate physical activities reduce many serious health risks including coronary heart disease, diabetes, hypertension and obesity.[12] Furthermore, as specific measures are developed, ARB and public health experts will work together to ensure that they are designed with an eye toward capturing a broad range of public health co-benefits.

The results of both the economic and public health analyses are clear: guiding California toward a clean energy future with reduced dependence on fossil fuels will grow our economy, improve public health, protect the environment and create a more secure future built on clean and sustainable technologies.

State Leadership

California is committed to once again lead and support a pioneering effort to protect the environment and improve public health while maintaining a vibrant economy. Every agency, department and division will bring climate change considerations into its policies, planning and analysis, building and expanding current efforts to green its fleet and buildings, and managing its water, natural resources, and infrastructure to reduce greenhouse gas emissions.

In all these efforts, California is exercising a leadership role in global action to address climate change. It is also exemplifying the essential role states play as the laboratories of innovation for the nation. As California has done in the past in addressing emissions that caused smog, the State will continue to develop innovative programs that benefit public health and improve our environment and quality of life.

Moving Beyond 2020

AB 32 requires a return to 1990 emission levels by 2020. The Proposed Scoping Plan is designed to achieve that goal. However, 2020 is by no means the end of California's journey to a clean energy future. In fact, that is when many of the strategies laid out in this plan will just be kicking into high gear.

Take, for example, the regional transportation-related greenhouse gas emissions targets. In order to achieve the deep cuts in greenhouse gas emissions we will need beyond 2020 it will be necessary to significantly change California's current land use and transportation planning policies. Although these changes will take time, getting started now will help put California on course to cut statewide greenhouse gas emissions by 80 percent in 2050 as called for by Governor Schwarzenegger.

[12] Appendix H contains a reference list of studies documenting the public health benefits of alternative transportation.

Similarly, measures like the cap-and-trade program, energy efficiency programs, the California clean car standards, and the renewables portfolio standard will all play central roles in helping California meet its 2020 reduction requirements. Yet, these strategies will also figure prominently in California's efforts beyond 2020. Some of these measures, like energy efficiency programs and the renewables portfolio standard, have already delivered greenhouse gas emissions reduction benefits that will expand over time. Others, like the cap-and-trade program, will put in place a foundation on which to build well into the future. All of these measures, and many others in the plan, will ensure that California meets its 2020 target and is positioned to continue its international role as leader in the fight against global warming to 2050 and beyond.

A Shared Challenge

Californians are already responding to the challenge of reducing greenhouse gas emissions. Over 120 California cities and counties have signed on to the U.S. Conference of Mayors Climate Protection Agreement[13] and many have established offices of climate change and are developing comprehensive plans to reduce their carbon footprint. Well over 300 companies, municipalities, organizations and corporations are members of the California Climate Action Registry, reporting their greenhouse gas emissions on an annual basis. Many other businesses and corporations are making climate change part of their fiscal and strategic planning. ARB encourages these initial efforts and has set in place a policy to support and encourage other voluntary early reductions.

Successful implementation of AB 32 will depend on a growing commitment by a majority of companies to include climate change as an integral part of their planning and operations. Individuals and households throughout the state will also have to take steps to consider climate change at home, at work and in their recreational activities. To support this effort, this plan includes a comprehensive statewide outreach program to provide businesses and individuals with the widest range of information so they can make informed decisions about reducing their carbon footprints.

Californians will not have to wait for decades to see the benefits of a low carbon economy. New homes can achieve a near zero-carbon footprint with better building techniques and existing technologies, such as solar arrays and solar water heaters. Many older homes can be retrofitted to use far less energy than at present. A new generation of vehicles, including plug-in hybrids, is poised to appear in dealers' showrooms, and the development of the infrastructure to support hydrogen fuel cell cars continues. Cities and new developments will be more walkable, public transport will improve, and high-speed rail will give travelers a new clean transportation option.

[13] Mayors Climate Protection Center. *List of Participating Mayors.* http://www.usmayors.org/climateprotection/list.asp (accessed October 12, 2008)

That world is just around the corner. What lies beyond is even more exciting. Where will California be in 2050? By harnessing the ingenuity and creativity of our society and sparking the imagination of the next generation of Californians, California will make the transition to a clean-energy, low-carbon society and become a healthier, cleaner and more sustainable place to live. This plan charts a course toward that future.

ARB invites comment and input from the broadest array of the public and stakeholders as we move forward over the next two years to develop the individual measures, and develop the policies that will move us toward sustainable clean energy and away from fossil fuels. Your participation will help craft the mechanisms and measures to make this plan a reality. This is California's plan and together, we need to make the necessary changes to address the greatest environmental challenge we face. As Governor Schwarzenegger stated when he signed AB 32 into law two years ago, "We owe our children and we owe our grandchildren. We simply must do everything in our power to fight global warming before it is too late."

I. INTRODUCTION: A Framework for Change

California strengthened its commitment to address climate change when Governor Schwarzenegger signed Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statutes of 2006). This groundbreaking legislation represents a turning point for California and makes it clear that a business-as-usual approach toward greenhouse gas emissions is no longer acceptable. In light of the need for strong and immediate action to counter the growing threat of global warming, AB 32 sets forth an aggressive timetable for achieving results.

AB 32 embodies the idea that California can continue to grow and flourish while reducing its greenhouse gas emissions and continuing its long-standing efforts to achieve healthy air, and protect and enhance public health. Achieving these goals will involve every sector of the state's $1.7 trillion economy and touch the life of every Californian.

As the lead agency for implementing AB 32, the California Air Resources Board (ARB or the Board) released a Draft Scoping Plan in June 2008, which laid out a comprehensive statewide plan to reduce California's greenhouse gas emissions to 1990 levels by 2020. This Proposed Scoping Plan builds upon that draft. This plan sets forth a comprehensive reduction strategy that combines market-based regulatory approaches, other regulations, voluntary measures, fees, policies, and programs that will significantly reduce emissions of greenhouse gases and help make our state cleaner, more efficient and more secure.

The Board will consider this Proposed Scoping Plan for approval at its December 2008 meeting. Once approved by the Board, the Scoping Plan will provide specific direction for the State's greenhouse gas emissions reduction program. The recommended measures will be developed into regulations over the next two years, to go into effect by January 1, 2012. As specific measures in the plan are developed, we will update and adjust our regulatory proposals as necessary to ensure that they reflect any new information, additional analyses, new technologies or other factors that emerge during the process.

ARB has conducted a transparent, wide-ranging public process to develop the Proposed Scoping Plan, including numerous meetings, workshops, and seminars with stakeholders. Substantial input on the development of the Proposed Scoping Plan came from formal advisory committees, meetings with industrial and business groups, non-profit organizations and members of the public, as well as written comments on the Draft Scoping Plan. ARB will continue its outreach activities to seek ongoing public input and will encourage early and continued involvement in the implementation of the plan from all Californians.

A. Summary of Changes from the Draft Scoping Plan

On June 26, 2008, ARB released the Draft Scoping Plan and requested public comment and input, while continuing to analyze the measures and their impact on California. Since the Draft Scoping Plan release, ARB has received almost 1,000 unique written comments as well as hundreds of verbal comments at workshops and in meetings. Taking into account that some written comments were submitted by multiple individuals, all told more than 42,000 people have commented on the draft plan. ARB has also completed detailed economic and public health evaluations of its recommendations. This Proposed Scoping Plan reflects changes made to the draft plan as a result of the comments and input received and the additional analysis performed. The Proposed Plan does not incorporate modifications as a result of comments on the economic and public health supplements. ARB is evaluating those comments and will propose any necessary modifications to the Board.

The key changes between the Draft Scoping Plan and the Proposed Scoping Plan are summarized below. The Proposed Scoping Plan includes the following modifications:

1. General

- Incorporates economic and public health analyses of the Proposed Scoping Plan. These analyses show that the recommendations in the Proposed Scoping Plan will have a net positive impact on both the economy and public health. These analyses follow the same methodology used to evaluate the Draft Scoping Plan. ARB is continuing to consider comments on the methodology and assumptions used in these analyses. Staff will provide an update to the Board as needed to respond to comments received on these analyses.
- Provides a “margin of safety” by recommending additional greenhouse gas emissions reduction strategies to account for measures in uncapped sectors that do not achieve the greenhouse gas emissions reductions estimated in the Proposed Scoping Plan. Along with the certainty provided by the cap, this will ensure that the 2020 target is met.
- Expands the discussion of workforce development, education, and labor to more fully reflect existing activities and the role of other state agencies in ensuring an adequate green technology workforce.
- Assesses how well the recommended measures put California on the long-term reduction trajectory needed to do our part to stabilize the global climate.
- Describes California’s role in the West Coast Regional Carbon Sequestration Partnership (WESTCARB), a public-private collaboration to characterize regional carbon capture and sequestration opportunities, and expresses support for near-term advancement of the technology and monitoring of its development. Acknowledges the important role of terrestrial sequestration.
- Provides greater detail on the mechanisms to be developed to encourage voluntary early action.
- Provides additional detail on implementation, tracking and enforcement of the recommended actions, including the important role of local air districts.

- Evaluates the potential environmental impacts of the Proposed Scoping Plan under the California Environmental Quality Act (CEQA). This evaluation is contained in Appendix J.

2. Proposed Measures

- Provides greater detail on the proposed cap-and-trade program including more detail on the allocation and auction of allowances, and clarification of the proposed role of offsets.
- Re-evaluates the potential benefits from regional targets for transportation-related greenhouse gases in consultation with regional planning organizations and researchers at U.C. Berkeley. Based on this information, ARB increased the anticipated greenhouse gas emissions reductions for Regional Transportation-Related Greenhouse Gas Targets from 2 to 5 million metric tons of CO_2 equivalent ($MMTCO_2E$).
- In recognition of the importance of local governments in the successful implementation of AB 32, adds a section describing this role and recommends a greenhouse gas emissions reduction target for local government municipal and community-wide emissions of a 15 percent reduction from current levels by 2020 to parallel the State's target.
- Adds four measures to address emissions from industrial sources. These proposed measures would regulate fugitive emissions from oil and gas recovery and gas transmission activities, reduce refinery flaring, and remove the methane exemption for refineries. These proposed measures are anticipated to provide 1.5 $MMTCO_2E$ of greenhouse gas reductions in 2020.
- In consultation with the California Integrated Waste Management Board, re-assesses potential measures in the Recycling and Waste sector. As a result of this assessment, ARB increased the reduction of greenhouse gas emissions that can ultimately be anticipated from the Recycling and Waste Sector from 1 to 10 $MMTCO_2E$, recommending measures to move toward high recycling and zero-waste. Research to help quantify these greenhouse gas emissions is continuing, so only 1 $MMTCO_2E$ of these reductions is currently counted towards the AB 32 goal in this plan.
- Estimates the potential reduction of greenhouse gas emissions from the Green Building sector. Green building systems have the potential to reduce approximately 26 $MMTCO_2E$ of greenhouse gas emissions. Since most of these emissions reductions are counted in the Electricity, Commercial/Residential Energy, Water or Waste sectors, emission reductions in the Green Building sector are not separately counted toward the AB 32 goal.
- Adds a High Global Warming Potential (GWP) Mitigation Fee measure to ensure that the climate impact of these gases is reflected in their price to encourage reduced use and end-of-life losses, as well as the development of alternatives.
- Reduces the expected greenhouse gas emissions reduction from the Heavy-Duty Vehicle Greenhouse Gas Emissions Reduction (Aerodynamic Efficiency) measure and the Tire Inflation measure based on ongoing regulatory

development. The Heavy-Duty Vehicle Greenhouse Gas Emissions Reduction (Aerodynamic Efficiency) measure is now expected to achieve 0.9 $MMTCO_2E$ and the Tire Inflation measure is now expected to achieve 0.4 $MMTCO_2E$.

- Modifies the expected reduction of greenhouse gas emissions from the Low Carbon Fuel Standard to account for potential overlap of benefits with the Pavley greenhouse gas vehicle standards. ARB discounted the expected emission reductions from the Low Carbon Fuel Standard by 10 percent.
- After further evaluation, moves the Heavy-Duty Truck Efficiency measure to the Goods Movement measure. ARB expects that market dynamics will provide an inducement to improve heavy-duty truck efficiency, and reductions in greenhouse gases in the future. ARB would consider pursuing direct requirements to reduce greenhouse gases if truck efficiency does not improve in the future.

B. Background

1. Climate Change Policy in California

California first addressed climate change in 1988 with the passage of AB 4420 (Sher, Chapter 1506, Statutes of 1988). This bill directed the California Energy Commission (CEC) to study global warming impacts to the state and develop an inventory of greenhouse gas emissions sources. In 2000, SB 1771 (Sher, Chapter 1018, Statutes of 2000) established the California Climate Action Registry to allow companies, cities and government agencies to voluntarily record their greenhouse gas emissions in anticipation of a possible program that would allow them to be credited for early reductions.

In 2001, the United Nations' Intergovernmental Panel on Climate Change (IPCC) reported that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." The following year, AB 1493 (Pavley, Chapter 200, Statutes of 2002) was signed into law, requiring ARB to develop regulations to reduce greenhouse gas emissions from passenger vehicles, light-duty trucks and non-commercial vehicles sold in California.

Recognizing the value of regional partners in addressing climate change, the governors of California, Washington, and Oregon created the West Coast Global Warming Initiative in 2003 with provisions for the states to work together on climate change-related programs.

Two years later Governor Schwarzenegger signed Executive Order S-3-05, calling for the State to reduce greenhouse gas emissions to 1990 levels by 2020 and to reduce greenhouse gas emissions to 80 percent below 1990 levels by 2050. The 2020 goal was established to be an aggressive, but achievable, mid-term target, and the 2050 greenhouse gas emissions reduction goal represents the level scientists believe is necessary to reach levels that will stabilize climate.

In 2006, SB 1368 (Perata, Chapter 598, Statutes of 2006) created greenhouse gas performance standards for new long-term financial investments in base-load electricity generation serving California customers. This law is designed to help spur the transition toward cleaner energy in California by placing restrictions on the ability of utilities to build new carbon-intensive plants or enter into new contracts with high carbon sources of electricity. Expiration of existing utility long-term contracts with coal plants will reduce greenhouse gas emissions when such generation is replaced by lower greenhouse gas-emitting resources. These reductions will reduce the need for utilities to submit allowances to comply with the cap-and-trade program.

2. Assembly Bill 32: The Global Warming Solutions Act

In 2006, the Legislature passed and Governor Schwarzenegger signed AB 32, the Global Warming Solutions Act of 2006, which set the 2020 greenhouse gas emissions reduction goal into law. It directed ARB to begin developing discrete early actions to reduce greenhouse gases while also preparing a Scoping Plan to identify how best to reach the 2020 limit. The reduction measures to meet the 2020 target are to become operative by 2012.

AB 32 includes a number of specific requirements for ARB:

- *Identify the statewide level of greenhouse gas emissions in 1990 to serve as the emissions limit to be achieved by 2020 (Health and Safety Code (HSC) §38550).* In December 2007, the Board approved the 2020 emission limit of 427 million metric tons of carbon dioxide equivalent ($MMTCO_2E$) of greenhouse gases.
- *Adopt a regulation requiring the mandatory reporting of greenhouse gas emissions (HSC §38530).* In December 2007, the Board adopted a regulation requiring the largest industrial sources to report and verify their greenhouse gas emissions. The reporting regulation serves as a solid foundation to determine greenhouse gas emissions and track future changes in emission levels.
- *Identify and adopt regulations for Discrete Early Actions that could be enforceable on or before January 1, 2010 (HSC §38560.5).* The Board identified nine Discrete Early Action measures including potential regulations affecting landfills, motor vehicle fuels, refrigerants in cars, port operations and other sources in 2007. The Board has already approved two Discrete Early Action measures (ship electrification at ports and reduction of high GWP gases in consumer products). Regulatory development for the remaining measures is ongoing.
- *Ensure early voluntary reductions receive appropriate credit in the implementation of AB 32 (HSC §38562(b)(3)).* In February 2008, the Board approved a policy statement encouraging voluntary early actions and establishing a procedure for project proponents to submit quantification methods to be evaluated by ARB. ARB, along with California's local air districts and the California Climate Action Registry, is working to implement this program. Voluntary programs are discussed further in Chapter II and in Chapter IV.

- *Convene an Environmental Justice Advisory Committee (EJAC) to advise the Board in developing the Scoping Plan and any other pertinent matter in implementing AB 32 (HSC §38591).* The EJAC has met 12 times since early 2007, providing comments on the proposed Early Action measures and the development of the Scoping Plan, and submitted its comments and recommendations on the draft Scoping Plan in October 2008. ARB will continue to work with The EJAC as AB 32 is implemented.
- *Appoint an Economic and Technology Advancement Advisory Committee (ETAAC) to provide recommendations for technologies, research and greenhouse gas emission reduction measures (HSC §38591).* After a year-long public process, The ETAAC submitted a report of their recommendations to the Board in February 2008. The ETAAC also reviewed and provided comments on the Draft Scoping Plan.

3. Climate Action Team

In addition to establishing greenhouse gas emissions reduction targets for California, Executive Order S-3-05 established the Climate Action Team (CAT) for State agencies in 2005. Chaired by the Secretary of the California Environmental Protection Agency (CalEPA), the CAT has helped to direct State efforts on the reduction of greenhouse gas emissions and engage key State agencies including ARB. The Health and Human Services Agency, represented by the Department of Public Health, is the newest member of the CAT. Based on numerous public meetings and the review of thousands of submitted comments, the CAT released its first report in March 2006, identifying key carbon reduction recommendations for the Governor and Legislature.

Climate Action Team
California Environmental Protection Agency
Business, Transportation, and Housing Agency
Health and Human Services Agency
Resources Agency
State and Consumer Services Agency
Governor's Office of Planning and Research
Air Resources Board
California Energy Commission
California Public Utilities Commission
Department of Food and Agriculture
Department of Forestry and Fire Protection
Department of General Services
Department of Parks and Recreation
Department of Transportation
Department of Water Resources
Integrated Waste Management Board
State Water Resources Control Board

In April 2007, the CAT released a second report, "Proposed Early Actions to Mitigate Climate Change in California," which details numerous strategies that should be initiated prior to the 2012 deadline for other climate action regulations and efforts.

AB 32 recognizes the essential role of the CAT in coordinating overall climate policy. AB 32 does not affect the existing authority of other state agencies, and in addition to

ARB, many state agencies will be responsible for implementing the measures and strategies in this plan. The CAT is central to the success of AB 32, which requires an unprecedented level of cooperation and coordination across State government. The CAT provides the leadership for these efforts and helps ARB work closely with our state partners on the development and implementation of the strategies in the Proposed Scoping Plan.

There are currently 12 subgroups within the CAT – nine that address specific economic sectors, and three that were formed to analyze broad issues related to implementing a multi-sector approach to greenhouse gas emissions reduction efforts. The CAT sector-based subgroups include: Agriculture, Cement, Energy, Forest, Green Buildings, Land Use, Recycling and Waste Management, State Fleet, and Water-Energy. The members of these subgroups are drawn from departments that work with or regulate industries in the sector. ARB participated in each of the subgroups. All of the subgroups held public meetings and solicited public input, and many had multiple public workshops.

In March 2008, the subgroups collectively submitted more than 100 greenhouse gas emissions reduction measures to ARB for consideration in the Draft Scoping Plan. Many of those recommendations are reflected in this plan, and a number of them focus on reducing greenhouse gas emissions from energy production and use.

Through the Energy Subgroup the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) are conducting a joint proceeding to provide recommendations on how best to address electricity and natural gas in the implementation of AB 32, including evaluation of how the Electricity sector might best participate in a cap-and-trade program. The two Commissions forwarded interim recommendations to ARB in March 2008 that supported inclusion of the Electricity sector in a multi-sector cap-and-trade program, and measures to increase the penetration of energy efficiency programs in both buildings and appliances and to increase renewable energy sources. The two Commissions have developed a second proposed decision that was released in September 2008. This proposed decision provides more detailed recommendations that relate to the electricity and natural gas sectors. Because implementation of the Scoping Plan will require careful coordination with the State's energy policy, ARB will continue working closely with the two Commissions on this important area during the implementation of the recommendations in the Scoping Plan.

There are also three subgroups which are not sector-specific. The Economic Subgroup reviewed cost information associated with potential measures that were included in the 2006 CAT report with updates reflected in the report, "Updated Macroeconomic Analysis of Climate Strategies," in October 2007. This report provided an update of the macroeconomic analysis presented in the March 2006 CAT report to Governor Schwarzenegger and the Legislature. The Research Subgroup coordinates climate change research and identifies opportunities for collaboration, and is presently working on a report to the Governor. The State Operations Subgroup has been created to work with State agencies to create a statewide plan to reduce State government's greenhouse gas emissions by a minimum of 30 percent by 2020.

In the first quarter of 2009, the Climate Action Team will release a report on its activities outside of its involvement in the development of the Proposed Scoping Plan. The CAT report will focus on several cross-cutting topics with which members of the CAT have been involved since the publication of the 2006 CAT report. The topics to be covered include research on the physical and consequent economic impacts of climate change as well as climate change research coordination efforts among the CAT members. There will also be an update on the important climate change adaptation efforts led by the Resources Agency and a discussion of cross-cutting issues related to environmental justice concerns. The CAT report will be released in draft form and will be available for public review in December 2008.

4. Development of the Greenhouse Gas Emission Reduction Strategy

In developing the Proposed Scoping Plan, ARB considered the State's existing climate change policy initiatives and the Early Action measures identified by the Board. Several advisory groups were formed to assist ARB in developing the Proposed Scoping Plan, including the Environmental Justice Advisory Committee (EJAC), the Economic and Technology Advancement Committee (ETAAC), and the Market Advisory Committee (MAC).

The Environmental Justice Advisory Committee (HSC §38591(a) et seq) advises ARB on development of the Scoping Plan and any other pertinent matter in implementing AB 32. The Board appoints its members, based on nominations received from environmental justice organizations and community groups.

The Economic and Technology Advancement Advisory Committee (HSC §38591(d)) includes members who are appointed by the Board based on expertise in fields of business, technology research and development, climate change, and economics. The ETAAC advises ARB on activities that will facilitate investment in, and implementation of, technological research and development opportunities, funding opportunities, partnership development, technology transfer opportunities, and related areas that lead to reductions of greenhouse gas emissions.

Members of the Market Advisory Committee (created under Executive Order S-20-06) were appointed by the Secretary of CalEPA based on their expertise in economics and climate change. The MAC advised ARB on the design of a cap-and-trade program for reducing greenhouse gas emissions.

Along with input from the advisory groups, ARB received submittals to a public solicitation for ideas, and numerous comments during public workshops, workgroup meetings, community meetings, and meetings with stakeholder groups. ARB held numerous workshops on the Draft Scoping Plan and convened workgroup meetings focused on program design and economic analysis. ARB and other involved State agencies also held sector-specific technical workshops to look in greater detail at potential emissions reduction measures.

ARB also looked outward to examine programs at the regional, national and international levels. ARB met with and learned from experts from the European Union, the United Kingdom, Japan, Australia, the United Nations, the Regional Greenhouse Gas Initiative, the RECLAIM program, and the U.S. Environmental Protection Agency (U.S. EPA).

After the release of the Draft Scoping Plan, ARB conducted workshops and community meetings around the state to solicit public input. The Environmental Justice Advisory Committee and the Economic and Technology Advancement Advisory Committee held meetings to review and provide additional comments on the Draft Scoping Plan. In addition, ARB held meetings with numerous stakeholder groups to discuss specific greenhouse gas emissions reduction measures.

As described before, ARB has reviewed and considered both the written comments and the verbal comments received at the public workshops and meetings with stakeholders. This input, along with additional analysis, has ultimately shaped this Proposed Scoping Plan.

5. Implementation of the Scoping Plan

The foundation of the Proposed Scoping Plan's strategy is a set of measures that will cut greenhouse gas emissions by nearly 30 percent by the year 2020 as compared to business as usual and put California on a course for much deeper reductions in the long term. In addition to pursuing the reduction of greenhouse gas emissions, other strategies to mitigate climate change, such as carbon capture and storage (underground geologic storage of carbon dioxide), should also be further explored. And, as greenhouse gas reduction measures are implemented, we will continually evaluate how these measures can be optimized to also help deliver a broad range of public health benefits.

Most of the measures in this Proposed Scoping Plan will be implemented through the full rulemaking processes at ARB or other agencies. These processes will provide opportunity for public input as the measures are developed and analyzed in more detail. This additional analysis and public input will likely provide greater certainty about the estimates of costs and expected greenhouse gas emission reductions, as well as the design details that are described in this Proposed Scoping Plan. With the exception of Discrete Early Actions, which will be in place by January 1, 2010, other regulations are expected to be adopted by January 1, 2011 and take effect at the beginning of 2012.

Some of the measures in the plan may deliver more emission reductions than we expect; others less. It is also very likely that we will figure out new and better ways to cut greenhouse gas emissions as we move forward. New technologies will no doubt be developed, and new ideas and strategies will emerge. The Scoping Plan puts

California squarely on the path to a clean energy future but it also recognizes that adjustments will probably need to occur along the way and that as additional tools become available they will augment, and in some cases perhaps even replace, existing approaches.

California will not be implementing the measures in this Plan in a vacuum. Significant new action on climate policy is likely at the federal level and California and its partners in the Western Climate Initiative are working together to create a regional effort for achieving significant reductions of greenhouse gas emissions throughout the western United States and Canada. California is also developing a state Climate Adaptation Strategy to reduce California's vulnerability to known and projected climate change impacts.

ARB and other State agencies will continue to monitor, lead and participate in these broader activities. ARB will adjust the measures described here as necessary to ensure that California's program is designed to facilitate the development of integrated and cost-effective regional, national, and international greenhouse gas emissions reduction programs. (HSC §38564)

6. Climate Change in California

The impacts of climate change on California and its residents are occurring now. Of greater concern are the expected future impacts to the state's environment, public health and economy, justifying the need to sharply cut greenhouse gas emissions.

In the Findings and Declarations for AB 32, the Legislature found that:

> "The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to the marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other health-related problems."

The Legislature further found that global warming would cause detrimental effects to some of the state's largest industries, including agriculture, winemaking, tourism, skiing, commercial and recreational fishing, forestry, and the adequacy of electrical power.

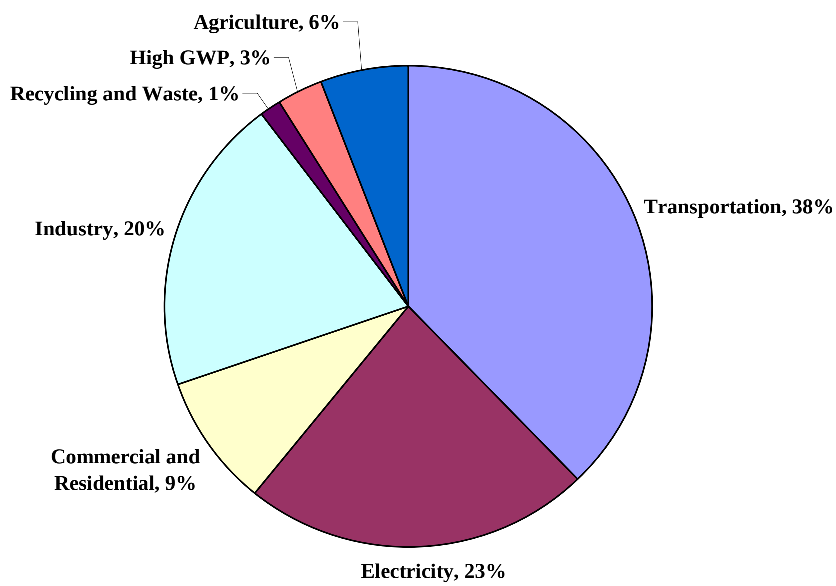
The impacts of global warming are already being felt in California. The Sierra snowpack, an important source of water supply for the state, has shrunk 10 percent in the last 100 years. It is expected to continue to decrease by as much as 25 percent by 2050. World-wide changes are causing sea levels to rise – about 8 inches of increase has been recorded at the Golden Gate Bridge over the past 100 years – threatening low coastal areas with inundation and serious damage from storms.

C. California's Greenhouse Gas Emissions and the 2020 Target

California is the fifteenth largest emitter of greenhouse gases on the planet, representing about two percent of the worldwide emissions. Although carbon dioxide is the largest contributor to climate change, AB 32 also references five other greenhouse gases: methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). Many other gases contribute to climate change and would also be addressed by measures in this Proposed Scoping Plan.

Figure 1 and Table 1 show 2002 to 2004 average emissions and estimates for projected emissions in 2020 without any greenhouse gas reduction measures (business-as-usual case). The 2020 business-as-usual forecast does not take any credit for reductions from measures included in this Proposed Plan, including the Pavley greenhouse gas emissions standards for vehicles, full implementation of the Renewables Portfolio Standard beyond current levels of renewable energy, or the solar measures. Additional information about the assumptions in the 2020 forecast is provided in Appendix F.

Figure 1: California's Greenhouse Gas Emissions (2002-2004 Average)[14]



As seen in Figure 1, the Transportation sector – largely the cars and trucks that move goods and people – is the largest contributor with 38 percent of the state's total greenhouse gas emissions. Table 1 shows that if we take no action, greenhouse gas emissions in the

[14] Air Resources Board. Greenhouse Gas Inventory. http://www.arb.ca.gov/cc/inventory/inventory.htm (accessed October 12, 2008)

Transportation sector are expected to grow by approximately 25 percent by 2020 (an increase of 46 $MMTCO_2E$).

The Electricity and Commercial/Residential Energy sector is the next largest contributor with over 30 percent of the statewide greenhouse gas emissions. Although electricity imported into California accounts for only about a quarter of our electricity, imports contribute more than half of the greenhouse gas emissions from electricity because much of the imported electricity is generated at coal-fired power plants. AB 32 specifically requires ARB to address emissions from electricity sources both inside and outside of the state.

California's Industrial sector includes refineries, cement plants, oil and gas production, food processors, and other large industrial sources. This sector contributes almost 20 percent of California's greenhouse gas emissions, but the sector's emissions are not projected to grow significantly in the future. The sector termed recycling and waste management is a unique system, encompassing not just emissions from waste facilities but also the emissions associated with the production, distribution and disposal of products throughout the economy.

Although high global warming potential (GWP) gases are a small contributor to historic greenhouse gas emissions, levels of these gases are projected to increase sharply over the next several decades, making them a significant source by 2020.

The Forest sector is unique in that forests both emit greenhouse gases and uptake carbon dioxide (CO_2). While the current inventory shows forests as a sink of 4.7 $MMTCO_2E$, carbon sequestration has declined since 1990. For this reason, the 2020 projection assumes no net emissions from forests.

The agricultural greenhouse gas emissions shown are largely methane emissions from livestock, both from the animals and their waste. Emissions of greenhouse gases from fertilizer application are also important contributors from the Agricultural sector. ARB has begun a research program to better understand the variables affecting these emissions. Opportunities to sequester CO_2 in the Agricultural sector may also exist; however, additional research is needed to identify and quantify potential sequestration benefits.

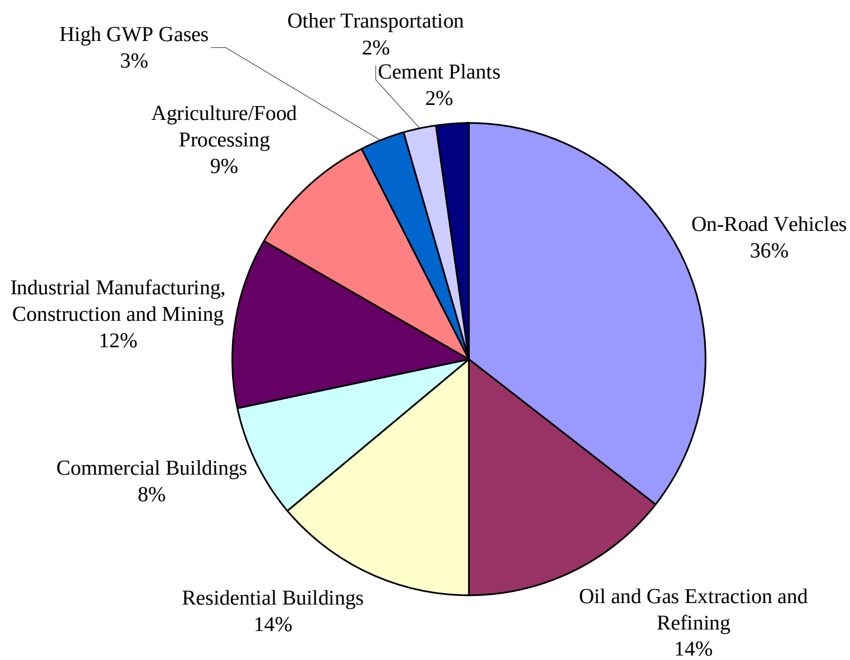
In December 2007, ARB approved a greenhouse gas emissions target for 2020 equivalent to the state's calculated greenhouse gas emissions level in 1990. ARB developed the 2020 target after extensive technical work and a series of stakeholder meetings. The 2020 target of 427 $MMTCO_2E$ requires the reduction of 169 $MMTCO_2E$, or approximately 30 percent, from the state's projected 2020 emissions of 596 $MMTCO_2E$ (business-as-usual) and the reduction of 42 $MMTCO_2E$, or almost 10 percent, from 2002-2004 average emissions.

Table 1: 2002-2004 Average Emissions and 2020 Projected Emissions (Business-as-Usual)[15]
(MMTCO$_2$E)

Sector	2002-2004 Average Emissions	Projected 2020 Emissions [BAU]
Transportation	179.3	225.4
Electricity	109.0	139.2
Commercial and Residential	41.0	46.7
Industry	95.9	100.5
Recycling and Waste	5.6	7.7
High GWP	14.8	46.9
Agriculture	27.7	29.8
Forest Net Emissions	-4.7	0.0
Emissions Total	**469**	**596**

Figure 2 presents California's historic greenhouse gas emissions in a different way – based not on the source of the emissions, but on the end use. This chart highlights the importance of addressing on-road transportation sources of greenhouse gas emissions, as well as the significant contribution from the heating, cooling, and lighting of buildings.

Figure 2: California's Greenhouse Gas Emissions – A Demand-Side View –



[15] Ibid.

The data shown in this section provide two ways to look at California's greenhouse gas profile – emissions-based and end use (demand side)-based. While it is possible to illustrate the inventory many different ways, no chart or graph can fully display how diverse economic sectors fit together. California's economy is a web of activity where seemingly independent sectors and subsectors operate interdependently and often synergistically. For example, reductions in water use reduce the need to pump water, directly lowering electricity use and associated greenhouse gas emissions. Similarly, reducing the generation of waste reduces the need to transport the waste to landfills – lowering transportation emissions and, possibly, landfill methane emissions. Increased recycling or re-use reduces the carbon emissions embedded in products – it takes less energy to make a soda can made from recycled aluminum than from virgin feedstock.

The measures included in this Proposed Scoping Plan are identified discretely, but many impact each other, and changes in one measure can directly overlap and have a ripple effect on the efficacy and success of other measures. The measures and policies outlined in this Plan reflect these interconnections, and highlight the need for all agencies to work collaboratively to implement the Scoping Plan.

II. RECOMMENDED ACTIONS

Achieving the goals of AB 32 in a cost-effective manner will require a wide range of approaches. Every part of California's economy needs to play a role in reducing greenhouse gas emissions. ARB's comprehensive greenhouse gas emissions inventory lists emission sources ranging from the largest refineries and power plants to small industrial processes and farm livestock. The recommended measures were developed to reduce greenhouse gas emissions from key sources and activities while improving public health, promoting a cleaner environment, preserving our natural resources, and ensuring that the impacts of the reductions are equitable and do not disproportionately impact low-income and minority communities. These measures also put the state on a path to meet the long-term 2050 goal of reducing California's greenhouse gas emissions to 80 percent below 1990 levels. This trajectory is consistent with the reductions that are needed globally to help stabilize the climate. While the scale of this effort is considerable, our experience with cultural and technological changes makes California well-equipped to handle this challenge.

ARB evaluated a comprehensive array of approaches and tools to achieve these emission reductions. Reducing greenhouse gas emissions from the wide variety of sources can best be accomplished though a cap-and-trade program along with a mix of complementary strategies that combine market-based regulatory approaches, other regulations, voluntary measures, fees, policies, and programs. ARB will monitor implementation of these measures to ensure that the State meets the 2020 limit on greenhouse gas emissions.

An overall limit on greenhouse gas emissions from most of the California economy – the "capped sectors" – will be established by the cap-and-trade program. (The basic elements of the cap-and-trade program are described later in this chapter.) Within the capped sectors, some of the reductions will be accomplished through direct regulations such as improved building efficiency standards and vehicle efficiency measures. Whatever additional reductions are needed to bring emissions within the cap are accomplished through price incentives posed by emissions allowance prices. Together, direct regulation and price incentives assure that emissions are brought down cost-effectively to the level of the overall cap. ARB also recommends specific measures for the remainder of the economy – the "uncapped sectors."

Key elements of California's recommendations for reducing its greenhouse gas emissions to 1990 levels by 2020 include:

- **Expanding and strengthening existing energy efficiency programs as well as building and appliance standards;**
- **Achieving a statewide renewables energy mix of 33 percent;**
- **Developing a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system;**
- **Establishing targets for transportation-related greenhouse gas emissions for regions throughout California and pursuing policies and incentives to achieve those targets;**
- **Adopting and implementing measures pursuant to existing State laws and policies, including California's clean car standards, goods movement measures, and the Low Carbon Fuel Standard; and**
- **Creating targeted fees, including a public goods charge on water use, fees on high global warming potential gases, and a fee to fund the administrative costs of the State's long-term commitment to AB 32 implementation.**

The recommended greenhouse gas emissions reduction measures are listed in Table 2 and are summarized in Section C below. The total reduction for the recommended measures slightly exceeds the 169 $MMTCO_2E$ of reductions estimated in the Draft Scoping Plan. This is the net effect of adding several measures and adjusting the emission reduction estimates for some other measures. The 2020 emissions cap in the cap-and-trade program is preserved at the same level as in the Draft Scoping Plan (365 $MMTCO_2E$).

The measures listed in Table 2 lead to emissions reductions from sources within the capped sectors (146.7 $MMTOCO_2E$) and from sources or sectors not covered by cap-and-trade (27.3 $MMTCO_2E$). As mentioned, within the capped sectors the reductions derive both from direct regulation and from the incentives posed by allowance prices. Further discussion of how the cap-and-trade program and the complementary measures work together to achieve the overall target is provided below.

Table 2 also lists several other recommended measures which will contribute toward achieving the 2020 statewide goal, but whose reductions are not (for various reasons including the potential for double counting) additive with the other measures. Those measures and the basis for not including their reductions are further discussed in Section C.

Table 2: Recommended Greenhouse Gas Reduction Measures

Recommended Reduction Measures	Reductions Counted Towards 2020 Target ($MMTCO_2E$)	
ESTIMATED REDUCTIONS RESULTING FROM THE COMBINATION OF CAP-AND-TRADE PROGRAM AND COMPLEMENTARY MEASURES		**146.7**
California Light-Duty Vehicle Greenhouse Gas Standards • Implement Pavley standards • Develop Pavley II light-duty vehicle standards	31.7	
Energy Efficiency • Building/appliance efficiency, new programs, etc. • Increase CHP generation by 30,000 GWh • Solar Water Heating (AB 1470 goal)	26.3	
Renewables Portfolio Standard (33% by 2020)	21.3	
Low Carbon Fuel Standard	15	
Regional Transportation-Related GHG Targets[16]	5	
Vehicle Efficiency Measures	4.5	
Goods Movement • Ship Electrification at Ports • System-Wide Efficiency Improvements	3.7	
Million Solar Roofs	2.1	
Medium/Heavy Duty Vehicles • Heavy-Duty Vehicle Greenhouse Gas Emission Reduction (Aerodynamic Efficiency) • Medium- and Heavy-Duty Vehicle Hybridization	1.4	
High Speed Rail	1.0	
Industrial Measures (for sources covered under cap-and-trade program) • Refinery Measures • Energy Efficiency & Co-Benefits Audits	0.3	
Additional Reductions Necessary to Achieve the Cap	34.4	
ESTIMATED REDUCTIONS FROM UNCAPPED SOURCES/SECTORS		**27.3**
High Global Warming Potential Gas Measures	20.2	
Sustainable Forests	5.0	
Industrial Measures (for sources not covered under cap and trade program) • Oil and Gas Extraction and Transmission	1.1	
Recycling and Waste (landfill methane capture)	1.0	
TOTAL REDUCTIONS COUNTED TOWARDS 2020 TARGET		**174**

Other Recommended Measures	Estimated 2020 Reductions ($MMTCO_2E$)
State Government Operations	1-2
Local Government Operations	TBD
Green Buildings	26
Recycling and Waste (other measures)	9
Water Sector Measures	4.8
Methane Capture at Large Dairies	1.0

[16] This number represents an estimate of what may be achieved from local land use changes. It is not the SB 375 regional target. ARB will establish regional targets for each Metropolitan Planning Organization (MPO) region following the input of the Regional Targets Advisory Committee and a public consultation process with MPOs and other stakeholders per SB 375.

The development of a California cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system is a central feature of the overall recommendation. This program will lead to prices on greenhouse gas emissions, prices that will spur reductions in greenhouse gas emissions throughout the California economy, through application of existing technologies and through the creation of new technological and organizational options. The rationale for combining a cap-and-trade program with complementary measures was outlined by the Market Advisory Committee, which noted the following in its recommendations to the ARB:

> Before setting out the key design elements of a cap-and-trade program it is important to explain how the proposed emissions trading approach relates to other policy measures. The following considerations seem especially relevant:
>
> - The emissions trading program puts a cap on the total emissions generated by facilities covered under the system. Because a certain number of emissions allowances are put in circulation in each compliance period, this approach provides a measure of certainty about the total quantity of emissions that will be released from entities covered under the program.
> - The market price of emissions allowances yields an enduring price signal for GHG emissions across the economy. This price signal provides incentives for the market to find new ways to reduce emissions.
> - By itself, a cap-and-trade program alone will not deliver the most efficient mitigation outcome for the state. There is a strong economic and public policy basis for other policies that can accompany an emissions trading system. [17]

The Economic and Technology Advancement Advisory Committee (ETAAC) also addressed the benefits associated with a combined policy of cap and trade and complementary measures.

> A declining cap can send the right price signals to shape the behavior of consumers when purchasing products and services. It would also shape business decisions on what products to manufacture and how to manufacture them. Establishing a price for carbon and other GHG emissions can efficiently tilt decision-making toward cleaner alternatives. This cap and trade approach (complemented by technology-forcing performance standards) avoids the danger of having government or other centralized decision-makers choose specific technologies, thereby limiting the flexibility to allow other options to emerge on a level playing field.

[17] Recommendations of the Market Advisory Committee to the California Air Resources Board. *Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California*. June 30, 2007. p. 19. http://www.climatechange.ca.gov/publications/market_advisory_committee/2007-06-29_MAC_FINAL_REPORT.PDF (accessed October 12, 2008)

> If markets were perfect, such a cap and trade system would bring enough new technologies into the market and stimulate the necessary industrial RD&D to solve the climate change challenge in a cost effective manner. As the Market Advisory Committee notes, however, placing a price on GHG emissions addresses only one of many market failures that impede solutions to climate change. Additional market barriers and co-benefits would not be addressed if a cap and trade system were the only state policy employed to implement AB 32. Complementary policies will be needed to spur innovation, overcome traditional market barriers (e.g., lack of information available to energy consumers, different incentives for landlords and tenants to conserve energy, different costs of investment financing between individuals, corporations and the state government, etc.) and address distributional impacts from possible higher prices for goods and services in a carbon-constrained world.[18]

The Environmental Justice Advisory Committee (EJAC) also supports an approach that includes a price on carbon along with complementary measures. Although the EJAC recommends that the carbon price be established through a carbon fee rather than through a cap-and-trade program, they recognize the importance of mutually supportive policies:

> California should establish a three-pronged approach for addressing greenhouse gases: (1) adopting standards and regulations; (2) providing incentives; and (3) putting a price on carbon via a carbon fee. The three pieces support one another and no single prong can work without equally robust support from the others.[19]

In keeping with the rationale outlined above, ARB finds that it is critically important to include complementary measures directed at emission sources that are included in the cap-and-trade program. These measures are designed to achieve cost-effective emissions reductions while accelerating the necessary transition to the low-carbon economy required to meet the 2050 target:

- The already adopted Light-Duty Vehicle Greenhouse Gas Standards are designed to accelerate the introduction of low-greenhouse gas emitting vehicles, reduce emissions and save consumers money at the pump.
- The Low Carbon Fuel Standard (LCFS) is a flexible performance standard designed to accelerate the availability and diversity of low-carbon fuels by taking into consideration the full life-cycle of greenhouse gas emissions. The LCFS will reduce emissions and make our economy more resilient to future petroleum price volatility.
- The Regional Transportation-Related Greenhouse Gas Targets provide incentives for channeling investment into integrated development patterns and transportation

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[18] Recommendations of the Economic and Technical Advancement Advisory Committee (ETAAC), Final Report. *Technologies and Policies to Consider for Reducing Greenhouse Gas Emissions in California*. February 14, 2008. pp. 1-4 http://www.arb.ca.gov/cc/etaac/ETAACFinalReport2-11-08.pdf (accessed October 12, 2008)

[19] Recommendations and Comments of the Environmental Justice Advisory Committee on the Implementation of the Global Warming Solutions Act of 2006 (AB32) on the Draft Scoping Plan. October 2008. p. 10. http://www.arb.ca.gov/cc/ejac/ejac_comments_final.pdf (accessed October 12, 2008)

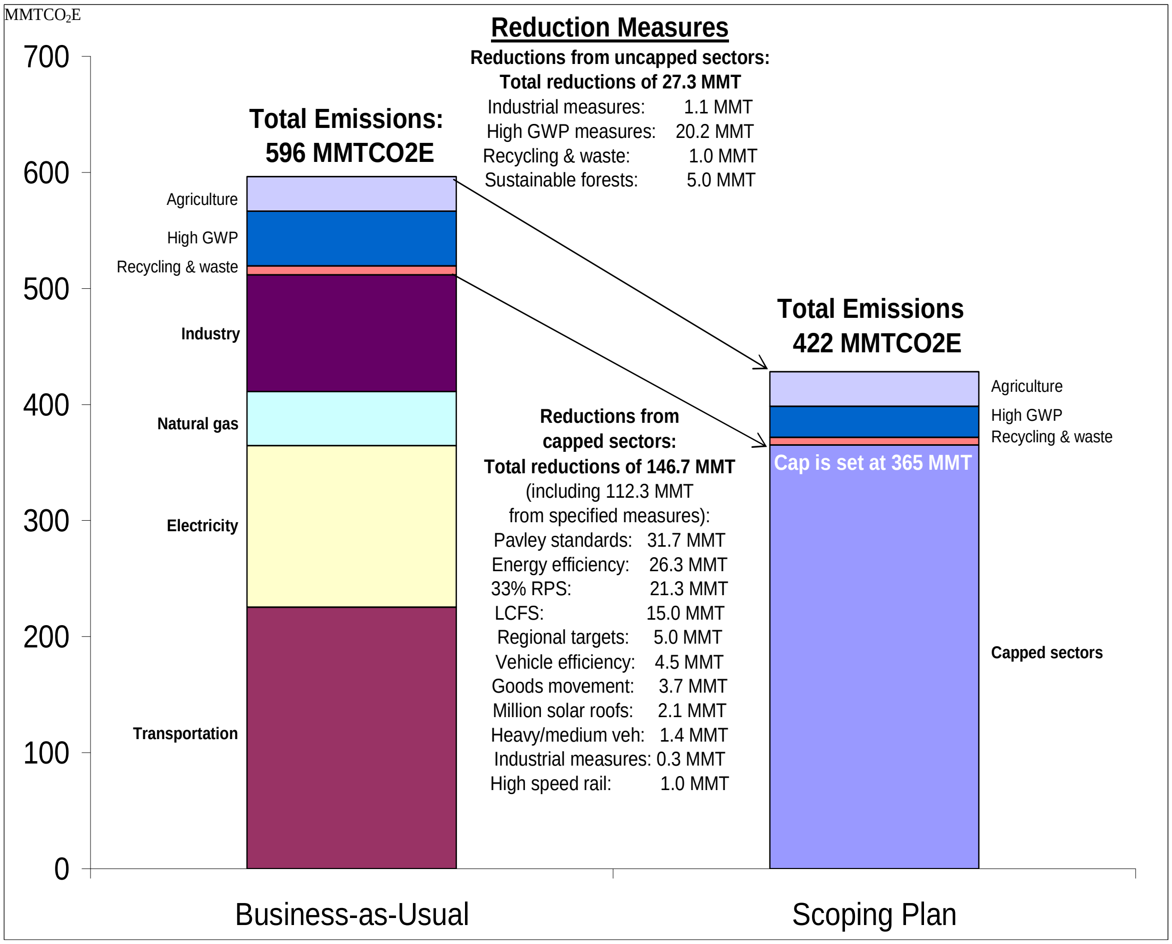
infrastructure, through improved planning. Improved planning and the resulting development are essential for meeting the 2050 emissions target.

- In the Energy sector, measures will provide better information and overcome institutional barriers that slow the adoption of cost-effective energy efficiency technologies. Enhanced energy efficiency programs will provide incentives for customers to purchase and install more efficient products and processes, and building and appliance standards will ensure that manufacturers and builders bring improved products to market.
- The Renewables Portfolio Standard (RPS) promotes multiple objectives, including diversifying the electricity supply. Increasing the RPS to 33 percent is designed to accelerate the transformation of the Electricity sector, including investment in the transmission infrastructure and system changes to allow integration of large quantities of intermittent wind and solar generation.
- The Million Solar Roofs Initiative uses incentives to transform the rooftop solar market by driving down costs over time.
- The Goods Movement program is primarily intended to achieve criteria and toxic air pollutant reductions but will provide important greenhouse gas benefits as well.
- Similar to the light duty vehicle greenhouse gas standards, the heavy duty and medium duty vehicle measures and the additional light duty vehicle efficiency measures aim to achieve cost-effective reductions of GHG emissions and save fuel.

Each of these complementary measures helps to position the California economy for the future by reducing the greenhouse gas intensity of products, processes, and activities. When combined with the absolute and declining emissions limit of the cap-and-trade program, these policies ensure that we cost-effectively achieve our greenhouse gas emissions goals and set ourselves on a path towards a clean low carbon future.

Figure 3 illustrates how the recommended emission reduction measures together put California on a path toward achieving the 2020 goal. The left hand column in Figure 3 shows total projected business as usual emissions in 2020, by sector (596 $MMTCO_2E$). The right hand column shows 2020 emissions after applying the Scoping Plan recommended reduction measures (422 $MMTCO_2E$). The measures that accomplish the needed reductions are listed in between the columns. As Figure 3 shows, there are a total of 27.3 $MMTCO_2E$ in reductions from uncapped sectors, and 146.7 $MMTCO_2E$ in reductions from capped sectors.

Figure 3: California Greenhouse Gas Emissions in 2020 and Recommended Reduction Measures



The recommended cap-and-trade program provides covered sources with the flexibility to pursue low cost reductions. It is important to recognize, however, that other recommended measures also provide compliance flexibility. As is often the case with ARB regulations, many of the measures establish performance standards and allow regulated entities to determine how best to achieve the required emission level. This approach rewards innovation and allows facilities to take advantage of the best way to meet the overarching environmental objective.

Table 3 lists the proposed measures that include compliance flexibility or market mechanisms. This flexibility ranges from the potential for tradable renewable energy credits in the Renewables Portfolio Standard to the incentives to encourage emission reductions in electricity and natural gas efficiency programs to the averaging, banking and trading mechanisms in the Pavley and Low Carbon Fuel Standard programs to a multi-sector cap-and-trade program.

Table 3: Measures With Flexible Market Compliance Features

Measure	Estimated Reductions
Additional Reductions from Capped Sectors	34.4
California Light-Duty Vehicle Greenhouse Gas Standards (Pavley I & II)	31.7
Renewables Portfolio Standard	21.3
Electricity Efficiency	15.2
Low Carbon Fuel Standard	15.0
Mitigation Fee on High GWP Gases	5.0
Natural Gas Efficiency	4.3
Goods Movement Systemwide Efficiency	3.5
Medium/Heavy Duty Vehicle Hybridization	0.5
Total	**130.9**

The recommended mix of measures builds on a strong foundation of previous action in California to address climate change and broader environmental issues. The program recommended here relies on implementing existing laws and regulations that were adopted to reduce greenhouse gas emissions and other policy goals; strengthening and expanding existing programs; implementing the discrete early actions adopted by the Board in 2007; and new measures developed during the Scoping Plan process itself.

The mix of measures recommended in this Proposed Plan provides a comprehensive approach to reduce emissions to achieve the 2020 target, and to initiate the transformations required to achieve the 2050 target. The cap-and-trade program and complementary measures will cover about 85 percent of greenhouse gas emissions throughout California's economy. ARB recognizes that due to several factors, including information discovered during regulatory development, technology maturity, and implementation challenges, actual reductions from individual measures aimed at achieving the 2020 target may be higher or lower than current estimates. The inclusion of many of these emissions within the cap-and-trade program, along with a margin of safety in the uncapped sectors, will help ensure that the 2020 target is met. The combination of approaches provides certainty that the overall program will meet the target despite some degree of uncertainty in the estimates for any individual measure. Additionally, by internalizing the cost of CO_2E emissions throughout the economy, the cap-and-trade program supports the complementary measures and provides further incentives for innovation and continuing emissions reductions from energy producers and consumers setting us on a path toward our 2050 goals.

Some emissions sources are not currently suitable for inclusion in the cap-and-trade program due to challenges associated with precise measurement, tracking or sector structure. For these emissions sources, ARB is including measures designed to focus on waste management, agriculture, forestry, and certain emissions of high GWP gases, a rapidly growing component of California's greenhouse gas emissions inventory.

California's economy is expected to continue to experience robust growth through 2020. Economic modeling, including evaluation of the effects on low-income Californians, shows that the measures included within this Proposed Scoping Plan can be implemented with a net positive effect on California's long-term economic growth. The evaluation of related public health and environmental benefits of the various measures also shows that implementation will result in not only reduced greenhouse gas emissions and improved public health, but also in a beneficial effect on California's environment. The results of these evaluations are presented in Chapter III.

AB 32 includes specific criteria that ARB must consider before adopting regulations for market-based compliance mechanisms to implement a greenhouse gas reduction program, and directs the Board, to the extent feasible, to design market-based compliance mechanisms to prevent any increase in the emissions of toxic air contaminants or criteria air pollutants. In the development of regulations that contain market mechanisms, ARB will consider the economic, environmental and public health effects, and the evaluation of potential localized impacts. These results will be used to institute appropriate economic, environmental and public health safeguards.

ARB has also designed the recommendation to ensure that reductions will come from throughout the California economy. Transportation accounts for the largest share of California's greenhouse gas emissions. Accordingly, a large share of the reduction of greenhouse gas emissions from the recommended measures comes from this sector. Measures include the inclusion of transportation fuels in the cap-and-trade program, the Low Carbon Fuel Standard to reduce the carbon intensity of transportation fuels, enforcement of regulations that reduce greenhouse gas emissions from vehicles, and policies to reduce transportation emissions by changes in future land use patterns and community design as well as improvements in public transportation.

In the Energy sector, the recommended measures increase the amount of electricity from renewable energy sources, and improve the energy efficiency of industries, homes and buildings. The inclusion of these sectors and the Industrial sector in the cap-and-trade program provides further assurance that significant cost-effective reductions will be achieved from the sectors that contribute the greatest emissions. Additional energy production from renewable resources may also rely on measures suggested in the Agriculture, Water, and the Recycling and Waste Management Sectors.

Other sectors are also called upon to cut emissions. The cap-and-trade program covers industrial sources and natural gas use. The recommended measures would require industrial processes to examine how to lower their greenhouse gas emissions and be more energy efficient, and would require goods movement operations through California's ports to be more energy efficient. Other measures address waste management, agricultural and forestry practices, as well as the transport and treatment of water throughout the state. Finally, the recommended measures address ways to reduce or eliminate the emissions of high global warming potential gases that, on a per-ton basis, contribute to global warming at a level many times greater than carbon dioxide.

As the Scoping Plan is implemented, ARB and other agencies will coordinate with the Green Chemistry Initiative, particularly in the Green Building and Recycling/Waste sectors. Green Chemistry is a fundamentally new approach to environmental protection that emphasizes environmental protection at the design stage of product and manufacturing processes, rather than focusing on end-of-pipe or end-of-life activities, or a single environmental medium, such as air, water or soil. This new approach will reduce the use of harmful chemicals, generate less waste, use less energy, and, accordingly, will contribute toward California's greenhouse gas reduction goals.

A. The Role of State Government: Setting an Example

For many years California State government has successfully incorporated environmental principles in managing its resources and running its business. The Governor has directed State agencies to sharply reduce their building-related energy use and encouraged our State-run pensions to invest in energy efficient and clean technologies.[20] The State also has been active in procuring low-emission, alternative fuel vehicles in its large fleet.

While State government has already accomplished much to reduce its greenhouse gas emissions, it can and must do more. State agencies must lead by example by continuing to reduce their greenhouse gas emissions. Therefore, California State government has established a target of reducing its greenhouse gas emissions by a *minimum* of 30 percent below its estimated business-as-usual emissions by 2020 – approximately a 15 percent reduction from current levels.

As an owner-operator of key infrastructure, State government has the ability to ensure that the most advanced, cost-effective environmental performance requirements are used in the design, construction, and operation of State facilities. As a purchaser with significant market power, State government has the ability to demand that the products and services it procures contribute positively toward California's targets to reduce greenhouse gas emissions, such as through the efforts of Environmentally Preferable Purchasing. As an investor of more than $400 billion,[21] State government has the ability to prioritize low-carbon investments. With more than 350,000 employees, State government is uniquely situated to adopt and implement policies that give State workers the ability to decrease their individual carbon impact, including encouraging siting facilities within communities to enhance balance in jobs and housing, encouraging carpooling, biking, walking, telecommuting, the use of public transit, and the use of alternative work schedules.

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[20]Governor Schwarzenegger signed Executive Order Executive Order S-20-04 on December 14, 2004. This Order contains a number of directives, including a set of aggressive goals for reducing state building energy use and requested the California Public Employees Retirement System (CalPERS) and the California State Teachers Retirement System (CalSTRS) to target resource-efficient buildings for real estate investments and commit funds toward clean, efficient and sustainable technologies.

[21] CalPERS and CalSTRS are the two largest pension systems in the nation with investments in excess of $400 billion as of August 2008.

Myriad opportunities exist for California State government to operate more efficiently. These opportunities will not only reduce greenhouse gas emissions but also will produce savings for California taxpayers. Initiatives now underway that will contribute to the State government reduction target include the Governor's Green Building Initiative and the Department of General Services' efforts to increase the number of fuel-efficient vehicles in the State fleet.

Major efforts to expand renewable energy use and divest from coal-fired power plants are currently underway. Together with energy conservation and efficiency strategies on water projects, roadways, parks, and bridges, these efforts all play major roles in reducing the State's greenhouse gas emissions. State agencies should review their travel practices and make greater use of teleconferencing and videoconferencing to reduce the need for business travel, particularly air travel.

State agencies are now examining their policies and operations to determine how they can reduce their greenhouse gas emissions. These findings will be instrumental as each cabinet-level agency registers with the California Climate Action Registry (CCAR) to record and report their individual carbon footprints. The Climate Action Team has created a new State Government Operations sub-group that will work closely with the agencies to review the results of their evaluations and the CCAR reports to determine how best to achieve the maximum reductions possible.

State agencies must take the lead in driving this low-carbon economy by reducing their own emissions, and also by serving as a catalyst for local government and private sector activity. New "Best Practices" implemented by State agencies can be transferred to other entities within California, the nation, and internationally. By increasing cooperation and coordination across organizational boundaries, State government will maximize the experience and contributions of each agency involved to achieve the 30 percent reduction of greenhouse gas emissions while growing the economy and protecting the environment.

State government's impact on emissions goes far beyond its own buildings, vehicles, projects, and employees. State government casts a sizable "carbon shadow"– that is, the climate change impact of legislative, executive, and financial actions of State agencies that affect Californians now and in the future. For example, the California Energy Commission (CEC) recently initiated a proceeding to consider how to align its permitting process with the State's greenhouse gas and renewable energy policy goals. ARB intends to work closely with the CEC during this proceeding. New power plants, both fossil-fuel fired and renewable generation, will be a critical part of the state's electricity mix in coming decades. The investments that are made in this new infrastructure in the next several years will become part of the backbone of the state's electricity supply for decades to come. This timely investigation will be a critical element of California's ability to meet the AB 32 emissions reduction target for 2020, the ambitious target set by the Governor for 2050, and also the specific goal of achieving 33 percent renewables in the state's electricity mix. The Governor's Office of Planning and Research and the Resources Agency are developing proposed amendments to the California Environmental Quality Act (CEQA) Guidelines to provide guidance on how to address greenhouse gases in CEQA documents. As required by SB 97 (Chapter 185, Statutes of 2007), the amended CEQA guidelines will be adopted by January 1, 2010.

In addition, agencies such as the California Labor and Workforce Development Agency, the Business, Transportation and Housing Agency and the newly created Green Collar Jobs Council (AB 3018, Chapter 312, Statutes of 2008) are dedicated to economic development, training, safety, labor relations, and employment development throughout the State. ARB will coordinate with the Council and also with other State agencies to address workforce needs and facilitate a smooth transition to California's emerging low-carbon economy that maximizes economic development and employment opportunities in California.

The State expends funds to provide services to California residents – from preserving our natural resources to building and maintaining infrastructure like roads, bridges and dams. California residents should reap all of the benefits of these projects, including any associated quantifiable and marketable reductions in greenhouse gas emissions. Because of this, California should retain ownership of these greenhouse gas emissions reductions and use them to promote the goals of AB 32 and other goals of the state.

California State government can also lead through example by aligning its efforts to reduce greenhouse gas emissions with efforts to protect and improve public health. As a new member of the Climate Action Team, the Department of Public Health will help ensure that measures to combat global warming also incorporate public health protection and improvement strategies. As discussed below, these and many other State leadership efforts can be built upon at the local level as well.

B. The Role of Local Government: Essential Partners

Local governments are essential partners in achieving California's goals to reduce greenhouse gas emissions. They have broad influence and, in some cases, exclusive authority over activities that contribute to significant direct and indirect greenhouse gas emissions through their planning and permitting processes, local ordinances, outreach and education efforts, and municipal operations. Many of the proposed measures to reduce greenhouse gas emissions rely on local government actions.

Over 120 California cities have already signed on to the U.S. Conference of Mayors Climate Protection Agreement. In addition, over 30 California cities and counties have committed to developing and implementing Climate Action Plans. Many local governments and related organizations have already begun educating Californians on the benefits of energy efficiency measures, public transportation, solar homes, and recycling. These communities have not only demonstrated courageous leadership in taking initiative to reduce greenhouse gas emissions, they are also reaping important co-benefits, including local economic benefits, more sustainable communities, and improved quality of life.

Land use planning and urban growth decisions are also areas where successful implementation of the Scoping Plan relies on local government. Local governments have primary authority to plan, zone, approve, and permit how and where land is developed to accommodate population growth and the changing needs of their jurisdictions. Decisions on how land is used will have large impacts on the greenhouse gas emissions that will result from the transportation, housing, industry, forestry, water, agriculture, electricity, and natural gas sectors.

To provide local governments guidance on how to inventory and report greenhouse gas emissions from government buildings, facilities, vehicles, wastewater and potable water treatment facilities, landfill and composting facilities, and other government operations, ARB recently adopted the Local Government Operations Protocol. ARB encourages local governments to use this protocol to track their progress in achieving reductions from municipal operations. ARB is also developing an additional protocol for community emissions. This protocol will go beyond just municipal operations and include emissions from the community as a whole, including residential and commercial activity. These local protocols will play a key role in ensuring that strategies that are developed and implemented at the local level, like urban forestry and greening projects, water and energy efficiency projects, and others, can be appropriately quantified and credited toward California's efforts to reduce greenhouse gas emissions.

In addition to tracking emissions using these protocols, ARB encourages local governments to adopt a reduction goal for municipal operations emissions and move toward establishing similar goals for community emissions that parallel the State commitment to reduce greenhouse gas emissions by approximately 15 percent from current levels by 2020. To consolidate climate action resources and aid local governments in their emission reduction efforts, the ARB is developing various tools and guidance for use by local governments, including the next generation of best practices, case studies, a calculator to help calculate local greenhouse gas emissions, and other decision support tools.

The recent passage of SB 375 (Steinberg, Chapter 728, Statutes of 2008) creates a process whereby local governments and other stakeholders work together within their region to achieve reduction of greenhouse gas emissions through integrated development patterns, improved transportation planning, and other transportation measures and policies. The implementation of regional transportation-related greenhouse gas emissions targets and SB 375 are discussed in more detail in Section C.

C. Emissions Reduction Measures

The Scoping Plan will build on California's successful history of balancing effective regulations with economic progress. Several types of measures have been recommended. The plan includes a California cap-and-trade program that will be integrated with a broader regional market to maximize cost-effective opportunities to achieve GHG emissions reductions. The plan also includes transformational measures that are designed to help pave the path toward California's clean energy future. For example, the Low Carbon Fuel

Standard (LCFS) is a performance standard with flexible compliance mechanisms that will incent the development of a diverse set of clean, low-carbon transportation fuel options. Similarly, the plan recognizes the importance of local and regional government leadership in ensuring that California's land use and transportation planning processes are designed to be consistent with efforts to achieve a clean energy future and to protect and enhance public health and safety.

The Proposed Scoping Plan also contains a number of targeted measures that are designed to overcome existing barriers to action such as lack of information, lack of coordination, or other regulatory and institutional factors. Energy efficiency is a classic example where cost-effective action often is not taken due to lack of complete information, relatively high initial costs, and mismatches between who pays for and who benefits from efficiency investments. These problems often mean that efficiency measures are not taken that would save money in the long term for small businesses, home owners and renters. While California has a long history of success in implementing regulations and programs to encourage energy efficiency, innovative methods to overcome these economic and information barriers are needed to provide the benefits of increased efficiency to more Californians and to meet our greenhouse gas emissions reduction goals.

Several of the recommended measures complement each other. For example, the LCFS will provide clean transportation fuel options. The Pavley performance standards help deploy vehicles that can use many of the low-carbon fuels, including advanced biofuels, electricity and hydrogen. The combined operation of both programs will make it more likely that more efficient, less polluting vehicles will use the cleanest possible fuels. In addition, both of these programs will benefit from ARB's zero-emission vehicle program, which focuses on deployment of plug-in battery-electric and fuel cell vehicles. All of these strategies are expandable beyond 2020, and are needed as vital components to reach the State's 2050 goal.

The cap-and-trade program creates an emissions limit or "cap" on the sectors responsible for the vast majority of California's greenhouse gas emissions and provides capped sources significant flexibility in how they collectively achieve the reductions necessary to meet the cap. The other measures in these capped sectors provide a clear path toward achieving reductions required by the cap, while simultaneously addressing market barriers and creating the low-carbon energy options needed to achieve our long term climate goals. In the design of the cap-and-trade program, ARB will also evaluate possible ways to include features that complement the other measures, such as consideration of allowance set-asides that could be used to help achieve or exceed the aggressive energy efficiency goals included in this Plan.

Both required measures and other cost-effective actions by capped sectors will contribute toward achievement of the cap. For example, increasing energy efficiency will reduce electricity demand, thereby reducing the need for utilities to submit allowances to comply with the cap-and-trade program. In this way, energy efficiency contributes to real reductions toward the cap. Expiration of existing utility long-term contracts with coal plants will reduce GHG emissions when such generation is replaced by renewable generation, coal with carbon sequestration, or natural gas generation, which emits less CO_2 per megawatt-hour.

Additionally, measures and other actions that result in reductions in energy demand 'downstream' of capped sectors will help achieve the cap. For example, the Pavley vehicle standards, building efficiency standards, and land use planning that contributes to reduced transportation fuel demand will all reduce emissions by reducing the demand for upstream energy production. These downstream entities will further benefit from these reductions by avoiding any costs that would be passed through from a cap-and-trade system.

Discrete Early Actions

In September 2007, ARB approved a list of nine Discrete Early Actions to reduce greenhouse gas emissions and is currently in the process of developing regulations and programs based on these measures. Regulations implementing the Discrete Early Action measures must be adopted and in effect by January 1, 2010 (HSC §38560.5 (b)). All the Discrete Early Actions are included in the recommended measures and are shown below in Table 4.

Table 4: Anticipated Board Consideration Dates for Discrete Early Actions

Discrete Early Action	Anticipated Board Consideration
Green Ports – Ship Electrification at Ports	December 2007 – Adopted
Reduction of High GWP Gases in Consumer Products	June 2008 – Adopted
SmartWay – Heavy-Duty Vehicle Greenhouse Gas Emission Reduction (Aerodynamic Efficiency)	December 2008
Reduction of Perfluorocarbons from Semiconductor Manufacturing	February 2009
Improved Landfill Gas Capture	January 2009
Reduction of HFC-134a from Do-It-Yourself Motor Vehicle Servicing	January 2009
SF_6 Reductions from the Non-Electric Sector	January 2009
Tire Inflation Program	March 2009
Low Carbon Fuel Standard	March 2009

The following sections describe the recommended measures in this Proposed Scoping Plan. Additional information about these measures is provided in Appendix C.

1. California Cap-and-Trade Program Linked to Western Climate Initiative Partner Jurisdictions

Implement a broad-based California cap-and-trade program to provide a firm limit on emissions. Link the California cap–and-trade program with other Western Climate Initiative Partner programs to create a regional market system to achieve greater environmental and economic benefits for California. Ensure California's program meets all applicable AB 32 requirements for market-based mechanisms.

California is working closely with other states and provinces in the Western Climate Initiative (WCI) to design a regional cap-and-trade program that can deliver reductions of greenhouse gas emissions throughout the region. ARB will develop a cap-and-trade program for California that will link with the programs in the other WCI Partner jurisdictions to create a regional cap-and-trade program. The WCI Partner jurisdictions released the program design document on September 23, 2008 (see Appendix D). ARB will continue to work with the WCI Partner jurisdictions to develop and implement the cap-and-trade program. ARB will also design the California program to meet the requirements of AB 32, including the need to consider any potential localized impacts and ensure that reductions are enforceable by the Board.

Based on the requirements of AB 32, regulations to implement the cap-and-trade program need to be developed by January 1, 2011, with the program beginning in 2012. This rule development schedule will be coordinated with the WCI timeline for developing a regional cap-and-trade program. Preliminary plans for this rulemaking are described later in this section.

A cap-and-trade program sets the total amount of greenhouse gas emissions allowable for facilities under the cap and allows covered sources, including producers and consumers of energy, to determine the least expensive strategies to comply. The emissions allowed under the cap will be denominated in metric tons of CO_2E. The currency will be in the form of allowances which the State will issue based upon the total emissions allowed under the cap during any specific compliance period. Emission allowances can be banked for future use, encouraging early reductions and reducing market volatility. The ability to trade allows facilities to adjust to changing conditions and take advantage of reduction opportunities when those opportunities are less expensive than buying additional emissions allowances.

Provisions could be made to allow a limited use of surplus reductions of greenhouse gas emissions that occur outside of the cap. These additional reductions are known as offsets and are discussed further below. In order to be used to meet a source's compliance obligation, offsets will be subject to stringent criteria and verification procedures to ensure their enforceability and consistency with AB 32 requirements.

Appendix C describes the fundamentals of a cap-and-trade program and program design elements. Appendix D contains the WCI Design Recommendations and related background documents.

California Cap-and-Trade Program

By providing a firm cap on 85 percent of the state's greenhouse gas emissions, the cap-and-trade regulatory program is an essential component of the overall plan to meet the 2020 target and provides a robust mechanism to achieve the additional reductions needed by 2050. To meet the emissions reduction target under AB 32, the limit on emissions allowed under the cap, plus emissions from uncapped sources, must be no greater than the 2020 emissions goal.

By setting a limit on the quantity of greenhouse gases emitted, a well-designed cap-and-trade program will complement other measures for entities within covered sectors. Additionally, starting a cap-and-trade program now will set us on a course to achieve further emissions cuts well beyond 2020 and ensure that California is primed to take advantage of opportunities for linking with other programs, including future federal and international efforts.

The proposed cap-and-trade measure phases in the following sectors:

Starting in the first compliance period (2012):

- Electricity generation, including imports not covered by a WCI Partner jurisdiction
- Large industrial facilities that emit over 25,000 metric tons CO_2E per year.

Starting in the second compliance period (2015):

- Upstream treatment of industrial fuel combustion at facilities with emissions at or below 25,000 metric tons CO_2E, and all commercial and residential fuel combustion regulated where the fuel enters into commerce
- Transportation fuel combustion regulated where the fuel enters into commerce.

For some energy-intensive industrial sources such as cement, stringent requirements in California, either through inclusion in a cap-and-trade program or through source-specific regulation, have the potential to create a disadvantage for California facilities relative to out-of-state competitors unless those locations have similar requirements (e.g., through the WCI). If production shifts outside of California in order to operate without being subject to these requirements, emissions could remain unchanged or even increase. This is referred to as "leakage." AB 32 requires ARB to design measures to minimize leakage. Minimizing leakage will be a key consideration when developing the cap-and-trade regulation and the other AB 32 program measures.[22]

[22] The cement industry is an example of a sector that may be susceptible to this type of leakage, and the Draft Scoping Plan included consideration of a measure to institute an intensity standard at concrete batch plants that would consider this type of life-cycle emissions. ARB will evaluate whether this type of intensity standard could be incorporated into the cap-and-trade program or instituted as a complementary measure during the cap-and-trade rulemaking.

As shown in Table 5, the preliminary estimate of the cap on greenhouse gas emissions for sectors covered by the cap-and-trade program is 365 $MMTCO_2E$ in 2020, which covers about 85 percent of California's total greenhouse gas emissions.[23] Greenhouse gas emissions from most of the sectors covered by a cap-and-trade program will also be governed by other measures, including performance standards, efficiency programs, and direct regulations. These other measures will provide real reductions which will contribute reductions toward the cap.

In addition, ARB will work closely with the CPUC, CEC, and The California Independent System Operator to ensure that the cap-and-trade program works within the context of the State's energy policy and enables the reliable provision of electricity.

Table 5: Sector Responsibilities Under Cap-and-Trade Program ($MMTCO_2E$ in 2020)

Sector	Projected 2020 Business-as-Usual Emissions		Preliminary 2020 Emissions Limit under Cap-and-Trade Program
	By Sector	Total	
Transportation	225	512	365
Electricity	139		
Commercial and Residential	47		
Industry	101		

Linkage with the Western Climate Initiative Partner Jurisdictions

The WCI was formed in 2007. Members are California, Arizona, New Mexico, Oregon, Washington, Utah, and Montana, and the Canadian provinces of British Columbia, Manitoba, Ontario, and Quebec. The WCI Partner jurisdictions, including California, have adopted goals to reduce greenhouse gas emissions that, in total, reduce regional emissions to 15 percent below 2005 levels by 2020. This regional goal is approximately equal to California's goal of returning to 1990 levels by 2020. A cap-and-trade program is one element of the effort by the WCI Partner jurisdictions to identify, evaluate, and implement ways to reduce greenhouse gas emissions and achieve related co-benefits.

The WCI Partner jurisdictions released their recommendation for the design of a regional cap-and-trade program in September 2008. This design document and the

[23] The actual cap for the program will be established as part of the rulemaking process. The preliminary cap of 365 $MMTCO_2E$ in 2020 assumes that all of California's electricity imports would be covered under a California cap. Because a significant portion of California's imported electricity is from power plants located in other WCI Partner Jurisdictions, emissions from those sources could be included in the cap of the states within which the power plants are located. In establishing the California cap, ARB will need to consider the degree to which emissions from these sources are addressed as part of the WCI regional market.

background paper that accompanied it are presented in Appendix D. These recommendations were developed collaboratively by the WCI Partner jurisdictions, including California, with a goal of achieving regional targets to reduce greenhouse gas emissions equitably and effectively. The WCI Partner jurisdictions' recommendations are generally consistent with the recommendations provided in June 2007 by the California Market Advisory Committee,[24] the recommendations provided to ARB by the California Public Utilities Commission and the California Energy Commission in March 2008,[25] and the proposed opinion released by the two Commissions in September 2008.[26]

Participating in a regional system has several advantages for California. The reduction of greenhouse gas emissions that can be achieved collectively by the WCI Partner jurisdictions are approximately double what can be achieved through a California-only program. The broad scope of a WCI-wide market will provide additional opportunities for reduction of emissions, therefore providing greater market liquidity and more stable carbon prices within the program. The regional system also significantly reduces the potential for leakage, which is a shift in economic and emissions activity out of California that could hurt the state's economy without reducing global greenhouse gas emissions. Harmonizing the approach and timing of California's requirements for reducing greenhouse gas emissions with other states and provinces in the region can encourage retention of local businesses in the state. Further, by creating a cost-effective regional market system, California and the other WCI Partner jurisdictions will continue to demonstrate leadership in preparation for future federal and international climate action.

To achieve the individual WCI Partner jurisdiction goals and the regional goal, each WCI Partner jurisdiction will have an allowance budget based on its goal that declines to 2020. For example, California's allowance budget will be based on the level of emissions needed to achieve the AB 32 target for 2020, as described above. Once California links with the other WCI Partner jurisdictions, allowances could be traded across state and provincial boundaries. As a result of trading, emissions in a

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[24] Recommendations of the Market Advisory Committee to the California Air Resources Board. *Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California*. June 30, 2007. p. 19. http://www.climatechange.ca.gov/publications/market_advisory_committee/2007-06-29_MAC_FINAL_REPORT.PDF (accessed October 12, 2008) CalEPAThe Market Advisory Committee (MAC) consisted of a consortium of economists, policy makers, academics, government representatives, and environmental advocates who came together through the auspices of CalEPA, pursuant to Executive Order S-20-06 from Governor Schwarzenegger.

[25] Joint Agency Decision of the CEC and the CPUC. *Final Adopted Interim Decision on Basic Greenhouse Gas Regulatory Framework for Electricity and Natural Gas Sectors*, March 13, 2008. Document number CEC-100-2008-002-F. http://www.energy.ca.gov/2008publications/CEC-100-2008-002/CEC-100-2008-002-F.PDF (accessed October 12, 2008)

[26] Joint Agency proposed final opinion of the CEC and the CPUC. *Proposed Final Opinion on Greenhouse Gas Regulatory Strategies*. Published September 12, 2008 and to be considered for adoption on October 16, 2008 by the CEC and the CPUC. Document Number CEC-100-2008-007-D http://www.energy.ca.gov/ghg_emissions/index.html (accessed October 12, 2008)

state may vary from its allowance budget, although total regional emissions will not exceed the regional cap.

The overall number of allowances issued in a given year by the WCI Partner jurisdictions will set a limit on emissions from sectors covered by the program for the region. Details of distribution of allowances will be established by each partner within the general guidelines set forth in the WCI program design framework. The WCI Partner jurisdictions have agreed to consider standardizing allowance distribution across specific sectors if necessary to address competitiveness issues. In addition, the WCI Partner jurisdictions have agreed to phase in regionally coordinated auctions of allowances, with a minimum percentage of allowances auctioned in each period starting with 10 percent in the first compliance period and increasing to 25 percent in 2020. WCI partners aspire to reach higher auction percentages over time, possibly to 100 percent. Under the program design, each WCI Partner jurisdiction, including California, can auction a greater portion of its allowance budget in any compliance period. The distribution of California's allowances will be determined during the cap-and-trade rulemaking process, as discussed below.

The WCI Partner jurisdictions are also proposing the use of an allowance reserve price for the first 5 percent of the auctioned allowances in the regional cap. A reserve price will help to ensure that the cap is set at a level that will motivate real emissions reductions and may provide an opportunity for the regional cap-and-trade program to provide reductions that exceed the regional target.

A regional coordinated cap-and-trade program with strong reporting and enforcement rules will provide a high degree of certainty that emissions will not exceed targeted levels and that leakage will not occur.

Federal Action

A cap-and-trade program is expected to be a significant element in any future federal action taken to reduce greenhouse gas emissions. ARB's efforts to design a broad cap-and-trade system that works in concert with sector- or source-related measures and meets the requirements of AB 32 can serve as a model for a federal program. An effective, enforceable regional cap-and-trade program can promote the type of federal legislation needed to meet the pressing challenge of climate change. In the event that California businesses, organizations, or individuals hold regional allowances when a federal system is implemented, California will work to ensure that those allowances continue to have value, either in a continuing regional program or within the federal program.

Cap-and-Trade Rulemaking

To implement the cap-and-trade program, ARB will embark on regulatory development that includes extensive and broad-based public participation. Major program design elements will include setting an emissions cap in conjunction with the WCI Partner jurisdictions, determining the method of distributing both allowances and revenues raised through auctions, and establishing the rules for the use of offsets. ARB will continue to work with all affected stakeholders, State and local agencies, and our WCI partners to create a robust regional market system.

After adoption of the Scoping Plan, ARB will establish a formal structure to elicit ongoing participation in the rulemaking process from a wide range of affected stakeholders. While the process will be open to involvement by all interested parties, ARB anticipates creation of a series of focused working groups that include participation by representatives of the regulated community, environmental and community advocates and other public interest groups, prominent academics with expertise in cap-and-trade issues and new technology development, local air pollution control districts, stakeholders in the WCI, and other State agencies with existing authority for regulating capped sectors.

This process will integrate economic and administrative design considerations and include consideration of environmental and public health issues. ARB will convene a series of technical workshops to examine mechanisms to address the concerns related to the cap-and-trade program raised by the Environmental Justice Advisory Committee and other stakeholders. The first workshop will explore cap-and-trade program design options that could provide incentives to maximize additional environmental and economic benefits, and to analyze the proposed program to prevent increases in emissions of toxic air contaminants or criteria pollutants through the design and architecture of the program itself. Similar technical workshops will focus on issues related to offsets and the WCI proposal.

Allowances and Revenues

Emission allowances represent a significant economic value whether they are freely allocated or sold through auction. Section E includes a preliminary discussion of some of the options that have been suggested for use of allowance value or revenues. ARB will evaluate the possible uses of allowances or revenues as part of the rulemaking process. One approach would be to dedicate a portion of the allowances for such purposes as rewarding early actions to reduce emissions, providing incentives for local governments and others to promote energy efficiency, better land use planning, and other reduction strategies, and targeting projects to reduce emissions in low-income or disadvantaged communities. This type of dedicated use of allowances is typically referred to as an allowance 'set-aside.'

The California Public Utilities Commission and the California Energy Commission addressed the question of allocation and auction of allowances in their joint proceeding on implementation of AB 32 for the Electricity and Natural Gas sectors. They have recently released a proposed opinion that recommends to ARB a transition to 100 percent auction for the Electricity sector by 2016.[27] The CPUC and CEC

[27] Op. Cit. The proposed opinion has not yet been voted on by either the CPUC or the CEC. The Commissions are expected to vote on this proposed opinion before the December Board meeting when the Proposed Scoping Plan will be considered for approval.

included in their draft opinion the recommendation that all auction revenues be used for purposes related to AB 32, and all revenue from allowances allocated to the Electricity sector and received by retail providers would be used for the benefit of the Electricity sector to support investments in renewable energy, efficiency, new energy technology, infrastructure, customer bill relief, and other similar programs.

The Market Advisory Committee also recommended the eventual transition to full auction within the cap-and-trade program, noting that a system in which California ultimately auctions all of its emission allowances is consistent with fundamental objectives of cost-effectiveness, fairness and simplicity.[28] ARB agrees that a transition to a 100 percent auction is a worthwhile goal for distributing allowances. However a broad set of factors must be considered in evaluating the potential timing of a transition to a full auction including competiveness, potential for emissions leakage, the effect on regulated vs. unregulated industrial sectors, the overall impact on consumers, and the strategic use of auction revenues.

Allowance allocation and revenue use decisions can greatly affect the equity of a cap-and-trade system. Addressing both these issues will be a major part of the rulemaking process. ARB will seek input from a broad range of experts in an open public process regarding the options for allocation and revenue use under consideration by ARB and the WCI Partner jurisdictions. This process will evaluate various mechanisms ARB is considering for allowance distribution and potential uses of allowance value, including the recommendations offered by CPUC and CEC. Issues to be considered will include the appropriate timing and structure of a transition to full auction of allowances, the potential need to harmonize the allocation process regionally for certain sectors subject to inter-state competition, and equity across the various sectors here in California.

Offsets

Individual projects can be developed to achieve the reduction of emissions from activities not otherwise regulated, covered under an emissions cap, or resulting from government incentives. These projects can generate "offsets," i.e., verifiable reductions of emissions whose ownership can be transferred to others. The cap-and-trade rulemaking will establish appropriate rules for use of offsets. As required by AB 32, any reduction of greenhouse gas emissions used for compliance purposes must be real, permanent, quantifiable, verifiable, enforceable, and additional (HSC §38562(d)(1) and (2)). Offsets used to meet regulatory requirements must be quantified according to Board-adopted methodologies, and ARB must adopt a regulation to verify and enforce the reductions (HSC §38571). The criteria developed will ensure that the reductions are quantified accurately and are not double-counted within the system.

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[28]Recommendations of the Market Advisory Committee to the California Air Resources Board. *Recommendations for Designing a Greenhouse Gas Cap-and-Trade System for California*. June 30, 2007. p. 55. http://www.climatechange.ca.gov/publications/market_advisory_committee/2007-06-29_MAC_FINAL_REPORT.PDF (accessed October 12, 2008)

Offsets can provide regulated entities a source of low-cost emissions reductions. Reductions from compliance offset projects must be quantified using rigorous measurement and enforcement protocols that provide a basis to determine whether the reductions are also additional, i.e., beyond what would have happened in the absence of the offset project. Establishing that reductions are additional is one of the major challenges in establishing the validity of particular offset projects. Once a project can quantify emissions using an approved methodology, the reductions of emissions must be verified to ensure that reductions actually occurred.

While some offsets provide benefits, allowing unlimited offsets would reduce the amount of reductions of greenhouse gas emissions occurring within the sectors covered by the cap-and-trade program. This could reduce the local economic, environmental and public health co-benefits and delay the transition to low-carbon energy systems within the capped sectors that will be necessary to meet our long term climate goals. The limit on the use of offsets and allowances from other systems within the WCI Partner jurisdiction program design assures that a majority of the emissions reductions required from 2012 to 2020 occur at entities and facilities covered by the cap and trade program. Consequently, the use of offsets and allowances from other systems are limited to no more than 49 percent of the required reduction of emissions. This quantitative limit will help provide balance between the need to achieve meaningful emissions reductions from capped sources with the need to provide sources within capped sectors the opportunity for low-cost reduction opportunities that offsets can provide. The WCI offset program may incorporate flexibility to use offsets and non-WCI allowances across the three compliance periods, which each WCI Partner jurisdiction could use at its discretion. ARB will apply the limit on offsets that is within its jurisdiction, such that the allowable offsets in each compliance period is less than half of the emissions reductions expected from capped sectors in that compliance period. Each WCI Partner jurisdiction may choose to adopt a more stringent limit on the use of offsets and non-WCI allowances.

Offsets can also encourage the spread of clean, low carbon technologies outside California. High quality offset projects located outside the state can help lower the compliance costs for regulated entities in California, while reducing greenhouse gas emissions in areas that would otherwise lack the resources needed to do so. International projects may also have significant environmental, economic and social benefits. Projects in the Mexican border region may be of particular interest, considering the opportunity to realize considerable co-benefits on both sides of the border. The Governor has recently signed a Memorandum of Understanding with the six Mexican border states that calls for cooperation on the development of project protocols for Mexican greenhouse gas emissions reduction projects.[29] Additionally,

[29] Memorandum of Understanding on Environmental Cooperation between the California Environmental Protection Agency, the California Department of Food and Agriculture and the California Resources Agency of the State of California, United States of America and the Ministry of Environment and Natural Resources of the United Mexican States. February 13, 2008. http://gov.ca.gov/pdf/press/021308_MOU_English.pdf (accessed October 12, 2008)

defining project types related to imported commodities (such as cement) would enable California to provide incentives to reduce emissions associated with products that are imported into the state for our consumption.

California is committed to working at the international level to reduce greenhouse gas emissions globally and finding ways to support the adoption of low-carbon technologies and sustainable development in the developing world. ARB will work with WCI Partner jurisdictions and within the rulemaking process to establish an offsets program without geographic restrictions that includes sufficiently stringent criteria for creating offset credits to ensure the overall environmental integrity of the program.

One concept being evaluated for accepting offsets from the developing world is to limit offsets to those jurisdictions that demonstrate performance in reducing emissions and/or achieving greenhouse gas intensity targets in certain carbon intensive sectors (e.g., cement), or in reducing emissions or enhancing sequestration through eligible forest carbon activities in accordance with appropriate national or sub-national accounting frameworks. This could be achieved through an agreement to work jointly to develop minimum performance standards or sectoral benchmarks, backed by appropriate monitoring and accounting frameworks. Such agreements would encourage early action in developing countries toward binding commitments, and could also reduce concerns about competitiveness and risks associated with carbon leakage.

2. California Light-Duty Vehicle Greenhouse Gas Standards

Implement adopted Pavley standards and planned second phase of the program. Align zero-emission vehicle, alternative and renewable fuel and vehicle technology programs with long-term climate change goals.

Passenger vehicles are responsible for almost 30 percent of California's greenhouse gas emissions. To address these emissions, ARB is proposing a comprehensive three-prong strategy – reducing greenhouse gas emissions from vehicles, reducing the carbon content of the fuel these vehicles burn, and reducing the miles these vehicles travel. Transportation fuels and regional transportation-related greenhouse gas targets are discussed later in the recommendations.

There are a number of efforts intended to reduce greenhouse gas emissions from California's passenger vehicles, including the Pavley greenhouse gas vehicle standards to achieve near-term emission reductions, the zero-emission vehicle (ZEV) program to transform the future vehicle fleet, and the Alternative and Renewable Fuel and Vehicle Technology Program created by AB 118 (Núñez, Chapter 750, Statutes of 2007).

Pavley Greenhouse Gas Vehicle Standards

AB 1493 (Pavley, Chapter 200, Statutes of 2002) directed ARB to adopt vehicle standards that lowered greenhouse gas emissions to the maximum extent technologically feasible, beginning with the 2009 model year. ARB adopted regulations in 2004 and applied to the U.S. Environmental Protection Agency (U.S. EPA) for a waiver under the federal Clean Air Act to implement the regulation. The Pavley regulations incorporate both performance standards and market-based compliance mechanisms. To obtain additional reductions from the light duty fleet, ARB plans to adopt a second, more stringent, phase of the Pavley regulations. Table 6 summarizes the estimated reduction of emissions for the Pavley regulations. In addition to delivering greenhouse gas emissions reductions, the standards will save money for Californians who purchase vehicles that comply with the Pavley standards – an estimated average of $30 each month in avoided fuel costs.

To date, 13 other states have adopted California's existing greenhouse gas standards for vehicles. Under federal law, California is the only state allowed to adopt its own vehicle standards (though other states are permitted to adopt California's more rigorous standards), but California cannot implement the regulations until U.S. EPA grants an administrative waiver. In December 2007, U.S. EPA denied California's waiver request to implement the Pavley regulations. California and others are challenging that denial in Federal court. The regulations have also been challenged by the automakers in federal courts, although to date, those challenges have been unsuccessful.

ARB is evaluating the use of feebates as a measure to achieve additional reductions from the mobile source sector, either as a backstop to the Pavley regulation if the regulation cannot be implemented, or as a supplement to Pavley if the waiver is approved and the regulation takes effect. AB 32 specifically states that if the Pavley regulations do not remain in effect, ARB shall implement alternative regulations to control mobile sources to achieve equivalent or greater reductions of greenhouse gas emissions (HSC §38590). ARB is currently evaluating the use of a feebate program as the mechanism to secure these reductions. A feebate regulation would combine a rebate program for low-emitting vehicles with a fee program for high-emitting vehicles. This program would be designed in a way to generate equivalent or greater cumulative reductions of greenhouse gas emissions compared to what would have been achieved under the Pavley regulations. ARB would also evaluate the potential to expand the program to include additional vehicle classes not currently included in the Pavley program for further greenhouse gas benefits.

If the U.S. EPA grants California's request for a waiver to proceed with implementation of the Pavley regulations, we will analyze the potential for pursuing a feebate program that could complement the Pavley regulations and achieve additional reductions of greenhouse gas emissions.

Zero-Emission Vehicle Program

The Zero Emission Vehicle (ZEV) program will play an important role in helping California meet its 2020 and 2050 greenhouse gas emissions reduction requirements. Through 2012, the program requires placement of hundreds of ZEVs (including hydrogen fuel cell and battery electric vehicles) and thousands of near-zero emission vehicles (plug-in hybrids, conventional hybrids, compressed natural gas vehicles). In the mid-term (2012-2015), the program will require placement of increasing numbers of ZEVs and near-zero emission vehicles in California. In 2009, the Board will consider a proposal that is currently being developed to ensure that the ZEV program is optimally designed to help the State meet its 2020 target and put us on the path to meeting our 2050 target of an 80 percent reduction in greenhouse gas emissions.

It is important to note that while the use of both battery-powered electric vehicles and plug-in hybrids (which can be plugged in to recharge batteries) is not expected to increase electricity demand in the near term, over the longer term these technologies could result in meaningful new electricity demand. However, the expected increased electricity demand is likely to be met by off peak vehicle battery charging (i.e., overnight) to provide a means of load leveling and other possible benefits.[30]

Air Quality Improvement Program/Alternative and Renewable Fuel and Vehicle Technology Program

Under AB 118 (Núñez, Chapter 750, Statutes of 2007), ARB is administering the Air Quality Improvement Program, which provides approximately $50 million per year for grants to fund clean vehicle/equipment projects and research on the air quality impacts of alternative fuels and advanced technology vehicles.

AB 118 also created the Alternative and Renewable Fuel and Vehicle Technology Program and authorized CEC to spend up to $120 million per year for over seven years (from 2008-2015) to develop, demonstrate, and deploy innovative technologies to transform California's fuel and vehicle types. This program creates the opportunities for investment in technologies and fuels that will help meet the Low Carbon Fuel Standard, the AB 1007 (Pavley, Chapter 371, Statutes of 2005) goal of increasing alternative fuels, the AB 32 goal of reducing greenhouse gas emissions to 1990 levels by 2020, and the State's overall goal of reducing greenhouse gas emissions 80 percent below 1990 levels by 2050. CEC and ARB are coordinating closely in the implementation of AB 118. In the long-term, programs to reduce greenhouse gas emissions from cars would reduce highway funds because less fuel would be sold, reducing tax revenue. In coordination with other State agencies, ARB will continue to evaluate the potential impacts of these shifts and identify potential solutions.

[30] There is also a potential for battery-electric and hybrid vehicles (both plug-in and traditional hybrid-electric) to be used in the future to provide electricity back into the electricity grid during times of especially high demand (peak periods).

Table 6: California Light-Duty Vehicle Greenhouse Gas Standards Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
T-1	Pavley I and II – Light-Duty Vehicle Greenhouse Gas Standards	31.7
	Total	**31.7**

3. Energy Efficiency

Maximize energy efficiency building and appliance standards, and pursue additional efficiency efforts including new technologies, and new policy and implementation mechanisms. Pursue comparable investment in energy efficiency from all retail providers of electricity in California (including both investor-owned and publicly-owned utilities).

Energy-efficiency measures for both electricity and natural gas can reduce greenhouse gas emissions significantly. In 2003, the CPUC and CEC adopted an Energy Action Plan that prioritized resources for meeting California's future energy needs, with energy efficiency being first in the "loading order," or highest priority. Since then, this policy goal has been codified into statute through legislation that requires electric utilities to meet their resource needs first with energy efficiency.[31]

This measure would set new targets for statewide annual energy demand reductions of 32,000 gigawatt hours and 800 million therms from business as usual[32] – enough to power more than 5 million homes, or replace the need to build about ten new large power plants (500 megawatts each). These targets represent a higher goal than existing efficiency targets established by CPUC for the investor-owned utilities due to the inclusion of innovative strategies above traditional utility programs. Achieving the State's energy efficiency targets will require coordinated efforts from the State, the federal government, energy companies and customers. ARB will work with CEC and CPUC to facilitate these partnerships. A number of these measures also have the potential to deliver significant economic benefits to California consumers, including low-income households and small businesses. California's energy efficiency programs for buildings and appliances have generated more than $50 billion in savings over the past three decades. Tables 7 and 8 summarize the reduction of greenhouse gas emissions.

[31] SB 1037 (Kehoe, Chapter 366, Statutes of 2005) and AB 2021 (Levine, Chapter 734, Statutes of 2006) directed electricity corporations subject to CPUC's authority and publicly-owned electricity utilities to first meet their unmet resource needs through all available energy efficiency and demand response resources that are cost effective, reliable and feasible.

[32] The savings targeted here are additional to savings currently assumed to be incorporated in CEC's 2007 demand forecasts. However, CEC has initiated a public process to better determine the quantity of energy savings from standards, utility programs, and market effects that are embedded in the baseline demand forecast.

Efficiency

Achieving the energy efficiency target will require redoubled efforts to target industrial, agricultural, commercial, and residential end-use sectors, comprised of both innovative new initiatives that have been embraced by CEC's energy policy reports and CPUC's long-term strategic plan, and improvements to California's traditional approaches of improved building standards and utility programs.

High-efficiency distributed generation applications like fuel cell technologies can also play an important role in helping the State meet its requirements for reduction of greenhouse gas emissions. Key energy efficiency strategies, grouped by type, include:

Cross-cutting Strategy for Buildings
- "Zero Net Energy" buildings[33]

Codes and Standards Strategies
- More stringent building codes and appliance efficiency standards
- Broader standards for new types of appliances and for water efficiency
- Improved compliance and enforcement of existing standards
- Voluntary efficiency and green building targets beyond mandatory codes

Strategies for Existing Buildings
- Voluntary and mandatory whole-building retrofits for existing buildings
- Innovative financing to overcome first-cost and split incentives for energy efficiency, on-site, renewables, and high efficiency distributed generation

Existing and Improved Utility Programs
- More aggressive utility programs to achieve long-term savings

Other Needed Strategies
- Water system and water use efficiency and conservation measures
- Local government programs that lead by example and tap into local authority over planning, development, and code compliance
- Additional industrial and agricultural efficiency initiatives
- Providing real time energy information technologies to help consumers conserve and optimize energy performance

With the support of key State agencies, utilities, local governments and others, the CPUC has recently adopted the *California Long Term Energy Efficiency Strategic Plan*.[34] Released September 2008, this Plan sets forth a set of strategies toward maximizing the achievement of cost-effective energy efficiency in California's Electricity and Natural Gas sectors between 2009 and 2020, and beyond. Its

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[33] Zero net energy refers to building energy use over the course of a typical year. When the building is producing more electricity than it needs, it exports its surplus to the grid. When the building requires more electricity than is being produced on-site, it draws from the grid. Generally, when constructing a ZNE building, energy efficiency measures can result in up to 70% savings relative to existing building practices, which then allows for renewables to meet the remaining load.

[34] California Public Utilities Commission. *California Long Term Energy Efficiency Strategic Plan.* September 2008. http://www.californiaenergyefficiency.com/docs/EEStrategicPlan.pdf (accessed October 12, 2008).

recommendations are the result of a year-long collaboration by energy experts, utilities, businesses, consumer groups, and governmental organizations in California, throughout the west, nationally and internationally.

For many of the above goals and others, the Strategic Plan discusses practical implementation strategies, detailing necessary partnerships among the state, its utilities, the private sector, and other market players and timelines for near-term, mid-term and long-term success. While the Strategic Plan is the most current and innovative summary of energy efficiency strategies needed to meet State goals, additional planning and new strategies will likely be needed, both to achieve the 2020 emissions reduction goals and to set the State on a trajectory toward 2050.

Other innovative approaches could also be used to motivate private investment in efficiency improvements. One example that will be evaluated during the development of the cap-and-trade program is the creation of a mechanism to make allowances available within the program to provide incentives for local governments, third party providers, or others to pursue projects to reduce greenhouse gas emissions, including the bundling of energy efficiency improvements for small businesses or in targeted communities.

Solar Water Heating

Solar water heating systems offer a potential for natural gas savings in California. A solar water heating system offsets the use of natural gas by using the sun to heat water, typically reducing the need for conventional water heating by about two-thirds. Successful implementation of the zero net energy target for new buildings will require significant growth in California's solar water heating system manufacturing and installation industry. The State has initiated a program to move toward a self sustaining solar water heater industry. The Solar Hot Water and Efficiency Act of 2007 (SHWEA) authorized a ten year, $250-million incentive program for solar water heaters with a goal of promoting the installation of 200,000 systems in California by 2017.[35]

Combined Heat and Power

Combined heat and power (CHP), also referred to as cogeneration, produces electricity and useful thermal energy in an integrated system. The widespread development of efficient CHP systems would help displace the need to develop new, or expand existing, power plants. This measure sets a target of an additional 4,000 MW of installed CHP capacity by 2020, enough to displace approximately 30,000 GWh of demand from other power generation sources.[36]

[35] Established under Assembly Bill 1470 (Huffman, Chapter 536, Statues of 2007).

[36] Accounting for avoided transmission line losses of seven percent, this amount of CHP would actually displace 32,000 GWh from the grid.

California has supported CHP for many years, but market and other barriers continue to keep CHP from reaching its full market potential. Increasing the deployment of efficient CHP will require a multi-pronged approach that includes addressing significant barriers and instituting incentives or mandates where appropriate. These approaches could include such options as utility-provided incentive payments, the creation of a CHP portfolio standard, transmission and distribution support payments, or the use of feed-in tariffs.

Table 7: Energy Efficiency Recommendation - Electricity
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
E-1	Energy Efficiency (32,000 GWh of Reduced Demand) • Increased Utility Energy Efficiency Programs • More Stringent Building & Appliance Standards • Additional Efficiency and Conservation Programs	15.2
E-2	Increase Combined Heat and Power Use by 30,000 GWh	6.7
	Total	**21.9**

Table 8: Energy Efficiency Recommendation - Commercial and Residential
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
CR-1	Energy Efficiency (800 Million Therms Reduced Consumption) • Utility Energy Efficiency Programs • Building and Appliance Standards • Additional Efficiency and Conservation Programs	4.3
CR-2	Solar Water Heating (AB 1470 goal)	0.1
	Total	**4.4**

4. Renewables Portfolio Standard

Achieve 33 percent renewable energy mix statewide.

CEC estimates that about 12 percent of California's retail electric load is currently met with renewable resources. Renewable energy includes (but is not limited to) wind, solar, geothermal, small hydroelectric, biomass, anaerobic digestion, and landfill gas. California's current Renewables Portfolio Standard (RPS) is intended to increase that share to 20 percent by 2010. Increased use of renewables will decrease California's reliance on fossil fuels, thus reducing emissions of greenhouse gases from the Electricity sector. Based on Governor Schwarzenegger's call for a statewide 33 percent RPS, the Plan anticipates that California will have 33 percent of its electricity provided by renewable resources by 2020, and includes the reduction of greenhouse gas emissions based on this level.

Senate Bill 107 (Simitian, Chapter 464, Statutes of 2006) obligates the investor-owned utilities (IOUs) to increase the share of renewables in their electricity portfolios to 20 percent by 2010. Meanwhile, the publicly-owned utilities (POUs) are encouraged but not required to meet the same RPS. The governing boards of the state's three largest POUs, the Los Angeles Department of Water and Power (LADWP), the Sacramento Municipal Utility District (SMUD), and the Imperial Irrigation District (IID), have adopted policies to achieve 20 percent renewables by 2010 or 2011. LADWP and IID have established targets of 35 and 30 percent, respectively, by 2020.

In 2005, CEC and CPUC committed in the Energy Action Plan II to "evaluate and develop implementation paths for achieving renewable resource goals beyond 2010, including 33 percent renewables by 2020, in light of cost-benefit and risk analysis, for all load serving entities." The proposed opinion in the CPUC/CEC joint proceeding lends strong support for obtaining 33 percent of California's electricity from renewables, and states the two Commissions' belief that this target is achievable if the State commits to significant investments in transmission infrastructure and key program augmentation. As with the energy efficiency target, achieving the 33 percent goal will require broad-based participation from many parties and the removal of barriers. CEC, CPUC, California Independent System Operator (CAISO), and ARB are working with California utilities and other stakeholders to formally establish and meet this goal.

A key prerequisite to reaching a target of 33 percent renewables will be to provide sufficient electric transmission lines to renewable resource zones and system changes to allow integration of large quantities of intermittent wind and solar generation. The Renewable Energy Transmission Initiative (RETI) is a broad collaborative of State agencies, utilities, the environmental community, and renewable generation developers that are working cooperatively to identify and prioritize renewable generation zones and associated transmission projects. Although biomass, geothermal, and small-scale hydroelectric generation can provide steady baseload power, other renewable generation is intermittent (wind) or varies over time (solar). Therefore, integration of intermittent generation into the electricity system will require grid improvements so that fluctuations in power availability can be accommodated. Improved communications technology, automated demand response, electric sub-station improvements and other modern technologies must be implemented both to facilitate intermittent renewables, and to improve grid reliability.

Another key action that may help to achieve the renewable energy goals is to reduce the complexity and cost faced by small renewable developers in contracting with utilities to supply renewable generation. This is particularly important for projects offering below 20 megawatts of generation capacity. One such option may be a feed-in tariff for all RPS-eligible renewable energy facilities up to 20 megawatts in size. This mechanism was recommended in CEC's 2007 Integrated Energy Policy Report. Such a tariff, set at an appropriate level, could benefit small-scale facilities by allowing them to be brought into the electricity grid more rapidly.

For the purposes of calculating the reduction of greenhouse gas emissions in this Proposed Scoping Plan, ARB is counting emissions avoided by increasing the percentage of renewables in California's electricity mix from the current level of 12 percent to the 33 percent goal, as shown in Table 9.

Table 9: Renewables Portfolio Standard Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
E-3	Achieve a 33% renewables mix by 2020	21.3
	Total	**21.3**

5. Low Carbon Fuel Standard

Develop and adopt the Low Carbon Fuel Standard.

Because transportation is the largest single source of greenhouse gas emissions in California, the State is taking an integrated approach to reducing emissions from this sector. Beyond including vehicle efficiency improvements and lowering vehicle miles traveled, the State is proposing to reduce the carbon intensity of transportation fuels consumed in California.

To reduce the carbon intensity of transportation fuels, ARB is developing a Low Carbon Fuel Standard (LCFS), which would reduce the carbon intensity of California's transportation fuels by at least ten percent by 2020 as called for by Governor Schwarzenegger in Executive Order S-01-07.

LCFS will incorporate compliance mechanisms that provide flexibility to fuel providers in how they meet the requirements to reduce greenhouse gas emissions. The LCFS will examine the full fuel cycle impacts of transportation fuels and ARB will work to design the regulation in a way that most effectively addresses the issues raised by the Environmental Justice Advisory Committee and other stakeholders. ARB identified the LCFS as a Discrete Early Action item, and is developing a regulation for Board consideration in March 2009. A 10 percent reduction in the intensity of transportation fuels is expected to equate to a reduction of 16.5 $MMTCO_2E$ in 2020. However, in order to account for possible overlap of benefits between LCFS and the Pavley greenhouse gas standards, ARB has discounted the contribution of LCFS to 15 $MMTCO_2E$.

Table 10: Low Carbon Fuel Standard Recommendation
(MMTCO_2E in 2020)

Measure No.	Measure Description	Reductions
T-2	Low Carbon Fuel Standard (Discrete Early Action)	15
	Total	**15**

6. Regional Transportation-Related Greenhouse Gas Targets

Develop regional greenhouse gas emissions reduction targets for passenger vehicles.

Establishment of Regional Targets

On September 30, 2008, Governor Arnold Schwarzenegger signed Senate Bill 375 (Steinberg) which establishes mechanisms for the development of regional targets for reducing passenger vehicle greenhouse gas emissions. Through the SB 375 process, regions will work to integrate development patterns and the transportation network in a way that achieves the reduction of greenhouse gas emissions while meeting housing needs and other regional planning objectives. This new law reflects the importance of achieving significant additional reductions of greenhouse gas emissions from changed land use patterns and improved transportation to help achieve the goals of AB 32.

SB 375 requires ARB to develop, in consultation with metropolitan planning organizations (MPOs), passenger vehicle greenhouse gas emissions reduction targets for 2020 and 2035 by September 30, 2010. It sets forth a collaborative process to establish these targets, including the appointment by ARB of a Regional Targets Advisory Committee to recommend factors to be considered and methodologies for setting greenhouse gas emissions reduction targets. SB 375 also provides incentives – relief from certain California Environmental Quality Act (CEQA) requirements for development projects that are consistent with regional plans that achieve the targets.

Reaching the Targets

Transportation planning is done on a regional level in major urban areas, through the Metropolitan Planning Organizations. These MPOs are required by the federal government to prepare regional transportation plans (RTPs) in order to receive federal transportation dollars. These plans must reflect the land uses called out in city and county general plans. Regional planning efforts provide an opportunity for community residents to help select future growth scenarios that lead to more sustainable and energy efficient communities. Such plans should be developed through an extensive public process to provide for local accountability.

SB 375 requires MPOs to prepare a sustainable communities strategy to reach the regional target provided by ARB. MPOs would use the sustainable communities strategy for the land use pattern underlying the region's transportation plan. If the strategy does not meet the target, the MPO must document the impediments and show how the target could be met with an alternative planning strategy. The CEQA relief would be provided to those projects that are consistent with either the sustainable communities strategy or alternative planning strategy, whichever meets the target.

Many regions in California have conducted comprehensive scenario planning, called Blueprint planning, that engages a broad set of stakeholders at the local level on the impacts of land use and transportation choices. The State has allocated resources to initiate or augment existing Blueprint efforts of MPOs. These efforts focus on fostering efficient land use patterns that not only reduce vehicle travel but also accommodate an adequate supply of housing, reduce impacts on valuable habitat and productive farmland, increase resource use efficiency, and promote a prosperous regional economy. Blueprint planning can play an important role in the SB 375 process by helping inform target-setting efforts and building strong sustainable communities strategies.

Local governments will play a significant role in the regional planning process to reach passenger vehicle greenhouse gas emissions reduction targets. Local governments have the ability to directly influence both the siting and design of new residential and commercial developments in a way that reduces greenhouse gases associated with vehicle travel, as well as energy, water, and waste. A partnership of local and regional agencies is needed to create a sustainable vision for the future that accommodates population growth in a carbon efficient way while meeting housing needs and other planning goals. Integration of the sustainable communities strategies or alternative planning strategies with local general plans will be key to the achievement of these goals. State, regional, and local agencies must work together to prioritize and create the supporting policies, programs, incentives, guidance, and funding to assist local actions to help ensure regional targets are met.

Enhanced public transit service combined with incentives for land use development that provides a better market for public transit will play an important role in helping to reach regional targets.

SB 375 maintains regions' flexibility in the development of sustainable communities strategies. There are many different ways regions can plan and work toward reducing the growth in vehicle travel. Increasing low-carbon travel choices (public transit, carpooling, walking and biking) combined with land use patterns and infrastructure that support these low-carbon modes of travel, can decrease average vehicle trip lengths by bringing more people closer to more destinations. The need for integrated strategies is supported by the current transportation and land use modeling literature.

Supporting measures that should be considered in both the regional target-setting and sustainable communities strategy processes include the following:

- Congestion pricing strategies can provide a method of efficiently managing traffic demand while raising funds for needed transit, biking and pedestrian infrastructure investment. Regional and local agencies, however, do not have the authority to pursue these strategies on their own, as federal approval and State authorization must be provided for regional implementation of most pricing measures.

- Indirect source rules for new development have already been implemented by some local air districts and proposed by others for purposes of criteria pollution reduction. Regions should evaluate the need for measures that would ensure the mitigation of high carbon footprint development outside of the sustainable communities strategies or alternative planning strategies that meet the targets established under SB 375.

- Programs to reduce vehicle trips while preserving personal mobility, such as employee transit incentives, telework programs, car sharing, parking policies, public education programs and other strategies that enhance and complement land use and transit strategies can be implemented and coordinated by regional and local agencies and stakeholder groups.

Another way to encourage greenhouse gas reductions from vehicle travel is through pay as you drive insurance (PAYD), a structure in which drivers realize a direct financial benefit from driving less. The California Insurance Commissioner recently announced support for PAYD and has proposed regulations to permit PAYD on a voluntary basis.

Separate emissions reduction estimates for these strategies are not quantified here. As regional targets are developed in the SB 375 process, ARB will work with regions to quantify the benefits in the context of the targets.

Estimating the Benefits of Regional Targets

The ARB estimate of the statewide benefit of regional transportation-related greenhouse gas emissions reduction targets is based on analysis of research results quantifying the effects of land use and transportation strategies. The emissions reduction number in Table 11 is not the statewide metric for regional targets that must be developed as SB 375 is implemented. The emissions target will ultimately be determined during the SB 375 process.

The possible impacts of land use and transportation policies have been well documented. Most recently, a 2008 U.C. Berkeley study[37] reviewed over 20 modeling studies from California (including the State's four largest MPOs), other states and Europe. The study found a range of 0.4 to 7.7 percent reduction in vehicle miles traveled (VMT) resulting from a combination of land use and enhanced transit policies compared to a business-as-usual case over a 10-year horizon, with benefits doubling by 2030, as shown in Figure 4. With the inclusion of additional measures

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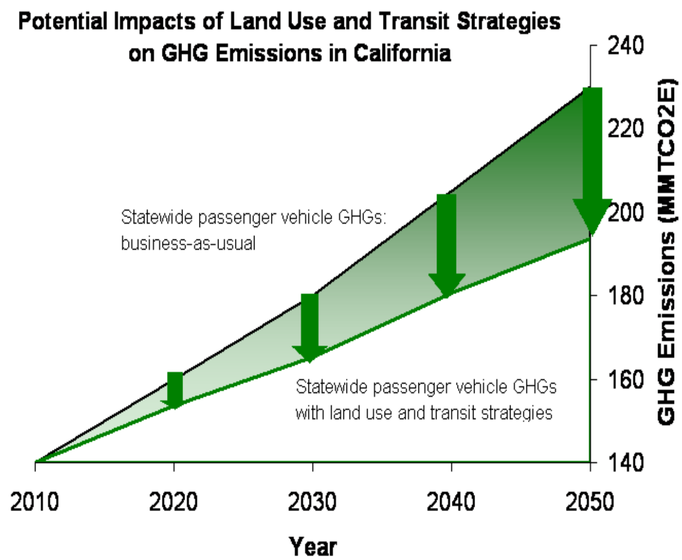
[37] Rodier, Caroline. U.C. Berkeley, Transportation Sustainability Research Center, "A Review of the International Modeling Literature: Transit, Land Use, and Auto Pricing Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gas Emissions," August 2008. http://www.arb.ca.gov/planning/tsaq/docs/rodier_8-1-08_trb_paper.pdf (accessed October 12, 2008)

such as pricing policies, the reduction of greenhouse gas emissions can be greater. These strategies will be considered during the target-setting process. Sophisticated land use and transportation models can best assess these effects. As part of the development of regional targets, technical tools will need to be refined to ensure sound quantification techniques are available.

Figure 4



The potential benefits of this measure that can be realized by 2020 (as shown in Table 11) were estimated after first accounting for the benefits of the vehicle technology and efficiency measures in the plan. It was calculated based on the U.C. Berkeley study's median value of 4 percent per capita VMT reduction over a 10-year time horizon. This value should not be interpreted as the final estimate of the benefits of this measure. The current academic literature supports this realistic statewide estimate of potential benefits, but the ultimate benefit will be determined as an outcome of SB 375 implementation on a regional level. The incentives for sustainable planning in SB 375 can set California on a new path. ARB's establishment of regional targets in 2010, combined with the Regional Targets Advisory Committee process, required by the legislation, provides a clear mechanism for maximizing the benefits of this measure.

Additional Benefits of Regional Targets and Land Use Strategies

Land use and transportation measures that help reduce vehicle travel will also provide multiple benefits beyond greenhouse gas reductions. Quality of life will be improved by increasing access to a variety of mobility options such as transit, biking, and walking, and will provide a diversity of housing options focused on proximity to jobs, recreation, and services. Other important state and community goals that could be met through better integrated land use and transportation planning include agricultural, open space and habitat preservation, improved water quality, positive health effects, and the reduction of smog forming pollutants.

Growing more sustainably has the potential to provide additional greenhouse gas and energy savings by encouraging more compact, mixed-use developments resulting in reduced demand for electricity and heating and cooling energy. These land use-related energy savings will contribute toward the Plan's energy efficiency measures to achieve the goal of reducing electricity and natural gas usage. ARB is continuing to evaluate the greenhouse gas emissions reductions that may be additional to the proposed measures in this plan.

Table 11: Regional Transportation-Related Greenhouse Gas Targets Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
T-3	Regional Transportation-Related Greenhouse Gas Targets[38]	5
	Total	**5**

7. Vehicle Efficiency Measures

Implement light-duty vehicle efficiency measures.

Several additional measures could reduce light-duty vehicle greenhouse gas emissions. The California Integrated Waste Management Board (CIWMB) with various partners continues to conduct a public awareness campaign to promote sustainable tire practices. ARB is pursuing a regulation to ensure that tires are properly inflated when vehicles are serviced. In addition, CEC in consultation with CIWMB is developing an efficient tire program focusing first on data gathering and outreach, then on potential adoption of minimum fuel-efficient tire standards, and lastly on the development of consumer information requirements for replacing tires. ARB is also pursuing ways to reduce engine load via lower friction oil and reducing the need for air conditioner use. ARB is actively engaged in the regulatory development process for the tire inflation component of this measure. Current information indicates the reduction of greenhouse gas emissions is likely to be less than estimated in the Draft Scoping Plan. ARB has adjusted the estimated reductions shown in Table 12 to reflect this.

[38] This number represents an estimate of what may be achieved from local land use changes. It is not the SB 375 regional target. ARB will establish regional targets for each MPO region following the input of the Regional Targets Advisory Committee and a public consultation process with MPOs and other stakeholders per SB 375.

Table 12: Vehicle Efficiency Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
T-4	Vehicle Efficiency Measures	4.5
	Total	**4.5**

8. Goods Movement

Implement adopted regulations for the use of shore power for ships at berth. Improve efficiency in goods movement activities.

A significant portion of greenhouse gas emissions from transportation activities comes from the movement of freight or goods throughout the state. Activity at California ports is forecast to increase by 250 percent between now and 2020. Both the Goods Movement Emission Reduction Plan (GMERP) and the 2007 State Implementation Plan (SIP) contain numerous measures designed to reduce the public health impact of goods movement activities in California. ARB has already adopted a regulation to require ship electrification at ports. Proposition 1B funds, as well as clean air plans being implemented by California's ports, will also help reduce greenhouse gas emissions while cutting criteria pollutant and toxic diesel emissions. ARB is proposing to develop and implement additional measures to reduce greenhouse gas emissions due to goods movement from trucks, ports and other related facilities. The anticipated reductions would be above and beyond what is already expected in the GMERP and the SIP. This effort should provide accompanying reductions in air toxics and smog forming emissions. The estimated reduction of greenhouse gas emissions is shown in Table 13.

After further evaluation, ARB incorporated the Draft Scoping Plan's Heavy-Duty Vehicle-Efficiency measure into the Goods Movement measure. A Heavy-Duty Engine Efficiency measure could reduce emissions associated with goods movement through improvements which could involve advanced combustion strategies, friction reduction, waste heat recovery, and electrification of accessories. ARB will consider setting requirements and standards for heavy-duty engine efficiency in the future if higher levels of efficiency are not being produced either in response to market forces (fuel costs) or federal standards.

Table 13: Goods Movement Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
T-5	Ship Electrification at Ports (Discrete Early Action)	0.2
T-6	Goods Movement Efficiency Measures • System-Wide Efficiency Improvements	3.5
	Total	**3.7**

9. Million Solar Roofs Program

Install 3,000 MW of solar-electric capacity under California's existing solar programs.

As part of Governor Schwarzenegger's Million Solar Roofs Program, California has set a goal to install 3,000 megawatts (MW) of new solar capacity by 2017 – moving the state toward a cleaner energy future and helping lower the cost of solar systems for consumers. The Million Solar Roofs Initiative is a ratepayer-financed incentive program aimed at transforming the market for rooftop solar systems by driving down costs over time. Created under Senate Bill 1 (Murray, Chapter 132, Statutes of 2006), the Million Solar Roofs Program includes CPUC's California Solar Initiative and CEC's New Solar Homes Partnership, and requires publicly-owned utilities (POUs) to adopt, implement and finance a solar incentive program. This measure would offset electricity from the grid, thereby reducing greenhouse gas emissions. The estimated emissions reductions are shown in Table 14.

Obtaining the incentives requires the building owners or developers to meet certain efficiency requirements: specifically, that new construction projects meet energy efficiency levels that exceed the State's Title 24 Building Energy Efficiency Standards, and that existing commercial buildings undergo an energy audit. Thus, the program is also a mechanism for achieving the efficiency targets for the Energy sector. By requiring greater energy efficiency for projects that seek solar incentives, the State would be able to reduce both electricity and natural gas needs and their associated greenhouse gas emissions.

Table 14: Million Solar Roofs Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
E-4	Million Solar Roofs (including California Solar Initiative, New Solar Homes Partnership and solar programs of publicly owned utilities) • Target of 3000 MW Total Installation by 2020	2.1
	Total	**2.1**

10. Medium/Heavy-Duty Vehicles

Adopt medium and heavy-duty vehicle efficiency measures.

Medium- and heavy-duty vehicles account for approximately 20 percent of the transportation greenhouse gas inventory. Requiring retrofits to improve the fuel efficiency of heavy-duty trucks could include a requirement for devices that reduce aerodynamic drag and rolling resistance. In addition, hybridization of medium- and heavy-duty vehicles would also reduce greenhouse gas emissions through increased fuel efficiency. Hybrid trucks would likely achieve the greatest benefits in urban, stop-and-go applications, such as parcel delivery, utility services, transit, and other vocational work trucks. The recommendation for this sector is summarized in Table 15.

Table 15: Medium/Heavy-Duty Vehicle Recommendation
(MMTCO_2E in 2020)

Measure No.	Measure Description	Reductions
T-7	Heavy-Duty Vehicle Greenhouse Gas Emissions Reduction Measure - Aerodynamic Efficiency (Discrete Early Action)	0.9
T-8	Medium/Heavy-Duty Vehicle Hybridization	0.5
	Total	**1.4**

11. Industrial Emissions

Require assessment of large industrial sources to determine whether individual sources within a facility can cost-effectively reduce greenhouse gas emissions and provide other pollution reduction co-benefits. Reduce greenhouse gas emissions from fugitive emissions from oil and gas extraction and gas transmission. Adopt and implement regulations to control fugitive methane emissions and reduce flaring at refineries.

Energy Efficiency and Co-Benefits Audits for Large Industrial Sources

This measure would apply to the direct greenhouse gas emissions at major industrial facilities emitting more than 0.5 MMTCO_2E per year. In general, these facilities also have significant emissions of criteria air pollutants, toxic air pollutants, or both. Major industrial facilities include power plants, refineries, cement plants, and miscellaneous other sources. ARB would implement this measure through a regulation, requiring each facility to conduct an energy efficiency audit of individual combustion and other direct sources of greenhouse gases within the facility to determine the potential reduction opportunities, including criteria air pollutants and toxic air contaminants. The audit would include an assessment of the impacts of replacing or upgrading older, less efficient units such as boilers and heaters, or replacing the units with combined heat and power (CHP) units. The measure is summarized in Table 16.

The audit would help ARB to identify potential reductions of greenhouse gas emissions reductions, the associated costs and cost-effectiveness, their technical feasibility, and the potential to reduce air pollution impacts at the local or regional level. ARB will use the results to determine if certain emissions sources within a facility can make cost-effective reductions of greenhouse gas emissions that also provide reductions in other criteria or toxic pollutants. Where this is the case, rule provisions or permit conditions would be considered to ensure the best combination of pollution reductions. Nothing in this measure would delay known cost-effective strategies that otherwise would be required.

The California Long Term Energy Efficiency Strategic Plan (CPUC) discusses a number of strategies associated with improving industrial sector efficiency and greenhouse gas emissions reductions, including the development of certification protocols for industrial efficiency improvements to develop market recognition for efficiency gains.

Oil and Gas Recovery Operations and Transmission/Refineries

California is a major oil and gas producer. Crude oil, both from in-state and imported sources, is processed at 21 oil refineries in the state. In addition to conforming to the requirements of the cap-and-trade program and the audit measure, ARB has identified four specific measures for development and implementation, two for oil and gas recovery operations and gas transmission, and two for refineries. Other industrial measures that were under consideration affect greenhouse gas emissions sources that are fully regulated under cap and trade, which ARB concluded would provide cost-effective reductions of greenhouse gas emissions. All measures would be designed to secure a combination of cost-effective reductions in greenhouse gas emissions, criteria air pollutants and air toxics. Two measures would be developed to reduce methane emissions in the oil and gas production and gas transmission processes from leaks and incomplete combustion of methane (used as fuel). These measures would include improved leak detection, process modifications, equipment retrofits, installation of new equipment, and best management practices. The first measure would affect oil and gas producers. The second would impact operators of natural gas pipeline systems. These fugitive emissions are not proposed to be covered by a cap and trade program, although combustion-related emissions from these operations are proposed to be covered. The WCI partner jurisdictions are currently evaluating the inclusion of fugitive methane emissions to the extent that adequate quantification methods exist. During implementation of this measure, ARB will determine whether these emissions will also be covered in California's cap-and-trade program. If the emissions are covered under the cap, ARB will evaluate the need for the measures described here.

Two measures would be developed for oil refineries. The first would limit the greenhouse gas emissions from refinery flares while preserving flaring as needed for safety reasons. The second would remove the current fugitive methane exemption in most refinery Volatile Organic Compounds (VOC) regulations. This exemption was established because methane does not appreciably contribute to urban smog, but is inappropriate given the role that methane plays in global warming. ARB believes these measures would provide cost-effective greenhouse gas, criteria pollutants and air toxics emissions reductions. Most combustion and other process emissions at refineries would be governed by the cap-and-trade program. As with the oil and gas production measures above, the need for these measures would be evaluated if fugitive methane is included in the WCI cap-and-trade program.

Table 16: Industrial Emissions Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
I-1	Energy Efficiency and Co-Benefits Audits for Large Industrial Sources	TBD
I-2	Oil and Gas Extraction GHG Emissions Reduction	0.2
I-3	GHG Leak Reduction from Oil and Gas Transmission	0.9
I-4	Refinery Flare Recovery Process Improvements	0.33
I-5	Removal of Methane Exemption from Existing Refinery Regulations	0.01
	Total	**1.4**

12. High Speed Rail

Support implementation of a high speed rail system.

A high speed rail (HSR) system is part of the statewide strategy to provide more mobility choice and reduce greenhouse gas emissions. This measure supports implementation of plans to construct and operate a HSR system between northern and southern California. As planned, the HSR is a 700-mile-long rail system capable of speeds in excess of 200 miles per hour on dedicated, fully-grade separated tracks with state-of-the-art safety, signaling and automated rail control systems. The system would serve the major metropolitan centers of California in 2030 and is projected to displace between 86 and 117 million riders from other travel modes in 2030.

For Phase 1 of the HSR, between San Francisco and Anaheim, 2020 is projected to be the first year of service, with 26 percent of the projected 2030 full system ridership levels. The anticipated reduction of greenhouse gas emissions are shown in Table 17. HSR system ridership and the benefits associated with it are anticipated to increase over time as additional portions of the planned system are completed. Over the long term, the system also has the potential to support the reduction of greenhouse gas emissions in the transportation sector from land use strategies, by providing opportunities for and encouraging low-impact transit-oriented development.

HSR implementation is dependent on voter approval, and the “Safe, Reliable High-Speed Passenger Train Bond Act for the 21st Century” will appear on the November 2008 ballot as Proposition 1A. If Proposition 1A is approved, construction of HSR is anticipated to begin in 2010, with full implementation anticipated in 2030.

Table 17: High Speed Rail Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
T-9	High Speed Rail	1.0
	Total	**1.0**

13. Green Building Strategy

Expand the use of green building practices to reduce the carbon footprint of California's new and existing inventory of buildings.

Collectively, energy use and related activities by buildings are the second largest contributor to California's greenhouse gas emissions. Almost one-quarter of California's greenhouse gas emissions can be attributed to buildings.[39] As the Governor recognized in his Green Building Initiative (Executive Order S-20-04), significant reductions in greenhouse gas emissions can be achieved through the design and construction of new green buildings as well as the sustainable operation, retrofitting, and renovation of existing buildings.

A Green Building strategy offers a comprehensive approach to reducing direct and upstream greenhouse gas emissions that cross-cuts multiple sectors including Electricity/Natural Gas, Water, Recycling/Waste, and Transportation. Green buildings are designed, constructed, renovated, operated, and maintained using an integrated approach that reduces greenhouse gas emissions by maximizing energy and resource efficiency. Employing a whole-building design approach can create tremendous synergies that result in multiple benefits at little or no net cost, allowing for efficiencies that would never be possible on an incremental basis.

A Green Building strategy will produce greenhouse gas saving through buildings that exceed minimum energy efficiency standards, decrease consumption of potable water, reduce solid waste during construction and operation, and incorporate sustainable materials. Combined these measures can also contribute to healthy indoor air quality, protect human health and minimize impacts to the environment. A Green Building strategy also includes siting considerations. Buildings that are sited close to public transportation or near mixed-use areas can work in tandem with transportation-related strategies to decrease greenhouse gas emissions that result from that sector.

In July 2008, the California Building Standards Commission (CBSC) adopted the Green Building Standards Code (GBSC) for all new construction in the state. While the current version of the commercial green building code is voluntary, CBSC anticipates adopting a mandatory code in 2011 which will institute minimum environmental performance standards for all occupancies. The Green Building Strategy includes Zero Net Energy (ZNE) goals for new and existing homes and commercial buildings consistent with the recently-adopted California Long Term Energy Efficiency Strategic Plan. ARB encourages local governments to raise the bar by adopting "beyond-code" green building requirements. To assist this effort, State government would develop and regularly tighten voluntary standards, written in GBSC language for easy adoption by local jurisdictions.

[39] Greenhouse gas emission estimates from electricity, natural gas, and water use in homes and commercial buildings.

As we approach the 2020 and 2030 targets for zero energy buildings, these "percent above code" targets must shift to "percent of ZNE" targets. Zero energy new and existing buildings can be an overarching and unifying concept for energy efficiency in buildings, as discussed above (building energy efficiency measures E-1 and CR-1). In order to achieve statewide GHG emission reductions, these targets should be expanded to address other aspects of environmental performance. For example, these targets could be re-framed as a carbon footprint reduction goal for a 35 percent reduction in both energy and water consumption. For commercial buildings, a 2011 target should be established such that a quarter of all new buildings reduce energy and water consumption by at least 25 percent beyond code.

Furthermore, retrofitting existing residential and commercial buildings would achieve substantial greenhouse gas emissions reduction benefits. This Proposed Scoping Plan recommends the establishment of an environmental performance rating system for homes and commercial buildings and further recommends that California adopt mechanisms to encourage and require retrofits for buildings that do not meet minimum standards of performance.

An effective green building framework can operate to deliver reductions of greenhouse gas emissions in multiple sectors. The green building strategies provide a vehicle to achieve the statewide electricity and natural gas efficiency targets and lower greenhouse gas emissions from the waste and water transport sectors. Achieving these green building emissions reductions will require coordinated efforts from a broad range of stakeholders, and new financing mechanisms to motivate investment in green building strategies.

Achieving significant greenhouse gas emissions reductions from new and existing buildings will require a combination of green building measures for new construction and retrofits to existing buildings. The State of California will set an example by requiring all new State buildings to exceed existing Green Building Initiative energy goals and achieve nationally-recognized building sustainability standards such as Leadership in Energy and Environmental Design - New Construction (LEED-NC) "Gold" certification. Existing State buildings would also be retrofitted to achieve higher standards equivalent to LEED-EB for existing buildings (EB) "Silver." All new schools should be required to meet the Collaborative for High Performance Schools (CHPS) 2009 criteria. Existing schools applying for modernization funds should also be required to meet CHPS 2009 criteria.

ARB estimates that the greenhouse gas savings from green building measures as approximately 26 $MMTCO_2E$, as shown in Table 18 below. Most of these reductions are accounted for in the Electricity, Waste, Water, and Transportation sectors. Because of this, ARB has assigned all emissions reductions that occur as a result of green building strategies to other sectors for purposes of meeting AB 32 requirements, but will continue to evaluate and refine the emissions from this sector. As such, this strategy will require implementation from various entities within

California, including CEC, PUC, State Architect, and others, each taking the lead in their area of authority and expertise.

Table 18: Green Buildings Recommendation
(MMTCO_2E in 2020)

Measure No.	Measure Description	Reductions
GB-1	Green Buildings[40]	26
	Total	**26**

14. High Global Warming Potential Gases

Adopt measures to reduce high global warming potential gases.

High global warming potential (GWP) gases pose a unique challenge. Just a few pounds of high GWP materials can have the equivalent effect on global warming as several *tons* of carbon dioxide. For example, the average refrigerator has about a half-pound of refrigerant and about one pound of “blowing agents” used to make the insulating foam. If these gases were released into the atmosphere, they would have a global warming impact equivalent to five metric tons of CO_2.

High GWP chemicals are very common and are used in many different applications such as refrigeration, air conditioning systems, fire suppression systems, and the production of insulating foam. Because these gases have been in use for years, old refrigerators, air conditioners and foam insulation represent a significant “bank” of these materials yet to be released. High GWP gases are released primarily in two ways. The first is through leaking systems, and the second is during the disposal process. Once high GWP materials are released, they persist in the atmosphere for tens or even hundreds of years. Recommended measures to address this growing problem take the form of direct regulations and use of mitigation fees.

ARB identified four Discrete Early Action measures to reduce greenhouse gas emissions from the refrigerants used in car air conditioners, semiconductor manufacturing, air quality tracer studies, and consumer products. ARB has identified additional potential reduction opportunities based on specifications for future commercial and industrial refrigeration, changing the refrigerants used in auto air conditioning systems, and ensuring that existing car air conditioning systems as well as stationary refrigeration equipment do not leak. Recovery and destruction of high GWP materials in the banks described above could also provide significant reductions.

[40] Although some of these emissions reductions may be additional, most of them are accounted for in the Energy, Waste, Water, and Transportation sectors. In addition, some of these reductions may occur out of state, making quantification more difficult. Because of this, these emissions reductions are not currently counted toward the AB 32 2020 goal.

ARB is also proposing to establish an upstream mitigation fee on the use of high GWP gases. Even with the reductions from the specific high GWP measures described above, this sector's emissions are still projected to more than double from current levels by 2020. This is because of the high growth in the sector due, in part, to the replacement of ozone-depleting substances being phased out of production. These emissions would be difficult to address via traditional approaches since the gases are used in small quantities in very diverse applications. Additionally, there are no proven substitutes or alternatives for some uses, and the relative low price of most high GWP compounds provides little incentive to develop alternatives, reduce leakage, or recover the gases at end-of-life.

An upstream fee would ensure that the climate impact of these substances is reflected in the total cost of the product, encouraging reduced use and end-of-life losses, as well as the development of alternatives. The fee would be variable and associated with the impact the product makes on public health and the environment. This could encourage product innovation because fees would correspondingly decrease as the manufacturer or producer redesigned their product or found lower-cost alternatives. This mitigation fee would complement many of the downstream high GWP regulations currently being developed.[41] Fees on high GWP gases would be set to be consistent with the cost of reducing greenhouse gas emissions and could be set to reduce multiple environmental impacts. Revenues could be used to mitigate greenhouse gas emissions either from other high GWP compounds or other greenhouse gases.

Table 19 summarizes the recommendations for measures in the High GWP sector. These measures address both high GWP gases identified in AB 32 and also other high GWP gases, such as ozone-depleting substances that are only partially covered by the Montreal Protocol. The emissions reductions shown are only for the six greenhouse gases explicitly identified in AB 32.

[41] Industrial process emissions of high GWP gases are also expected to be part of the cap-and-trade program. As ARB moves through the rulemaking for both the high GWP fee and the cap-and-trade program, staff will evaluate whether these are complementary approaches or if one or the other needs to be adjusted to prevent duplicative regulation of the industrial process emissions of these gases.

Table 19: High GWP Gases Sector Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
H-1	Motor Vehicle Air Conditioning Systems: Reduction of Refrigerant Emissions from Non-Professional Servicing (Discrete Early Action)	0.26
H-2	SF_6 Limits in Non-Utility and Non-Semiconductor Applications (Discrete Early Action)	0.3
H-3	Reduction of Perfluorocarbons in Semiconductor Manufacturing (Discrete Early Action)	0.15
H-4	Limit High GWP Use in Consumer Products (Discrete Early Action) (Adopted June 2008)	0.25
H-5	High GWP Reductions from Mobile Sources • Low GWP Refrigerants for New Motor Vehicle Air Conditioning Systems • Air Conditioner Refrigerant Leak Test During Vehicle Smog Check • Refrigerant Recovery from Decommissioned Refrigerated Shipping Containers • Enforcement of Federal Ban on Refrigerant Release during Servicing or Dismantling of Motor Vehicle Air Conditioning Systems	3.3
H-6	High GWP Reductions from Stationary Sources • High GWP Stationary Equipment Refrigerant Management Program: o Refrigerant Tracking/Reporting/Repair Deposit Program o Specifications for Commercial and Industrial Refrigeration Systems • Foam Recovery and Destruction Program • SF_6 Leak Reduction and Recycling in Electrical Applications • Alternative Suppressants in Fire Protection Systems • Residential Refrigeration Early Retirement Program	10.9
H-7	Mitigation Fee on High GWP Gases[42]	5
	Total	**20.2**

[42] The 5 $MMTCO_2E$ reduction is an estimate of what might occur with a fee in place. Additional emissions reductions from a fee would be expected as resulting revenues are used in mitigation programs. Using the funds to mitigate greenhouse gas emissions could substantially increase the emissions reductions from this measure.

15. Recycling and Waste

Reduce methane emissions at landfills. Increase waste diversion, composting, and commercial recycling. Move toward zero-waste.

California has a long track record of reducing greenhouse gas emissions by turning waste into resources, exemplified by the waste diversion rate from landfills of 54 percent (which exceeds the current 50 percent mandate) resulting from recovery of recyclable materials. Re-introducing recyclables with intrinsic energy value back into the manufacturing process reduces greenhouse gas emissions from multiple phases of product production including extraction of raw materials, preprocessing and manufacturing. Additionally, by recovering organic materials from the waste stream, and having a vibrant compost industry, there is an opportunity to further reduce greenhouse gas emissions through the indirect benefits associated with the reduced need for water and fertilizer for California's Agricultural sector. Incentives may also be an effective way to secure greenhouse gas emissions reductions in this sector. Table 20 summarizes the emissions reductions from Recycling and Waste sector.

Reduction in Landfill Methane

Methane emissions from landfills, generated when wastes decompose, account for one percent of California's greenhouse gas emissions. Greenhouse gas emissions can be substantially reduced by properly managing all materials to minimize the generation of waste, maximize the diversion from landfills, and manage them to their highest and best use. Capturing landfill methane results in greenhouse gas benefits, as well as reductions in other air pollutants such as volatile organic compounds. ARB is working closely with the California Integrated Waste Management Board (CIWMB) to develop a Discrete Early Action measure for landfill methane control that will be presented to ARB in January.

CIWMB is also pursuing efforts to reduce methane emissions by diverting organics from landfills, and to promote best management practices at smaller uncontrolled landfills. Landfill gas may also provide a viable source of liquefied natural gas (LNG) vehicle fuel. Reductions from these types of projects would be accounted for in the Transportation sector.

High Recycling / Zero Waste

This measure reduces greenhouse gas emissions primarily by reducing the substantial energy use associated with the acquisition of raw materials in the manufacturing stage of a product's life-cycle. As virgin raw materials are replaced with recyclables, a large reduction in energy consumption should be realized. Implementing programs with a systems approach that focus on consumer demand, manufacturing, and movement of products will result in the reduction of greenhouse gas emissions and other co-benefits. Reducing waste and materials at the source of generation, increased use of compost to benefit soils, coupled with increased recycling – especially in the commercial sector – and Extended Producer Responsibility (EPR) plus Environmentally Preferable Purchasing (EPP) also have the potential to reduce emissions, both in-state and within the connected global economy. This measure could also assist in meeting the 33 percent renewables energy goal through deployment of anaerobic digestion for production of fuels/energy.

As noted by ETAAC, recycling in the commercial sector could be substantially increased. This could be implemented, for example, through voluntary or mandatory programs, including protocols, enhanced partnerships with local governments, and provision of appropriate financial incentives. ARB will work with CIWMB to develop and implement these types of programs. ARB will also work with CIWMB, the California Department of Food and Agriculture, the Department of Transportation, and others to provide direct incentives for the use of compost in agriculture and landscaping. Further, CIWMB will explore the use of incentives for all Recycling and Waste Management measures, including for commercial recycling and for local jurisdictions to encourage the collection of residentially and commercially-generated food scraps for composting and in-vessel anaerobic digestion.

Table 20: Recycling and Waste Sector Recommendation - Landfill Methane Capture and High Recycling/Zero Waste
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
RW-1	Landfill Methane Control (Discrete Early Action)	1
RW-2	Additional Reductions in Landfill Methane • Increase the Efficiency of Landfill Methane Capture	TBD
RW-3	High Recycling/Zero Waste • Commercial Recycling • Increase Production and Markets for Compost • Anaerobic Digestion • Extended Producer Responsibility • Environmentally Preferable Purchasing	9
	Total	**10**[(43)]

16. Sustainable Forests

Preserve forest sequestration and encourage the use of forest biomass for sustainable energy generation.

The 2020 Proposed Scoping Plan target for California's forest sector is to maintain the current 5 $MMTCO_2E$ of sequestration through sustainable management practices, including reducing the risk of catastrophic wildfire, and the avoidance or mitigation of land-use changes that reduce carbon storage. California's Board of Forestry and

[43] Reductions from RW-2 and RW-3 are not counted toward the AB 32 goal. ARB is continuing to work with CIWMB to quantify these emissions and determine what portion of the reductions can be credited to meeting the AB 32 2020 goal. These measures may provide greater emissions reductions than estimated.

Fire Protection has the existing authority to provide for sustainable management practices, and will, at a minimum, work to maintain current carbon sequestration levels. The Resources Agency and its departments will also have an important role to play in implementing this measure.

In addition, the Resources Agency is supporting voluntary actions, including expenditure of public funds for projects focused largely on conserving biodiversity, providing recreation, promoting sustainable forest management and other projects that also provide carbon sequestration benefits. The federal government must also use its regulatory authority to, at a minimum, maintain current carbon sequestration levels for land under its jurisdiction in California.

Forests in California are now a carbon sink. This means that atmospheric removal of carbon through sequestration is greater than atmospheric emissions from processes like fire and decomposition of wood. However, several factors, such as wildfires and forest land conversion, may cause a decline in the carbon sink. The 2020 target would provide a mechanism to help ensure that current carbon stocks are, at a minimum, maintained and do not diminish over time. The 5 $MMTCO_2E$ emission reduction target is set equal to the magnitude of the current estimate of net emissions from California's forest sector. As technical data improve, the target can be recalibrated to reflect new information.

California's forests will play an even greater role in reducing carbon emissions for the 2050 greenhouse gas emissions reduction goals. Forests are unique in that planting trees today will maximize their sequestration capacity in 20 to 50 years. As a result, near-term investments in activities such as planting trees will help us reach our 2020 target, but will also play a greater role in reaching our 2050 goals.

Monitoring carbon sequestered on forest lands will be necessary to implement the target. The Board of Forestry and Fire Protection, working with the Resources Agency, the Department of Forestry and Fire Protection and ARB would be tasked with developing a monitoring program, improving greenhouse gas inventories, and determining what actions are needed to meet the 2020 target for the Forest sector. Future climate impacts will exacerbate existing wildfire and insect disturbances in the Forest sector. These disturbances will create new uncertainties in reducing emissions and maintaining sequestration levels over the long-term, requiring more creative strategies for adapting to these changes. In the short term, focusing on sustainable management practices and land-use issues is a practical approach for moving forward.

Future land use decisions will play a role in reaching our greenhouse gas emissions reduction goals for all sectors. Loss of forest land to development increases greenhouse gas emissions levels because less carbon is sequestered. Avoiding or mitigating such conversions will support efforts to meet the 2020 goal. When significant changes occur, the California Environmental Quality Act is a mechanism providing for assessment and mitigation of greenhouse gas emissions.

Going forward there are a number of forestry-related strategies that can play an important role in California's greenhouse gas emissions reduction efforts. Biomass resources from forest residue will factor into the expansion of renewable energy sources (this is currently accounted for in the Energy sector). Similarly, no reductions are yet attributed to future actions to reduce wildfire risk, but that accounting will be done following implementation. Additionally, public investments to purchase and preserve forests and woodlands would also provide greenhouse gas emission reductions that will be accounted for as projects are funded and urban forest projects can also provide the dual benefit of carbon sequestration and shading to reduce air conditioning load.

Furthermore, the Forest sector currently functions as a source of voluntary reductions that would not otherwise occur and this role could expand even further in the future. ARB has already adopted a methodology to quantify reductions from forest projects, and recently adopted additional quantification methodologies. Table 21 summarizes the emission reductions from the forest measure.

Table 21: Sustainable Forests Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
F-1	Sustainable Forest Target	5
	Total	**5**

17. Water

Continue efficiency programs and use cleaner energy sources to move and treat water.

Water use requires significant amounts of energy. Approximately one-fifth of the electricity and one-third of the non-power plant natural gas consumed in the state are associated with water delivery, treatment and use. Although State, federal, and local water projects have allowed the state to grow and meet its water demands, greenhouse gas emissions can be reduced if we can move, treat, and use water more efficiently. As is the case with energy efficiency, California has a long history of advancing water efficiency and conservation programs. Without this ongoing, critical work, baseline or business-as-usual greenhouse gas emissions associated with water use would be much higher than is currently the case.

Six greenhouse gas emission reduction measures are proposed for the Water sector, and are shown in Table 21. Three of the measures target reducing energy requirements associated with providing reliable water supplies and two measures are aimed at reducing the amount of non-renewable electricity associated with conveying and treating water. The final measure focuses on providing sustainable funding for implementing these actions. The greenhouse gas emission reductions from these measures are indirectly realized through reduced energy requirements and are accounted for in the Electricity and Natural Gas sector.

In addition, a mechanism to make allowances available in a cap-and-trade program could be used to provide additional incentives for local governments, water suppliers, and third party providers to bundle water and energy efficiency improvements. This type of allowance set-aside will be evaluated during the rulemaking for the cap-and-trade program.

ARB recommends a public goods charge for funding investments in water management actions that improve water and energy efficiency and reduce GHG emissions. As noted by the Economic and Technology Advancements Advisory Committee, a public goods charge on water can be collected on water bills and then used to fund end-use water efficiency improvements, system-wide efficiency projects, water recycling, and other actions that improve water and energy efficiency and reduce GHG emissions. Depending on how the fee schedule is developed in a subsequent rulemaking process, a public goods charge could generate $100 million to $500 million annually. These actions would also have the co-benefit of improving water quality and water supply reliability for customers.

Table 22: Water Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
W-1	Water Use Efficiency	1.4
W-2	Water Recycling	0.3
W-3	Water System Energy Efficiency	2.0
W-4	Reuse Urban Runoff	0.2
W-5	Increase Renewable Energy Production	0.9
W-6	Public Goods Charge	TBD
	Total	**4.8**[(44)]

18. Agriculture

In the near-term, encourage investment in manure digesters and at the five-year Scoping Plan update determine if the program should be made mandatory by 2020.

Encouraging the capture of methane through use of manure digester systems at dairies can provide emission reductions on a voluntary basis. This measure is also a

[44] Greenhouse gas emission reductions from the water sector are not currently counted toward the 2020 goal. ARB anticipates that a portion of these reductions will be additional to identified reductions in the Electricity sector and is working with the appropriate agencies to refine the electricity/water emissions inventory.

renewable energy strategy to promote the use of captured gas for fuels or power production. Initially, economic incentives such as marketable emission reduction credits, favorable utility contracts, or renewable energy incentives will be needed. Quantified reductions for this measure (shown in Table 23) are not included in the sum of statewide reductions shown in Table 2 since the initial approach is voluntary. ARB and the California Climate Action Registry worked together on a manure digester protocol to establish methods for quantifying greenhouse gas emissions reductions from individual projects; the Board adopted this protocol in September 2008. The voluntary approach will be re-assessed at the five-year update of the Scoping Plan to determine if the program should become mandatory for large dairies by 2020.

Nitrogen fertilizer, which produces N_2O emissions, is the other significant source of greenhouse gases in the Agricultural sector. ARB has begun a research program to better understand the variables affecting fertilizer N_2O emissions (Phase 1), and based on the findings, will explore opportunities for emission reductions (Phase 2).

There may be significant potential for additional voluntary reductions in the agricultural sector through strategies, such as those recommended by ETAAC. These opportunities include increases in fuel efficiency of on-farm equipment, water use efficiency, and biomass utilization for fuels and power production.

Increasing carbon sequestration, including on working rangelands, hardwood and riparian woodland reforestation, also hold potential as a greenhouse gas strategies. As we evaluate the role that this sector can play in California's emissions reduction efforts, we will explore the feasibility of developing sound quantification protocols so that these and other related strategies may be employed in the future.

Table 23: Agriculture Recommendation
($MMTCO_2E$ in 2020)

Measure No.	Measure Description	Reductions
A-1	Methane Capture at Large Dairies[45]	1.0
	Total	**1.0**

D. Voluntary Early Actions and Reductions

Many individual activities that are not currently addressed under regulatory approaches can nevertheless result in cost-effective, real, additional, and verifiable greenhouse gas emissions reductions that will help California meet its 2020 target. Ensuring that appropriate credit is available to these types of emissions reduction projects will also help jump-start a new wave of technologies that will feature prominently in California and the world's long-term efforts

[45] Because the emission reductions from this measure are not required, they are not counted in the total.

to combat climate change. ARB will pursue several approaches that will recognize and reward these types of projects.

1. Voluntary Early Action

ARB is required to design regulations to encourage early action to reduce greenhouse gas emissions, and to provide appropriate recognition or credit for that action. (HSC §38562(b)(1) and (3)) Recognizing and rewarding greenhouse gas emissions reductions that occur prior to the full implementation of the AB 32 program can set the stage for innovation by incentivizing the development and employment of new clean technologies and by generating economic and environmental benefits for California.

In February 2008, ARB adopted a policy statement encouraging the early reductions of greenhouse gas emissions.[46] The policy statement describes a process for interested parties to submit proposed emission quantification methodologies for voluntary greenhouse gas emissions reductions to ARB for review. The intent is to provide a rapid assessment of methodologies for evaluating potential greenhouse gas emissions reduction projects to encourage early actions. Where appropriate, ARB will issue Executive Orders to confirm the technical soundness of the methodologies, and the methodology would be available for use by other parties to demonstrate the creation of voluntary early reductions. ARB is currently in the process of evaluating a number of submitted project methodologies.

ARB will provide appropriate credit for voluntary early reductions that can be adequately quantified and verified through three primary means. First, within the cap-and-trade program, ARB would set aside a certain number of allowances from the first compliance period to use to reward voluntary reductions that occur before 2012. In addition, ARB will assure that the allocation process in the first compliance period does not disadvantage facilities that have made reductions after AB 32 went into effect at the start of 2007 and before 2012.[47] The third approach will be to design other regulations, to the extent feasible, to recognize and reward early action. These approaches are discussed in more detail in Appendix C.

2. Voluntary Reductions

Emissions reduction projects that are not otherwise regulated, covered under an emissions cap, or undertaken as a result of government incentive programs can generate "offsets." These are verifiable reductions whose ownership can be

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[46]Board Meeting Agenda. California Air Resources Board. February 28, 2008. http://www.arb.ca.gov/board/ma/2008/ma022808.htm (accessed October 12, 2008)

[47] ARB will evaluate whether some reductions that occurred prior to AB 32 going into effect on January 1, 2007, should also receive credit under these rules. For example, many facilities in California registered with the California Climate Action Registry after its creation in 2002 to document early actions to reduce emissions by having a record of entities profiles and baselines. ARB will evaluate what reductions made prior to 2007 should be eligible for credit from the allowance set-aside as part of the cap-and-trade program rulemaking.

transferred to others. Voluntary offset markets have recently flourished as a way for companies and individuals to offset their own emissions by purchasing reductions outside of their own operations. These sorts of voluntary efforts to reduce greenhouse gas emissions can play an important role in helping the State meet its overall greenhouse gas reduction goals.

ARB will adopt methodologies for quantifying voluntary reductions. (HSC §38571) The Board adopted a methodology for forest projects in October 2007, and for local government operations, urban forestry, and manure digesters in September 2008. The recognition of voluntary reduction or offset methodologies does not in any way guarantee that these offsets can be used for other compliance purposes. The Board would need to adopt regulations to verify and enforce reductions achieved under these or other approved methodologies before they could be used for compliance purposes. (HSC §38571)

Allowance set-asides, in addition to being used to potentially reward voluntary early actions by facilities that will be included in the cap-and-trade program, could also be used to reward voluntary early action at other facilities not covered by the cap. An early action allowance set-aside could be utilized both by entities that are covered by the cap, and by those who develop emissions reducing projects outside of the cap, or purchase the reductions associated with those projects, and have not sold or used them. Additional discussion of voluntary offsets is included in Appendix C.

E. Use of Allowances and Revenues

Revenues may be generated from the implementation of various proposed components of the Scoping Plan, including by the use of auctions within a cap-and-trade system or through the imposition of more targeted measures, such as a public goods charge on water. These revenues could be used to support AB 32 requirements for greenhouse gas emissions reductions and associated socio-economic considerations. This section summarizes some of the recommendations and ideas that ARB has received to date. As discussed in the description of the cap-and-trade measure above, ARB will seek input from a broad range of experts in an open public process regarding the options for allocation and revenue use under consideration.

The Economic and Technology Advancement Advisory Committee (ETAAC) recommended the creation of a California Carbon Trust as a possible mechanism for using revenues generated by the program, leveraged with private funds, to further the overall program goals. ETAAC's recommendation is roughly based on the United Kingdom Carbon Trust. The United Kingdom program was established with public funds, but now functions as a stand-alone corporation, providing management and consulting services to corporations and small and medium businesses on reducing greenhouse gas emissions. It also funds innovations in carbon reduction technologies. ETAAC recommended the creation of a similar organization that would use revenue from the sale of carbon allowances or from carbon fees to:

- Fund research, development and demonstration projects,
- Help bring promising and high potential technologies through the often challenging early stages of development and get them to market,
- Manage the early carbon market and mitigate price volatility, purchasing credits and selling them or retiring them as needed,
- Dedicate resources to fund projects to achieve AB 32 Environmental Justice goals, or
- Support a green technology workforce training program.

The most appropriate use for some of the allowances and revenue generated under AB 32 may be to retain it within or return it to the sector from which it was generated. For example, CEC and CPUC specifically recommended that significant portions of the revenue generated from the electricity sector under a cap-and-trade program be used for the benefit of that sector to support investments in renewable energy, efficiency, new energy technology, infrastructure, customer utility bill relief, and other similar programs. In the case of more targeted revenues from a public goods charge, the intent would be to use the funds for program purposes within the sector in which it was raised, for example in the water sector. ARB will seek input from a broad range of experts in an open public process, and will work with other agencies, the WCI partner jurisdictions, and stakeholders to consider the options for use of revenues from the AB 32 program.

Possible uses of allowances and of the revenue generated under the program include:

- **Reducing costs of emissions reductions or achieving additional reductions –** Funding energy efficiency and renewable resource development could lower overall costs to consumers and companies, and provide the opportunity to achieve greater emissions reductions than would otherwise be possible. Program revenues could be used to fund programs directly, or create financial incentives for others.
- **Achieving environmental co-benefits –** Criteria and toxic air pollutants create health risks, and some communities bear a disproportionate burden from air pollution. Revenues could be used to enhance greenhouse gas emission reductions that also provide reductions in air and other pollutants that affect public health.
- **Incentives to local governments –** Funding or other incentives to local governments for well-designed land-use planning and infrastructure projects could lead to shorter commutes and encourage walking, bicycling and the use of public transit. Funding of other incentives for local governments could also be used to increase recycling, composting, and to generating renewable energy from anaerobic digestion.
- **Consumer rebates –** Utilities and other businesses could use revenues to support and increase rebate programs to customers to offset some of the cost associated with increased investments in renewable resources and to encourage increased energy efficiency.

- **Direct refund to consumers –** Revenue from the program could be recycled directly back to consumers in a variety of forms including per capita dividends, earned income tax credits, or other mechanisms.
- **Climate change adaptation programs –** Climate change will impact natural and human environments. Program revenues could be used to help the state adapt to the effects of climate change which will be detailed in the State's Climate Adaptation Strategy being prepared by the Resources Agency to be completed in early 2009.
- **Subsidies –** Revenues could be used to reduce immediate cost impacts to covered industries required to make substantial upfront capital investments to reduce greenhouse gas emissions.
- **RD&D funding –** Revenues could be used to support research, development, and deployment of green technologies.
- **Worker transition assistance –** Regulating greenhouse gas emissions will probably shift economic growth to some sectors and green technologies and away from higher carbon intensity industries. Worker training programs could help the California labor force be competitive in these new industries.
- **Administration of a greenhouse gas program –** A portion of revenues could be used to underwrite the State's AB 32 programs and operating costs.
- **Direct emission reductions –** Revenues could be used to purchase greenhouse gas reductions for the sole purpose of retirement, providing direct additional greenhouse gas emission reductions. Potential projects, such as afforestation and reforestation, would both sequester CO_2 and provide other environmental benefits.

Many of the potential uses of revenue would help ARB implement the community benefit section of the AB 32 (HSC §38565) which directs the Board, where applicable and to the extent feasible, to ensure that the greenhouse gas emissions reduction program directs public and private investment toward the most disadvantaged communities in California.

III. EVALUATIONS

The primary purpose of the Scoping Plan is to develop a set of measures that will provide the maximum technologically feasible and cost-effective greenhouse gas emission reductions. In developing this Plan, ARB evaluated the effect of these measures on California's economy, environment, and public health. This Chapter outlines these analyses.

ARB conducted broad evaluations of the potential impacts of the Scoping Plan, and will conduct more specific evaluations during regulatory development (HSC §38561(d), and HSC §38562(b)). Prior to inclusion of market-based compliance mechanisms in a regulation, to the extent feasible, the Board will consider direct, indirect and cumulative emission impacts, and localized impacts in communities that are already adversely impacted by air pollution (HSC §38570(b)).

Based on the evaluation of the recommendations included in this Proposed Plan, implementing AB 32 is expected to have an overall positive effect on the economy. In addition, implementation of the measures in the Recommended Actions section (Chapter II) will reduce statewide oxides of nitrogen (NOx), volatile organic compounds (VOC) and atmospheric particulate matter (PM) emissions primarily due to reduced fuel consumption, with resulting public health benefits. ARB will also work at the measure-specific level to further maximize the public health benefits that can accompany implementation of greenhouse gas emissions reduction strategies. The following sections provide a summary of the ARB evaluations of the recommended measures included in this Proposed Scoping Plan. More detailed information on the evaluations and their results are provided in Appendices G and H.

A. Economic Modeling

To evaluate the economic impacts of the Scoping Plan, ARB compared estimated economic activity under a business-as usual (BAU) case to the results obtained when actions recommended in this Plan are implemented. The BAU case is briefly described below. The estimated costs and savings used as model inputs for individual measures are outlined in Appendix G, and additional documentation on the calculation of those costs and savings is provided in Appendix I. All dollar estimates are in 2007 dollars.

Under the BAU case, Gross State Product (GSP) in California is projected to increase from $1.8 trillion in 2007 to almost $2.6 trillion in 2020. The results of our economic analysis indicate that implementation of the Scoping Plan will have an overall positive net economic benefit for the state. Positive impacts are anticipated primarily because the investments motivated by several measures result in substantial energy savings that more than pay back the cost of the investments at expected future energy prices.

The business-as-usual case is a representation of what the State of the California economy will be in the year 2020 assuming that none of the measures recommended in the Scoping Plan are implemented. While a number of the measures in the plan will be implemented as the result of existing federal or State policies and do not require additional regulatory action resulting from the implementation of AB 32, they are not included in the BAU case to ensure that the economic impacts of all of the measures in the Scoping Plan are fully assessed.

The BAU case is constructed using forecasts from the California Department of Finance, the California Energy Commission, and other sources, and is described in more detail in Appendix G. ARB used a conservative estimate of future petroleum price in this analysis, $89 per barrel of oil in 2020. Aspects of the BAU case are subject to uncertainty, for example, the possibility that future energy prices could deviate from those that are included in the BAU case.

1. Macro-economic Modeling Results

Table 24 summarizes the key findings from the economic modeling. Gross State Product, personal income and employment are shown for 2007 and for two cases for 2020, the BAU case and for implementation of the Proposed Scoping Plan. For both the BAU case and the Scoping Plan case, Gross State Product increases by almost $800 billion between 2007 and 2020, personal income grows by 2.8 percent per year from $1.5 trillion in 2007 to $2.1 trillion in 2020, and employment grows by 0.9 percent per year from 16.4 million jobs in 2007 to 18.4 million (BAU) or 18.5 million (Scoping Plan) in 2020. The results consistently show that implementing the Scoping Plan will not only significantly reduce California's greenhouse gas emissions, but will also have a net positive effect on California's economic growth through 2020.

Table 24: Summary of Key Economic Findings from Modeling the Scoping Plan Using E-DRAM

Economic Indicator	2007	Business-as-Usual*		Scoping Plan		
		2020	Average Annual Growth	2020	Change from BAU	Average Annual Growth
Gross State Product ($Billion)	1,811	2,586	2.8%	2,593	0.3%	2.8%
Personal Income ($Billion)	1,464	2,093	2.8%	2,109	0.8%	2.8%
Employment (Million Jobs)	16.41	18.41	0.9%	18.53	0.7%	0.9%
Emissions ($MMTCO_2E$)	500**	596	1.4%**	422	-28%	-1.2%**
Carbon Prices (Dollars)	-	-	-	10.00	NA	-

* Business-as-usual is a forecast of the California economy in 2020 without implementation of any of the measures identified in the Proposed Scoping Plan.

** Approximate value. ARB is in currently estimating greenhouse gas emissions for 2007.

The macroeconomic modeling results presented here understate the benefits of market-based policies, including the cap-and-trade program. Consequently, our estimate of the economic impact of implementing the Scoping Plan understates the positive impact on the California economy. Nonetheless, using the current best estimates of the costs and savings of the measures, which are documented in Appendix I, the models demonstrate that implementing the Plan will have a positive effect on California's economy.

The modeling results reflect a carbon price for the cap-and-trade program of $10 per-ton. It is important to note that the $10 per-ton figure does not reflect the average cost of reductions; rather it is the *maximum* price at which reductions to achieve the cap are pursued based on the marketing program.

The positive impacts are largely attributable to savings that result from reductions in expenditures on energy. These savings translate into increased consumer spending on goods and services other than energy. Many of the measures entail more efficient use of energy in the economy, with savings that exceed their costs. In this way, investment in energy efficiency results in money pumped back into local economies. Table 25 summarizes the energy savings that are projected from implementation of the Scoping Plan. These savings are estimated to exceed $20 billion annually by 2020.

Table 25: Fuels and Electricity Saved in 2020 from Implementation of the Scoping Plan

	Gasoline	Diesel	Electricity	Natural Gas*
Use Avoided**	4,600 million gallons	670 million gallons	74,000 GWh	3,400 million therms
Value of Avoided Fuel Use (Million $2007)	$17,000	$2,500	$6,400***	$2,700
Percent Reduction from BAU	25%	17%	22%****	24%

* Not including natural gas for electric generation.

** These estimates are based on reduced use of these fuels due to increased efficiencies, reduced vehicle miles travelled, etc. Changes to the fuel mix, such as those called for under the RPS or the LCFS, are not included here. These estimates are not the same as the estimates of reduced fuel consumption used in the public health analysis.

*** Based on estimated avoided cost based on average base-load electricity, including generation, transmission and distribution.

**** This is as a percentage of BAU total California electricity consumption in 2020.

2. Impact on Specific Business Sectors

As indicated in Table 26 and Table 27, the effects of the Plan are not uniform across sectors. Implementation of the Scoping Plan would have the strongest positive impact on output and employment for the agriculture, forestry and fishing sector, the finance, insurance and real estate sector, and the mining sector. Similar to the statewide economic impacts projected by the model, however, these results also indicate that relative to the business-as-usual case, the impacts due to implementation of the Plan change current growth projections for most sectors by only very small amounts.

Table 26 and Table 27 also show that a decrease in output is projected for the utility and retail trade sectors as compared to the business-as-usual case, and a decrease in employment is projected for the utility sector. In the utility sector, the modeling indicates that implementation of the Scoping Plan would significantly reduce the need for additional power generation and natural gas consumption, which subsequently reduces the growth in output for this sector. This results in a reduction from business-as-usual for economic output and employment of approximately 17 and 15 percent respectively in 2020. The primary reason for these projections is the implementation of efficiency measures and programs for both consumers and producers. While increasing spending on efficiency and renewable energy is expected to increase employment, many of the resulting jobs will not appear in the utility sector.

The retail trade sector, which is projected to grow by nearly 50 percent in both the business-as-usual and the Scoping Plan case, is also projected to experience a slight net decline in output relative to business-as-usual. Since gasoline is considered a consumer retail purchase under this model, the reduced growth is mostly due to the decrease of approximately $19 billion in retail transportation fuel purchases, which is largely offset by the positive $14 billion increase in spending at other retail enterprises.

Table 26: Summary of Economic Output by Sector from Modeling the Scoping Plan Using E-DRAM

Sector	Output ($Billions)			
	2007	Business-as-Usual	Scoping Plan	Percent Change from BAU
Agriculture, Forestry and Fishing	76	109	113	3.9%
Mining	27	29	31	7.2%
Utilities	51	72	60	-16.7%
Construction	114	164	166	1.7%
Manufacturing	673	943	948	0.5%
Wholesale Trade	120	171	173	1.0%
Retail Trade	207	296	291	-1.6%
Transportation and Warehousing	76	109	111	1.9%
Information	164	235	238	1.1%
Finance, Insurance and Real Estate	391	559	572	2.3%
Services	636	910	927	1.9%
Government	-	-	-	-
Total	**2,535**	**3,597**	**3,630**	**0.8%**

Table 27: Summary of Employment Changes by Sector from Modeling the Scoping Plan Using E-DRAM

Sector	Employment (thousands)			
	2007	Business-as-Usual	Scoping Plan	Percent Change from BAU
Agriculture, Forestry and Fishing	398	449	464	3.5%
Mining	26	26	26	1.3%
Utilities	60	67	57	-14.7%
Construction	825	929	934	0.5%
Manufacturing	1,821	2,046	2,057	0.5%
Wholesale Trade	703	791	793	0.1%
Retail Trade	1,688	1,901	1,916	0.8%
Transportation and Warehousing	447	503	510	1.2%
Information	398	448	450	0.4%
Finance, Insurance and Real Estate	911	1,026	1,046	2.0%
Services	5,975	6,729	6,773	0.7%
Government	3,100	3,491	3,502	0.3%
Total	**16,352**	**18,405**	**18,528**	**0.6%**

3. Household Impacts

Implementation of the Scoping Plan will provide low- and middle-income households savings on the order of a few hundred dollars per year in 2020 compared to the business-as-usual case, primarily as a result of increased energy efficiencies.

Low-Income Households: Based on current U.S. Department of Health and Human Services poverty guidelines, we evaluated the projected impacts of the plan on households with earnings at or below both 100 and 200 percent of the poverty guidelines. For all households, including those with incomes at 100 percent and 200 percent of the poverty level, implementation of the Scoping Plan produces a slight increase in per-capita income relative to the business-as-usual case.

At the same time, the analysis projects an increase of approximately 50,000 jobs available for lower-income workers[48] relative to business-as-usual as a result of implementing the Plan. The largest employment gains come in the retail, food service, agriculture, and health care fields. A decline in such jobs is projected in the retail gasoline sector due to the overall projected decrease in output from this sector. This decline, however, is more than offset by the increases experienced in other areas.

Another important factor to consider when analyzing the impact of the Scoping Plan on households is how it will affect household expenditures. As indicated in Table 28, analysis based on the modeling projections estimates a savings (i.e., reduced expenditures) of around $400 per household in 2020 for low-income households under both federal poverty guideline definitions. These savings are driven primarily by the implementation of the clean car standards and energy efficiency measures in the Scoping Plan that over time are projected to outweigh potential increases in electricity and natural gas prices that may occur. As the measures in the Scoping Plan are implemented, ARB will work to ensure that the program is structured so that low income households can fully participate in and benefit from the full range of energy efficiency measures. Many of California's energy efficiency efforts are targeted specifically at low income populations, and the CPUC's Long Term Strategic Plan for energy efficiency has redoubled its objective for the delivery of energy efficiency measures to low income populations. Additional information regarding the data in Table 28 can be found in Appendix G.

[48] Low-income jobs are defined as those with a median hourly wage below $15 per hour (2007 dollars) based on wage data and staffing pattern projections from the California Employment Development Department. The shares of low-wage occupations for each industry are then applied to the corresponding E-DRAM sector employment projections.

Table 28: Impact of Implementation of the Scoping Plan on Total Estimated Household Savings in 2020 (2007 $)

Income at 100% of Poverty Guideline	Income at 200% of Poverty Guideline	Middle Income*	High Income**	All Households***
$400	$400	$500	$500	$500

* All households between 200% and 400% of the poverty guidelines.

** All households above 400% of the poverty guidelines.

*** Average of households of all income levels.

The analysis indicates that implementation of the Scoping Plan is likely to result in small savings for most Californians, with little difference across income levels. Largely due to increased efficiencies, low-income households are projected to be slightly better off from an economic perspective in 2020 as a result of implementing AB 32.

Middle-Income Households: Implementation of the plan produces a small increase in household income across all income levels, including middle-income households, relative to the business-as-usual case.[49] In terms of how jobs for middle-income households[50] would be impacted, the modeling indicates a slight overall increase of almost 40,000 in 2020.

As shown in Table 28, the analysis projects a net-savings in annual household expenditures of about $500 in 2020 for middle-income households. These savings are driven by the emergence of greater energy efficiencies that will be implemented as a result of the plan.

4. WCI Economic Analysis

The Proposed Scoping Plan recommends that California develop a cap-and-trade program that links to the broader regional market being developed by the Western Climate Initiative (WCI). In order to examine the economic impacts of WCI program design options, WCI Partner jurisdictions contracted with ICF International and Systematic Solutions, Inc. (SSI) to perform economic analyses using ENERGY 2020, a multi-region, multi-sector energy model. The WCI economic modeling results are reported in full in Appendix D and are discussed in the Background Report on the Design Recommendations for the WCI Regional Cap-and-Trade Program, also included in Appendix D.

To help inform the program design process, the WCI analysis examined the implications of key design decisions, including: program scope, allowance banking,

[49] For purposes of our analysis we define "middle-income" households as those earning between 200% and 400% of the federal poverty guidelines.

[50] Hourly wage between $15 and $30 per hour.

and the use of offsets. Due to time and resource constraints, the modeling was limited to the eight WCI Partner jurisdictions in the Western Electric Coordinating Council (WECC) area, thereby excluding from the analysis three Canadian provinces, Manitoba, Quebec, and Ontario. Future analyses are planned that will integrate these provinces so that a full assessment of the WCI Partner jurisdictions can be performed.

The WCI modeling work is not directly comparable to the ARB results reported here. The WCI analysis relies on a more aggregated set of greenhouse gas emissions reduction measures rather than the specific individual policies recommended in the Proposed Scoping Plan; it uses somewhat different assumptions regarding what measures are included in the "business-as-usual" case, and it models the entire WECC rather than California. Nevertheless, the results of the WCI modeling provide useful insight into the economic impact of greenhouse gas emissions reduction policies.

Consistent with the conclusions of the ARB evaluation, overall the WCI analysis found that the WCI Partner jurisdictions can meet the regional goal of reducing emissions to 15 percent below 2005 levels by 2020 (equivalent to the AB 32 2020 target) with small overall savings due to reduced energy expenditures exceeding the direct costs of greenhouse gas emissions reductions. The savings are focused primarily in the residential and commercial sectors, where energy efficiency programs and vehicle standards are expected to have their most significant impacts. Energy-intensive industrial sectors are estimated to have small net costs overall (less than 0.5 percent of output).

The WCI analysis does not examine the potential macroeconomic impacts of the costs and savings estimated with ENERGY 2020. The WCI Partner jurisdictions are planning to continue the analysis so that macroeconomic impacts, such as income, employment, and output, can be assessed. Once completed, the macroeconomic impacts can be compared to previous studies of cap-and-trade programs considered in the United States and Canada.

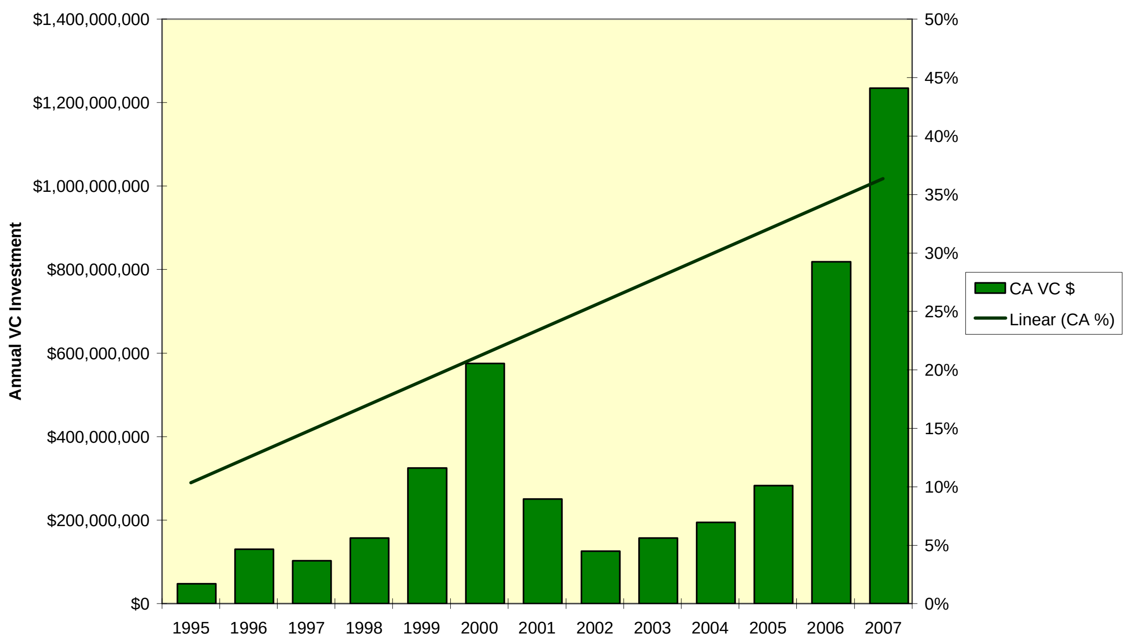
B. Green Technology

The development of green technologies and a trained workforce equipped to design, develop and deploy them will be key to the success of California's long-term efforts to combat global warming. Bold, long-range environmental policies help drive innovation and investment in emission-reducing products and services in part by attracting private capital. Typically, the private sector under invests in research and development for products that yield public benefits. However, when environmental policy is properly designed and sufficiently robust to support a market for such products, private capital is attracted to green technology development as it is to any strategic growth opportunity.

California's leadership in environmental and energy efficiency policy has helped attract an increasing share of venture capital investment in green technologies. According to statistics from PricewaterhouseCoopers and the National Venture Capital Association, California's share of U.S. venture capital investment in innovative energy technologies increased dramatically from 1995 to 2007 (see Figure 5 below).[51] The same period saw a stream of pioneering environmental policy initiatives, including energy efficiency codes for buildings and appliances, a renewables portfolio standard for electricity generation, climate change emissions standards for light-duty automobiles and, most recently, AB 32. Flows of venture capital into California are escalating as a direct result of the focus on reductions of greenhouse gas emissions. As mentioned above, California captured the largest single portion of global venture capital investment ($800 million out a total of two billion dollars) during the second quarter of 2008.

Figure 5

California's Growing Share of Venture Capital Investment in Energy Innovation, 1995-2007 (current $, % share)



Source: PricewaterhouseCoopers MoneyTree Report, available at: [https://www.pwcmoneytree.com].

A survey of clean technology investors by Global Insight and the National Venture Capital Association found that public policy influences where venture capitalists invest.[52] Furthermore, investments in green technology solutions produce jobs at a higher rate than

[51] Based on historical trend data for the 'Industrial/Energy' industry for California and the United States from the PricewaterhouseCoopers MoneyTree Report. https://www.pwcmoneytree.com/MTPublic/ns/nav.jsp?page=historical (accessed October 12, 2008)

[52] Clean Tech Entrepreneurs & Cleantech Venture Network LLC. *Creating Cleantech Clusters: 2006 Update*. May 2006. p.43 http://www.e2.org/ext/doc/2006%20National%20Cleantech%20FORMATTED%20FINAL.pdf (accessed October 12, 2008)

investments in comparable conventional technologies.[53] Venture capitalists estimate that each $100 million in venture capital funding, over a period of two decades, helps create 2,700 jobs, $500 million in annual revenues, and many indirect jobs.[54]

Access to capital controlled by institutional investors is also enhanced by policies that encourage early adoption of green technologies. When California-based corporations use green technologies to reduce their exposure to climate change risk, institutional investors reward them by facilitating their access to capital. The Investor Network on Climate Risk – including institutional investors with more than $8 trillion of assets under management – endorsed an action plan in 2008 that calls for requiring asset managers to consider climate risks and opportunities when investing; investing in companies developing and deploying clean technologies; and expanding climate risk scrutiny by investors and analysts.[55]

Additional capital for green technologies helps drive increased employment, both indirectly, as energy savings are plowed back into other sectors of the economy, and directly, as new green products are successfully commercialized.

McKinsey & Company projects average annual returns of 17 percent on global investments in energy productivity, and estimates the global investment opportunity at $170 billion annually through 2020.[56] Meanwhile, global investment in energy efficiency and renewable energy has grown from $33 billion to more than $148 billion in the last four years. Beyond 2020, green technologies are expected to attract investment of more than $600 billion annually.[57] In short, green technology is now a *bona fide* global growth industry.

Today, green technology businesses directly employ at least 43,000 Californians, primarily in energy efficiency and energy generation, according to a 2008 study from the California Economic Strategy Panel. Green jobs are concentrated in manufacturing (41 percent), and

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[53] Report of the Renewable and Appropriate Energy Laboratory. *Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?* Energy and Resources Group/Goldman School of Public Policy at University of California, Berkeley. April 13, 2004. http://rael.berkeley.edu/old-site/renewables.jobs.2006.pdf (accessed October 12, 2008)

[54] Report prepared for the National Venture Capital Association. *Venture Impact 2004: Venture Capital Benefits to the U.S. Economy*. Prepared by: Global Insight. June 2004. http://www.globalinsight.com/publicDownload/genericContent/07-20-04_fullstudy.pdf (accessed October 12, 2008)

[55] The Investor Network on Climate Risk. *Final Report, 2008 Investor Summit on Climate Risk*. February 14, 2008. http://www.ceres.org//Document.Doc?id=331 (accessed October 12, 2008)

[56] McKinsey Global Institute. *The Case for Investing in Energy Productivity.* McKinsey & Company. February, 2008. p.8 http://www.mckinsey.com/mgi/reports/pdfs/Investing_Energy_Productivity/Investing_Energy_Productivity.pdf (accessed October 12, 2008)

[57] United Nations Environment Programme-New Energy Finance Ltd. *Global Trends in Sustainable Energy Investment 2008: Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency* 2008. p.12 ISBN: 978-92-807-2939-9 http://www.unep.fr/energy/act/fin/sefi/Global_Trends_____2008.pdf (accessed October 12, 2008)

professional, scientific and technical services (28 percent), with median annual earnings of $35,725 and $56,754, respectively.[58] By 2030, under a moderate growth scenario, green businesses nationwide are expected to generate revenues of $2.4 trillion, (2006 dollars), and employ 21 million Americans.[59]

As a leader in green technology development and use, California has already realized substantial economic benefits from the adoption of energy efficiency policies. State energy efficiency measures have saved enough energy over the past 30 years to avoid construction of two dozen 500-megawatt power plants. Today, California's per capita electricity consumption is 40 percent below the national average, and the carbon intensity of California's economy is among the lowest in the nation.[60]

Renewable energy, such as solar, wind, biomass, geothermal, will also bring new employment opportunities to Californians while spurring economic growth. California enjoys significant comparative advantages for renewable energy: concentrated innovation resources, a large potential customer base, key natural resources such as reliable solar and wind, and supportive regulatory programs, including the California Renewables Portfolio Standard, the Million Solar Roofs Initiative, the California Global Warming Solutions Act of 2006, and the Solar Water Heating and Efficiency Act of 2007.

Other researchers have estimated that under a national scenario with 15 percent renewables penetration by 2020, California will experience a net gain in direct employment of 140,000 jobs.[61] Because investments in green technologies produce jobs at a higher rate than investments in conventional technologies, jobs losses that occur in traditional fossil fuel industries will be more than compensated for by gains in the clean energy sector.

Furthermore, if California's renewable energy suppliers field products that are sufficiently competitive to penetrate the export market, employment and earnings dividends for the state will also increase. California renewable energy industries servicing the export market can generate up to 16 times more employment than those that only manufacture for domestic

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[58] California Economic Strategy Panel with Collaborative Economics. *Clean Technology and the Green Economy*. March 2008. P.14-15 http://www.labor.ca.gov/panel/pdf/DRAFT_Green_Economy_031708.pdf (accessed October 12, 2008)

[59] The American Solar Energy Society. *Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century.* 2007. p.39 ISBN 978-0-89553-307-3 http://www.ases.org/images/stories/ASES-JobsReport-Final.pdf (accessed October 12, 2008)

[60] California Energy Commission. *2007 Integrated Energy Policy Report*. Document No. CEC-100-2007-008-CMF. 2007. p. 3 http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF (accessed October 12, 2008)

[61] Tellus Institute and MRG Associates. *Clean Energy: Jobs for America's Future.* As cited in: Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? Energy and Resources Group/Goldman School of Public Policy at University of California, Berkeley. April 13, 2004. http://rael.berkeley.edu/old-site/renewables.jobs.2006.pdf (accessed October 12, 2008)

consumption, according to a study by the Research and Policy Center of Environment California.[62]

C. Cost-Effectiveness

As noted in several provisions of AB 32, cost-effectiveness is an important requirement to be considered in the design and implementation of emission reduction strategies. (See HSC §§38505, 38560, 38561, 38562.) AB 32 defines "cost-effective" or "cost-effectiveness" as "the cost per unit of reduced emissions of greenhouse gases adjusted for its global warming potential." (HSC §38505(d)) This definition specifies the metric (i.e., dollars per ton) by which the Board must express cost-effectiveness, but it does not provide criteria to assess if a regulation is or is not cost-effective. It also does not specify whether there should be a specific upper-bound dollar per ton cost that can be considered cost-effective, or how such a bound would be determined or adjusted over time. ARB has investigated different approaches that could be used to evaluate the cost-effectiveness of regulations and is recommending the following approach.

The estimated cost per ton of greenhouse gas emissions reduced by the measures recommended in this Plan ranges from $-408 (net savings) to $133, with all but one (the Renewables Portfolio Standard) costing less than $55 per ton. The RPS is being implemented for energy diversity purposes, not just greenhouse gas reductions, and the $133 per ton figure does not take these other benefits into account. Therefore, it should not be used as a reference to define the range of cost-effective greenhouse gas measures. These estimates are based on the best information available as ARB prepared this Proposed Plan. Updated estimates and greater certainty will be provided as the measures are further developed during the rulemaking process.

In the meantime, the current estimates provide a range illustrating the cost per ton of the mix of measures that collectively meet the 2020 target. This range will assist the Board in evaluating the cost-effectiveness of individual measures when considering adoption of regulations. The range of acceptable cost-effectiveness may change if effective lower-cost measures and options are identified. Because both the projections of "business-as-usual" 2020 emissions and the degree of reductions from any given measures may be greater or less than current estimates, the determination should remain flexible to accommodate a higher or lower estimate of cost-effectiveness. In addition, the approach must provide flexibility to pursue measures that simultaneously achieve policy objectives other than greenhouse gas emissions reduction (such as energy diversity).

The criteria for judging cost-effectiveness will be updated as additional technological data and strategies become available. As ARB moves from adoption of the Scoping Plan to

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[62] Environment California Research and Policy Center. *Renewable Energy and Jobs. Employment Impacts of Developing Markets for Renewables in California*. July 2003. As cited in: Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? Energy and Resources Group/Goldman School of Public Policy at University of California, Berkeley. April 13, 2004. http://rael.berkeley.edu/old-site/renewables.jobs.2006.pdf (accessed October 12, 2008)

developing specific regulations, and as regulations continue to be adopted, updated cost-effectiveness estimates will be established in a rigorous and transparent process with full stakeholder participation. As ARB progresses from proposed measures and estimated costs to actual regulations, the comparison of cost-effectiveness would move toward the well established practice of comparing the cost-effectiveness of new regulations to the cost-effectiveness of previously enacted and/or similar regulations. This approach is consistent with how cost-effectiveness is evaluated for strategies to reduce criteria and toxic pollutants.

D. Small Business Impact

Small businesses play an important role in California's economy. As required under AB 32, ARB analyzed the impact that implementation of the Scoping Plan would have on small businesses in the state. The analysis indicates that the primary impacts on small businesses as a result of AB 32 will come in the form of changes in the costs of goods and services that they procure, and in particular, changes in energy expenditures. Due to the number of measures in the plan that will deliver significantly greater energy efficiencies, our analysis projects that implementation of the plan will have a positive impact on small business in California even after taking into account the higher per-unit energy prices that are likely to occur between now and 2020. Small businesses also will benefit as a result of the robust economic growth and the increases in jobs, production, and personal income that are projected between now and 2020 as AB 32 is implemented. Additional information is provided in Appendix G.

Recent analysis from Energy and Environmental Economics, Inc. (E3) forecasts that a package of greenhouse gas emissions reduction measures similar to those recommended in this Plan would deliver a five percent decrease in electricity expenditures for the average California electricity customer relative to business-as-usual in 2020.[63] This projection is based on the assumption that increases in electricity prices will be more than offset by the continued expansion of energy efficiency measures and that more efficient technologies will be developed and implemented.[64] For purpose of this analysis, expenditures on natural gas are assumed to remain the same, balancing the projected 29 percent decrease in natural gas consumption in California with the model's projected natural gas price increase of almost 9 percent.

Based on this assessment, implementation of the Scoping Plan will likely have minor but positive impacts on small businesses in the state. These benefits are attributable primarily to the measures in the plan that will deliver significantly greater energy and fuel efficiencies. Even when higher per unit energy prices are taken into account, these efficiencies will decrease overall energy expenditures for small businesses. Additionally, as previously described, the California economy is projected to experience robust economic growth

[63] Based on their GHG Calculator, CPUC/CEC GHG Docket (CPUC Rulemaking.06.04.009, CEC Docket 07-OIIP-01), available at http://www.ethree.com/cpuc_ghg_model.html.

[64] The E3 analysis focuses on direct programmatic measures and does not include the incremental price impact of the cap-and-trade program, which will depend upon allowance price, allocation strategy, the capped sector industry response, and other program design decisions.

between now and 2020 as AB 32 is implemented. Small businesses will experience many of the benefits associated with this growth in the form of more jobs, greater production activity, and rising personal income.

The projected decrease in electricity expenditures is especially important for small businesses since they typically spend more on energy as a percentage of revenue compared to larger enterprises. For example, firms with a single employee spend approximately 3.3 percent of each sales dollar on electricity, while businesses with between ten and forty-nine employees spend around 1.2 percent. As a result, smaller businesses are likely to experience a greater relative benefit from decreased energy expenditures relative to their larger counterparts.

From the broader economic perspective, these changes will make California more competitive as a location for small business, moving it from 7th highest to 19th among all states in terms of the percentage of revenue that businesses expend on electricity.[65] As was noted above for low income households, care must be taken to ensure that the program is structured to allow small businesses to participate in and benefit from the energy efficiency measures.

While ARB's analysis indicates a positive impact on small businesses from AB 32 implementation, to ensure that these benefits are realized to the fullest potential it will take additional outreach and communication efforts on the part of ARB and many other state and local entities. There are a number of existing programs that are designed to help small businesses achieve greater efficiencies in energy use. These programs can be enhanced and expanded upon, and new programs and efforts can be developed to ensure that all small businesses in California are aware of and able to take cost-effective steps to reduce energy use and enjoy the associated economic savings. For example, as discussed more completely in Chapter IV, ARB and our partners in State government are working together to develop an on-line small business "toolkit" designed for small and medium-sized businesses to provide a one-stop shop of technical and financial information resources. As further development and implementation of the measures in the plan proceeds, we will work with other state and local partners to ensure that small businesses can both benefit from and play a role in helping to achieve our greenhouse gas emission reduction requirements.

E. Public Health/Environmental Benefits Analyses

AB 32 requires ARB to evaluate the environmental and public health impacts of the Scoping Plan. The analysis of this plan is focused primarily on the quantification of public health benefits from air quality improvements that would result from implementation. Unlike traditional pollutants and toxic emissions, global warming pollutants do not typically have localized impacts. At ambient levels, carbon dioxide, which makes up over 80 percent of global warming pollutants in California, has no direct environmental or public health consequences. Climate change caused by greenhouse gas pollutants emitted in another state

[65] Although the natural gas data is less specific, a similar scenario is expected where increased prices are typically offset by greater efficiencies for most small businesses.

or country has the same potential to damage our public health and the environment as does climate change due to pollutants emitted within California. Although this analysis does not consider the public health impacts of climate change, the potential public health impacts are great, and have been well documented elsewhere. However, many of the measures aimed at reducing global warming pollutants also provide co-benefits to public health and California's natural resources.

The environmental and cumulative impacts of the Plan are discussed in the California Environmental Quality Act (CEQA) document that is included in Appendix J. As the Scoping Plan is implemented, and specific measures are developed, ARB will conduct further CEQA analyses, including cumulative and multi-media impacts. As ARB further develops its approach for consideration of these issues in future rulemakings, and updates needed analytical tools and data sets, we will consult with outside experts and the EJAC. ARB recognizes that the adoption of the Scoping Plan will launch a variety of regulatory proceedings in many different venues. ARB will work closely with other California State agencies including: the Office of Planning and Research, Environmental Protection Agency, Resources Agency, Integrated Waste Management Board, Department of Public Health, Office of Environmental Health Hazard Assessment, State Water Resources Control Board, Department of Toxic Substances Control, Department of Water Resources, Board of Forestry, Department of Fish and Game, Public Utilities Commission, California Energy Commission, and others to identify and address potential multi-media environmental impacts early in the regulatory development process.

California's actions to reduce greenhouse gas emissions will help transition the State to new technologies, improved efficiencies, and land use patterns also necessary to meet air quality standards and other public health goals. California's challenging public health issues associated with air pollution are already the focus of comprehensive regulatory and incentive programs. These programs are reducing smog forming pollutants and toxic diesel particulate matter at a rapid pace. However, to meet increasingly stringent air quality standards and air toxics reduction goals, transformative changes are needed in the 2020 timeframe and beyond. Implementation of AB 32 will provide additional support to existing State efforts devoted to protecting and improving public health.

1. Key Air Quality-Related Public Health Benefits

The primary direct public health benefits of the Proposed Scoping Plan are reductions in smog forming emissions and toxic diesel particulate matter. The most significant reductions are of oxides of nitrogen (NOx), which forms both ozone and particulate pollution (PM2.5), and directly emitted PM2.5, which includes diesel particulate matter. The analysis focuses on PM2.5 impacts and quantifies 2020 public health benefits of this plan in terms of avoided premature deaths, hospitalizations, respiratory effects, and lost work days. Additional benefits associated with the reductions in ozone forming emissions were not quantified since statewide 2020 photochemical modeling is not available.

The estimated air quality-related public health benefits of the Proposed Scoping Plan are above and beyond the much greater benefits of California's existing programs, which are reducing air pollutant emissions every year. This continuing progress is the result of California's plans for meeting air quality standards ("State Implementation Plans" or SIPs), reducing emissions from goods movement activities, and addressing health risk from diesel particulate matter. These programs address both existing and new sources of air pollution, taking into account population and economic growth. The additional benefits of the Proposed Scoping Plan in 2020 are significant, and in the longer term, can be expected to increase with further reductions in fossil fuel combustion, the primary basis for the estimated public health benefits.

The recommended measures in the Proposed Scoping Plan that reduce smog forming ("criteria") pollutants are shown in Table 29 along with the estimated reductions. Statewide, these measures would reduce approximately 61 tons per day of NOx and 15 tons per day of PM2.5 in 2020. As shown in Table 30, this equates to an estimated air quality-related public health benefit of 400 avoided premature deaths statewide. In comparison, reductions in PM2.5 from California's existing programs and 2007 SIP measures are estimated to result in 3,700 avoided premature deaths statewide in the same timeframe.

Table 29: Statewide Criteria Pollutant Emission Reductions in 2020 from Proposed Scoping Plan Recommendation[66]

(tons per day)

Measure	NOx	PM2.5
Light-Duty Vehicle • Pavley I and Pavley II GHG Standards • Vehicle Efficiency Measures	1.6	1.4
Goods Movement Efficiency Measures	16.9	0.6
Medium and Heavy-Duty Vehicle GHG Emission Reduction • Aerodynamic Efficiency • Hybridization • Engine Efficiency	5.6	0.2
Local Government Actions and Regional Targets	8.7	1.4
Energy Efficiency and Conservation (Electricity)	7.0	4.0
Energy Efficiency and Conservation (Natural Gas)	10.4	0.8
Solar Water Heating	0.3	0.03
Million Solar Roofs	1.0	0.6
Renewables Portfolio Standard	9.8	5.6
Total	**61**	**15**

[66] Table 29 does not include the criteria pollutant co-benefits of additional greenhouse gas reductions that would be achieved from the proposed cap-and-trade regulation because we cannot predict in which sectors they would be achieved.

Table 30: Estimates of Statewide Air Quality-Related Health Benefits in 2020

Health Endpoint	Health Benefits of Existing Measures and 2007 SIP *mean*	Health Benefits of Recommendations in the Proposed Scoping Plan *mean*
Avoided Premature Death	3,700	400
Avoided Hospital Admissions for Respiratory Causes	770	84
Avoided Hospital Admissions for Cardiovascular Causes	1,400	150
Avoided Asthma and Lower Respiratory Symptoms	110,000	11,000
Avoided Acute Bronchitis	8,700	910
Avoided Work Loss Days	620,000	67,000
Avoided Minor Restricted Activity Days	3,600,000	380,000

In addition to the quantified air-quality-related health benefits, our analysis indicates that implementation of the Proposed Scoping Plan can deliver other public health benefits as well. These include potential health benefits associated with local and regional transportation-related greenhouse gas targets that can facilitate greater use of alternative modes of transportation, such as walking and bicycling. These types of moderate physical activities reduce many serious health risks including coronary heart disease, diabetes, hypertension and obesity.[67] Finally, it is important to note that the steps California is taking to address global warming, along with actions by other regions, states, and nations, will help mitigate the public health effects of heat waves, more widespread incidence of illness and disease, and other potentially severe impacts.

The measures in the Proposed Scoping Plan are designed primarily to help spur the transition to a lower carbon economy. However, in addition to improving air quality, these measures can also improve California's environmental resources, including land, water, and native species. Land resources will be affected by regional transportation-related targets leading to improved land use planning, and forest carbon sequestration targets which can result in better stewardship of California lands and reduced wildfire risk. A number of conservation measures will aid in effective management of the State's precious water resources. Demand for waste disposal and hazardous materials should decrease as measures to encourage recycling and reuse transform our wastes into fuel, energy, and other useful products are implemented. Additional analysis of the way that implementation of the Scoping Plan will impact these environmental resources will be conducted as we proceed. Many of these measures serve the dual purpose of mitigating greenhouse gas emissions and helping California adapt to the impacts of climate change.

[67] Appendix H contains a reference list of studies documenting the public health benefits of alternative transportation.

2. Approach

ARB quantified the potential reductions of NOx and PM2.5 from implementation of the Proposed Plan's recommendations, and the public health benefits associated with the resulting potential air quality improvement. These analyses compare NOx and PM2.5 emissions in 2020 with the implementation of the Scoping Plan with NOx and PM2.5 emissions in 2020 in the absence of the Scoping Plan – a "business-as-usual" scenario. The methodology used to evaluate the public health benefits of the emission reductions is similar to the methodology used in ARB's 2006 Goods Movement Emission Reduction Plan (GMERP).[68] This methodology is based on a peer-reviewed methodology developed by the U.S. Environmental Protection Agency (U.S. EPA). ARB augmented U.S. EPA's methodology by incorporating the result of new epidemiological studies relevant to California's population, including regionally specific studies, as they became available.

AB 32 directs ARB to conduct several levels of analysis as we proceed through the development and implementation of a comprehensive greenhouse gas emissions reduction strategy. As part of the Scoping Plan development, ARB is required to assess both the economic and non-economic impacts of the plan as noted above. Additionally, AB 32 requires ARB to undertake additional analysis at the time of adoption of regulations, including market-based compliance mechanisms.

Although not yet at the stage of regulatory development and adoption, in this analysis ARB conducted an evaluation of the air quality-related public health benefits associated with the Proposed Scoping Plan based on a community level emissions analysis example. As regulations that rely on market-based compliance mechanisms are further developed for consideration by the Board, more detail about the specific regulatory proposals will be developed, enabling ARB to more closely evaluate the potential for direct, indirect and cumulative impacts.

3. Existing Programs for Air Quality Improvement in California

The public health analysis of the Proposed Scoping Plan presents air-quality benefits that will occur in addition to the benefits of California's comprehensive air quality programs designed to meet health-based standards and reduce health risk from air toxics. It is also important to note that under both a "business-as-usual" scenario and under the implementation of the Proposed Scoping Plan, the population and economy of California are projected to continue to grow. New businesses and industries will continue to be sited in California, bringing both economic opportunity and potential environmental impacts. Federal, State, and local laws and regulations have established requirements to ensure that new and modified sources of pollution are carefully evaluated and that significant impacts are mitigated. Emissions from existing businesses are also tightly controlled by local air pollution control districts.

[68] Air Resources Board. Technical Supplement on Health Analysis. *Technical Supplement on Quantification of the Health Impacts and Economic Valuation of Air Pollution from Ports and Goods Movement in California.* March 2006 http://www.arb.ca.gov/planning/gmerp/gmerp.htm (accessed October 12, 2008)

Statewide programs are in place to reduce emissions from cars, trucks, and off-road equipment, along with smog check, cleaner gasoline and diesel fuels, and regulations to reduce evaporative emissions from consumer products, paints, and refueling. Additional information about the existing regulatory framework for sources of air pollution is provided in Appendix H.

It is important to evaluate the air quality and public health benefits of the Proposed Scoping Plan in the context of the State's on-going air quality improvement efforts. California's long-standing air pollution control programs have substantially improved air quality in the state and will continue to do so in the future. By 2020, these programs will deliver reductions in statewide NOx emissions of 441 tons per day and direct fine particle emission reductions of 34 tons per day. Through 2020, three key ARB efforts will deliver deep reductions in air pollutant emissions despite continuing growth:

- Diesel Risk Reduction Plan
- Goods Movement Emission Reduction Plan
- 2007 State Implementation Plan

Measures in these plans will result in the accelerated phase-in of cleaner technology for virtually all of California's diesel engine fleets including trucks, buses, construction equipment, and cargo handling equipment at ports. Adoption and implementation of these and other measures are critical to achieving clean air and public health goals statewide.

The U.S. Environmental Protection Agency has set a new, more stringent, national ambient air quality standard for ozone that will have compliance deadlines well past 2020 for the most severely impacted areas like southern California.[69] The unmitigated impacts of climate change will make it harder to meet this standard and to provide healthful air to Californians.

4. Statewide Analysis

For this evaluation, ARB examined the recommended measures to determine the potential for impacts on air, land, water, native species and biological resources, and waste and hazardous materials. Local government, State government, and green building sectors were not included in this evaluation as they represent means of implementation of the greenhouse gas emission reduction measures. As noted, the main focus of this analysis is on air quality. To the extent feasible, ARB quantified estimated emissions reductions in criteria pollutants associated with each recommended measure except cap-and-trade. Reductions in NOx and PM2.5 were used to estimate public health benefits. The estimated statewide reductions are

[69] U.S. Environmental Protection Agency. *National Ambient Air Quality Standards for Ozone. Final Rule.* 73 Federal Register 16436. March 27, 2008. http://www.epa.gov/fedrgstr/EPA-AIR/2008/March/Day-27/a5645.pdf (accessed October 12, 2008)

61 tons per day of NOx and 15 tons per day of PM2.5. Further analysis of the potential criteria pollutant benefits of a cap-and-trade program will be done as part of regulatory development.

5. Regional Assessment: South Coast Air Basin Example

In order to assess potential air quality benefits of the Proposed Scoping Plan on a regional level, ARB evaluated associated criteria pollutant reductions in the South Coast Air Basin as an example case. Existing programs will reduce current NOx emissions by almost 50 percent in 2020. With the new 2007 SIP measures, NOx emissions will be reduced almost 60 percent. Because of the large population and high pollutant concentrations in this region, greater benefits occur from each ton of pollution reduced. The estimated air quality-related public health benefits of the Proposed Scoping Plan for the South Coast region are shown in Table 31. The significant air quality-related public health benefits in this region are largely attributed to the additional reductions in PM2.5.

Table 31: Estimated Air Quality-Related Health Benefits of Existing Program, 2007 SIP, and Proposed Scoping Plan in the South Coast Air Basin, 2020

Health Impacts / Scenario	Benefits from Existing Program	Additional Benefits from 2007 SIP	Additional Co-Benefits from Proposed Scoping Plan
Premature Deaths Avoided	1,600	920	200
Hospitalizations Avoided – Respiratory	330	200	42
Hospitalizations Avoided – Cardiovascular	610	360	78
Asthma & Lower Respiratory Symptoms Avoided	46,000	28,000	5,900
Acute Bronchitis Avoided	3,800	2,300	490
Work Loss Days Avoided	270,000	160,000	35,000
Minor Restricted Activity Days Avoided	1,600,000	940,000	200,000

6. Community Level Assessment: Wilmington Example

ARB also conducted an evaluation of the potential air quality impacts of the Proposed Scoping Plan in the community of Wilmington as an illustration of the potential for localized impacts. Wilmington is in southern Los Angeles County and includes a diverse range of stationary and mobile emissions sources, including the ports of Los Angeles and Long Beach, railyards, major transportation corridors, refineries, power plants, and other industrial and commercial operations. Like the regional analysis, additional emission reductions from the 2007 SIP were estimated and show significant reductions in Wilmington by 2020 – approximately a 45 percent reduction in NOx and a 40 percent reduction in directly-emitted PM2.5. Mobile source emissions are projected to continue to be proportionately greater than stationary source emissions in 2020 even as mobile source emissions decline.

For this assessment, ARB evaluated criteria pollutant emission reductions in the Wilmington study area assuming that the source-specific quantified measures are implemented, including measures to reduce emissions from oil and gas extraction and refineries. It was further assumed that the non-source specific program elements, such as the proposed cap-and-trade program, result in a 10 percent reduction in fuel combustion by affected sources within the study area. For example, it is estimated that industrial sources would achieve greenhouse gas emission reductions through efficiency measures that reduce on site fuel use by 10 percent either in response to a cap-and-trade program, or due to the results of the facility energy efficiency audits. While it is likely that the actual onsite reductions will differ across individual facilities from the assumed uniform ten percent reduction,[70] the analysis identifies how reductions at these facilities affect the overall level of co-benefits.

The estimated NOx co-benefit of about 1.7 tons per day is small relative to the projected reductions of 24 tons per day that will occur as a result of the SIP and other measures. For example, an 8 ton per day NOx reduction is expected from cleaner port trucks. In comparison, the potential NOx benefit from a 10 percent efficiency improvement in major goods movement categories is estimated at about 1.5 tons per day. The estimated PM2.5 co-benefits, on the order of 0.12 tons per day, are also small relative to the projected reductions of 2.3 tons per day that will occur as a result of the SIP and other measures. Approximately 30 percent (0.04 ton per day) of the PM 2.5 co-benefit reduction is associated with assumed energy efficiency measures at the four large refineries in the study area, while another 30 percent would occur due to a 10 percent efficiency improvement by goods movement sources.

The co-benefit emissions reductions in the study area would produce regional air quality-related health benefits. A relatively small portion of these benefits would occur in the study area (approximately 300,000 area residents). Health benefits due to reductions in NOx are mostly at the regional levels, since NOx emissions have usually travelled some distance before they are transformed into PM via atmospheric reactions. Point source combustion PM emissions persist in the atmosphere and increase exposures both in the area where they are emitted and broadly throughout the region. Based on previous modeling studies of the impact of port and rail yard PM emissions in the South Coast Air Basin conducted by ARB, PM exposures will be reduced far beyond the study area, and a majority of the health benefits are expected to occur in areas outside of the Wilmington community.[71]

Using the previously described methodology that correlates emission reductions in the air basin with expected regional health benefits there would be an estimated

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[70] The reductions at any one facility could be much greater or lesser than 10 percent For example, very small or no reductions might occur because available cost-effective industrial emission reductions have already been implemented at a particular site.

[71] ARB analysis indicates that about 20 percent of the health benefits would occur in the Wilmington area.

11 avoided premature deaths attributed to emission reductions that occur in Wilmington as a result of the Scoping Plan.[72]

F. Summary of Societal Benefits

AB 32 requires ARB to "consider the overall societal benefits, including reductions in other air pollutants, diversification of energy sources, and other benefits to the economy, environment, and public health" (HSC § 38562(b)(6)) when developing regulations to implement the Scoping Plan. ARB conducted an initial assessment of societal benefits associated with AB 32 implementation. This section summarizes those that have been identified during development of the Scoping Plan, including diversification of energy sources, mobility, regressivity, and job creation. More detailed economic and environment/public health analyses can be found in Appendix G and H, respectively. The impact of low income households (regressivity), impacts on small businesses, and impact on jobs are described in the Economic Analysis section and Appendix G.

1. Energy Diversification

Generally, energy-related measures in this Proposed Scoping Plan are expected to result in a transformation of the State's energy portfolio, driven primarily by the Low Carbon Fuel Standard (LCFS), which addresses transportation fuel, and the 33 percent RPS, which increases renewably-produced electricity production and distribution to households and businesses.

The LCFS aims to achieve at least a 10 percent reduction in the carbon intensity of California's transportation fuels by 2020. As the State moves toward less dependence upon one source of fuel for transportation, our economy will be less at risk from significant fluctuations in fuel prices. Measures within the Scoping Plan will force energy diversification in California toward low-carbon intensive energy sources and encourage significant growth in infrastructure, capital, and investment in biofuels.

The move toward 33 percent renewables will, by definition, increase the diversification of California's electrical supply. Increased use of wind, solar, geothermal and biomass (including from the organic fraction of municipal solid waste) generation will all add to ensuring the state has a broader portfolio of energy inputs.

Based on ARB's economic analysis, the combined energy diversification and increased energy efficiency expected from implementation of the Scoping Plan is predicted to result in: a 25 percent decrease in gasoline usage (4.6 billion gallons), a 17 percent decrease in diesel fuel use (670 million gallons), a 22 percent decrease in electricity (74,000 GWh reduction) and a 24 percent reduction in natural gas (3,400 therms).

[72] See Appendix H

The cap-and-trade program, offsets, and other measures that contain market-based features may also help diversify California's energy portfolio by incentivizing the development and deployment of clean and efficient energy generating technologies.

2. Mobility and Shifts in Land Use Patterns

Mobility is analyzed through multiple approaches in the Proposed Scoping Plan. Appendix C includes an analysis of a proposed measure for regional transportation-related greenhouse targets. Reductions in vehicle miles traveled (VMT) are expected to result from regional and local planning which target land use, building and zoning improvements.

As the Scoping Plan is implemented, measures that support shifts in land use patterns are expected to emphasize compact, low impact growth in urban areas over development in greenfields. Communities could realize benefits, such as improved access to transit, improved jobs-housing balance, preservation of open spaces and agricultural fields, and improved water quality due to decreased runoff. Local and regional strategies promoting appropriate land use patterns could encourage fewer miles traveled, lowering emissions of greenhouse gases, criteria pollutants and PM. More compact communities with improved transit service could increase mobility, allowing residents to easily access work, shopping, childcare, health care and recreational opportunities.

Furthermore, if open spaces and desirable locations become more accessible and communities are designed to encourage walkability between neighborhoods and shopping, entertainment, schools and other destinations, residents are likely to increase their levels of physical activity. Research shows that regular physical activity can reduce health risks, including coronary heart disease, diabetes, hypertension, anxiety and depression, and obesity. Measures in the Proposed Scoping Plan encourage Californians to use alternatives to personal vehicle travel that could result in increased personal exercise. To complement these changes, future community developments may evolve to include trails and pedestrian access to major centers. However, where compact development may increase proximity to large sources of pollution, such as high traffic arterials, distribution centers, and industrial facilities, it will be critical to analyze the anticipated and unanticipated impacts and benefits, to ensure that increases in exposure to vehicular air pollution and other toxics and particulates do not occur .

G. California Environmental Quality Act Functional Equivalent Document

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential adverse environmental impacts of proposed projects. ARB's analysis of the potential adverse environmental impacts of the Proposed Scoping Plan is presented in Appendix J. The analysis summarizes and discusses the specific strategies in the Scoping Plan that, if adopted and implemented, will reduce greenhouse gas emissions throughout the state. The evaluation is programmatic by necessity; it allows consideration of broad policy alternatives and program-wide mitigation measures at a time when an agency has greater flexibility to deal with basic problems of cumulative impacts. A programmatic document also plays an important role in establishing a structure within which future reviews of related actions can be effectively conducted. The Secretary of California's Resources Agency determined that ARB meets the criteria for a Certified Regulatory Program and requires ARB to prepare a substitute document. This functionally equivalent document (FED) is intended to disclose potential adverse impacts and identify mitigation measures specific to the actions identified in the Proposed Scoping Plan. The analysis generally found that the proposed Low Carbon Fuel Standard, Renewables Portfolio Standard and Water measures have the most potential to cause adverse environmental impacts due to the potential for land conversion when projects are undertaken. Additional environmental analysis will be needed when regulations are adopted and at the individual project level to identify mitigation for project specific impacts.

H. Administrative Burden

ARB conducted a assessment of the administrative burden of implementing the Proposed Scoping Plan recommendation. (HSC §38562 (b)(7)) The recommendation calls for ARB to develop a cap-and-trade program – a market-based regulatory program to cap and reduce emissions from the Industrial, Electricity, Natural Gas, and Transportation sectors. This program would require stringent monitoring and reporting on the part of the regulated community, and comprehensive enforcement on the part of ARB. Sources under the cap would need to analyze the best approach for their company to comply with a cap – assessing the cost of reducing emissions and comparing that to the cost of purchasing emission reductions in a market. Although ARB has not previously developed this type of market regulation, there is extensive experience to draw upon from within California, nationally, and internationally. In addition, the other regulatory components of the recommendation would require ARB and other State agencies to adopt a series of measures requiring regulatory development, outreach to stakeholders and the public, implementation by industry, and enforcement for numerous measures and programs.

I. De Minimis Emission Threshold

A minimum level at which regulations are determined not to apply is termed the 'de minimis threshold.' In recommending a de minimis level, ARB must take into account the relative contribution of each source or source category to statewide greenhouse gas emissions and the adverse effect on small business. (HSC §38561(e)) This threshold acts as a buffer below which the burden of regulation is determined to outweigh the potential harmful effect of the minimal level of emissions. However, it should not be assumed that an individual source of greenhouse gas emissions that is minimal if taken by itself will fall below the threshold. ARB often looks at the aggregate emissions from a source category or related source category when determining regulatory applicability.

A source category may be evaluated as the aggregate of businesses doing the same type of work (e.g., semiconductor manufacturers), a type of equipment (cargo handling equipment, cars), a process or product (cans of pressurized duster), or other aggregated sources of emissions. Emissions of greenhouse gases from any individual entity within these source categories by themselves could be small. However, when emissions from the source category are evaluated, the relative contribution to climate change can be significant.

As ARB developed the Proposed Scoping Plan, potential measures were evaluated against criteria that included the relative contribution of the source to climate change. After this review and considering the level of emissions needed to meet the 1990 target established by AB 32, ARB recommends a de minimis level 0.1 $MMTCO_2E$ annual emissions per source category.[73] Source categories whose total aggregated emissions are below this level are not proposed for emission reduction requirements in the Proposed Scoping Plan but may contribute toward the target via other means.

ARB and other agencies implementing measures included in the Scoping Plan should carefully consider this de minimis level in developing regulations, and only regulate smaller source categories if there is a compelling necessity.

As each regulation to implement the Scoping Plan is developed, ARB and other agencies will consider more specific de minimis levels below which the regulatory requirements would not apply. These levels will consider the cost to comply, especially for small businesses, and other factors.

[73] The Forest sector was not included in determining the de minimis level because this sector serves both as a source and a sink for carbon, making the concept of a de minimis level less applicable.

IV. IMPLEMENTATION: Putting the Plan into Action

Adoption of this Scoping Plan will be a groundbreaking step forward for California. However it is only the beginning of a journey that will last for decades, gradually moving the State into a low-carbon, clean energy future. Putting the Scoping Plan into action will be challenging but with adequate commitment and leadership from Californians up and down the state, it will be a success.

A. Personal Action

The greenhouse gas emission reductions required under AB 32 cannot be realized without the active participation of the people of California. While many of the measures in this Plan must be taken by large sources of emissions, such as power plants and industrial facilities, it is the voluntary commitment and involvement of millions of individuals and households throughout the State that will truly make this California's Plan.

Shifts in individual choices and attitudes drive changes in the economy and in institutions. This dynamic of changing individual behavior will influence California's effort to reduce greenhouse gas emissions. For example, as market forces and environmental awareness encourage more people to drive low-greenhouse gas emitting vehicles, the auto manufacturers will respond with more innovative models and more intensive research. Regulations requiring auto manufacturers to provide these cars will complement the market demand.

This means that thinking about climate change and our carbon footprint will naturally become part of how individuals make decisions about travel, work, and recreation. Some families may choose to purchase a more efficient vehicle when it comes time to replace their current model. Households may choose to lower their thermostat to 68 degrees Fahrenheit during the colder months, and raise it to 78 degrees when air conditioning is required. Some households may choose to swap out incandescent light bulbs for more efficient compact fluorescent lights. Others may choose to install solar water heaters, or arrays of solar electric panels on their roofs to take advantage of renewable energy, and lower their household energy bills. Many households may choose to plant trees to shade and cool their homes, and use landscaping and plants that require less water.

This Proposed Plan recommends measures that will help support many of these individual decisions to improve energy efficiency. Statewide measures and regional efforts will result in programs to promote public transportation or riding in carpools, subsidize the purchase of energy efficient appliances, or provide incentives to better insulate and weatherize older homes. ARB is fully committed to assuring California consumers have the widest possible choice of vehicles that emit fewer greenhouse gases than today's models, including the most advanced technology vehicles produced anywhere in the world.

Californians have embraced statewide programs that support positive change in home and business behavior. In less than two decades, separating household waste and recycling at home and work have become commonplace, as has the widespread purchase of appliances with the Energy Star label to save energy. Reducing our carbon footprint by moving toward a cleaner more efficient economy will produce a wide range of benefits to individuals, through lower energy bills and a healthier environment for all.

Conservation can also play a key role. By employing practices to use our resources more sparingly, consumers can both save money and reduce greenhouse gas emissions. On August 18, 2008, Governor Arnold Schwarzenegger launched the EcoDriving program – a comprehensive effort to save consumers money at the gas pump, reduce fuel use and cut CO_2 emissions. By following a set of easy-to-use best practices for driving and vehicle maintenance, a typical EcoDriver can improve mileage by approximately 15 percent. Furthermore, safety is improved when driving speeds are reduced, a key EcoDriving strategy.

Similarly, consumers and businesses can save money and reduce greenhouse gas emissions by conserving resources at homes, offices and commercial buildings. For example, wireless monitor devices to provide instantaneous energy-usage information inside the home are being developed to show users how many kilowatt hours they're consuming at any given moment – as well as how much it's costing them.[74] Providing real-time information on appliance energy use can greatly assist consumers in conserving electricity use.

Many Californians concerned about climate change have also begun to buy carbon offsets to mitigate the impact of their daily activities. These can take various forms, including options that allow consumers to add 'carbon credits' when buying airline tickets, or paying a small monthly charge on utility bills to buy green power. ARB will be working to establish clear rules for voluntary reductions and offsets that might be used for compliance with AB 32. These rules will also help establish clear guidelines for these types of voluntary carbon credit programs and provide California's businesses and consumers greater assurance that money spent on these programs result in real reductions in greenhouse gas emissions.

For more information about how to reduce one's personal carbon footprint, visit www.coolcalifornia.org. This web site provides a carbon footprint calculator and a "top ten" list of ways to save energy at home.

B. Public Outreach and Education

To be successful, a climate action program needs an effective public outreach and education program. The Proposed Plan calls for a robust statewide program designed to generate awareness and involvement in California's climate change efforts.

[74] The Sacramento Municipal Utility District (SMUD) is subsidizing PowerCost Monitors to 5,000 customers as a part of a demonstration program. [www.smud.org/residential/saving-energy/monitor.html]

The Climate Action Team will convene a steering team that includes State agencies and other public agencies such as the state's air districts, and public and private utilities, which have a strong track record of successful efforts at public education to reduce driving (Spare the Air) or promote energy efficiency and reduce energy demand. With the release of the California Energy Efficiency Strategic Plan, the CPUC has committed to the launch of a new brand for California Energy Efficiency in 2009, focused on energy efficiency opportunities and coordinated with climate change messaging under AB 32. The steering committee will develop a coordinated array of messages and draw upon a wide range of messengers to deliver them. These will include regional and local governments whose individual outreach campaigns can reinforce the broader State outreach themes while also delivering more targeted messages directly tied to specific local and regional programs.

To ensure that all Californians are included in efforts to address climate change, California will also support highly localized efforts at public education and outreach at the community and neighborhood level. This includes service club organizations and existing faith-based communities – churches, mosques and synagogues. Other private-sector entities including businesses and local chambers of commerce will be invited to partner in spreading the word.

1. Involving the Public and Stakeholders in Measure Development

In keeping with the requirements of AB 32 and the legacy of four decades of regulatory development at ARB, we have worked to make this process fully transparent and will continue to do so as regulations to implement the plan are developed. We will continue our efforts to involve the public to the greatest extent feasible at every stage of the process, including informal and formal rulemaking activities. This will include disadvantaged communities and those with localized concerns, as well as affected industries and small businesses.

Local and community meetings and outreach have been and will continue to be a central element of all rulemaking, with State agencies working closely with disadvantaged communities, EJAC, public health experts, and other stakeholders to fully evaluate the impacts associated with California's greenhouse gas emissions reduction strategies. State agencies involved in measure development will continue to meet periodically with communities to assess any challenges to implementation, or to discover possible new measures or approaches. Stakeholders will be invited to participate in the many additional workshops, workgroups and seminars that will be held as individual measures are developed.

2. Education and Workforce Development

The transition to a clean energy future presents California with a tremendous opportunity to continue growing its green economy and to expand the growth of green job opportunities throughout the state. Making this transition will require a technically educated workforce that is equipped with the skills to develop and deploy 21st century technologies. Investments in training, career technical education, worker transition assistance, and collaboration between public and private partners will be key to ensuring that California fully reaps the economic and job opportunities that will accompany implementation of AB 32.

Setting California on track to a low-carbon future beyond 2020 will be a multi-generational challenge. To meet this challenge, climate-related education in schools must be a central element of California's plan. By 2010, California will develop climate change education components to the State's new K-12 model school curriculum as part of the Education and the Environment Initiative (AB 1548, Pavley, Chapter 665, Statutes of 2003). Expanding the knowledge and opportunities of young people to participate in promoting their own and their communities' environmental health will be an important theme for all these efforts. In the meantime, ARB's educational outreach will continue through the Cool California web pages (www.coolcalifornia.org) and the continued support of student educators through the California Climate Champions programs. ARB will also rely on partners throughout the state to develop and display options for curricula that will enhance the K-12, community college, trade technical training programs, and programs at four-year colleges.

The demand for workers to fill green jobs is rising. There are currently more than 3,000 green businesses in the state, accounting for about 44,000 jobs: 36 percent of these jobs are in professional, scientific, and technical services; 19 percent are in construction; and 15 percent are in manufacturing.[75] Some of these jobs are in new fields, yet many others are simply augmentations of existing skills and vocations such as electrical, construction, machining, auto tech, and heating ventilation and air conditioning. As we move toward 2020, tens of thousands of new green job opportunities will be created.[76] Whether these opportunities come in entirely new fields of employment or in existing areas, it will be critical for California to have a trained workforce available.

Ensuring that California can continue to meet the demand for green jobs will require close coordination between workforce development agencies, businesses, State and local governments, labor unions, and community colleges and universities. Many organizations are already developing strategies and identifying steps to simultaneously meet industry workforce needs and help build a more sustainable economy. For instance, the California Labor and Workforce Development Agency (LWDA) provides a comprehensive range of employment and training services in partnership with State and local agencies and organizations. Similar additional efforts will be crucial in ensuring that the transition to a green economy benefits working families in California by providing a steady supply of livable-wage jobs. In the area

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[75] U.C. Berkeley Labor Center. *California's Global Warming Solutions Act of 2006, A Background Paper for Labor Unions*. August 2008. p.7 http://laborcenter.berkeley.edu/greenjobs/AB32_background_paper08.pdf (accessed October 12, 2008)

[76] California Economic Strategy Panel. *Clean Technology and the Green Economy; Growing Products, Services, Businesses and Jobs in California's Value Network*, Draft, March 2008. http://www.labor.ca.gov/panel/pdf/DRAFT_Green_Economy_031708.pdf

of energy efficiency, the California Long Term Energy Efficiency Strategic Plan, adopted by the CPUC, details a vision and supporting strategies for the development of a workforce trained and engaged to achieve California's energy-efficiency objectives.

The following strategies will be key to ensure that California's workforce is equipped to help lead the transition to a clean energy future:

- **Strengthen and expand access to Career and Technical Education (CTE) in California public schools for the next generation of workers who will build a green economy.** Over the past several decades, there has been a steady decline in career and technical education. In 2007, less than one-third of all high school students in the state were enrolled in some form of CTE.[77] To take full advantage of the emerging green economy and meet the goals of AB 32, California needs to expand opportunities for CTE in schools. This could include pursuing strategies such as requiring CTE coursework for all middle- and high-school students; increasing the number of CTE credentialed teachers; expanding investment in facilities and equipment for career and technical education; and aligning educational curricula more closely with the skill and workforce needs of the emerging green economy.

- **Ensure an adequate pipeline of skilled workers who are trained in the new technologies of a greener economy.** While some green jobs will be in new businesses and new occupations, most green jobs are variations of traditional occupations in sectors like construction, utilities, manufacturing and transportation.[78] In light of the fact that forty percent of the nation's skilled workers are slated to retire in the next 5 to 10 years,[79] there is an urgent need for educational and training programs to fill these jobs. Strategies to create a steady pipeline of skilled workers include expanding curriculum choices in schools, colleges, and universities to fully reflect career opportunities available in an economy increasingly centered on clean technologies. Other strategies include offering a greater array of industry- and technology-specific courses that would link directly with postsecondary training such as apprenticeship programs, vocational training, or college.

- **Ensure that California's higher education institutions continue to produce the next generation of clean tech engineers, scientists and business leaders.** In addition to providing valuable research on potential climate-change mitigation and adaptation strategies, California's world-class research institutions are the incubators for many of the clean tech companies that will contribute to

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[77] Get REAL. *Aligning California's Public Education System with the 21st Century Economy Policy Paper for Discussion at Governor Arnold Schwarzenegger's Summit on Career and Technical Education*, March 6, 2007

[78] Ibid.

[79] The New Apollo Program, Clean Energy, Good Jobs: A National Economic Strategy for the New American Century, July 2008. p. 20 http://apolloalliance.org/downloads/fullreportfinal.pdf (accessed October 12, 2008)

California's environmental and economic future. It will be critical for California to continue to cultivate university research and training programs in a way that takes full advantage of this valuable state resource.

A successful transition to a clean energy future depends heavily on California's ability to provide a well-trained workforce to meet the demands of the growing green economy. ARB and our key partners will continue working throughout the state to ensure that an adequate supply of skilled workers is positioned to take advantage of the growing opportunities for high quality jobs and careers that implementation of AB 32 will bring.

3. Small Businesses

Small businesses play a crucial role in California's economy. As noted in Chapter III, our analysis indicates that this plan will have a net positive impact on small businesses. These impacts are attributable primarily to the measures in the plan that will deliver significantly greater energy and fuel efficiencies. However, as also noted in the analysis, ensuring that these benefits are realized to the fullest potential will require additional outreach and communication efforts by ARB and many other state and local entities.

One of ARB's Early Action measures is designed to help businesses during AB 32 implementation. With our State partners, we are developing an on-line small business "toolkit" designed for small and medium-sized businesses that will provide a one-stop shop for technical and financial resources. Toolkit components will include a business-specific calculator to assess a company's carbon footprint; a voluntary greenhouse gas inventory protocol for measuring greenhouse gas emissions; recommended best practices for energy, transportation, building, purchasing, and recycling; case studies demonstrating how small and medium California businesses have reduced greenhouse gas emissions; program financing resources; peer-networking opportunities; and an awards program to recognize reductions of greenhouse gas emissions among California businesses.

ARB will also continue working with the many business associations, organizations, and other State partners, such as the Small Business Advocate's AB 32 Small Business Task Force, the Labor and Workforce Development Agency, and Business, Transportation, and Housing Agency that have the resources, input and expertise to provide. These partners will help to further develop and implement an effective outreach plan to provide technical assistance to businesses through a variety of means, including attendance at business events, workshops, and working with local economic development agencies.

C. Implementation of the Plan

This Proposed Scoping Plan outlines the regulations and other mechanisms needed to reduce greenhouse gas emissions in California. ARB and other State agencies will work closely with stakeholders and the public to develop regulatory measures and other programs to implement the Plan. ARB and other State agencies will develop any regulations in accordance with established rulemaking guidelines. Table 32 shows the status of the proposed measures in the plan.

Table 32: Status of Proposed Scoping Plan Measures

Existing Laws, Regulations, Policies And Programs
Light-Duty Vehicle Greenhouse Gas Standards (Pavley I)
Renewables Portfolio Standard (to 20%)
Solar Hot Water Heaters
Million Solar Roofs
High Speed Rail
Measures Strengthening & Expanding Existing Policies & Programs
Electricity Efficiency
Natural Gas Efficiency
Renewables Portfolio Standard (from 20% to 33%)
Sustainable Forests
Light-Duty Vehicle Greenhouse Gas Standards (Pavley II)
Discrete Early Actions
Low Carbon Fuel Standard
High GWP in Consumer Products (Adopted)
Smartways
Landfill Methane Capture
High GWP in Semiconductor Manufacturing
Ship Electrification (Adopted)
SF6 in non-electrical applications
Mobile Air Conditioner Repair Cans
Tire Pressure Program
New Measures
California Cap-and-Trade Program Linked to WCI Partner Jurisdictions
Increase Combined Heat and Power
Regional Transportation-Related GHG Targets
Goods Movement Systemwide Efficiency
Vehicle Efficiency Measures
Medium/Heavy Duty Vehicle Hybridization
High GWP Reductions from Mobile Sources
High GWP Reductions from Stationary Sources
Mitigation Fee on High GWP Gases
Oil and Gas Extraction
Oil and Gas Transmission
Refinery Flares
Removal of Methane Exemption from Existing Refinery Regulations

Rulemakings will take place over the next two years. As with all rulemaking processes, there will be ample opportunity for both informal interaction with technical staff in meetings and workshops, and formal interaction. ARB will consider all information and stakeholder input during the rulemaking process. Based on this information, ARB may modify proposed measures to reflect the status of technological development, the cost of the measure, the cost-effectiveness of the measures and other factors before presenting them to the Board for consideration and adoption.

In addition to these existing approaches, AB 32 imposes other requirements for the rulemaking process. Section 38562(b) explicitly added requirements for any regulations adopted for greenhouse gas emissions reductions. ARB also recognizes the need to expand the scope of analysis required when adopting future greenhouse gas emission reduction regulations. These expanded evaluations include the unique enforcement nature of climate change-related regulations and the possible extended permitting considerations and timelines that must be taken into account when establishing compliance dates. An important consideration in developing regulations will be the potential impact on California businesses. The potential for leakage, the movement of greenhouse gas emissions (and economic activity) out of state, will be carefully evaluated during the regulatory development.

As noted above, as the Scoping Plan is implemented and specific measures are developed, ARB and other implementing agencies will also conduct further CEQA analyses, including cumulative and multi-media impacts. ARB must design equitable regulations that encourage early action, do not disproportionately impact low-income and minority communities, ensure that AB 32 programs complement and do not interfere with the attainment and maintenance of ambient air quality standards, consider overall societal benefits (such as diversification of energy resources), minimize the administrative burden, and minimize the potential for leakage. AB 32 requires that, to the extent feasible and in furtherance of achieving the statewide greenhouse gas emission limit, ARB must consider the potential for direct, indirect and cumulative emission impacts from market-based compliance mechanisms, including localized impacts in communities that are already adversely impacted by air pollution, design the program to prevent any increase in emissions, and maximize additional environmental and economic benefits prior to the inclusion of market-based compliance mechanisms in the regulations. As ARB further develops its approach for consideration of these issues in future rulemakings, and updates needed analytical tools and data sets, we will consult with outside experts and the EJAC.

ARB already conducts robust environmental and environmental justice assessments of our regulatory actions. Many of the requirements in AB 32 overlap with ARB's traditional evaluations. In adopting regulations to implement the measures recommended in the Scoping Plan, or including in the regulations the use of market-based compliance mechanisms to comply with the regulations, ARB will ensure that the measures have undergone the aforementioned screenings and meet the requirements established in HSC §38562 (b) (1-9) and §38570 (b) (1-3).

D. Tracking and Measuring Progress

Many State agencies, working with the diverse set of greenhouse gas emissions sources, have collaborated in the process of developing the strategies presented in this plan. As the agency responsible for ensuring that AB 32 requirements are met, ARB must track the regulations adopted and other actions taken by both ARB and other State agencies as the plan is implemented.

The emissions reductions enumerated in this plan are estimates that may be modified based on additional information. As the proposed measures are developed over the coming years, it is possible that some of these strategies will not develop as originally thought or not be technologically feasible or cost-effective at the level given in the plan. It is equally likely that new technologies and strategies will emerge after the initial adoption schedule required in AB 32, that is, regulation adoption by January 1, 2011. If promising new tools or strategies emerge, ARB and other affected State agencies will evaluate how to incorporate the new measures into the AB 32 program. In this way, new strategies ensuring that the commitments in the plan remain whole and that the 2020 goal can be met will be incorporated into the State strategy.

ARB will update the plan at least once every five years (HSC §38561(h)). These updates will allow ARB to evaluate the progress made toward the State's greenhouse gas emission reduction goals and correct the Plan's course where necessary. This section discusses the tracking and measurement of progress that ARB envisions. The Report Cards and audits, along with an evaluation of new technologies – both emerging and those recently incorporated into the Plan – will also provide valuable input into ARB's update process. Continuous atmospheric monitoring of greenhouse gases may also be useful for determining the effectiveness of emission reduction strategies and for future inventory development.

1. Report Card

SB 85 (Budget Committee, Chapter 178, Statutes of 2007) requires every State agency to prepare an annual "Report Card," detailing measures the agency has adopted and taken to reduce greenhouse gas emissions, including the actual emissions reduced as a result of those actions. The information must be submitted to CalEPA, which is then required to compile all the State agency data into a report format, which is made available on the Internet and submitted to the Legislature. The information allows comparisons of each agency's projected and actual greenhouse gas emissions reductions with the targets established by the CAT or the Scoping Plan. This would be the State's 'Report Card' on its efforts to reduce greenhouse gas emissions.

Agencies are also required, as funds are available, to have an outside audit of greenhouse gas-related actions completed every three years to verify actual and projected reductions.

2. Tracking Progress by Implementing Agencies

As the lead agency responsible for implementing AB 32, ARB must track the progress of both our efforts and the efforts of our partners in implementing their respective provisions of this plan. Communication between ARB and the other implementing agencies will be especially important as regulations and programs are developed. In support of the Report Card requirement noted above, ARB will work with CalEPA to develop a process to track and report on progress toward the plan's goals and commitments.

3. Progress Toward the State Government Target

The CAT recently established a State Government Subgroup to work with State agencies to create a statewide approach to meet the Scoping Plan's commitment to reduce greenhouse gas emissions by a minimum of 30 percent by 2020 below the State's estimated business-as-usual emissions – approximately a 15 percent reduction from current levels. State agencies must lead by example by doing their part to reduce emissions and employ practices that can also be transferred to the private sector. The statewide plan will serve as a guide for State agencies to achieve realistic, measurable objectives within specific timelines. This newly created State Government Subgroup will assist State agencies through these steps in a timely manner.

4. Mandatory Reporting Regulation

ARB's mandatory reporting rule, adopted in December 2007, will help the State obtain facility-level data from the largest sources of greenhouse gas emissions in California. This data will help ARB better understand these sources to develop the proposed emissions reduction measures outlined in this plan.

The regulation requires annual reporting from the largest facilities in the state, accounting for 94 percent of greenhouse gas emissions from industrial and commercial stationary sources in California. There are approximately 800 separate sources that fall under the new reporting rules, which include electricity generating facilities, electricity retail providers and power marketers, oil refineries, hydrogen plants, cement plants, cogeneration facilities, and industrial sources that emit over 25,000 tons of carbon dioxide each year from on-site stationary source combustions such as large furnaces. This last category includes a diverse range of facilities such as food processing, glass container manufacturers, oil and gas production, and mineral processing.

Affected facilities will begin tracking their greenhouse gas emissions in 2008, to be reported beginning in 2009 with a phase-in process to allow facilities to develop reporting systems and train personnel in data collection. Emissions for 2008 may be based on best available data. Beginning in 2010, emissions reports will be more rigorous and will be subject to third-party verification. Reported emissions data will allow ARB to improve its facility-based emissions inventory data. Originally, the statewide greenhouse gas inventory was based on aggregated sector data and could not be broken down to the facility level. The facility-level reporting required under the Mandatory Reporting regulation will improve data on greenhouse gas emissions for individual facilities and their emitting processes. This information could also help improve emissions inventories for criteria pollutants, and provide additional data for assessing cumulative emission impacts on a community level.

ARB emissions reporting requirements are expected to be modified over time as AB 32 is implemented.

E. Enforcement

Enforcement is a critical component of all of the State's regulatory programs, both to ensure that emissions are actually reduced and to provide a level playing field for entities complying with the law. To meet the 2020 target this plan calls for aggressive action by a number of State agencies. Each of those agencies will employ its full range of compliance and enforcement options to ensure that planned reductions are achieved. The remainder of this section discusses ARB's portion of the enforcement program in more detail.

ARB has an extensive and effective enforcement program covering a wide variety of regulated sources, from heavy-duty vehicle idling, to consumer products, to fuel standards and off-road equipment. To increase the effectiveness of its enforcement efforts and provide greater assurance of compliance, ARB also partners with local, State and federal agencies to carry out inspections and, when necessary, prosecute violators.

ARB will continue its strong enforcement presence as the State's primary air pollution control agency. A critical function of this responsibility is to ensure that all enforcement actions are timely, effective, and appropriate with the severity of the situation. ARB will also continue its close working relationship with local air districts in the development and enforcement of applicable regulations contained within the Scoping Plan and collaborate with the appropriate State agencies on greenhouse gas emission reductions measures.

For the stationary source regulations called for in the plan, ARB will work closely with the local air districts that have primary responsibility for implementing and enforcing criteria pollutant regulations. Not only are local air districts familiar with the individual facilities and their compliance history, but information contained in district permits can be used to verify the accuracy of greenhouse gas emissions reported by sources subject to ARB mandatory reporting requirements. Using this data, regulators can also examine any correlation between greenhouse gases and toxic or criteria air pollutants as a result of emissions trading or direct regulations.

ARB will also continue to partner with the California Highway Patrol and other State and local enforcement agencies on mobile source and other laws and regulations where joint enforcement authorities apply.

Although many of the measures in the Proposed Scoping Plan are modeled on existing ARB regulations, a multi-sector, regional cap-and-trade program would bring unique enforcement challenges. ARB and CalEPA have begun the process of engaging and consulting with other State agencies, such as California's Department of Justice, Public Utilities Commission, Energy Commission, as well as the Independent System Operator, on market tracking and enforcement. These working group meetings are ongoing and will culminate in a comprehensive enforcement plan to accompany the proposed cap-and-trade program when the Board considers regulatory requirements. This enforcement plan would describe the administrative structures needed for market monitoring, prosecution, and penalty setting. Public input regarding these issues would also be a key part of the public stakeholder process conducted during development of the cap-and-trade programs regulations.

Accurate measurement and reporting of all emissions would be necessary to assure accountability, establish the integrity of allowances, and provide sufficient transparency to sustain confidence in the market. To ensure compliance, ARB would administer penalties for entities that hold an insufficient quantity of allowances to cover their emissions or fail to report their greenhouse gas emissions. Missed compliance deadlines would also result in the application of stringent administrative, civil, or criminal penalties.

This plan recommends that California implement a cap-and-trade program that links with other Western Climate Initiative partner programs to create a regional market system. This system would require California to formalize enforcement agreements with its WCI partner jurisdictions for all phases of cap-and-trade program operations, including verification of emissions, certification of offsets based on common protocols, and detection of and punishment for non-compliance. As needed, California would also work with federal regulatory and enforcement agencies that oversee trading markets, such as the Commodity Futures Trading Commission and the Federal Energy Regulatory Commission. While California would work with other jurisdictions on joint enforcement activities, ARB will exercise all of its authority under HSC §38580 and other provisions of law to enforce its regulations against any violator wherever they may be.

F. State and Local Permitting Considerations

Some of the proposed emissions reduction strategies in this Proposed Scoping Plan may require affected entities to modify or obtain state or local permits. California's existing permit process ensures that health and safety concerns are evaluated, met, and when appropriate, mitigated. The State recognizes the potential for conflicts between various federal, state and local permitting requirements, which may cross various media – air, water, etc. CalEPA is actively involved in identifying and addressing these regulatory overlap issues with the ultimate goal of consolidating permits where feasible while maintaining all permit requirements. Two such examples are CalEPA's digester permit working group and the CalEPA-Air District Compost Emissions Work Group.

ARB recognizes that the permitting process may affect the viability of certain strategies and that the length of the permitting process could affect the timing of emissions reductions.

ARB, along with CalEPA and other State agencies, will continue to evaluate steps to ensure that permit requirements harmonize across the affected media.

This Plan has been developed with an understanding of the important cross-media impacts. These efforts will continue during the implementation of the Plan. Particular focus on the potential permitting impacts and cross-media consequences of a proposed rule will take place during the rulemaking process.

G. Role of Local Air Districts

Local air districts are ARB's partners in addressing air pollution. ARB takes primary responsibility for transportation, off-road equipment and consumer products. Local districts lead in controlling industrial, commercial and other stationary sources of air emissions. AB 32 recognizes the need to develop a program that meshes with local and regional activities. Although AB 32 does not provide an explicit role for air districts, their local presence as advocates for clean air and their resources, experience and expertise in regulating and enforcing rules for stationary sources make them a logical choice to have an important role in several aspects of implementing California's greenhouse gas program. ARB would partner with local air districts to develop and effectively enforce both source-specific requirements on industrial sources, and to enforce related programs, such as the high GWP rules, that affect a large number of local businesses.

ARB and local air districts are also actively working to coordinate emission reporting requirements. Some districts, like the South Coast Air Quality Management District, have developed software to allow their industrial sources to simultaneously report their criteria pollutant emissions to the District and their greenhouse gas emissions to ARB. Many air district staff are being trained as third-party verifiers to confirm the greenhouse gas emissions information provided by industrial sources under the mandatory reporting regulation, and, similarly, could provide verification of voluntary greenhouse gas reductions in the future.

Local air districts will be key in both encouraging greenhouse gas emissions reductions from other regional and local government entities, and providing technical assistance to quantify and verify those reductions. Local agencies are an important component of ARB's outreach strategy.

Many local air districts have already taken a leadership role in addressing greenhouse gas emissions in their communities. These efforts are intended to encourage early voluntary reductions. For example, local districts are "lead agencies" under the California Environmental Quality Act (CEQA) for some projects. In order to ensure high-quality mitigation projects, some districts have established programs to encourage local greenhouse gas reductions that could be used as CEQA mitigation. As the State begins to institutionalize mechanisms to generate and verify greenhouse gas emissions reductions, ARB and the districts must work together to smoothly transition to a cohesive statewide program with consistent technical standards.

H. Program Funding

Administration, implementation, and enforcement of the emissions reduction measures contained in the Proposed Scoping Plan will require a stable and continuing source of funding. AB 32 authorizes ARB to collect fees to fund implementation of the statute. This fall ARB will initiate a rulemaking for a fee program to fund administration of the program.

Approximately $55 million per year will be needed on an ongoing basis to fund implementation by ARB and other State agencies, based on the positions and funding included in the 2008-2009 fiscal year budget. Additional revenues are needed to repay the loans from State funds that were used to pay ARB and CalEPA expenses in the startup of the program. ARB is moving on an expedited schedule to develop a fee regulation and expects to take a regulation to the Board in early 2009, with the aim of beginning to collect fees in the 2009-2010 fiscal year.

V. A VISION FOR THE FUTURE

California has the know-how, ingenuity, research capabilities, and culture of innovation to meet the challenge of addressing climate change. However, reaching the goals we have set for ourselves will not be easy. Successful implementation of many of the proposed programs and measures described in this plan will require strong leadership and a shared understanding of the need to reach viable and lasting solutions quickly.

This challenge will also require establishing a wide range of partnerships, both within California and beyond our borders. We will need to support additional research, and further develop our culture of innovation and technological invention. In order to continue the momentum and the commitment to a clean energy future, we will need to both build on existing solutions and develop new ones.

The following sections lay out some of the elements that will be necessary to forge a broad-based institutional strategy to address climate change both within California and beyond. Also discussed is the need to build partnerships on the regional, national and international levels to ensure that our actions complement and support those being taken on a global scale. This section also looks forward to 2030, showing that California is on the trajectory needed to do our part to stabilize global climate.

A. Collaboration

1. Working Closely with Key Partners

True climate change mitigation will require many parties to work together for a global mitigation plan. California and other states are filling a vacuum created by the current lack of leadership at the federal level. By its bold actions, California is moving the United States closer to a seat at the table among the developed countries that have agreed to reduce their carbon emissions, and lead a new international effort for an agreement to replace the Kyoto Protocol that expires in 2012.

Any national climate program must be built on a partnership with State and local governments to ensure that states can continue their role as incubators of climate change policy and can implement effective programs such as vehicle standards, energy efficiency programs, green building codes, and alternative fuel development.

California will work for climate solutions with key federal agencies, including the U.S. Department of Energy and their national labs, the U.S. Environmental Protection Agency, the U.S. Bureau of Land Management, the U.S. Department of Agriculture, the U.S. Department of Transportation, and others.

Through the Western Climate Initiative and in collaboration with other regional alliances of states, California can promote its own best practices and learn from others while helping to formulate the structure of a regional and ultimately national cap-and-trade program.

2. International

As one of the largest economies in the world, California is committed to working at the international level to reduce global greenhouse gas emissions. As part of this effort, Governor Schwarzenegger and other U.S. governors taking the lead in climate change are co-hosting a Global Climate Summit on Finding Solutions Through Regional and Global Action. This summit, to be held on November 18th and 19th, 2008, will begin a state-province partnership with leaders from the U.S., Australia, Brazil, Canada, China, India, Indonesia, Mexico, the European Union, and other nations, to take urgent steps to contain global climate change and jointly set forth a blueprint for the next global agreement on climate change solutions.

California is also a charter member of the International Carbon Action Partnership (ICAP), an organization composed of countries and regions that have adopted carbon caps and that are actively pursuing the implementation of carbon markets through mandatory cap-and-trade systems. California's continued involvement in ICAP will be very beneficial for sharing experiences and knowledge as we design our own market program.

In addition to participating in ICAP, California hopes to engage developing countries to pursue a low-carbon development path. With developing nations expected to suffer the most from the effects of climate change, California and others have an obligation to share information and resources on cost-effective technologies and approaches for mitigating both emissions and future impacts as changes in climate and the environment occur.

California recognizes the "common but differentiated responsibilities" among developed and developing countries (as articulated in the Kyoto Protocol), but the reality is that rapidly escalating greenhouse gas emissions in developing countries could possibly negate any efforts undertaken in California. To the extent that we are part of the global economy, California's demand for goods manufactured in developing countries further exacerbates growth of greenhouse gas emissions globally. Therefore, it is critical for California to help support the adoption of low-carbon technologies and sustainable development in the developing world.

California can advance the international policy debate through state-provincial partnerships for achieving early climate action in developing countries. This approach envisions commitments by developed countries to provide capacity building through technological assistance and investment support in return for developing countries adopting enhanced mitigation actions. California will consider working with developing countries or provinces that have, at a minimum, pledged to achieve greenhouse gas intensity targets in certain carbon-intensive sectors through mechanisms, such as minimum performance standards or sector benchmarks. California also recognizes that developing countries have the challenge and responsibility to reduce domestic emissions in a way that will promote sustainable development, but not undermine their economic growth.

One possible manifestation of these collaborations could be the establishment of sectoral agreements that help to grow developing countries' economies in a low-carbon manner. In a sectoral approach, energy-intensive sectors adopt programs for reducing greenhouse gas emissions and/or energy use. Such sector-based approaches seem likely to win the support of developing countries and could also reduce concerns in developed countries about international competitiveness and carbon leakage.

A state-provincial partnership related to imported commodities (such as cement) would enable California to provide incentives to reduce greenhouse gas emissions associated with products that are imported by our state. California should continue to develop current relations and existing partnership arrangements with China – now the largest emitter of greenhouse gases in the world – because in addition to other compelling reasons much of the state's imported cement originates in China. California should also work to establish similar relations with India and other countries to share research on both greenhouse gas mitigation and climate change adaptation activities. Projects in the Mexican border region may also be of particular interest, considering the opportunity to realize considerable co-benefits on both sides of the border.

Deforestation accounts for approximately 20 percent of global greenhouse gas emissions. California has set a strong precedent in the effort to incorporate forest management and conservation into climate policy by adopting the CCAR forest methodology in October 2007. California also hopes to engage developing countries, including Brazil and Indonesia, to reduce emissions and sequester carbon through eligible forest carbon activities. Activities aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD) were excluded from the rules governing the first Kyoto commitment period, but there is considerable momentum behind the effort to include provisions that would recognize such activities in a post-2012 international agreement. Providing incentives to developing countries to help cut emissions by preserving standing forests, and to sequester additional carbon through the restoration and reforestation of degraded lands and forests and improved forest management practices, will be crucial in bringing those countries into the global climate protection effort. California recognizes the importance of establishing mechanisms that will facilitate global partnerships and sustainable financing mechanisms to support eligible forest carbon activities in the developing world.

B. Research

1. Unleash the Potential of California's Universities and Private Sector

Bringing greenhouse gas emissions down to a level that will allow the climate to stabilize will take a generation or longer. Many of the ultimate solutions to achieve stabilization will be developed and implemented well into the future. Innovation in energy and climate will come from people who are now in school. These young people will face unprecedented challenges, and they will need both wisdom and imagination to craft solutions. California's respected public and private academic institutions must continue to develop and fund programs based on climate change science that cut across disciplines to address the multi-dimensional aspects of climate change.

2. Public-Private Partnerships

To most effectively address the climate change dilemma, we must encourage collaborations between academia and the private sector. Industry is well-positioned to quickly attack problems. Combining the vast knowledge housed in universities with businesses' acumen and agility can unleash a powerful collaborative force to tackle the problems associated with climate change.

Several important programs have already been initiated at California universities, including Stanford's Global Climate and Energy Project and the University of California at Berkeley's Energy Biosciences Institute (EBI).[80] These and other efforts need to be recognized and encouraged, along with others that can link the results of research directly to policy decisions that the State must make.

Carbon Sequestration

In addition to terrestrial carbon sequestration or natural carbon sinks such as forests and soil, CO_2 can be prevented from entering the atmosphere through carbon capture and storage (CCS). This consists of separating CO_2 from industrial and energy-related sources and transporting the CO_2 to a storage location for long-term isolation from the atmosphere. Potential technical storage methods include geological storage, industrial fixation of CO_2 into inorganic carbonates, and other strategies. Large point sources of CO_2 that may pursue CCS include large power plants, fossil fuel-based hydrogen production plants, and oil refineries.[81]

[80] The EBI is being developed in cooperation with Lawrence Berkeley National Laboratory, the University of Illinois at Urbana-Champaign and BP.

[81] Intergovernmental Panel on Climate Change. *Carbon Dioxide Capture and Storage: A Special Report of Working Group III of the IPCC*. Cambridge University Press, UK; 2005. http://www.ipcc.ch/ipccreports/srccs.htm (accessed October 12, 2008)

According to a 2005 report by the Intergovernmental Panel for Climate Change (IPCC), a power plant with CCS could reduce CO_2 emissions to the atmosphere by approximately 80 to 90 percent compared to a plant without CCS (including the energy used to capture, compress and transport CO_2).[82] While more research and development needs to occur, California should both support near-term advancement of the technology and ensure that an adequate framework is in place to provide credit for CCS projects when appropriate.

The State is currently an active member of the West Coast Regional Carbon Sequestration Partnership (WESTCARB), a public-private collaboration to characterize regional carbon sequestration opportunities in seven western states and one Canadian province. Established in 2003, this research project is comprised of more than 80 public and private organizations. WESTCARB is conducting technology validation field tests, identifying major sources of CO_2 in its territory, assessing the status and cost of technologies for separating CO_2 from process and exhaust gases, and determining the potential for storing captured CO_2 in secure geologic formations.[83]

C. Reducing California's Emissions Further – A Look Forward to 2030

In order to assess whether implementing this plan achieves the State's long-term climate goals, we must look beyond 2020 to see whether the emissions reduction measures set California on the trajectory needed to do our part to stabilize global climate.

Governor Schwarzenegger's Executive Order S-3-05 calls for an 80 percent reduction below 1990 greenhouse gas emission levels by 2050. This results in a 2050 target of about 85 $MMTCO_2E$ (total emissions), as compared to the 1990 level (also the 2020 target) of 427 $MMTCO_2E$. Climate scientists tell us that the 2050 target represents the level of greenhouse gas emissions that advanced economies must reach if the climate is to be stabilized in the latter half of the 21st century. Full implementation of the Proposed Scoping Plan will put California on a path toward these required long-term reductions. Just as importantly, it will put into place many of the measures needed to keep us on that path.

Figure 6 depicts what an emissions trajectory might look like, assuming California follows a linear path from the 2020 AB 32 emissions target to the 2050 goal needed to help stabilize climate. While the measures needed to meet the 2050 goal are too far in the future to define in detail, we can examine the policies needed to keep us on track through at least 2030.

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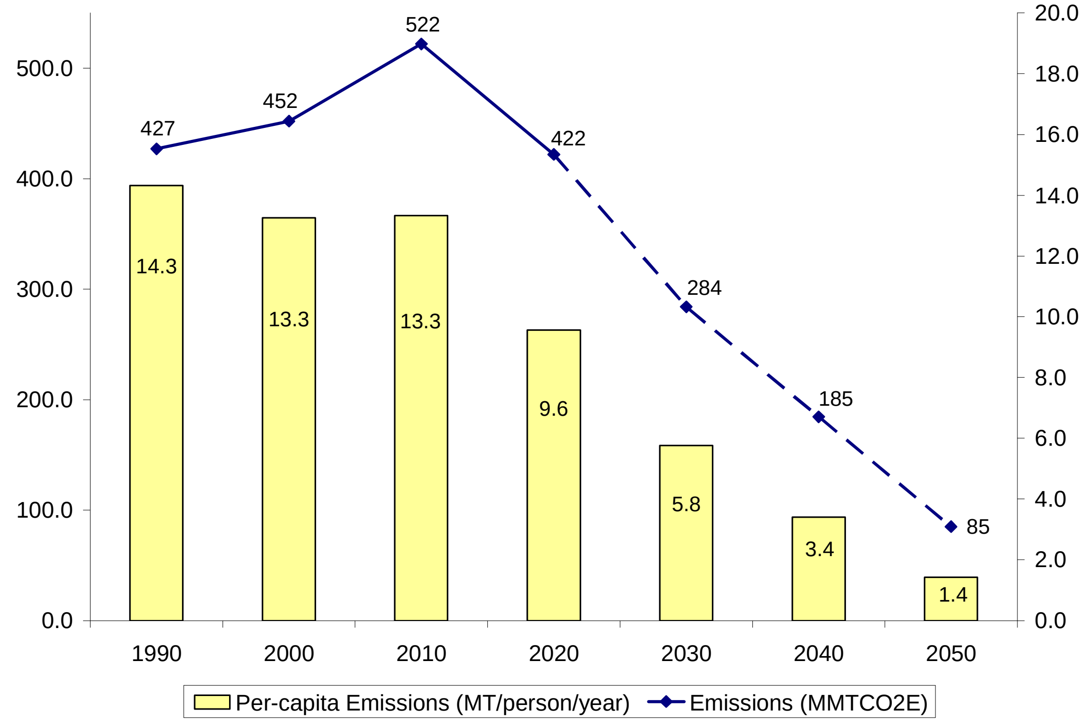
[82] Ibid

[83] WESTCARB. *WESTCARB Overview.* http://www.westcarb.org/about_overview.htm (accessed October 12, 2008)

Figure 6: Emissions Trajectory Toward 2050



To stay on course toward the 2050 target our State's greenhouse gas emissions need to be reduced to below 300 $MMTCO_2E$ by 2030. This translates to an average reduction of four percent per year between 2020 and 2030. An additional challenge comes from the fact that California's population is expected to grow by about 12 percent between 2020 and 2030. To counteract this trend, per-capita emissions must decrease at an average rate of slightly less than five percent per year during the 2020 to 2030 period.

Are such reductions possible by 2030? What measures might be able to provide the needed reductions? How do the needed measures relate to the efforts put into place to reach the 2020 goal? All of these are critical questions, and are addressed below.

The answer to the first question is yes, the reductions are possible. Furthermore, the measures needed are logical expansions of the programs recommended in the Proposed Scoping Plan that get us to the 2020 goal. We could keep on track through 2030 by extending those programs in the following ways:

- Using a regional or national cap-and-trade system to further limit emissions from the 85 percent of greenhouse gas emissions in capped sectors (Transportation Fuels and other fuel use, Electricity, Residential/Commercial Natural Gas, and Industry). By 2030 a comprehensive cap-and-trade program could lower emissions in the capped sectors from 365 $MMTCO_2E$ in 2020 to around 250 $MMTCO_2E$ in 2030;

- Achieving a 40 percent fleet-wide passenger vehicle reduction by 2030, approximately double the almost 20 percent expected in 2020;
- Increasing California's use of renewable energy;
- Reducing the carbon intensity of transportation fuels by 25 percent (a further decrease from the 10 percent level set for 2020);
- Increasing energy efficiency and green building efforts so that the savings achieved in the 2020 to 2030 timeframe are approximately double those accomplished in 2020; and
- Continuing to implement sound land use and transportation policies to lower VMT and shift travel modes.

The effects of these strategies are presented in Table 33.

Table 33: Potential Distribution of California Greenhouse Gas Emissions by Sector in 2030

Sector	Potential Emissions ($MMTCO_2E$)
Transportation Fuels*	102
Other Fuel Use*	149
Uncapped Sectors	33
Total	**284**

* Capped sector

With these polices and measures in place, per-capita electricity consumption would decrease by another five percent. Well over half of our electricity demand could be met with zero or near zero greenhouse gas emitting technologies, assuming nuclear and large hydro power holds constant at present-day levels. In response to a lower cap on emissions, existing coal generation contracts would not be renewed, or carbon capture and storage would be utilized to minimize emissions. The remaining electricity generation would come from natural gas combustion either in cogeneration applications or from highly efficient generating units.

By 2030, the transportation sector would undergo a similarly massive transition both in terms of the vehicle fleet and the diversity of fuel supplies. Due to the combination of California's clean car standards (ARB's ZEV program and the Low Carbon Fuel Standard), the number of battery-electric vehicles, plug-in hybrid electric vehicles, and fuel cell vehicles would increase dramatically, to about a third of the vehicle fleet. Flex-fuel vehicles would comprise a large fraction of the remaining fleet, with more efficient gasoline and diesel vehicles making up the difference. Electricity, advanced biofuels, improved gasoline and diesel, renewable natural gas and hydrogen would all play a role in powering this high-tech fleet of efficient vehicles.

Regional land use and transportation strategies would grow in importance and would reverse the trend of per-capita vehicle miles traveled, a reduction of about eight percent below business-as-usual in 2030. With ambitious but reasonable action, statewide passenger vehicle greenhouse gas emissions could be reduced to half of 2020 levels in 2030, which is also about half of business-as-usual for 2030. Efficiency strategies and low carbon fuels for heavy-duty and off-road vehicles, as well as for ships, rail, and aviation, would need to be greatly expanded in order to achieve additional reductions from the transportation sector in 2030.

In tandem with efficiency measures that lower demand for electricity, natural gas and transportation fuels, California's cap-and-trade program would incent large industrial sources as well as commercial and residential natural gas customers to further reduce emissions. By tightening the cap over time, it is expected that facilities in the industrial and natural gas sectors would achieve reductions well beyond those needed to meet the 2020 emissions cap.

The Proposed Scoping Plan proposes several measures for reducing high GWP gases that collectively, will substantially reduce emissions. With a transition toward reduced consumption of these gases, improved containment in their end uses, and substitution of low GWP alternative gases, it is expected that emissions from this sector could decrease by 75 percent between 2020 and 2030.

For uncapped sectors, we assume that the agriculture sector will reduce emissions by about 15 percent between 2020 and 2030. Net forest uptake of CO_2 must be preserved or enhanced, likely through both expansion of forests and reduction in carbon loss from forest fires, which are predicted to increase over this time period. This example assumes a 10 percent reduction in direct landfill emissions from the recycling and waste sector; however, aggressive implementation of the suite of measures proposed in this Plan could further reduce emissions from this sector by 2030.

In total, the measures described above would produce reductions to bring California's statewide greenhouse gas emissions to an estimated 284 $MMTCO_2E$ in 2030. While the potential mix of future climate policies articulated in this section is only an example, it serves to demonstrate that the measures in the Proposed Scoping Plan can not only move California to its 2020 goal, but also provide an expandable framework for much greater long-term greenhouse gas emissions reductions.

D. Conclusion

California's commitment to address global warming has never been greater. The vast amount of interest, support, and input that ARB has received since this plan began to take shape is evidence of a clear understanding of the need to take action and support for the State's efforts to lead the way. The time has come to shift away from a 'business-as-usual' approach to climate change and to move toward the lasting and sustainable goal of a clean energy future.

Reaching our goals will take a great deal of leadership, commitment, and a willingness to embrace new approaches and seek out new solutions. California's plan to reduce greenhouse gas emissions must also take into account the impacts of this transition and be designed in particular to address the needs of low-income communities, small businesses, and California's working families.

Reaching our goals will also require involvement and support from all levels of government in California, and a coordinated effort with other states, regions, and countries. The solutions and technologies we develop here will be used around the world to help others transition to a clean energy future and contribute to the fight against global warming.

Reaching our goals will also require flexibility. As we move forward, we must be prepared to make mid-course corrections. AB 32 wisely requires ARB to update its Scoping Plan every five years, thereby ensuring that California stays on the path toward a low carbon future.

This plan is part of a new chapter for California that in many ways began with the passage and signing of AB 32. It proposes a comprehensive set of actions designed to reduce greenhouse gas emissions in California, improve our environment, reduce our dependence on oil, diversify our energy sources, save energy, create new jobs, and enhance public health. The challenge California has taken on is large but the opportunities are even greater. It is now time to turn this plan into action.

ACKNOWLEDGMENTS

This Proposed Scoping Plan was prepared by the Air Resources Board. This document was made possible by the hard work of numerous contributors. Below is a list of advisory committees and State agencies that directly provided input to this Proposed Scoping Plan.

Team Support

Climate Action Team

Climate Action Team Sector Subgroups

- Agriculture
- Cement
- Energy
- Forest
- Green Buildings
- Land Use
- Recycling and Waste Management
- State Fleet
- Water-Energy
- Economics

Advisory Committees

Market Advisory Committee

Environmental Justice Advisory Committee

Economic and Technology Advancement Advisory Committee

State Agencies

Governor's Office of Planning and Research

California Environmental Protection Agency

Business, Transportation and Housing Agency

Resources Agency

State and Consumer Services Agency

Department of Food and Agriculture

California Energy Commission

California Public Utilities Commission

California Transportation Commission

Department of Conservation

Department of Forestry and Fire Protection

Department of General Services

Department of Parks and Recreation

Department of Public Health

Department of Toxic Substances Control

Department of Transportation

Department of Water Resources

Housing and Community Development

Integrated Waste Management Board

Office of Environmental Health Hazard Assessment

State Water Resources Control Board

Department of Pesticide Regulation

California Air Resources Board

Preliminary Draft Staff Proposal

Recommended Approaches for Setting Interim Significance Thresholds for Greenhouse Gases under the California Environmental Quality Act

Released: October 24, 2008

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DOCUMENT AVAILABILITY

Electronic copies of this document and related materials can be found at: http://www.arb.ca.gov/cc/localgov/ceqa/ceqa.htm. Alternatively, paper copies may be obtained from the Board's Public Information Office, 1001 I Street, 1st Floor, Visitors and Environmental Services Center, Sacramento, California, 95814, (916) 322-2990.

For individuals with sensory disabilities, this document is available in Braille, large print, audiocassette or computer disk. Please contact ARB's Disability Coordinator at (916) 323-4916 by voice or through the California Relay Services at 711, to place your request for disability services. If you are a person with limited English and would like to request interpreter services, please contact ARB's Bilingual Manager at (916) 323-7053.

DISCLAIMER

(October 24, 2008)

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INTRODUCTION

Climate change is one of the most serious environmental problems facing the world, the United States, and California today. In this State, climate change already is impacting our coastlines, water supplies, agriculture, and public health, and putting millions of acres of forested land at increased risk of fire. These adverse effects will only increase in number and intensity if we do not promptly and substantially reduce pollution of the atmosphere with greenhouse gases (GHGs).

California law provides that climate change is an environmental effect subject to the California Environmental Quality Act (CEQA).[1] Lead agencies therefore are obligated to determine whether a project's climate change-related effects may be significant, requiring preparation of an Environmental Impact Report,[2] and to impose feasible mitigation to substantially lessen any significant effects.[3] Determining significance, however, can be a challenging task. Accordingly, the Governor's Office of Planning and Research in its June 2008 Technical Advisory, "CEQA and Climate Change,"[4] asked the Air Resources Board (ARB) to make recommendations for GHG-related thresholds of significance – identifiable benchmarks or standards that assist lead agencies in the significance determination.[5]

With this Staff Proposal, ARB staff is taking the first step toward developing recommended statewide interim thresholds of significance for GHGs that may be adopted by local agencies for their own use. The task that ARB staff is undertaking is, however, a limited one. Staff will not attempt to address every type of project that may be subject to CEQA, but instead will focus on common project types that, collectively, are responsible for substantial GHG emissions – specifically, industrial, residential, and commercial projects.[6] ARB staff believes that thresholds in these important sectors will advance our climate objectives, streamline project review, and encourage consistency and uniformity in the CEQA analysis of GHG emissions throughout the State.

Staff intends to make its final recommendations on thresholds in early 2009, in order to harmonize with OPR's timeline for issuing draft CEQA guidelines addressing GHG emissions[7] and to provide much needed guidance to lead agencies in the near term.

Public, stakeholder, and local lead agency participation is essential to the success of this project. ARB staff believes that the comment and feedback it receives, along with

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[1] Senate Bill 97, Public Resources Code, § 21083.05.
[2] California Code of Regulations, tit. 14, § 15064, subd. (f)(1).
[3] Id., § 15021, subd. (a)(2).
[4] See: http://opr.ca.gov/download.php?dl=ceqa/pdfs/june08-ceqa.pdf
[5] Id., § 15064.7, subd. (a).
[6] The collective greenhouse gas emissions from the industrial, residential and commercial sectors, together with the transportation sector, represent approximately 80% of the statewide greenhouse gas emissions inventory in 2004.
[7] See Senate Bill 97, Public Resources Code § 21083.05 (providing that draft guidelines are due June 1, 2009).

additional data and analyses, can form a body of evidence that lead agencies may rely on in adopting thresholds of significance consistent with ARB staff's recommendations.

Because the schedule is expedited, staff's recommendations must necessarily be interim and subject to review and revision as more information becomes available.[8]

BACKGROUND

Significance Under CEQA

A significant effect on the environment means a substantial, or potentially substantial, change in the environment caused directly or indirectly by the project.[9] The incremental effect of a project can be significant when it is cumulatively considerable – that is, when the effect is added to that of other past, present, and reasonably foreseeable probable future projects that also contribute to the problem.[10]

To streamline and facilitate consistency in the significance determination, the CEQA Guidelines[11] encourage agencies "to develop and publish thresholds of significance that the agency uses in the determination of the significance of environmental effects."[12] A threshold of significance is an identifiable quantitative, qualitative or performance level that marks the division between an impact that is significant and one that is not. A threshold of significance gives rise to a presumption, which can be rebutted by evidence that the threshold should not apply to a particular project.

Thresholds of significance must be supported by "substantial evidence." This does not mean that there is one best threshold. In CEQA, substantial evidence "means enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached."[13]

Climate Change and GHG Thresholds of Significance

"The capacity of the environment is limited, and it is the intent of the Legislature that the government of the state take immediate steps to identify any critical thresholds for the health and safety of the people of the state and take all coordinated actions necessary to prevent such thresholds being reached."[14] But where should a threshold of significance be set for GHG emissions and climate change? This question can be answered only after considering the nature of the environmental problem.

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[8] ARB staff intends to monitor the implementation of thresholds that are adopted as a result of this process for effectiveness. In the same time frame as the update of the AB 32 Scoping Plan, staff intends to revisit its recommendations and to modify them if necessary.

[9] California Code of Regulations, title 14, §§ 15064, subd. (d), 15382.

[10] *Id.*, § 15355, subd. (b).

[11] Id., § 15000, et. seq.

[12] *Id.*, § 15064.7, subd. (a).

[13] *Id.*, § 15384, subd. (a).

[14] Public Resources Code, § 21000, subd. (d).

There is a scientific consensus that human activities, chief among them the burning of fossil fuels, profoundly affect the world's climate by increasing the atmospheric concentration of GHG beyond natural levels. Contributing additional GHG pollution to the atmosphere leads to higher global average temperatures, changes to climate, and adverse environmental impacts here in California and around the world.[15] Climate change, caused by "collectively significant projects taking place over a period of time[,]"[16] is a quintessential cumulative impact.

The experts tell us that an additional increase in global average temperatures of just 2 degrees Celsius (3.6 degrees Fahrenheit) is very likely dangerous.[17] With a 2 degree Celsius increase, disastrous effects become likely, including more extreme and more frequent severe weather, more wildfires, greater frequency of droughts and floods, rapid and higher sea level rise, and increased habitat destruction and extinctions.[18] These environmental effects will undoubtedly lead to serious economic, political, and national security disruptions.

In order to reduce the risk of dangerous climate change, we must stabilize atmospheric levels of GHGes at approximately 450 parts per million (ppm) by mid-century.[19] We are fast approaching this limit. Since the beginning of the industrial era, atmospheric concentrations of carbon dioxide, the primary GHG, have climbed to their highest point in the last half-million years, increasing from just under 300 ppm at the turn of the last century, to over 380 ppm today, and rising at about 2 ppm per year.[20]

In response to the challenge of climate change, California has taken a leadership role by committing to reduce its GHG emissions to 1990 levels by 2020 (about a thirty percent reduction in business-as-usual emissions in 2020) and to eighty percent below 1990 levels by 2050.[21] The latter target is consistent with the scientific consensus of the reductions needed to stabilize atmospheric levels of GHGs at 450 ppm by mid-century. Assembly Bill 32, the Global Warming Solutions Act of 2006, codifies the 2020 reduction

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[15] There is a large body of authoritative sources on the causes and current and projected impacts of climate change. An extended discussion of climate change is beyond the scope of this Staff Proposal. For additional information, ARB recommends the Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) and, in particular, the IPCC's "Frequently Asked Questions," available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf and the 2006 California Climate Action Team's Report to the Governor and Legislature, available at: http://www.climatechange.ca.gov/climate_action_team/reports/index.html.

[16] See California Code of Regulations, tit. 14, § 15355, subd. (b).

[17] See IPCC 4th Assessment Report, Working Group II, Summary for Policymakers, Figure 2, available at: http://www.ipcc.ch/graphics/graphics/ar4-wg2/jpg/spm2.jpg (chart showing global impacts at various temperature increases); California Climate Change Center, Our Changing Climate: Assessing the Risks to California (2008) at p. 15, available at http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF (chart showing impacts in California at various temperature increases.)

[18] *Id.*

[19] See IPCC 4th Assessment Report, Working Group III, Summary for Policymakers at p. 17, available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf.

[20] IPPC 4th Assessment Report, Working Group I, Figure FAQ 2.1, available at: http://www.ipcc.ch/graphics/graphics/ar4-wg1/jpg/faq-2-1-fig-1.jpg.

[21] Executive Order S-03-05

target and charges ARB with development of a Scoping Plan to map out how the State will achieve this target, including regulatory, voluntary, and market-based mechanisms beginning in 2012.[22]

There is strong need, however, to aggressively address GHG emissions right now. The pollution we contribute to the atmosphere today will continue to have climate impacts for years, decades, and, in some cases, millennia to come. And the longer we delay in addressing the problem, the more we risk being unable to meet our climate objective. CEQA provides a mechanism that is independent of AB 32 through which lead agencies can begin immediately to reduce the climate change-related impacts of the projects that come before them.

<u>What Type of Threshold is Appropriate</u>?

Some have suggested that because of the need for urgent action and the uncertainty of the precise "tipping point" for dangerous climate change, any contribution of GHGs to the atmosphere may be significant – a so-called "zero threshold."

ARB staff believes that for the project types under consideration, non-zero thresholds can be supported by substantial evidence. ARB staff believes that zero thresholds are not mandated in light of the fact that (1) some level of emissions in the near term and at mid-century is still consistent with climate stabilization and (2) current and anticipated regulations and programs apart from CEQA (e.g., AB 32, the Pavley vehicle regulations, the Renewable Portfolio Standard, the California Solar Initiative, and the commitment to net-zero-energy buildings by 2020 (residential) and 2030 (commercial)) will proliferate and increasingly will reduce the GHG contributions of past, present, and future projects.

But any non-zero threshold must be sufficiently stringent to make substantial contributions to reducing the State's GHG emissions peak, to causing that peak to occur sooner, and to putting California on track to meet its interim (2020) and long-term (2050) emissions reduction targets. ARB staff believes that the preliminary interim approaches outlined in this Staff Proposal are consistent with these objectives.

RECOMMENDED THRESHOLDS – CONCEPTUAL APPROACH

ARB staff believes that different GHG thresholds of significance may apply to projects in different sectors. Two primary reasons that sector-specific thresholds are appropriate are: (1) some sectors contribute more substantially to the problem, and therefore should have a greater obligation for emissions reductions, and, (2) looking forward, there are differing levels of emissions reductions expected from different sectors in order to meet California's climate objectives. We also believe that different types of thresholds **–** quantitative, qualitative, and performance-based **–** can apply to different sectors under the premise that the sectors can and must be treated separately given the state of the science and data. A sector-specific approach is consistent with ARB's

[22] Health and Safety Code, § 38500, et. seq.

Proposed Scoping Plan. Consequently, the Staff Proposal takes different, although harmonious, approaches to setting thresholds for different sectors.

The attached flowcharts describe ARB staff's preliminary interim threshold concepts for two important sectors: industrial projects (**Attachment A**) and residential and commercial projects (**Attachment B**). The objective is to develop thresholds for projects in these sectors that will result in a substantial portion of the GHG emissions from new projects being subject to CEQA's mitigation requirement, consistent with a lead agency's obligation to "avoid or minimize environmental damage where feasible."[23] ARB staff is working on a proposal for an interim approach for thresholds for transportation projects and large dairies. Electricity generation is another sector where clarity is needed in the near term. The California Energy Commission (CEC) recently began a public process for identifying an approach for assessing the significance of GHG emissions from power plant projects. CEC staff anticipates concluding that work in Spring 2009.[24]

ARB staff's proposed recommendations for GHG thresholds address projects for which local agencies are typically the CEQA lead agency. In addition to the CEC, other State agencies also serve as lead agencies under CEQA. ARB is coordinating with these State agencies on their approaches to thresholds of significance.

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[23] California Code of Regulations, title 14, § 15021.

[24] The CEC adopted an Order Instituting Informational Proceeding on October 8, 2008 to address GHG emissions in power plant licensing cases: http://www.energy.ca.gov/ghg_powerplants/notices/2008-10-06_PROPOSED_GHG_CEQA_OII.PDF.

REQUEST FOR PUBLIC COMMENT

ARB staff believes that the concepts in this Staff Proposal can be further developed into interim thresholds of significance. However, staff recognizes that additional analyses and data are needed to fill in some of the blanks, and to understand how the thresholds will operate in the real world.

Comments on all aspects of the Staff Proposal are encouraged. In particular, ARB seeks the active participation of local lead agencies. Staff has identified a few questions to solicit public comment, but this list is not exhaustive.

- Will the recommended approaches have any unintended consequences, for example, encouraging the piecemealing of projects?

- As set out in the attachments to the Staff Proposal, staff proposes to define certain performance standards (*e.g.*, for energy efficiency) by referencing or compiling lists from existing local, State or national standards. For some sub-sources of GHG emissions (*e.g.*, construction, transportation, waste), ARB staff has not identified reference standards. How should the performance standards for these sub-sources be defined?

- Are any of the industrial, residential, or commercial project types eligible for categorical exemptions likely to contribute more significantly to climate change than staff's preliminary analysis indicates?

- For residential and commercial projects, staff has proposed that the GHG emissions of some projects that meet GHG performance standards might under some circumstances still be considered cumulatively considerable and therefore significant. What types of projects might still have significant climate change-related impacts?

(October 24, 2008)

ATTACHMENT A
Preliminary Draft Proposal for Industrial Projects

1. The project is exempt under existing statutory or categorical exemptions.

No

2. (a) The project meets both of the below minimum performance standards, or includes equivalent mitigation measures:

Construction
- Meets an interim ARB performance standard for construction-related emissions.

Transportation
- Meets an interim ARB performance standard for transportation.

AND

(b) The project, with mitigation, will emit no more than ~7,000 metric tons CO2e/yr from non-transportation-related GHG sources (which addresses ~90% of industrial sector GHG emissions). Includes:
- Combustion-related components/equipment;
- Process losses (fugitive, working, evaporative, etc.);
- Purchased electricity; and
- Water usage and wastewater discharge

No

3. Project will have significant GHG impacts. An EIR must be prepared and all feasible GHG mitigation measures implemented.

Yes

Yes

Yes

Presumption of less than significant impacts related to climate change

Presumption of significant impacts related to climate change

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Preliminary Draft Proposal for Industrial Projects

Introduction

CEQA guidelines provide that thresholds of significance can be qualitative, quantitative, or in the form of performance standards. ARB staff's objective is to develop a threshold of significance that will result in the vast majority (~90% statewide) of the greenhouse gas (GHG) emissions from new industrial projects being subject to CEQA's requirement to impose feasible mitigation. ARB staff believes this can be accomplished with a threshold that allows small projects to be considered insignificant. ARB staff used existing data for the industrial sector to derive a proposed hybrid threshold. The threshold consists of a quantitative threshold of 7,000 metric tons of CO2 equivalent per year (MTCO2e/year) for operational emissions (excluding transportation), and performance standards for construction and transportation emissions.

The goal of this effort is to provide for the mitigation of GHG emissions from industrial projects on a statewide level. Over time, implementation of AB 32 will reduce or mitigate GHG emissions from industrial sources. Once such requirements are in place, they could become the performance standard for industrial projects for CEQA purposes. ARB staff intends to pursue this approach in conjunction with development of the regulatory requirements for industrial sources in the Proposed AB 32 Scoping Plan. Staff is proposing the use of a quantitative significance threshold at least until such time that performance standards, such AB 32 regulatory requirements, are in place to ensure mitigation of significant impacts of GHG emissions from projects in the industrial sector.

The performance standards are largely self explanatory and similar to the approaches proposed for residential and commercial projects. The method for deriving the quantitative aspect of the threshold warrants further explanation.

Technical foundation for proposed quantitative aspect of the threshold

Based on the available data, ARB staff found that for the industrial sector, small projects – defined as the portion of new projects that, when viewed collectively, were responsible for only a relatively small amount of emissions – could be allowed to proceed without requiring additional mitigation under CEQA. The question for ARB staff was what line divides these small projects from the rest of the projects that should undergo mitigation to achieve the larger environmental objective.

ARB decided to construct a representative small project and to estimate that project's expected emissions. First, ARB considered the common sub-sources of GHG emissions in the industrial sector. The four main broad emission categories and their approximate statewide contribution to GHG emissions from industrial facilities other than power plants are:

Category	MMTCO2e/year	Percent (%)
Combustion processes	70	63 %
Process Losses (evaporative, fugitive, working, etc.)	15	13 %
Purchased Electricity	18	17 %
Water Use and Wastewater Treatment	7	7 %

As the table indicates, GHG emissions from industrial sources are dominated by combustion emissions. To ensure that significant industrial emissions would be captured by the proposed threshold, ARB staff evaluated industrial boilers because they are a very common piece of equipment, are essential in many energy-intensive industries, and are a top contributor to industrial combustion emissions.

A recent comprehensive survey of industrial boilers by Oak Ridge National Laboratory[25] found that boilers with an input capacity of 10 MMBtu/hr or greater correspond to 93 percent of total industrial boiler input capacity. Based on this data, ARB staff used a natural gas boiler input capacity benchmark of 10 MMBtu/hr which equates to emissions of 4,660 MTCO2e/yr. This capacity benchmark defines a significant combustion source.

As shown in the above table, combustion processes account for 63 percent of the statewide GHG emissions from industrial facilities. Process losses, purchased electricity, and water use and water treatment account for the remaining 27 percent of emissions. Staff applied these proportions to the benchmark combustion emissions estimate (4,660 MTCO2e/yr). The result is an overall emissions estimate of approximately 7,000 MTCO2e/yr for a representative small project that accounts for the four main categories in the table above.

Based on the available data, staff believes that the 7,000 MTCO2e/year benchmark can be used to effectively mitigate industrial projects with significant GHG emissions.

[25] Characterization of the U.S. Industrial/Commercial Boiler Population, Energy, and Environmental Analysis, Inc. submitted to Oak Ridge National Laboratory, available at:: http://ww.eea-inc.com/natgas_reports/BoilersFinal.pdf.

(October 24, 2008)

ATTACHMENT B
Preliminary Draft Proposal for Residential and Commercial Projects

1. The project is exempt under existing statutory or categorical exemptions.

Yes → Presumption of less than significant impacts related to climate change

No →

2. The project complies with a previously approved plan that addresses GHG emissions, satisfies (15064(h)(3)), and has all of the following attributes:

- Meets a community level GHG target consistent with the statewide emissions limit in AB 32 and, where the plan will apply beyond 2020, Executive Order S-3-05;
- Is consistent with a transportation-related GHG reduction target adopted by ARB pursuant to SB 375.
- Includes a GHG inventory and mechanisms to regularly monitor and evaluate emissions;
- Includes specific, enforceable GHG requirements;
- Incorporates mechanisms that allow the plan to be revised in order to meet targets; and
- Has a certified final CEQA document (see 15152(f)).

Yes → Presumption of less than significant impacts related to climate change

No →

3. (a) The project meets all of the below minimum performance standards, or includes equivalent mitigation measures.

Construction

- Meets an interim ARB performance standard for construction-related emissions;

Operations

- Meets an energy use performance standard defined as CEC's Tier II Energy Efficiency goal;
- Meets an interim ARB performance standard for water use;
- Meets an interim ARB performance standard for waste;
- Meets an interim ARB performance standard for transportation;

AND

(b) The project, with performance standards or equivalent mitigation, will emit no more than X metric tons CO2e/yr (criteria to be developed).

Yes → Presumption of less than significant impacts related to climate change

No →

4. Project will have significant GHG impacts. An EIR must be prepared and all feasible GHG mitigation measures implemented.

Yes → Presumption of significant impacts related to climate change

Presumption of less than significant impacts related to climate change

Presumption of significant impacts related to climate change

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Preliminary Draft Proposal for Residential and Commercial Projects

Introduction

CEQA guidelines provide that thresholds of significance can be qualitative, quantitative, or in the form of performance standards. ARB staff's objective is to develop a threshold for residential and commercial projects that will substantially reduce the greenhouse gas (GHG) emissions from new projects and streamline the permitting of carbon-efficient projects. To achieve this, staff's preliminary recommendation is to develop a threshold based on clear and stringent performance standards.

Performance standards will address the five major emission sub-sources for the sector: energy use, transportation, water use, waste, and construction. For the energy use performance standard, staff recommends reliance on the California Energy Commission's (CEC) Tier II Energy Efficiency standards for solar energy incentive programs. These standards are consistent with what is needed to meet the state's goal of zero net energy buildings and are continuously updated to reflect energy efficiency best practices. For the remaining sub-sources (water, waste, etc.), staff intends to compile benchmark performance standards as part of its final threshold recommendation. Projects may alternatively incorporate mitigation equivalent to these performance standards.

Staff recognizes that a substantial body of measures to address GHG emissions exists through programs like LEED, GreenPoint Rated, and the California Green Building Code. As work on performance standards moves forward, staff intends to make use of these projects.

In addition, staff proposes that a presumption of non-significance apply only to projects whose total net emissions, after meeting the performance standards or equivalent, are below a specified level. Staff proposes to develop this emissions level as part of its final threshold recommendation.

Discussion of Flow Chart

Box 1: In general, categorical exemptions will continue to apply.

Based on its preliminary analysis, ARB staff believes that projects described in CEQA's categorical and statutory exemption provisions (Articles 18 and 19 of the California Code of Regulations, title 14) will not interfere with achieving the objective to minimize emissions from new projects in this sector. GHG emissions from residential and commercial projects that are described in the categorical exemption language appear to be relatively small from a GHG perspective. For example, staff's preliminary analysis indicates that emissions from a project qualifying for the statutory infill project exemption (Cal. Code Regs., tit. 14, § 15195) will emit approximately 1,600 metric tons (MT)CO2e/yr. Staff believes such infill projects represent some of the largest projects described in the exemption provisions. ARB staff expects to provide additional analyses to support a lead agency's determination that the GHG impact of these project types is less than significant. Staff invites the public and stakeholders to provide further evidence on the application of categorical exemptions to residential and commercial projects.

Box 2: If GHGs are adequately addressed at the programmatic level, the impact of certain individual projects can be found to be insignificant.

As OPR noted in its June 2008 Technical Advisory:

> CEQA can be a more effective tool for greenhouse gas emissions analysis and mitigation if it is supported and supplemented by sound development policies and practices that will reduce greenhouse gas emissions on a broad planning scale and that can provide the basis for a programmatic approach to project-specific CEQA analysis and mitigation…. For local government lead agencies, adoption of general plan policies and certification of general plan EIRs that analyze broad jurisdiction-wide impacts of greenhouse gas emissions can be part of an effective strategy for addressing cumulative impacts and for streamlining later project-specific CEQA reviews.

ARB staff encourages local agencies to take advantage of a programmatic approach to address climate change, consistent with existing law.

If a project complies with the requirements of a previously adopted GHG emission reduction plan or mitigation program that satisfies California Code of Regulations, title 14, section 15064(h)(3), and includes the attributes specified in that provision and Box 2, the lead agency may determine that the project's GHG impacts are less than significant with no further analysis required. Examples of plans that may satisfy this provision include Climate Action Plans incorporated into General Plans that have inventories, an emissions target, suites of specific and enforceable measures to reach that target, monitoring and reporting, and mechanisms to revise the plan to stay on target. Moreover, a prior EIR that "adequately addressed" climate change may be used for tiering purposes. (See Cal. Code Regs. tit. 14, § 15152.)

Box 3: Projects that meet performance standards, or include equivalent mitigation, can be found to be insignificant.

The threshold incorporates performance standards requiring carbon efficiency for each major sub-source of emissions from projects in these sectors. Provided they are set at a sufficiently stringent level, performance standards will dramatically reduce GHG emissions and promote a transition toward zero and low emission projects. In most cases, ARB staff expects that performance standards will need to reach beyond current State mandates by a substantial amount, given that GHG emission reduction goals have not yet been adequately incorporated into State programs. Staff anticipates that performance standards will become more stringent over time.

ARB staff has identified the California Energy Commission's Tier II Energy Efficiency goals as an appropriate performance standard for energy use. Under State law, the CEC is required to establish eligibility criteria, conditions for incentives, and rating standards to qualify for ratepayer-funded solar energy system incentives in California. As part of this effort, the CEC establishes energy efficiency standards for homes and commercial structures, and requires new buildings to exceed current building standards by meeting Tier Energy Efficiency goals. CEC's Tier II Energy Efficiency goals will continue to be updated to achieve energy efficiency best practices, and are consistent with what is needed to meet the California Public Utilities Commission Strategic Plan goals of zero net energy buildings. Currently, the CEC's proposed guidelines for the solar energy incentive program recommend a Tier II goal for residential and commercial projects of a 30 percent reduction in building combined space heating, cooling, and water heating energy compared to the 2008 Title 24 Standards.[26]

For the remaining sub-sources, staff intends to compile benchmark performance standards as part of its final threshold recommendation. ARB staff believes that existing progressive green building standards provide a starting point for performance standards for transportation, water use, waste, and construction-related emissions. Existing green building rating systems like LEED, GreenPoint Rated, the California Green Building Code, and others, contain examples of measures that are likely to result in substantial GHG emission reductions from residential and commercial projects. The key to this approach will be identifying effective GHG reduction measures within these systems. ARB staff would like input from the public and stakeholders on appropriate performance standards for these sub-sources. Performance standards that already exist and have been proven to be effective – at the local, State, national or international level – are preferable.

Under staff's proposed approach, lead agencies would be allowed to find that a project's mitigation is "equivalent" to identified performance standards, thereby allowing for cost-effective and innovative approaches to reducing GHG emissions.

Staff believes that under some circumstances, projects that meet performance standards or include equivalent mitigation measures will have impacts that may still be cumulatively considerable and therefore significant. For this reason, staff recommends that, in addition to meeting performance standards or including

[26] Guidelines for California's Solar Electric Incentive Program Pursuant to Senate Bill 1 - SECOND EDITION - Draft Guidelines can be found at: http://www.energy.ca.gov/2008publications/CEC-300-2008-007/CEC-300-2008-007-D.PDF

equivalent mitigation measures, a project must also emit no more than "X" MTCO2e/yr. Criteria for determining this emissions level have yet to be defined. ARB requests public and stakeholder input on what types of projects might still have significant climate change-related impacts.

Box 4: Presumption of significant impacts.

If a project cannot meet the requirements in the previous boxes, it should be presumed to have significant impacts related to climate change. The lead agency must then prepare an EIR, or other appropriate document, and implement all feasible GHG mitigation measures.

Last reviewed on May 22, 2009

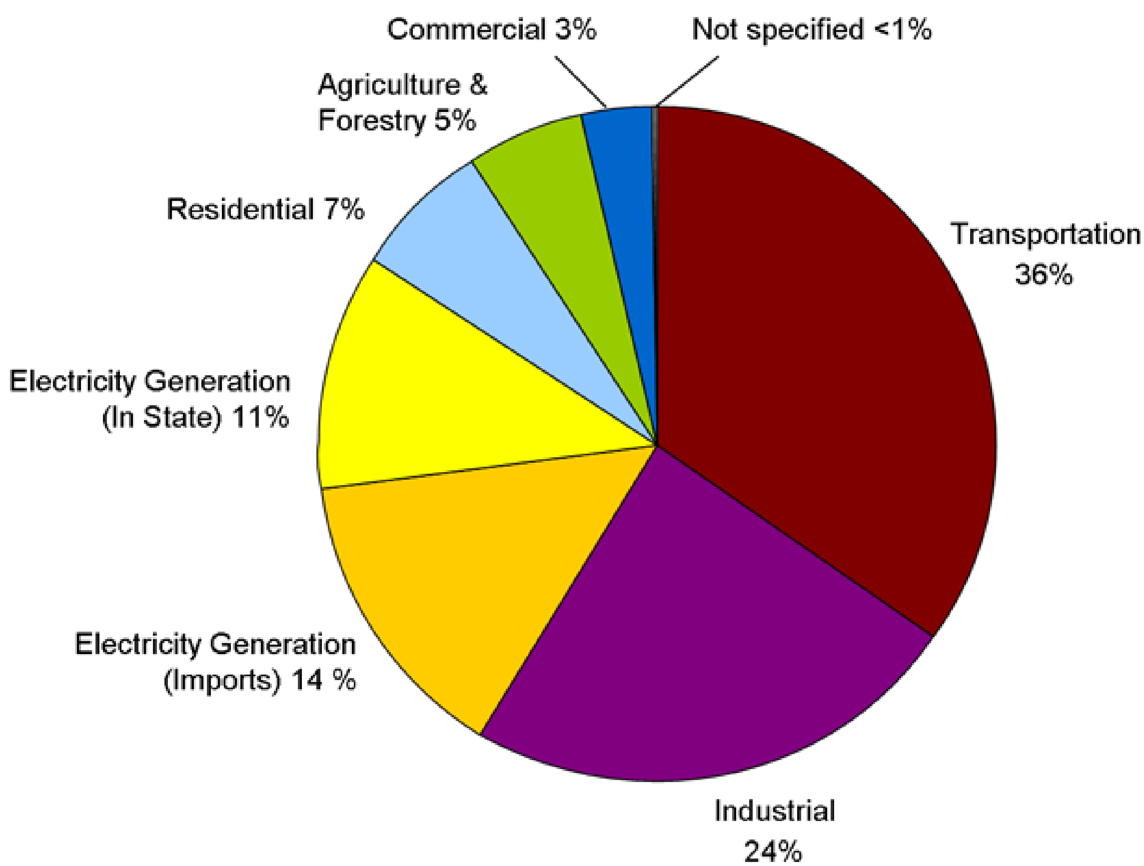
Greenhouse Gas Inventory Data - Graphs

Graph Gallery

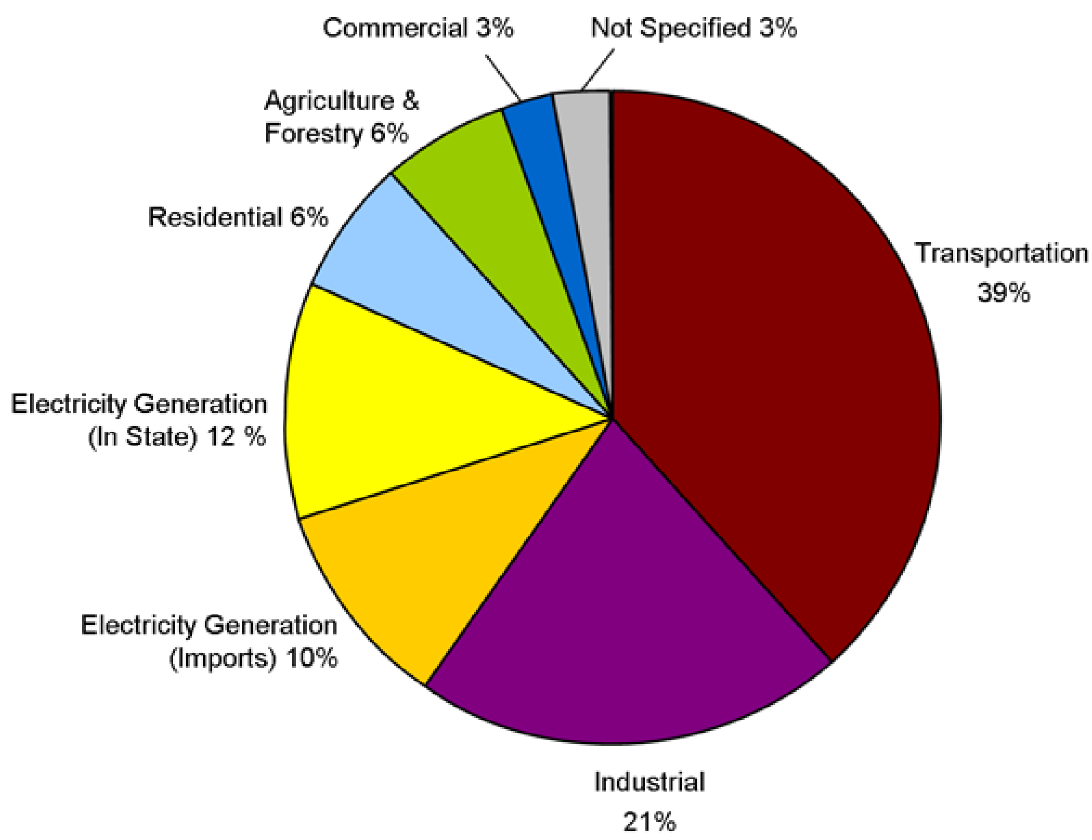
The California greenhouse gas (GHG) Inventory compiles statewide anthropogenic GHG emissions and sinks. It includes estimates for carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). The current inventory covers years 1990 to 2004.

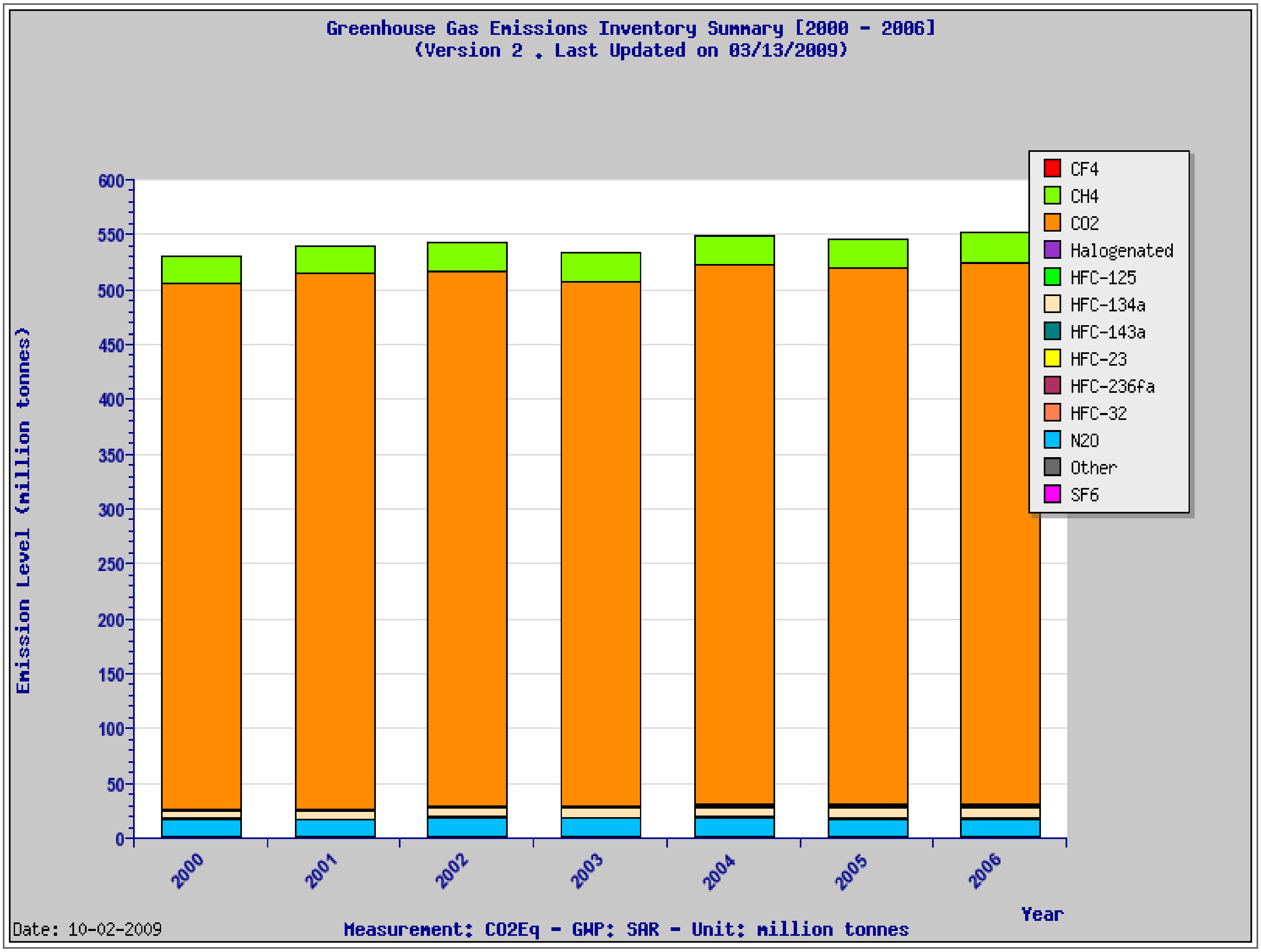
Scroll down to see summary plots of the current inventory data.

1990 GHG emissions by Sector (Gross emissions: 433.3 MMT CO_2e)



2006 GHG emissions by Sector (Gross emissions: 483.9 MMT CO_2e)


Commercial 3%
Not Specified 3%
Agriculture & Forestry 6%
Residential 6%
Transportation 39%
Electricity Generation (In State) 12 %
Electricity Generation (Imports) 10%
Industrial 21%



	2000	2001	2002	2003	2004	2005	2006
CF4	0.001	0.001	0.001	0.001	0.001	0.002	0.002
CH4	25.022	25.292	25.846	25.662	25.434	26.745	27.641
CO2	478.696	487.885	487.501	477.728	493.110	489.491	493.505
Halogenated gases (in CO2 Eq.)	1.229	0.862	0.690	0.690	0.690	0.706	0.770
HFC-125	0.632	0.729	0.831	0.954	1.099	1.249	1.491
HFC-134a	6.893	7.511	8.055	8.525	8.995	9.259	9.283
HFC-143a	0.499	0.651	0.822	1.015	1.229	1.475	1.742
HFC-23	0.001	0.001	0.001	0.001	0.001	0.001	0.001
HFC-236fa	0.065	0.072	0.079	0.085	0.091	0.095	0.100
HFC-32	0.003	0.007	0.013	0.021	0.032	0.044	0.072
N2O	15.840	15.207	16.930	16.535	16.377	15.807	15.667
Other ODS substitutes	0.487	0.470	0.527	0.598	0.633	0.661	0.693
SF6	1.135	1.120	1.040	1.013	1.022	1.014	0.993
Total	530.503	539.807	542.335	532.829	548.712	546.549	551.959

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

Last reviewed on May 21, 2009 at 15:19

Back to Index | Year 2000 | Previous year | Next year | Year 2006

♦ Category: Energy

IPCC: 1A3biii - Fuel Combustion Activities - Transport - Road Transportation - Heavy-duty Trucks and Buses

Sector: Transportation : On Road : Heavy-duty Vehicles : Heavy-duty Trucks, Buses & Motorhomes

♦ Greenhouse gas: Nitrous oxide (N2O)

► 2006 N2O from Fuel combustion - Distillate —

(Version 2 - Last updated on 03/13/2009)

● GREENHOUSE GAS EMISSION ESTIMATE —

Amount: 964.97 tonnes of N2O Emitted (299,140 tonnes CO2 Eq.)

Basis: Calculation

Calculation: [Fuel Combustion] * [Fuel N2O emission]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● ACTIVITY LEVEL USED IN CALCULATIONS —

Activity: Fuel combustion = 2,910,041,641 gal of Distillate

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion])

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● PARAMETERS AND CONSTANTS USED IN CALCULATIONS —

Parameter: EMFAC category fuel combustion = 3,284,416,051 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 340,390,326,602 g (i.e. 340.39 thousand tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 3,379,231,038 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fuel N2O emission = 0.332 g / gal

Reference: Long, J. (2007). Personal communication between Kevin Eslinger of CA Air Resources Board and Jeff Long, Air Resources Board Mobile Sources Assessment Branch, September 2007.

Parameter: Fuel sales = 2,994,049,134 gal

Reference: Dwarka R. (2008). Personal communication between Larry Hunsaker of the Air Resources Board and Ronil Dwarka of the California State Board of Equalization. Spring 2008.

Parameter: Vehicle miles traveled = 20,296,159,821 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

- ***GREENHOUSE GAS EMITTED PER UNIT ACTIVITY —***

  Amount: 0.332 g of N_2O per gal of Distillate
  103 g of CO_2eq. per gal of Distillate

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California's Greenhouse Gas Emissions Inventory

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

Last reviewed on May 21, 2009 at 15:19

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♦ Category: Energy

IPCC: 1A3bi - Fuel Combustion Activities - Transport - Road Transportation - Cars

Sector: Transportation : On Road : Light-duty Vehicles : Passenger Cars

♦ Greenhouse gas: Nitrous oxide (N2O)

► 2006 N2O from Fuel combustion - Gasoline —

(Version 2 - Last updated on 03/13/2009)

● GREENHOUSE GAS EMISSION ESTIMATE —

Amount: 4,237 tonnes of N2O Emitted (1,313,457 tonnes CO2 Eq.)

Basis: Calculation

Calculation: ([Vehicle miles traveled] * (0.0318 * ([EMFAC NOx emission] / [Vehicle miles traveled]) + 0.0167)) * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● ACTIVITY LEVEL USED IN CALCULATIONS —

Activity: Fuel combustion = 6,346,722,748 gal of Gasoline

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● PARAMETERS AND CONSTANTS USED IN CALCULATIONS —

Parameter: EMFAC category fuel combustion = 7,108,718,129 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 68,854,369,222 g (i.e. 68.85 thousand tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 16,389,786,721 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fraction of fuel mix = 0.943

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

Parameter: Fuel sales = 15,509,940,000 gal

Reference: FHWA (various). US Department of Transportation, Federal Highway Administration - Highway Statistics Series. Motor Fuel. Data accessed online at: http://www.fhwa.dot.gov/policy/ohpi/qffuel.cfm

Parameter: Vehicle miles traveled = 153,058,882,143 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate

Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

- ***GREENHOUSE GAS EMITTED PER UNIT ACTIVITY —***

Amount: 0.668 g of N2O per gal of Gasoline
207 g of CO2eq. per gal of Gasoline

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California's Greenhouse Gas Emissions Inventory

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

Last reviewed on May 21, 2009 at 15:19

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♦ Category: Energy

IPCC: 1A3bi - Fuel Combustion Activities - Transport - Road Transportation - Cars

Sector: Transportation : On Road : Light-duty Vehicles : Passenger Cars

♦ Greenhouse gas: Nitrous oxide (N2O)

► 2006 N2O from Fuel combustion - Distillate —

(Version 2 - Last updated on 03/13/2009)

● GREENHOUSE GAS EMISSION ESTIMATE —

Amount: 5.11 tonnes of N2O Emitted (1,583 tonnes CO2 Eq.)

Basis: Calculation

Calculation: [Fuel Combustion] * [Fuel N2O emission]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● ACTIVITY LEVEL USED IN CALCULATIONS —

Activity: Fuel combustion = 15,397,810 gal of Distillate

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion])

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● PARAMETERS AND CONSTANTS USED IN CALCULATIONS —

Parameter: EMFAC category fuel combustion = 17,378,725 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 712,992,532 g (i.e. 712.99 tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 3,379,231,038 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fuel N2O emission = 0.332 g / gal

Reference: Long, J. (2007). Personal communication between Kevin Eslinger of CA Air Resources Board and Jeff Long, Air Resources Board Mobile Sources Assessment Branch, September 2007.

Parameter: Fuel sales = 2,994,049,134 gal

Reference: Dwarka R. (2008). Personal communication between Larry Hunsaker of the Air Resources Board and Ronil Dwarka of the California State Board of Equalization. Spring 2008.

Parameter: Vehicle miles traveled = 483,304,018 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

- ***GREENHOUSE GAS EMITTED PER UNIT ACTIVITY —***

  Amount: 0.332 g of N2O per gal of Distillate
  103 g of CO2eq. per gal of Distillate

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

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♦ Category: Energy

IPCC: 1A3bii - Fuel Combustion Activities - Transport - Road Transportation - Light-duty Trucks

Sector: Transportation : On Road : Light-duty Vehicles : Light-duty Trucks & SUVs

♦ Greenhouse gas: Nitrous oxide (N2O)

► 2006 N2O from Fuel combustion - Gasoline —

(Version 2 - Last updated on 03/13/2009)

● GREENHOUSE GAS EMISSION ESTIMATE —

Amount: 4,937 tonnes of N2O Emitted (1,530,560 tonnes CO2 Eq.)

Basis: Calculation

Calculation: ([Vehicle miles traveled] * (0.0318 * ([EMFAC NOx emission] / [Vehicle miles traveled]) + 0.0167)) * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● ACTIVITY LEVEL USED IN CALCULATIONS —

Activity: Fuel combustion = 7,472,562,952 gal of Gasoline

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● PARAMETERS AND CONSTANTS USED IN CALCULATIONS —

Parameter: EMFAC category fuel combustion = 8,369,728,100 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 102,169,167,145 g (i.e. 102.17 thousand tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 16,389,786,721 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fraction of fuel mix = 0.943

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

Parameter: Fuel sales = 15,509,940,000 gal

Reference: FHWA (various). US Department of Transportation, Federal Highway Administration - Highway Statistics Series. Motor Fuel. Data accessed online at: http://www.fhwa.dot.gov/policy/ohpi/qffuel.cfm

Parameter: Vehicle miles traveled = 136,592,020,714 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate

Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

- ***GREENHOUSE GAS EMITTED PER UNIT ACTIVITY —***

  Amount: 0.661 g of N_2O per gal of Gasoline
  205 g of CO_2eq. per gal of Gasoline

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California's Greenhouse Gas Emissions Inventory

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

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♦ Category: Energy

IPCC: 1A3bii - Fuel Combustion Activities - Transport - Road Transportation - Light-duty Trucks

Sector: Transportation : On Road : Light-duty Vehicles : Light-duty Trucks & SUVs

♦ Greenhouse gas: Nitrous oxide (N2O)

► 2006 N2O from Fuel combustion - Distillate —

(Version 2 - Last updated on 03/13/2009)

● GREENHOUSE GAS EMISSION ESTIMATE —

Amount: 22.75 tonnes of N2O Emitted (7,053 tonnes CO2 Eq.)

Basis: Calculation

Calculation: [Fuel Combustion] * [Fuel N2O emission]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● ACTIVITY LEVEL USED IN CALCULATIONS —

Activity: Fuel combustion = 68,609,683 gal of Distillate

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion])

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● PARAMETERS AND CONSTANTS USED IN CALCULATIONS —

Parameter: EMFAC category fuel combustion = 77,436,261 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 3,322,367,689 g (i.e. 3.32 thousand tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 3,379,231,038 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fuel N2O emission = 0.332 g / gal

Reference: Long, J. (2007). Personal communication between Kevin Eslinger of CA Air Resources Board and Jeff Long, Air Resources Board Mobile Sources Assessment Branch, September 2007.

Parameter: Fuel sales = 2,994,049,134 gal

Reference: Dwarka R. (2008). Personal communication between Larry Hunsaker of the Air Resources Board and Ronil Dwarka of the California State Board of Equalization. Spring 2008.

Parameter: Vehicle miles traveled = 2,245,635,268 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

- ***GREENHOUSE GAS EMITTED PER UNIT ACTIVITY —***

  Amount: 0.332 g of N2O per gal of Distillate
  103 g of CO2eq. per gal of Distillate

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♦ Category: Energy

IPCC: 1A3biii - Fuel Combustion Activities - Transport - Road Transportation - Heavy-duty Trucks and Buses

Sector: Transportation : On Road : Heavy-duty Vehicles : Heavy-duty Trucks, Buses & Motorhomes

♦ Greenhouse gas: Nitrous oxide (N2O)

► 2006 N2O from Fuel combustion - Gasoline —

(Version 2 - Last updated on 03/13/2009)

● GREENHOUSE GAS EMISSION ESTIMATE —

Amount: 1,024 tonnes of N2O Emitted (317,500 tonnes CO2 Eq.)

Basis: Calculation

Calculation: ([Vehicle miles traveled] * (0.0318 * ([EMFAC NOx emission] / [Vehicle miles traveled]) + 0.0167)) * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● ACTIVITY LEVEL USED IN CALCULATIONS —

Activity: Fuel combustion = 755,078,926 gal of Gasoline

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

● PARAMETERS AND CONSTANTS USED IN CALCULATIONS —

Parameter: EMFAC category fuel combustion = 845,734,636 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 31,560,224,877 g (i.e. 31.56 thousand tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 16,389,786,721 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fraction of fuel mix = 0.943

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

Parameter: Fuel sales = 15,509,940,000 gal

Reference: FHWA (various). US Department of Transportation, Federal Highway Administration - Highway Statistics Series. Motor Fuel. Data accessed online at: http://www.fhwa.dot.gov/policy/ohpi/qffuel.cfm

Parameter: Vehicle miles traveled = 8,595,550,000 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate

Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

- ***GREENHOUSE GAS EMITTED PER UNIT ACTIVITY —***

  Amount: 1.36 g of N2O per gal of Gasoline
  420 g of CO2eq. per gal of Gasoline

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California's Greenhouse Gas Emissions Inventory

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? Category: Energy

IPCC: 1A3biv - Fuel Combustion Activities - Transport - Road Transportation - Motorcycles

Sector: Transportation : On Road : Light-duty Vehicles : Motorcycles

? Greenhouse gas: Nitrous oxide (N2O)

? 2006 N2O from Fuel combustion - Gasoline —

(Version 2 - Last updated on 03/13/2009)

? Greenhouse gas emission estimate —

Amount: 139.28 tonnes of N2O Emitted (43,178 tonnes CO2 Eq.)

Basis: Calculation

Calculation: ([Vehicle miles traveled] * (0.0318 * ([EMFAC NOx emission] / [Vehicle miles traveled]) + 0.0167)) * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

? Activity level used in calculations —

Activity: Fuel combustion = 58,573,456 gal of Gasoline

Basis: Calculation

Calculation: [EMFAC category fuel combustion] * ([Fuel sales] / [EMFAC total fuel combustion]) * [Fraction of fuel mix]

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

? Parameters and Constants used in calculations —

Parameter: EMFAC category fuel combustion = 65,605,857 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC NOx emission = 3,572,260,230 g (i.e. 3.57 thousand tonnes)

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: EMFAC total fuel combustion = 16,389,786,721 gal

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Parameter: Fraction of fuel mix = 0.943

Reference: ARB (2009). Upcoming technical support document on GHG inventory methodologies. Version 2 (1990-2006 inventory). Specific questions may be directed to ARB staff, see: http://www.arb.ca.gov/cc/inventory/contacts.htm

Parameter: Fuel sales = 15,509,940,000 gal

Reference: FHWA (various). US Department of Transportation, Federal Highway Administration - Highway Statistics Series. Motor Fuel. Data accessed online at: http://www.fhwa.dot.gov/policy/ohpi/qffuel.cfm

Parameter: Vehicle miles traveled = 2,539,357,143 mile

Reference: ARB (2007). The California Air Resources Board's EMission FACtors (EMFAC) model was used to calculate emission rates from all motor vehicles, such as passenger cars to heavy-duty trucks, operating on highways, freeways and local roads in California. Model and documentation available online at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

? Greenhouse gas emitted per unit activity —

Amount: 2.38 g of N2O per gal of Gasoline
737 g of CO2eq. per gal of Gasoline

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California's Greenhouse Gas Emissions Inventory

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California Greenhouse Gas Inventory for 2000-2006 — by IPCC Category

million tonnes of CO2 equivalent - (based upon IPCC Second Assessment Report's Global Warming Potentials)

Gross emissions & sinks	2000	2001	2002	2003	2004	2005	2006
Not Specified Not Specified > Use of substitutes for ozone depleting substances > HFC-134a	6.893	7.511	8.055	8.525	8.995	9.259	9.283
Not Specified Not Specified > Use of substitutes for ozone depleting substances > HFC-143a	0.499	0.651	0.822	1.015	1.229	1.475	1.742
Not Specified Not Specified > Use of substitutes for ozone depleting substances > HFC-23	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Not Specified Not Specified > Use of substitutes for ozone depleting substances > HFC-236fa	0.065	0.072	0.079	0.085	0.091	0.095	0.100
Not Specified Not Specified > Use of substitutes for ozone depleting substances > HFC-32	0.003	0.007	0.013	0.021	0.032	0.044	0.072
Not Specified Not Specified > Use of substitutes for ozone depleting substances > Other ODS substitutes	0.487	0.470	0.527	0.598	0.633	0.661	0.693
2G - Other Product Manufacture and Use	***1.78***	***1.68***	***1.67***	***1.60***	***1.65***	***1.63***	***1.67***
2G1 - Electrical Equipment	**1.13**	**1.12**	**1.04**	**1.01**	**1.02**	**1.01**	**0.99**
2G1b - Use of Electrical Equipment	1.13	1.12	1.04	1.01	1.02	1.01	0.99
Imported Electricity : Transmission and Distribution > Electricity transmitted > SF6	0.308	0.322	0.352	0.328	0.340	0.322	0.289
In State Generation : Transmission and Distribution > Electricity transmitted > SF6	0.826	0.797	0.687	0.685	0.682	0.691	0.704
2G4 - Other (Please specify)	**0.65**	**0.56**	**0.63**	**0.59**	**0.62**	**0.62**	**0.68**
Not Specified Industrial > CO2 consumption > CO2	0.169	0.097	0.122	0.159	0.146	0.158	0.194
Not Specified Industrial > Limestone and dolomite consumption > CO2	0.155	0.142	0.197	0.124	0.160	0.136	0.177
Not Specified Industrial > Soda ash consumption > CO2	0.321	0.317	0.315	0.308	0.318	0.322	0.307
2H - Other	***6.23***	***5.99***	***6.05***	***6.03***	***5.99***	***6.04***	***6.25***
2H3 - Other (please specify)	**6.23**	**5.99**	**6.05**	**6.03**	**5.99**	**6.04**	**6.25**
Petroleum Refining : Transformation > Fuel consumption - Naphtha > CO2	0.173	0.403	0.403	0.227	0.227	0.227	0.694
Petroleum Refining : Transformation > Fuel consumption - Natural gas > CO2	1.930	1.465	1.223	1.466	2.230	1.837	2.083
Petroleum Refining : Transformation > Fuel consumption - Refinery gas > CO2	4.124	4.118	4.427	4.333	3.537	3.976	3.474
Petroleum Refining : Transformation > Fuel consumption - Residual fuel oil > CO2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 - Agriculture, Forestry and Other Land Use	**21.83**	**21.85**	**24.35**	**24.65**	**24.64**	**24.78**	**25.10**
3A - Livestock	***13.53***	***14.04***	***14.53***	***14.90***	***14.80***	***15.41***	***15.68***
3A1 - Enteric Fermentation	**7.07**	**7.21**	**7.42**	**7.54**	**7.50**	**7.78**	**7.88**
3A1a - Cattle	6.77	6.90	7.10	7.20	7.14	7.39	7.48
3A1ai - Dairy Cows	*4.484*	*4.655*	*4.868*	*4.972*	*4.997*	*5.183*	*5.344*
Livestock population - Dairy cows > CH4	3.579	3.718	3.903	3.991	4.080	4.226	4.354
Livestock population - Dairy replacements 12-23 months > CH4	0.713	0.740	0.760	0.777	0.722	0.752	0.780
Livestock population - Dairy replacements 7-11 months > CH4	0.192	0.197	0.205	0.204	0.196	0.205	0.210
3A1aii - Other Cattle	*2.288*	*2.246*	*2.234*	*2.229*	*2.145*	*2.208*	*2.134*
Livestock population - Beef cows > CH4	1.419	1.401	1.365	1.330	1.294	1.294	1.222
Livestock population - Beef replacements 12-23 months > CH4	0.113	0.109	0.105	0.102	0.098	0.102	0.094
Livestock population - Beef replacements 7-11 months > CH4	0.030	0.029	0.028	0.027	0.026	0.027	0.025
Livestock population - Bulls > CH4	0.075	0.075	0.070	0.070	0.070	0.076	0.080
Livestock population - Heifer feedlot > CH4	0.100	0.102	0.112	0.124	0.116	0.123	0.132
Livestock population - Heifer stockers > CH4	0.079	0.075	0.077	0.080	0.072	0.086	0.080
Livestock population - Steer feedlot > CH4	0.172	0.173	0.195	0.218	0.203	0.215	0.230
Livestock population - Steer stockers > CH4	0.299	0.281	0.282	0.280	0.267	0.286	0.271
3A1c - Sheep	0.14	0.14	0.13	0.12	0.11	0.11	0.11
Livestock population - Sheep > CH4	0.136	0.135	0.127	0.123	0.114	0.113	0.109

California Environmental Protection Agency
AIR RESOURCES BOARD

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

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? Category: Waste

IPCC: 4D1 - Wastewater Treatment and Discharge - Domestic Wastewater Treatment and Discharge

Sector: Industrial : Wastewater Treatment : Domestic Wastewater : Centralized Anaerobic

? Greenhouse gas: Methane (CH_4)

? 2006 CH_4 from California population - —

(Version 2 - Last updated on 03/13/2009)

? Greenhouse gas emission estimate —

Amount: 19,479 tonnes of CH_4 Emitted (409,065 tonnes CO_2 Eq.)

Basis: Calculation

Calculation: [California Population] * [Per Capita biological organic demand (BOD5)]* [Average number of days per year] * [Proportion centrally treated] * [Proportion anaerobic] * ([Proportion anaerobic without primary treatment] + ([Proportion anaerobic with primary treatment] * (1 - [Proportion of BOD removed in primary treatment]))) * [Maximum methane production capacity] * [Methane correction factor for anaerobic systems]

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

? Activity level used in calculations —

Activity: California population = 37,332,976 person

Basis: Data

Reference: CDOF (2008). California Department of Finance, California Demographic Research Unit: Population Estimates and Projections. Accessed online at: http://www.dof.ca.gov/HTML/DEMOGRAP/ReportsPapers/ReportsPapers.php

? Parameters and Constants used in calculations —

Parameter: Digester gas production rate = 1 cf / person / day

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Maximum methane production capacity = 0.6 g / g

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Methane correction factor for anaerobic systems = 0.8

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Methane correction factor for septic systems = 0.5

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Methane correction for aerobic not well managed = 0.3

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Methane destruction efficiency = 0.99

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Per capita biological organic demand (BOD5) = 90 g / day

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Per capita wastewater flow = 100 gal / person / day

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion aerobic = 0.953

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion aerobic with primary treatment = 0.819

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion aerobic without primary treatment = 0.182

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion anaerobic = 0.047

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion anaerobic with primary treatment = 0.671

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion anaerobic without primary treatment = 0.329

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion centrally treated = 0.9

Reference: CWTRC, 2003. Status Report: Onsite Wastewater Treatment Systems in California. Jointly presented by: California Wastewater Training & Research Center, California State University Chico and USEPA Region 9 Ground Water Office. August 2003. http://www.csuchico.edu/cwtrc/Pages/InfoandReoprtspage.htm

Parameter: Proportion in septic systems = 0.1

Reference: CWTRC, 2003. Status Report: Onsite Wastewater Treatment Systems in California. Jointly presented by: California Wastewater Training & Research Center, California State University Chico and USEPA Region 9 Ground Water Office. August 2003. http://www.csuchico.edu/cwtrc/Pages/InfoandReoprtspage.htm

Parameter: Proportion of BOD removed in primary treatment = 0.325

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion of CH4 in biogas = 0.65

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Proportion of operations not well managed = 0

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Wastewater flow to plants with anaerobic digesters = 17,926,500,000 gal / day

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. ARB staff scaled USEPA's national data down to California pro-rata to yearly population estimates. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Constant: Average number of days per year = 365.2425 day

Reference: USNO (2004). U.S. Naval Observatory, Astronomical Applications Department, Leap Years. Accessed online at: http://aa.usno.navy.mil/faq/docs/leap_years.php

Constant: Methane density = 662 g / m3

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. USEPA 430-R-08-005. Annex 3.10: Methodology for Estimating CH4 and N2O Emissions from Manure Management. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Constant: Global warming potential of CH4 = 21

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

? Greenhouse gas emitted per unit activity —

Amount: 522 g of CH4 per person
10,957 g (i.e. 10.96 kg) of CO2eq. per person

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California's Greenhouse Gas Emissions Inventory

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California Environmental Protection Agency
AIR RESOURCES BOARD

DOCUMENTATION OF CALIFORNIA'S GREENHOUSE GAS INVENTORY

Last reviewed on May 21, 2009 at 15:20

Back to Index | Year 2000 | Previous year | Next year | Year 2006

? Category: Waste

IPCC: 4D1 - Wastewater Treatment and Discharge - Domestic Wastewater Treatment and Discharge

Sector: Industrial : Wastewater Treatment : Domestic Wastewater : Effluent Emissions

? Greenhouse gas: Nitrous oxide (N2O)

? 2006 N2O from California population - —

(Version 2 - Last updated on 03/13/2009)

? Greenhouse gas emission estimate —

Amount: 3,197 tonnes of N2O Emitted (991,007 tonnes CO2 Eq.)

Basis: Calculation

Calculation: (([California Population]*[Protein Consumption Rate]*[Fraction of nitrogen in protein]*[Non-consumption protein factor] * [Industrial and commercial codischarge factor]) - [Sewage sludge N not entering aquatic environment]) * [Effluent water emission factor] * [Molecular weight ratio of N2O to N2]

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

? Activity level used in calculations —

Activity: California population = 37,332,976 person

Basis: Data

Reference: CDOF (2008). California Department of Finance, California Demographic Research Unit: Population Estimates and Projections. Accessed online at: http://www.dof.ca.gov/HTML/DEMOGRAP/ReportsPapers/ReportsPapers.php

? Parameters and Constants used in calculations —

Parameter: CA population served by biological denitrification = 272,148 Person

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. ARB staff scaled USEPA's national data down to California pro-rata to yearly population estimates. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Effluent water emission factor = 5.000E-03 g / g

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Emission factor w/o nitrification denitrification = 3.2 g / person

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Emission factor with nitrification denitrification = 7 g / person

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Fraction of nitrogen in protein = 0.16

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Fraction using wastewater treatment plants = 0.9

Reference: CWTRC, 2003. Status Report: Onsite Wastewater Treatment Systems in California. Jointly presented by: California Wastewater Training & Research Center, California State University Chico and USEPA Region 9 Ground Water Office. August 2003. http://www.csuchico.edu/cwtrc/Pages/InfoandReoprtspage.htm

Parameter: Industrial and commercial codischarge factor = 1.25

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Non-consumption protein factor = 1.4

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Protein consumption rate = 41,885 g / person / year

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Parameter: Sewage sludge N not entering aquatic environment = 30,892,798,089 g (i.e. 30.89 thousand tonnes)

Reference: USEPA (2008). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. United States Environmental Protection Agency. EPA 430-R-08-005. Chapter 8: Waste. April 15, 2008. Washington DC. ARB staff scaled USEPA's national data down to California pro-rata to yearly population estimates. http://www.epa.gov/climatechange/emissions/usgginv_archive.html

Constant: Molecular weight ratio of N2O to N2 = 1.571133815

Reference: IUPAC (2006). ATOMIC WEIGHTS OF THE ELEMENTS 2005 (IUPAC TECHNICAL REPORT). Pure Appl. Chem., Vol. 78, No. 11, pp. 2051–2066, 2006.

Constant: Global warming potential of N2O = 310

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

? Greenhouse gas emitted per unit activity —

Amount: 85.6 g of N2O per person
26,545 g (i.e. 26.55 kg) of CO2eq. per person

State of California
AIR RESOURCES BOARD

DRAFT
CEQA Functional Equivalent Document
SCH# 2010081021

FOR PROPOSED

REGIONAL GREENHOUSE GAS EMISSION REDUCTION TARGETS FOR AUTOMOBILES AND LIGHT TRUCKS PURSUANT TO SENATE BILL 375

Date of Release: **August 9, 2010**
Scheduled for Consideration: **September 23, 2010**

Electronic copies of this document can be found on ARB's website at http://www.arb.ca.gov/cc/sb375/sb375.htm. Alternatively, paper copies may be obtained from the Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, California 95814, (916) 322-2990.

If you need this document in an alternate format (i.e. Braille, large print) or another language, please contact Ms. Lezlie Kimura Szeto at (916) 322-1504. TTY/TDD/Speech to Speech users may dial 711 for the California Relay Service.

Comments

This report will be considered at a meeting of the Board, which will commence on September 23, 2010. Interested members of the public may present comments orally or in writing at the meeting.

Comments may also be submitted by postal mail or by electronic submittal before the meeting. To be considered by the Board, written comment submissions on the Functional Equivalent Document that are not physically submitted at the meeting must be received no later than 5:00 P.M., September 22, 2010, and addressed to the following:

Postal mail: Clerk of the Board, Air Resources Board
1001 I Street, Sacramento, California 95814

Electronic submittal: http://www.arb.ca.gov/lispub/comm/bclist.php

Please note that for electronic submittal, the webpage provided above has a link for comments on the CEQA Functional Equivalent Document, as well as a separate link for commenting on the Staff Report and proposed targets.

For commenting on the Functional Equivalent Document:
The link is titled "ceqa2010".

The Board requests, but does not require 20 copies of any written submission. Also, ARB requests that written and e-mail statements be filed at least 10 days prior to the meeting so that ARB staff and Board members have time to fully consider each comment.

Please note that under the California Public Records Act (Government Code section 6250 et seq.), your written and oral comments, attachments, and associated contact information (e.g., your address, phone, email, etc.) become part of the public record and can be released to the public upon request. Additionally, this information may become available via Google, Yahoo, and any other search engines.

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I. Introduction and Background

The California Environmental Quality Act (CEQA) and Air Resources Board (ARB) policy require an analysis to determine the potentially adverse environmental impacts of proposed projects. This document presents a proposed determination that the establishment of regional greenhouse gas reduction targets (Regional Targets) for passenger vehicles (automobiles and light-duty trucks) and subsequent actions by Metropolitan Planning Organizations (MPOs) to implement policies that achieve those targets may have adverse impacts on the environment. However, we cannot speculate at this time what those specific impacts may be because the manner of implementation of Regional Targets will be at the discretion of MPOs. Further, the overall effect of setting Regional Targets will be beneficial for the environment.

California Public Resources Code §21080.5 allows public agencies with regulatory programs to prepare a plan or other written document in lieu of an environmental impact report once the Secretary of the Resources Agency has certified the regulatory program. The California Secretary for Resources has determined that ARB meets the criteria for a Certified State Regulatory Program (Title 14, California Code of Regulations (CCR) §15251(d)). This certification allows ARB to adopt rules and plans used in ARB's regulatory program without preparing formal CEQA documents such as Initial Studies, Notices of Preparation, Negative Declarations or Environmental Impact Reports (EIRs). As a certified agency, however, ARB is required to prepare a substitute document subject to other provisions of CEQA, such as avoiding significant adverse effects on the environment where feasible. This document considers environmental impacts associated with the proposed action, including cumulative impacts.

CEQA requires a certified agency to provide a description of the proposed action and include one of the following in its environmental document: 1) alternatives to the activity and mitigation measures to avoid or reduce any significant or potentially significant adverse impacts that the project might have on the environment; or 2) a statement that the agency's review of the project has determined the project would not have any significant or potentially significant adverse impacts on the environment, and therefore no alternatives or mitigation measures are proposed (CEQA Guidelines §15252).

ARB is required to set Regional Targets as a first step to achieve the ultimate goal of Senate Bill 375 (Steinberg, Chapter 728, Statutes of 2008) which is to reduce greenhouse gas emissions by reducing passenger vehicle travel. This action is intended to be part of a larger statewide effort to reduce the greenhouse gas emissions that lead to global climate change and to encourage sustainable development. However, because SB 375 was designed to allow regions to independently determine how they will achieve Regional Targets, ARB staff acknowledges there may be a potential for significant adverse impacts on the environment, depending upon the compliance path chosen by each region.

Based on the numerous policies that MPOs may employ to achieve targets and the possibility of varying intensities of deployment of each policy by the regions, there are an infinite number of compliance paths available to the 18 affected regions. Speculation on the adverse impacts within each region associated with those as yet unknown compliance paths is not reasonable at this time; region-specific analyses will be necessary when each MPO prepares either its Sustainable Communities Strategy (SCS) as part of its Regional Transportation Plan (RTP), or its Alternative Planning Strategy.

II. Proposed Project Description: Setting Regional Greenhouse Gas Emission Reduction Targets

SB 375 aligns regional land use, transportation, housing, and greenhouse gas reduction planning efforts. SB 375 requires ARB to set regional greenhouse gas emission reduction targets for passenger vehicles and light trucks for 2020 and 2035 (GC § 65080(b)(2)(A)). The targets are for the 18 MPOs in California. MPOs must develop an element (an SCS) as part of their RTPs to demonstrate how they will achieve the targets, if it is feasible to do so. If it is not feasible for the MPO to achieve its target through an SCS, then the MPO must prepare an Alternative Planning Strategy (APS) which is independent of the RTP.

Prior to setting targets for a region, ARB is required to exchange technical information with each MPO and the affected air districts. GC § 65080(b)(2)(A)(ii). In establishing the Regional Targets, ARB must take into account greenhouse gas emission reductions to be achieved by improved vehicle emission standards, changes in the carbon-intensity of fuels, and other ARB-approved measures that will reduce greenhouse gas emissions in affected regions. GC § 65080(b)(2)(A)(iii). As these factors may change, ARB may revise the Regional Targets every four years, and at a minimum, must update them every eight years. GC § 65080(b)(2)(A)(iv).

The Regional Targets may be expressed in gross tons, tons per capita, tons per household, or in any other metric deemed appropriate by ARB. As discussed more fully in the Staff Report, ARB staff proposes a percent reduction per capita metric for targets. Additionally, each MPO may recommend a target for its region. GC § 65080(b)(2)(A)(v).

Under this framework and based on the data and analysis prepared by the MPOs, ARB staff is recommending the Board adopt the following percent per-capita reduction targets, which together are the Preferred Alternative. The proposed Regional Targets are discussed in detail in the ARB staff report dated August 9, 2010 and posted on the ARB website at http://www.arb.ca.gov/cc/sb375/sb375.htm.

Proposed Greenhouse Gas Reduction Targets for 2020 and 2035
(Percent Change in Per Capita Emissions Relative to 2005)

MPO Regions	2020 (in %)	2035 (in %)
SCAG	-8	-13
MTC	-7	-15
SANDAG	-7	-13
SACOG	-7	-16
8 San Joaquin Valley MPOs[1]	-5	-10
6 Remaining MPOs[2]		
TMPO (Tahoe)	-7	+6
SCRTPA (Shasta)	0	0
BCAG (Butte)	-1	-1
SLOCOG (San Luis Obispo)	-8	-8
SBCAG (Santa Barbara)	+6	+4
AMBAG (Monterey Bay)	+13	+14

The metric for the proposed targets is a percent reduction per capita as compared to a 2005 base year. As part of the Regional Targets Advisory Committee's (RTAC) discussions and later technical discussions with MPOs, this metric was recommended by the RTAC and confirmed through later discussions with the MPOs as a preferred metric because it takes into account several factors.

The proposed metric directly addresses growth rate differences between MPO regions. Addressing growth rate differences between the MPO regions is important given that growth rates are expected to affect the magnitude of change that any given region can achieve with land use and transportation strategies. The per capita metric ensures that both fast and slow growth regions take reasonable advantage of any established transit systems and infill opportunity sites to reduce the region's overall regional greenhouse gas emissions.

The proposed metric also gives regions some "credit" for early actions taken to reduce greenhouse gas emissions since 2005. The per capita metric gives regions that have taken early actions and, as a result have a low level of greenhouse gas emissions per person, responsibility for a lower total reduction

[1] These are placeholder targets for the 8 San Joaquin Valley MPOs, with recognition of model improvements and scenario development efforts. ARB staff will reassess the Valley's progress in 2012.

[2] ARB staff proposes 2020 and 2035 targets that reflect each region's currently projected per capita change from 2005 in greenhouse gas emissions. ARB's target update in 2014 will result in greater emission reductions as a result of better tools to reflect the region's current and projected future land development and transportation infrastructure strategies, and additional time to advance sustainable communities efforts within the regions.

compared to regions that start with a higher level of greenhouse gas emissions per person.

The remainder of this Section II describes the proposed project in context, including significant steps remaining before local or regional environmental analysis can be performed.

A. Steps in SB 375 Implementation

While Regional Targets are the focus of this analysis, their establishment is only the first step among many to implement the planning process described in SB 375 to reduce emissions from passenger vehicle travel.

California's Climate Change Scoping Plan, adopted in December 2008, is the overarching framework for meeting the greenhouse gas emissions reduction goal of the Global Warming Solutions Act of 2006 (AB 32): Return to 1990 emissions levels by 2020. The comprehensive Scoping Plan proposes actions to reduce emissions from major sources, including establishment of Regional Targets for reductions from land use and transportation. The Scoping Plan refers specifically to SB 375 as the process for reducing greenhouse gas emissions through more sustainable land use and transportation planning.

Creating and implementing the plans envisioned by SB 375 involves three steps or phases. The first phase required ARB to convene a Regional Targets Advisory Committee (RTAC) to recommend factors and methods ARB should use to set Regional Targets. This phase was completed in September of 2009. The second phase is for ARB to set Regional Targets, the environmental impacts of which are described in this document. The third phase will be the development of Sustainable Communities Strategies (SCS) and possibly Alternative Planning Strategies (APS) by each MPO to meet Regional Targets in the next update of their Regional Transportation Plan (RTP).

The third phase will require independent analysis by each MPO to determine if there are any potentially significant impacts to the environment resulting from their unique approach, or compliance path, to meeting their area's Regional Target.

B. Regional Transportation Planning Process

SB 375 requires consideration of alternative land use and transportation patterns through pre-existing state and federal planning processes. SB 375 also strengthens the linkage between the Regional Housing Need Allocation (RHNA) process required by State Housing Element Law and the RTP development and adoption process. The development of an RTP requires adherence to local ordinances, state statutes, regulations, and guidelines, as well as federal law. RTPs must take into account local population, growth projections, and local general plans, among other factors.

RTPs are approved by an MPO's board, together with the certification of a CEQA environmental document for the RTP (typically an Environmental Impact Report or EIR) and a transportation conformity determination that ensures the region is on track to meet federal air quality requirements. The documents are then transmitted to the Federal Highway Administration, Federal Transit Administration, and U.S. Environmental Protection Agency for joint consideration. The RTP serves as one of the key documents used by the federal government to identify and fund transportation projects, programs, and services in a region.

Adoption of RTP planning documents as well as the projects listed in them are considered to be projects for purposes of CEQA. To comply with CEQA, MPOs, acting as lead agencies, typically initiate an Initial Study or an equivalent environmental assessment. Based on that work, an environmental document, often an Environmental Impact Report (EIR), is completed. These reports require MPOs to examine the environmental effects of the RTP (i.e. broad policy alternatives, program wide mitigation, growth inducing impacts, and cumulative impacts). After RTP adoption, additional CEQA documents are prepared as needed to address any impacts of individual projects contained within an RTP.

C. Role of MPOs and ARB

Once the Regional Targets are set by ARB, SB 375 requires MPOs to integrate their region's greenhouse gas emission reduction target for automobiles and light-duty trucks into their next RTP development process. Under federal and state law, each of the 18 California MPOs are required to develop an RTP. SB 375 adds a new state requirement to include an SCS, which will contain an underlying land use plan for the RTP tied to the regional transportation system resulting in greenhouse gas emission reductions. The SCS constitutes a fourth element of the RTP, in addition to the three existing elements (policy, financial, and action) that are required in a region's long range RTP.

Since the SCS is part of the RTP, it must also comply with all applicable state and federal requirements, including financial constraint and the use of latest planning assumptions.

SB 375 requires the MPO to prepare an APS only if it cannot feasibly achieve its Regional Target through an SCS. The APS is a separate document from the RTP and is not required to meet federal and state requirements for RTPs, however, the APS may be adopted concurrently with the RTP.

Finally, SB 375 sets out a very limited role for ARB in determining how and whether the Regional Targets will be achieved. Specifically, after establishing targets, ARB's role is to comment on the methodology to be used by each MPO for measuring GHG emissions and then to accept or reject the MPO's determination that their SCS or APS would achieve the targets, if implemented.

Thus, the policy choices relating to how the MPO will meet the targets are left to the discretion of the MPO.

D. General Statewide Impact of Target Setting

The purpose of setting Regional Targets is to implement one of numerous measures to reduce the severe environmental damage caused by greenhouse gas emissions. The Regional Targets will encourage regional planning agencies to deliberately plan in a manner that reduces greenhouse gas emissions from passenger vehicles and light trucks, which will have the added environmental and health benefits of reducing other associated air pollutants from tailpipe emissions. While it is not feasible to predict the nature or extent of localized impacts of individual measures or strategies regions will employ to meet Regional Targets, the overarching statewide impacts of targets we can reasonably conclude will benefit California. This is because the proposed targets would result in a reduction of greenhouse gas emissions of over three million metric tons of CO2 per year (MMTCO2/year) in 2020, and 15 MMTCO2/year in 2035.

SB 375 represents a shift toward planning principles that improve the quality of communities, increase transportation choices of residents, and reduce the frequency and distances Californians drive. Employing these principles in future transportation plans and a growing number of local general and climate action plans will reduce the State's levels of greenhouse gas and other emissions and benefit the public's health and environment.

III. Project Impacts Analysis – Preferred Alternative Levels

A. Incorporation of the Climate Change Scoping Plan Functional Equivalent Document by Reference in Lieu of Tiering

ARB incorporates by reference Appendix J of the Climate Change Scoping Plan (State Clearinghouse Number 2008102060). The programmatic analysis contained in the 2008 Climate Change Scoping Plan Functional Equivalency Document (FED) provides one basis for this environmental analysis. However, ARB staff prepared this analysis as a stand-alone document, rather than a second-tier document based on the Scoping Plan FED.

The establishment of Regional Targets was identified as Measure T-3 in the Climate Change Scoping Plan. The Scoping Plan identified the potential for the Regional Target measure to have a potentially significant impact on: 1) Land Use and Planning; 2) Transportation and Traffic (Appendix J-56, -63); and 3) Public Health and Safety (Appendix J-72). However, the Scoping Plan environmental analysis of these issues concludes that the Regional Target measure would have potentially beneficial impacts on the environment, rather than adverse impacts.

B. Analytical Approach

CEQA discourages forecasting and speculation about potential environmental impacts (CEQA Guidelines §15144 and §15145), though performing an environmental analysis necessarily involves some degree of forecasting. While foreseeing the unforeseeable is not possible, an agency must use its best efforts to find out and disclose all that it reasonably can. Further, if after thorough investigation, a lead agency finds that a particular impact is too speculative for evaluation, the agency should note its conclusion and terminate discussion of the impact.

In evaluating Regional Targets it was necessary to rely upon target-setting scenarios submitted by the MPOs. These scenarios do not represent draft SCS or APS documents, which will be developed by the MPOs over the coming months and years. However, MPO scenarios constitute the best available results of region-specific modeled analysis of policies that may be employed to meet targets, and therefore serve as critical input to ARB staff's analysis of Regional Targets.

In the regional planning process, MPOs will have the exclusive authority to determine whether, and by what means, they will achieve the targets set for them by ARB. MPOs will prepare future SCSs or APSs to demonstrate greenhouse gas reductions consistent with the Regional Targets. Forecasting or speculating about what those RTPs will look like and whether they may cause adverse impacts in any particular region is not possible at this time, and will need to be analyzed and discussed in detail by the MPOs through an established process that involves preparation of EIRs for the RTPs. However, ARB staff's best efforts have resulted in proposed determinations regarding general categories of impacts that could occur in one or more MPO region, depending on their chosen strategies to meet their Regional Target. These impacts are described in Section III.E.

C. Regional and Local Planning Decision Autonomy

While each MPO will need to determine how to meet their Regional Targets, ARB staff acknowledges that meeting Regional Targets may not be possible within an adopted RTP. For example, many emission reduction measures may be beyond the MPO's capacity to fund or authority to implement and therefore cannot be included in an SCS. Additionally, the California Constitution and planning statute clearly indicate that any proposed land use measures in a SCS or APS are solely within a local government's, and not an MPO's discretion to implement (Cal. Const. Art. 11 § 7, GC § 65080(b)(2)(K)). SB 375 contains specific provisions clarifying that neither an SCS nor an APS regulates the use of land. City and county land use policies and regulations are not required to be consistent with the regional transportation plan or APS. (GC § 65080(b)(2)(J))

For these reasons it is crucial for regional planning documents as well as local government planning documents that may implement the Regional Targets, to undergo independent environmental analyses based on the particular proposed action(s) by the MPO, city, or county. Each of these agencies must comply with a body of laws, regulations, and other guidance prior to making decisions, each of which must undergo independent environmental review.

D. Possible Regional Target Compliance Measures

The following is a sampling of the many policies that regions may consider as part of their SCS or APS to reduce greenhouse gases from passenger vehicle travel. The list is based on ARB review of existing academic and practitioner resources and has been shared with the MPOs. Sources for the above list of policies include reports and publications from federal, state, regional and local government agencies and organizations. (See Appendix D: References in the August 9, 2010 Staff Report.) It is not intended to be exhaustive or binding on the MPOs, but is presented to illustrate the numerous and varied compliance options each MPO may choose to employ when developing a region specific strategy to meet their target.

<u>Land Use Policies</u>

Density

- Increase infill and development in areas with existing infrastructure
- Increase opportunities for redevelopment/reuse (e.g., brownfields)
- Increase residential/commercial density near transit (e.g., transit oriented developments)
- Increase use of compact building design in new and existing developments

Diversity

- Increase mixed use development (e.g., residential and commercial uses in infill, reuse/redevelopment or greenfield projects)
- Increase transit oriented development

Design

- Improve connectivity of streets and pedestrian network (e.g., through streets)
- Improve neighborhood and site design (e.g., traffic calming, beautification)

Distance to Transit

- Increase residential/commercial density near transit (e.g., transit oriented development)
- Make developments transit ready

Housing

- Increase local housing for local workforce (e.g., jobs-housing fit, jobs-housing balance)
- Integrate affordable and market rate housing
- Improve accessibility of housing to transit

Open Space and Agricultural Land Conservation

- Reduce pressure on greenfields by directing growth to existing developed areas
- Adopt mechanisms to protect key natural resources

Location of Development

- Locate major regional activity centers near existing development (e.g., "destinations")
- Locate schools in neighborhoods that house the student population or maximize access by alternate modes
- Implement other location-related policies

Incentives

- Provide financial incentives (e.g., grants, tax credits) for non-transportation investments like housing, parks, and storm water management
- Provide regulatory relief (e.g., expedited permit processing)
- Provide recognition programs

<u>Transportation Policies</u>

Transit Facilities and Service

- Expand transit network
- Improve transit facilities (e.g., safety)
- Reduce passenger travel time (e.g., more frequent headways)
- Adopt competitive fare structure

Pedestrian Infrastructure and Environment

- Improve pedestrian facilities and infrastructure
- Improve pedestrian environment (e.g., beautification, access)
- Implement "safe routes to schools" program

Bike Infrastructure and Environment

- Improve bicycle facilities and infrastructure
- Improve cyclist environment (e.g., safety, access)
- Implement "safe routes to schools" program

Interconnectivity Among Alternative Modes

- Improve linkages between modes of travel
- Use Intelligent Transportation System technologies (e.g., "smart card")

Road Quality and Service

- Rehabilitate and maintain pavement
- Use transportation system management (e.g., congestion management)

Parking Management

- Implement effective pricing
- Alter parking requirements and types of supply (e.g., maximum parking, shared parking)

- Improve circulation efficiency through information (e.g., signage)

Employer-Based Commute Trip Reduction

- Encourage telecommuting and flexible/alternative work schedules
- Implement and coordinate use of employee vehicle sharing programs and alternative modes (e.g., incentives for carpool, bike, transit, vanpool use)
- Improve employer parking management (e.g., employee parking "cash out", unbundling parking cost from property cost)

Other Trip Reduction (Commute and Other)

- Implement vehicle sharing programs (e.g., car sharing, bike sharing, park and ride lots)
- Provide local shuttles

<u>Pricing Policies</u>

Parking Pricing

- Implement metered pricing
- Implement parking "cash-out" program

Road User Pricing

- Implement congestion pricing
- Implement High Occupancy Toll (HOT) lanes
- Implement area or cordon pricing
- Implement distance-based (VMT) pricing

Fuel Tax

Additional measures or policies for transportation system management and demand management include:

<u>System Development</u>

- Eliminate or reduce highway and arterial projects that result in additional "general purpose" lane miles
- Expand regional park and ride facilities
- Implement regional bicycle facilities and infrastructure
- Expand high occupancy toll (HOT lanes) system
- Implement traffic signal coordination
- Queue jumps/Bus priority at intersections
- Provide real time transit information
- Speed limit reductions to 55 MPH
- Ramp metering
- Incident management system
- Freeway travelers information system
- Anti-idling traffic codes for commercial vehicles
- Enhance vehicle inspection and maintenance programs
- Operation improvements to relieve bottlenecks

Demand Management

- Eco driver education
- Student carpool programs
- Staggered school class schedules
- On-site child care facilities
- Pay-as-you-drive insurance

E. Potential Environmental Impacts

CEQA and ARB regulations require ARB's functional equivalent document to describe both potentially beneficial and potentially adverse effects of adopting the proposed targets (the Preferred Alternative). The following is a discussion of potential beneficial impacts, project-level adverse impacts, growth inducing impacts, and cumulative impacts. Mitigation measures which could reduce or minimize the potential significant adverse impacts are also discussed in this section.

Beneficial Impacts

Many experts in the fields of land use, transportation, public health and environment have identified the potential for emission-reducing sustainable communities strategies to result in a number of additional benefits, or co-benefits. The implementation of Regional Targets, and the resulting changes in development patterns, may result in a variety of environmental, economic and social benefits. ARB staff agrees that the following list of potential co-benefits, excerpted from the September 29, 2009 RTAC report, provides a concise summary of potential co-benefits of the proposed project:

> "Communities that are well designed and supported by a range of transportation options will significantly reduce greenhouse gas emissions and contribute towards climate change solutions. In addition, many other advantages can result including increased mobility, economic benefits, reduced air and water pollution, and healthier, more equitable and sustainable communities. The Committee recommends that MPOs identify, quantify to the extent possible, and highlight these co-benefits throughout the SB 375 target setting and implementation processes. Co-benefits include the following:
>
> *Increased Mobility*
>
> - Congestion Relief – Fewer cars on the road results in less congestion, which has a number of benefits and helps to improve quality of life.
> - More Transportation Choices – Greater investment in a balanced transportation system and transit-oriented developments can provide increased use of public transportation, and sustainable, healthy transportation options such as walking and bicycle riding.

- Reduced Commute Time and Increased Productivity – Homes closer to job centers can reduce commute time and distance, especially if other modes of transportation are available. People can save time by not sitting in traffic commuting. Public transit provides the opportunity for relaxing or getting work done. Mixed use communities also mean more opportunities to shop and access daily needs near home, saving additional travel time.

Economic Benefits

- Savings – Taking public transit and driving less can save individuals money for fuel costs. Infrastructure/operating costs for transit can also decrease when such costs are spread among an increased number of riders.
- Taxpayer Savings – Services such as maintaining sewer systems, and police and fire services can be more efficient and cost less if they cover more people in less space.
- Neighborhood Economic Development – Increasing density puts more residents within walking distance of neighborhood businesses, providing opportunities for neighborhood economic development.
- Lower up-front infrastructure costs for roads, parking structures, and lower associated environmental impacts.

Reduced Air and Water Pollution

- Less Air Pollution – Reducing the number and length of car and truck trips means less pollution that directly or indirectly creates summertime smog and particulate pollution. Harmful pollution that can cause cancer and other health problems are greatly reduced.
- Improved Water Supply and Quality – Compact development can reduce water use and put less strain on sewer systems. Water quality can also be improved because run off can be filtered by natural lands instead of paved surfaces.

Conservation of Open Space, Farm Land and Forest Land

- The Committee also recognizes there are greenhouse gas benefits inherent in conserving land-based resources including farm and forest land. They play a vital role in California’s agricultural economy and maintaining biological health and diversity in the state. These resources also are capable of sequestering carbon in plant and tree matter as well as in soil.
- Urban parks can provide a great opportunity to enhance the aesthetic quality and function of urban neighborhoods. Urban parks, stream corridors, and trails strategically located can encourage non-motorized modes of transportation. When located in urban areas that people can walk or bicycle to, small parks can

obviate the need for automobile trips to other parts of the city to satisfy everyday recreational needs.

Healthier, More Equitable and Sustainable Communities

- More Opportunities for Active Lifestyles – Increased walking and bicycle riding can contribute to cardiovascular fitness and weight control, both of which can make people healthier and increase quality of life. Increased physical activity can reduce a number of chronic health risks such as obesity, diabetes, heart disease, cancer and depression.
- Less Dependence on Foreign Oil – Using alternative means of transportation and alternative forms of energy and fuel will reduce our dependence on foreign oil, which can help add to national security and economic stability.
- Improved Safety – Thriving, walkable neighborhoods mean more people on the street, helping to improve safety and discourage unlawful activity.
- Greater Housing Choices – Communities can be designed to include a mix of housing options, which can better meet a growing market demand for a variety of housing types. Recent studies indicate that homebuyers are willing to pay a premium to live in a walkable community.
- Preservation of Farmland, Habitat and Open Space – Dense, mixed-use communities can encourage infill and Brownfield redevelopment, thereby preserving open space, farmland and wildlife habitats.
- More Equitable Communities – Social equity issues can be partially addressed by improving local access and transportation to nutritious foods and health care services that are often out of reach in low income communities and communities of color."

<u>Project-Level Adverse Impacts</u>

While various combinations of the measures listed and referenced above in Section III.D. should have the effect of reducing greenhouse gas emissions and creating some combination of the above-listed co-benefits from the regions' transportation systems, there may be potential adverse consequences from implementing these measures. ARB cannot anticipate what development policies, if any, will be adopted and implemented at the regional or local level.

MPOs will need to take these potential impacts into account when developing RTPs, and local government agencies will need to take these into account when approving subsequent site-specific projects in furtherance of the RTPs.

The nature and extent of any of the following potential impacts is difficult to predict. There are numerous and varied compliance options available to meet

Regional Targets. In addition, ARB is not able to speculate about the nature of the SCSs or APSs that may be developed and implemented by the 18 regions. Therefore, the list of impacts below is speculative, at best. However, if one of the purposes of SB 375 is to encourage more compact, mixed-use, urban infill and redevelopment activity along transportation corridors, then it is reasonable to assume that some of the following impacts may occur, although the extent of the impacts and the specific locations where the impacts will occur cannot be predicted.

Use of individual measures or combinations of measures in an SCS or APS may lead to development activity (projects) that could have the following significant adverse impacts:

Air Quality
Placement of sensitive receptors close to high traffic areas where exposure to criteria air pollutants is increased, could create potential health hazards in localized areas. This could occur if new housing and other sensitive receptors, such as schools, are developed close to transportation corridors such as roads and freeways.

Traffic Congestion
Increased traffic congestion in localized areas or on individual roadways could occur as a result of additional residential and/or commercial development in existing urbanized areas where the road and transit systems are not adequate to handle the increased amount of vehicle traffic.

Population Growth
Substantial population growth in localized areas or communities could occur where new infill development or redevelopment is approved at greater densities or concentrations within existing urban centers, existing neighborhoods, or along major transit routes.

Displacement of Residents
Displacement of existing residents and/or businesses due to redevelopment could occur in situations where existing residential and/or commercial properties will be replaced with new infill development.

Utilities and Services
Requirement for new, expanded or altered utility and service systems to accommodate increased concentration of development (i.e. increased density) could occur in situations where the capacity of existing infrastructure (roads, sewers, water lines, power lines) in existing developed areas must be expanded or rehabilitated as a result of increased levels of residential and non-residential development.

Noise
Increased noise pollution in areas surrounding new development or redevelopment sites could occur as a result of urban infill development that places sensitive receptors (homes, schools, parks) in close proximity to noise from adjacent transportation corridors, commercial centers, or other noise generators.

Light and Glare
Increased light pollution in areas surrounding new development or redevelopment sites could occur as a result of intensified development and infill development that places sensitive receptors (homes, schools) in close proximity to uses that require night-time lighting such as transit stops, sports fields, and commercial signage.

Aesthetic/Visual Effects
Changes could occur in the visual character or aesthetics of areas in or adjacent to new development or redevelopment sites. New development or redevelopment may involve increased building heights and reduced setbacks between buildings, changing the visual character of a neighborhood and potentially obstructing views.

<u>Growth-Inducing Impacts</u>

Growth inducement occurs when an activity removes an obstacle to growth or accelerates normal rates of growth. The proposed project will not have a growth inducing impact because it will not influence the amount or rate of population growth in the State. SB 375 anticipates that the State's population will grow and encourages regions to develop plans for accommodating that growth. The proposed project will have no effect on demographics, population growth rates, or external factors such as immigration policy that might influence the rate of growth in the State. Population projections used for SCS planning will be based on regional forecasts and state projections.

SB 375 is intended to reduce greenhouse gas emissions as a result of better coordinated transportation and land use planning that generally commits fewer petroleum and other resources to accommodate a given level of population growth. There should be no net increase or decrease in overall growth resulting from the proposed project; instead the proposed project calls for an incremental decrease in per capita greenhouse gas emissions, even as the State's population increases.

<u>Cumulative Impacts</u>

The only identifiable cumulative impact of the proposed project that is not speculative is the change in greenhouse gas emissions from business as usual.

As discussed above, this is a positive impact in that greenhouse gas emissions are expected to be reduced from business-as-usual levels.

Using the data provided by the MPOs over the past four months, the proposed targets would result in a reduction of greenhouse gas emissions of over three million metric tons of CO2 per year (MMTCO2/year) in 2020, and 15 MMTCO2/year in 2035. When these reductions are applied to the most recent statewide 2020 emissions forecast, the emissions target for passenger vehicles in California's 2008 Climate Change Scoping Plan is met.

Given the numerous potential compliance measures that may or may not be combined in myriad ways within individual regions, quantification or even a qualitative discussion of the cumulative impacts of potential adverse impacts identified above for any single region are even less certain than the already speculative individual impacts identified and therefore cannot be estimated at this time.

Potential Mitigation Measures

Future actions that may be taken by regional and local agencies to implement the Regional Targets will be subject to local control and these actions will be required to undergo independent CEQA review, at which time the potential for adverse impacts and appropriate mitigation measures will be analyzed and implemented.

The following are general mitigation strategies that could be employed to mitigate the potential adverse impacts identified in section III.E. above. ARB does not have the authority to implement any of the following mitigation measures, as these measures are the responsibility and within the control of regional and local agencies that may act later to implement the Regional Targets through adoption of regional and local plans (see Section II.A.-C. above). In addition, the selection of appropriate mitigation measures must be made by the regional or local agency in the context of the particular action being proposed.

This following is not intended to be a comprehensive list of potential mitigation measures. Each regional and local agency that proposes to implement the Regional Targets in an SCS, APS, or local plan or project must determine on a case by case basis, the necessity and feasibility of mitigation measures that are appropriate to a specific later action being taken.

Air Quality

The potential exposure for residents is place-specific and varies due to regional characteristics and the intensity of vehicle emissions from roadways. Exposure to air pollutants for residents living in close proximity to freeways and arterial roadways can be reduced through consideration of project location, appropriate site design and building design, including: sensitive placement of residential buildings on the development site, use of natural and manmade buffers (e.g., vegetation, soundwalls), and where feasible, constructing transportation corridors below grade; and through use of appropriate indoor air filters, placement of buildings as far away from roadways as possible, designing building air intakes to be downwind and away from roadways, and limiting the number of openable windows on sides of buildings facing busy roadways. Site and building design should be considered in the context of a broader regional strategy for air pollution control measures.

Traffic Congestion
Adopt and implement trip reduction and traffic calming measures in areas with high vehicular traffic. Reduce traffic congestion through implementation of parking management programs, provision of adequate bike and pedestrian facilities, and establishment or expansion of transit opportunities. Conduct project-specific traffic analyses where warranted and require appropriate mitigation measures as a condition of permit approval. Local traffic mitigation should be considered in the context of a broader regional strategy for transportation and traffic management.

Population Growth
Adopt and implement local land use and zoning policies that establish building density or population density standards for neighborhoods, including designation of high density areas suitable for compact urban development. Plan for areas within existing communities where growth can be accommodated with appropriate supporting infrastructure, including public services and transportation access.

Displacement of Residents
Adopt and implement local regulations to provide replacement housing within the community for residents who are displaced as a result of redevelopment projects. Comply with all state and federal laws and regulations providing relocation benefits and services. Require development projects to include affordable housing units within the project that may be occupied by displaced residents.

Utilities and Services
Adopt and implement location-specific utility master plans and infrastructure plans to plan for increased capacity of sewer, water, and storm drainage facilities in existing urban areas that are planned for new growth, consistent with local land use policies. Adopt appropriate financing mechanisms to ensure that new development pays its fair share toward the provision of required public services such as fire and police protection.

Noise Pollution
Adopt and implement local noise standards and noise control measures, including limits on decibel levels and/or performance standards for indoor and outdoor noise levels. Project design should ensure that stationary noise sources are placed as far as possible from sensitive receptors to meet local noise

standards. Adopt and implement building acoustical insulation standards where setbacks and sound barriers do not sufficiently reduce indoor noise levels. Limit hours of operation of construction activities and other noise-generating activities to mitigate impacts on residents and other sensitive receptors. Conduct project-specific noise evaluations where warranted and require appropriate noise mitigation as a condition of permit approval.

Light and Glare
Adopt and implement local design guidelines, lighting standards, site development standards and building standards to minimize light and glare impacts on sensitive receptors. Regulate the type and placement of street lighting, parking lot lighting, building exterior lighting, reflective building materials, lighted outdoor signage, and lighting used in landscaping, to ensure sensitive receptors are protected. Conduct project-specific light and glare evaluations where warranted and impose appropriate mitigation measures as a condition of permit approval.

Aesthetic/Visual
Adopt and implement local design guidelines and other policies and regulations that protect scenic views and avoid visual intrusions through both site design and building design. Design buildings and other structures to minimize contrast in scale, massing, color and grading between the project and surrounding areas. Make use of natural landscaping as a screen or to soften contrast. Relocate or avoid development that may impact state and locally designated scenic highways and vistas. Conduct project-specific aesthetic/visual evaluations where warranted and impose appropriate mitigation measures as a condition of permit approval.

<u>Unavoidable Adverse Impacts</u>

It is too speculative to determine whether these or other mitigation measures will be available or effective in reducing potential site-specific impacts to a less than significant level, without knowing the specific characteristics of the future actions that might be taken by other agencies. While it is likely that future actions by regional and local agencies will be governed by their own regulations, development standards, and environmental performance measures which will serve to mitigate the impacts of any given future action, ARB does not have a basis for concluding that any future adverse impacts will be adequately mitigated.

In the absence of evidence to support a finding that any potential future impact will be mitigated to a less-than-significant level, ARB staff concludes that there may be unavoidable potential impacts of Regional Target setting, as a result of future implementing actions by regional and local agencies. This conclusion is not intended to pre-determine any environmental determinations that must be made in the future by regional or local agencies on a case-by-case basis. These future determinations must be made in the context of the particular action (project) that is being considered for approval.

IV. Project Alternatives

CEQA and ARB regulations require ARB's functional equivalent document to describe and evaluate a range of reasonable alternatives to a proposed project that would feasibly attain most of the basic objectives of the proposed project but would avoid or substantially lessen any of the significant adverse impacts of the proposed project (CEQA Guidelines §15126.6(a), 17 CCR § 60006). The range of alternatives required in an EIR is governed by the "rule of reason" that the EIR set forth only those alternatives necessary to permit a reasoned choice. An EIR need not consider an alternative whose effect cannot be reasonably ascertained and whose implementation is remote and speculative (CEQA Guidelines §15126.6(f)(3)).

ARB analyzed five possible alternatives to the proposed project:

- No project (Alternative 1)
- Increase proposed targets substantially (Alternative 2)
- Decrease proposed targets substantially (Alternative 3)
- Use an absolute emissions metric instead of a per capita reduction metric (Alternative 4)
- Use a vehicle miles traveled metric instead of a per capita reduction metric (Alternative 5)

A. Alternative 1 – No Project

ARB staff acknowledges that MPOs and local governments throughout the State are already independently improving and integrating transportation and land use practices consistent with the intent of SB 375. Setting Regional Targets is designed to foster these pre-existing planning efforts by setting ambitious achievable targets for each region. Without Regional Targets, future land use and transportation decisions will continue to promote change but are likely to take longer in overcoming current business as usual practices because:

- Local governments and developers will not be able to utilize CEQA streamlining incentives available from SB 375;
- It will be more difficult to leverage grants and other funding sources without being able to quantify data and staffing needs necessary to minimize environmental impacts due to growth; and
- Without targets collaboration and communication between MPOs is less likely as they develop and refine lower-impact planning strategies.

Without Regional Targets, it is likely that statewide planning improvement efforts will advance at a slower pace than with Regional Targets. This could result in regional transportation plans that do not minimize greenhouse gas related environmental impacts and, due to population growth and the vehicle miles travelled associated with it, erode gains made by other greenhouse gas reduction measures such as introducing cleaner vehicles and fuels to California. For these reasons, ARB staff has concluded that Alternative One has greater adverse environmental impact than the proposed project and should not be pursued.

Under CEQA, the alternatives are required to feasibly obtain most of the basic objectives of the proposed project. For this reason, it is important to note that SB 375 requires ARB to prepare and approve regional greenhouse passenger vehicle emission reduction targets for the State's 18 MPOs (GC § 65080(b)(2)(A)). If targets were not adopted (i.e., the "No Project" alternative) ARB would fail to fulfill the legal mandates specified in SB 375. While a No Project alternative might reduce at least some of the identified potential adverse impacts, it would be outweighed by foregone greenhouse gas emission reductions and would not meet the statutorily mandated target-setting objectives of the proposed project.

B. Alternative 2 – Increase Proposed Targets Substantially

Over the past year and a half ARB staff has worked closely with MPOs and stakeholders in an effort to set the most ambitious achievable Regional Targets. It has been widely acknowledged that if targets are set too high (more ambitious but less achievable) many MPOs would need to use an APS rather than SCS to demonstrate achievement of their targets. By using an APS rather than an SCS it becomes less likely that:

- Extensive and comprehensive environmental review is conducted on the region's plan to meet targets since the APS appears not to need CEQA review;
- Local governments and developers have multiple opportunities to utilize CEQA streamlining incentives and therefore a cost-effective means to construct sustainable projects; and
- Real long-term sustainable planning reforms are able to assist statewide efforts in achieving AB 32 greenhouse gas emission goals to minimize the effects of global climate change.

There are many valid reasons an MPO may need to temporarily rely on an APS for one planning cycle, for example a short-term decrease in funding. This is, however, different than setting targets that ensure the majority of MPOs must rely on an APS over the long term to meet targets.

For these reasons, if targets are substantially increased from proposed levels the actual gains of that increase are far less likely to ever come to fruition. Many or even most MPOs would likely adopt an APS and the status quo development patterns could continue for the foreseeable future because the incentives designed into SB 375 are no longer attainable. In addition, even if Alternative 2 did not trigger substantially more APSs, increased use of the compliance measures identified above for SCSs would likely produce more of the identified potential adverse impacts. Therefore ARB staff has concluded that Alternative Two has greater adverse environmental impact than the proposed project and should not be pursued.

C. Alternative 3 – Decrease Proposed Targets Substantially

Decreasing the target may have equally adverse effects as increasing them. By reducing Regional Targets, it becomes increasingly more likely that each region can adopt an SCS strategy that closely resembles past RTPs making it possible for many projects within an RTP to continue past patterns of leap frog development and sprawl. Since SB 375 provides CEQA streamlining benefits to projects that are consistent with an SCS that meets the region's target, these less sustainable projects will be more easily approved which is counter to the intent of the statute. This alternative is likely to result in:

- Failure to foster further investment and development in regional models, jobs-housing balance and jobs-housing fit, diversity in available housing, and transportation alternatives;
- Maintenance of cost incentives for developers and landowners to convert agricultural and greenfield lands for development, rather than taking advantage of infill opportunities; and
- Erosion of the gains made with improved vehicle technologies and fuels by continuing the trend of growth in vehicle miles traveled (VMT).

We acknowledge that substantially decreased targets could in theory reduce the number and severity of potential adverse impacts identified above for the proposed project. However, as described here for Alternative 3, substantially decreased targets would not only undermine the fundamental statutory objectives for target-setting but might actually worsen the existing baseline situation by allowing CEQA streamlining for business-as-usual developments, and potentially causing other environmental impacts associated with sprawl development (such as loss of wildlife habitat and agricultural lands). For these reasons ARB staff concludes that Alternative Three has greater adverse environmental impact than the proposed project and should not be pursued.

D. Alternative 4 – Use a Total Emissions Metric Rather Than a Percent Reduction Per Capita Metric for Proposed Targets

SB 375 gives ARB discretion to use any metric it deems appropriate. The rationale for the per capita reduction target is explained in the description of the proposed project. The Regional Targets could be expressed as a reduction in the total amount of greenhouse gas emissions, in million metric tons, that must be achieved by each region, by the years 2020 and 2035. This would involve converting the percent per capita reduction targets to total million metric tons of greenhouse gas emissions that must be reduced.

Using this alternative metric would not have the advantages of the percent per capita reduction metric which is proposed. The per capita metric is a relative metric. The benefit of this is that as the assumptions for 2005 change, making the 2005 emission levels higher or lower, the target increases or decreases appropriately. An absolute metric, as represented by this alternative, does not adjust to changing assumptions, and therefore may require an excess of emission reductions (if 2005 emissions decrease) or too few emission reductions (if 2005 emissions increase). At the same time, the absolute emission reduction metric ensures that overall emissions are decreasing, but not necessarily equitably across regions. Some regions may not experience the population growth that they expect, in which case they would be obligated to reducing an absolute amount of emissions with no growth to accomplish it. Other regions may grow faster than anticipated at the time that the absolute target was set, thereby making it easier to achieve the target as compared to the slower growth regions.

The total emissions target has the disadvantage of not being responsive to changing assumptions, especially in population growth, and it may handicap regions that are slow-growing while being easier to achieve for fast growth regions. Alternative Four does not provide the ability to address growth rate differences among the regions and could result in unfairly distributed emission reduction burdens if assumptions were to change after the targets are set. For these reasons, ARB staff concludes that Alternative Four is less desirable than the proposed project and should not be pursued.

E. Alternative 5 – Use a Vehicle Miles Traveled (VMT) Metric Rather Than An Emission Metric for Proposed Targets

SB 375 gives ARB discretion to use any metric it deems appropriate. The statute requires the target to result in a reduction of greenhouse gas emissions, not VMT. While there is a correlation between emissions and VMT, they are not necessarily interchangeable or directly related. By setting a VMT reduction metric, there is no guarantee that consistent and progressive reductions in greenhouse gas emissions will occur. Using a VMT metric may therefore interfere with meeting the statutory mandate to reduce emissions.

Staff concluded a greenhouse gas emissions metric was preferable to a VMT metric due to its simplicity. Over the past several years the public, through various forms of the media, has become increasingly aware of the potential effects of global climate change. The costs and benefits associated with implementation efforts to reduce the effects of global climate change have been expressed in emissions levels. This metric has also been used in state and federal policy discussions. Therefore, while staff will continue to collect information related to vehicle miles traveled the proposed metric should be expressed as emissions levels.

For these reasons, ARB staff concludes that Alternative Five is less desirable and may have greater environmental impact than the proposed project and should not be pursued.

F. Rationale for Selecting the Preferred Alternative (Proposed Regional Targets)

The purpose of alternatives is to identify ways to avoid or reduce the potential adverse impacts of the proposed project, but still allow most of the project objectives to be met. While it is difficult to say with certainty what the particular adverse impacts of the proposed project would be, for the reasons explained in this document, it is similarly difficult to predict whether any of these alternatives would result in better environmental outcomes than the proposed project. However, based on the analysis above, several of the alternatives have the potential to result in greater adverse effects as compared to the proposed project. Others do not meet the basic project objectives.

- Alternative 1 does not meet project objectives and could result in greater environmental impacts because there would be no state goals for reducing emissions.
- Alternatives 2 and 3 could result in greater environmental impacts as compared to the proposed project.
- Alternative 4 is not responsive to changes in planning assumptions and could result in unfair distribution of burden for reducing emissions.
- Alternative 5 may not meet project objectives because a VMT metric may not translate directly into desired emission reductions.

Setting Regional Targets requires a balance between setting goals that are high enough to motivate a departure from business-as-usual planning and development, but not so high as to be out of reach of the regions and local governments. Setting targets too high negates the potential to reduce statewide emissions levels through reduced passenger vehicle travel. Setting targets too low leads to a similar outcome. This is why after months of extensive consultation with academic experts, MPOs, state agencies, local governments, and the public, staff concludes that the proposed Regional Targets are the most ambitious and achievable based on information available at this time, and result in the greatest environmental benefit, as compared to the alternatives described above. The proposed Regional Targets will foster the most change by challenging each region yet allowing them to be able to achieve the targets and take advantage of SB 375 incentives.

V. Conclusion

ARB staff has concluded that the subsequent actions of MPOs after ARB establishes Regional Targets may have adverse impacts on the environment. However, we cannot speculate at this time what those specific impacts may be, due to lack of sufficient information about the mix, location, and nature of those subsequent actions.

While there is a potential for adverse impacts based on subsequent regional and local decisions, the net benefit to the environment from minimizing long-term transportation-related greenhouse gas emissions is potentially substantial. SB 375 is designed to institutionalize an alternative approach to planning for new growth, at the state, regional and local levels. Over time, this approach will result in minimizing the impact of California's transportation-related greenhouse gas emissions. The cumulative impact of greenhouse gas reductions from SB 375 combined with reductions from sources both within and outside of California is intended to reduce the substantial environmental impacts of climate change.

In addition, ARB staff considered several alternatives to the proposed Regional Targets and concluded that the proposed project is preferred for minimizing adverse impacts to the environment while meeting the intent of SB 375 to achieve greenhouse gas reductions from the land use and transportation sector. This determination was reached only after staff:

- Consulted the Climate Change Scoping Plan Functional Equivalent Document;
- Thoroughly reviewed MPO RTPS, data, and scenario submittals;
- Determined that ARB cannot predict what land use, transportation, and other policy measures will be implemented by MPOs to achieve the regional targets in future RTP planning cycles;
- Recognized that each individual SCS would have to undergo a substantial environmental review as part of the RTP adoption process; and
- Concluded ARB's proposed action cannot interfere with local government land use decisions (Cal. Const. Art. 11 § 7, GC § 65080(b)(2)(K).

A 45-day public review period of this Functional Equivalent Document is provided pursuant to CEQA. ARB will respond to all significant environmental concerns raised by the public during this comment period or at the ARB Board Hearing prior to taking final action to establish Regional Targets.


California Climate Action Registry
General Reporting Protocol

Reporting Entity-Wide Greenhouse Gas Emissions

Version 3.1 | January 2009

Table C.8 Methane and Nitrous Oxide Emission Factors for Stationary Combustion by Fuel Type and Sector

Fuel Type/End-Use Sector	CH_4 (kg/MMBtu)	N_2O (kg/MMBtu)
Coal		
Residential	0.316	0.0016
Commercial/Institutional	0.011	0.0016
Manufacturing/Construction	0.011	0.0016
Electric Power	0.001	0.0016
Petroleum Products		
Residential	0.011	0.0006
Commercial/Institutional	0.011	0.0006
Manufacturing/Construction	0.003	0.0006
Electric Power	0.003	0.0006
Natural Gas		
Residential	0.005	0.0001
Commercial/Institutional	0.005	0.0001
Manufacturing/Construction	0.001	0.0001
Electric Power	0.001	0.0001
Wood		
Residential	0.316	0.0042
Commercial/Institutional	0.316	0.0042
Manufacturing/Construction	0.032	0.0042
Electric Power	0.032	0.0042
Pulping Liquors		
Manufacturing	0.0025	0.0020

Source: EPA Climate Leaders, Stationary Combustion Guidance (2007), Table A-1, based on U.S. EPA, Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005 (2007), Annex 3.1.

Emission Factors for Stationary Combustion

Table C.7 Carbon Dioxide Emission Factors for Stationary Combustion

Fuel Type	Carbon Content	Heat Content	Fraction Oxidized	CO_2 Emission Factor	CO_2 Emission Factor
Coal and Coke	kg C/ MMBtu	MMBtu/ short ton		kg CO_2/ metric ton	kg CO_2/MMBtu
Anthracite	28.26	25.09	1.00	2,865.77	103.62
Bituminous	25.49	24.93	1.00	2,568.39	93.46
Sub-bituminous	26.48	17.25	1.00	1,846.19	97.09
Lignite	26.30	14.21	1.00	1,510.49	96.43
Residential/Commercial	26.00	22.05	1.00	2,317.13	95.33
Industrial Coking	25.56	26.27	1.00	2,713.87	93.72
Other Industrial	25.63	22.05	1.00	2,284.16	93.98
Electric Power	25.76	19.95	1.00	2,077.10	94.45
Coke	31.00	24.80	1.00	3,107.29	113.67
Petroleum Products (Gaseous)	kg C/ MMBtu	Btu/ standard cubic foot		kg CO_2/ standard cubic foot	kg CO_2/MMBtu
Natural Gas (weighted U.S. average)	14.47	1,029	1.00	0.0546	53.06
Acetylene (C_2H_2)	19.48	1,476	1.00	.1043	71.42
Petroleum Products (Liquid)	kg C/ MMBtu	MMBtu/ barrel		kg CO_2/gallon	kg CO_2/MMBtu
Asphalt & Road Oil	20.62	6.636	1.00	11.95	75.61
Aviation Gasoline	18.87	5.048	1.00	8.32	69.19
Distillate Fuel Oil (#1,2&4)	19.95	5.825	1.00	10.15	73.15
Jet Fuel	19.33	5.670	1.00	9.57	70.88
Kerosene	19.72	5.670	1.00	9.76	72.31
LPG (average for fuel use)	17.23	3.849	1.00	5.79	63.16
Propane	17.20	3.824	1.00	5.74	63.07
Ethane	16.25	2.916	1.00	4.14	59.58
Isobutane	17.75	4.162	1.00	6.45	65.08
n-Butane	17.72	4.328	1.00	6.70	64.97
Lubricants	20.24	6.065	1.00	10.72	74.21
Motor Gasoline	19.33	5.218	1.00	8.81	70.88
Residual Fuel Oil (#5 & 6)	21.49	6.287	1.00	11.80	78.80
Crude Oil	20.33	5.800	1.00	10.29	74.54
Naphtha (<401 deg. F)	18.14	5.248	1.00	8.31	66.51
Natural Gasoline	18.24	4.620	1.00	7.36	66.88
Other Oil (>401 deg. F)	19.95	5.825	1.00	10.15	73.15

Table C.6 Methane and Nitrous Oxide Emission Factors for Non-Highway Vehicles

Vehicle Type/Fuel Type	N_2O (g/gallon)	CH_4 (g/gallon)
Ships & Boats		
Residual Fuel Oil	0.30	0.86
Diesel Fuel	0.26	0.74
Gasoline	0.22	0.64
Locomotives		
Diesel Fuel	0.26	0.80
Agricultural Equipment		
Gasoline	0.22	1.26
Diesel Fuel	0.26	1.44
Construction		
Gasoline	0.22	0.50
Diesel Fuel	0.26	0.58
Other Non-Highway		
Snowmobiles (Gasoline)	0.22	0.50
Other Recreational (Gasoline)	0.22	0.50
Other Small Utility (Gasoline)	0.22	0.50
Other Large Utility (Gasoline)	0.22	0.50
Other Large Utility (Diesel)	0.26	0.58
Aircraft		
Jet Fuel	0.31	0.27
Aviation Gasoline	0.11	7.04
All Non-Highway/Construction Vehicles		
Butane*	0.41	0.09
Propane*	0.41	0.09

Source: U.S. EPA, Climate Leaders, Mobile Combustion Guidance (2008) based on U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005 (2007), Annex 3.2, Table A-101, except butane and propane.

* Butane and propane emission factors based on stationary combustion emission factors for these fuels from U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2000 (2002).

Appendix C Calculation References

Converting to CO_2 Equivalent

To incorporate and evaluate non-CO_2 gases in your GHG emissions inventory, the mass estimates of these gases will need to be converted to CO_2 equivalent (CO_2e). To do this, multiply the emissions in units of mass by the GHGs global warming potential (GWP).

Global warming potentials were developed by the Intergovernmental Panel on Climate Change (IPCC) to quantify the globally averaged relative radiative forcing effects of a given GHG, using carbon dioxide as the reference gas. In 1996, the IPCC published a set of GWPs for the most commonly measured greenhouse gases in its Second Assessment Report (SAR). In 2001, the IPCC published its Third Assessment Report (TAR), which adjusted the GWPs to reflect new information on atmospheric lifetimes and an improved calculation of the radiative forcing of carbon dioxide. However, SAR GWPs are still used by international convention and the U.S. to maintain the value of the carbon dioxide "currency". To maintain consistency with international practice, the California Registry requires participants to use GWPs from the SAR for calculating their emissions inventory.

Table C.1 lists the 100-year GWPs from SAR and TAR. The equation above provides the basic calculation required to determine CO_2e from the total mass of a given GHG using the GWPs published by the IPCC.

Converting Mass Estimates to Carbon Dioxide Equivalent

Metric Tons of CO_2e = Metric Tons of GHG x GWP

Table C.1 Comparison of GWPs from the IPCC's Second and Third Assessment Reports

Greenhouse Gas	GWP (SAR, 1996)	GWP (TAR, 2001)
CO_2	1	1
CH_4	21	23
N_2O	310	296
HFC-23	11,700	12,000
HFC-32	650	550
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
HFC-4310mee	1,300	1,500
CF_4	6,500	5,700
C_2F_6	9,200	11,900
C_3F_8	7,000	8,600
C_4F_{10}	7,000	8,600
C_6F_{14}	7,400	9,000
SF_6	23,900	22,000

Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003 (April 2005).

Emission Factors for Electricity Use

Table C.2 Carbon Dioxide, Methane and Nitrous Oxide Electricity Emission Factors by eGRID Subregion

eGRID Subregion Acronym	eGRID Subregion Name	CO_2 (lbs/MWh)	CH_4 (lbs/MWh)	N_2O (lbs/MWh)
AKGD	ASCC Alaska Grid	1,232.36	0.0256	0.0065
AKMS	ASCC Miscellaneous	498.86	0.0208	0.0041
AZNM	WECC Southwest	1,311.05	0.0175	0.0179
CAMX	WECC California	724.12	0.0302	0.0081
ERCT	ERCOT All	1,324.35	0.0187	0.0151
FRCC	FRCC All	1,318.57	0.0459	0.0169
HIMS	HICC Miscellaneous	1,514.92	0.3147	0.0469
HIOA	HICC Oahu	1,811.98	0.1095	0.0236
MROE	MRO East	1,834.72	0.0276	0.0304
MROW	MRO West	1,821.84	0.0280	0.0307
NEWE	NPCC New England	927.68	0.0865	0.0170
NWPP	WECC Northwest	902.24	0.0191	0.0149
NYCW	NPCC NYC/Westchester	815.45	0.0360	0.0055
NYLI	NPCC Long Island	1,536.80	0.1154	0.0181
NYUP	NPCC Upstate NY	720.80	0.0248	0.0112
RFCE	RFC East	1,139.07	0.0303	0.0187
RFCM	RFC Michigan	1,563.28	0.0339	0.0272
RFCW	RFC West	1,537.82	0.0182	0.0257
RMPA	WECC Rockies	1,883.08	0.0229	0.0288
SPNO	SPP North	1,960.94	0.0238	0.0321
SPSO	SPP South	1,658.14	0.0250	0.0226
SRMV	SERC Mississippi Valley	1,019.74	0.0243	0.0117
SRMW	SERC Midwest	1,830.51	0.0212	0.0305
SRSO	SERC South	1,489.54	0.0263	0.0255
SRTV	SERC Tennessee Valley	1,510.44	0.0201	0.0256
SRVC	SERC Virginia/Carolina	1,134.88	0.0238	0.0198

Source: eGRID2007 Version 1.1, December 2008 (Year 2005 data).
Note: Reporters calculating historical data for calendar years 1990-2007 should use the electricity emission factors in Appendix E.

III.7.6 Example: Carbon Dioxide Emissions from Biodiesel

BioClean Drycleaning Service

BioClean is an environmentally-friendly dry cleaning service with a delivery fleet of 10 biodiesel vans. Last year, the company purchased 12,000 gallons of B20 to fuel their vans.

Step 1: Identify the biodiesel blend being used.

BioClean is using B20, which is made up of 20% biodiesel and 80% petroleum-based diesel.

Step 2: Identify total annual biodiesel consumption.

BioClean purchased 12,000 gallons of B20 – they do not store fuel on-site, so no additional mass balance calculation is needed.

Step 3: Based on the blend, calculate the annual consumption of diesel and biodiesel.

Annual consumption of B20 = 12,000 gallons

12,000 gallons x 80% = 9,600 gallons diesel consumed

12,000 gallons x 20% = 2,400 gallons biodiesel consumed

Step 4: Select the appropriate emission factor for the petroleum-based diesel from Appendix C, Table C.3 to calculate the anthropogenic CO_2 emissions.

The CO_2 emission factor for diesel is 10.15 kilograms per gallon, and the biogenic CO_2 emission factor for biodiesel is 9.46 kilograms per gallon.

Carbon Dioxide Emission Factors for Transport Fuels

Fuel	kg CO_2/gallon
Diesel	10.15
Biodiesel (B100)	9.46*

* Note that the CO_2 emissions from burning biodiesel are biogenic, and should not be included as direct mobile emissions in your inventory. These emissions may be reported optionally.

Step 5: Multiply fuel consumed by the emission factor to calculate total CO_2 emissions and convert to metric tons.

Equation III.7c	CO_2 Emissions Contribution of Each Fuel							
CO_2 from diesel	=	10.15 kg/gallon	x	9,600 gallons	x	0.001 metric tons/kg	=	97.44 metric tons CO_2
Biogenic CO_2 from biodiesel	=	9.46 kg/gallon	x	2,400 gallons	x	0.001 metric tons/kg	=	22.70 metric tons biogenic CO_2

III.6.3 Example: Indirect Emissions from Electricity Use

Costlo Clothing Distributors

Costlo is a discount retail clothing chain with two outlets in Los Angeles, California, one in Portland, Oregon, and one in Tucson, Arizona. The company only purchases electricity and has no other GHG emissions.

Step 1: Determine annual electricity consumption.

Step 2: Select electricity emission factors that apply to the electricity purchased.

Because emission factors for electricity vary from region-to-region, Costlo tracks its electricity purchases by utility providing the electricity.

Annual Electricity Emissions and Emissions Factors

Region/ State	Power Generator	Annual Electricity Purchases (MWh)	CO_2 lbs/MWh	CH_4 lbs/MWh	N_2O lbs/MWh
CAMX/ California	Los Angeles	1,600	724.12	0.0302	0.0081
NWPP/Oregon	Portland	600	902.24	0.0191	0.0149
AZNM/Arizona	Tucson	800	1,311.05	0.0175	0.0179

Step 3: Determine total annual emissions and convert to metric tons.

Equation III.6b	Total Carbon Dioxide, Methane, and Nitrous Oxide Emissions for Electricity Use from Each Utility							
Los Angeles, CA	=	1,600 MWh	x	724.12 (lbs/MWh)	÷	2,204.62 lbs/mt	=	525.53 mt CO_2
Portland, OR	=	600 MWh	x	902.24 (lbs/MWh)	÷	2,204.62 lbs/mt	=	245.55 mt CO_2
Tucson, AZ	=	800 MWh	x	1,311.05 (lbs/MWh)	÷	2,204.62 lbs/mt	=	475.75 mt CO_2
						Subtotal	=	1,246.83 mt CO_2
Los Angeles, CA	=	1,600 MWh	x	0.0081 (lbs/MWh)	÷	2,204.62 lbs/mt	=	0.00588 mt N_2O
Portland, OR	=	600 MWh	x	0.0149 (lbs/MWh)	÷	2,204.62 lbs/mt	=	0.00406 mt N_2O
Tucson, AZ	=	800 MWh	x	0.0179 (lbs/MWh)	÷	2,204.62 lbs/mt	=	0.00650 mt N_2O
						Subtotal	=	0.01644 mt N_2O
Los Angeles, CA	=	1,600 MWh	x	0.0302 (lbs/MWh)	÷	2,204.62 lbs/mt	=	0.02192 mt CH_4
Portland, OR	=	600 MWh	x	0.0191 (lbs/MWh)	÷	2,204.62 lbs/mt	=	0.00520 mt CH_4
Tucson, AZ	=	800 MWh	x	0.0175 (lbs/MWh)	÷	2,204.62 lbs/mt	=	0.00635 mt CH_4
						Subtotal	=	0.03347 mt CH_4

Step 4: Convert Non-CO_2 emissions to CO_2e and sum the total. Use Equation III.6c and III.6d.

Equation III.6c	Convert Non-CO_2 GHGs to Carbon Dioxide Equivalent and Sum Total					
Metric Tons of CO_2e	=	Metric Tons of GHG	x	GWP (SAR, 1996)		
Metric Tons of CO_2					=	1,246.83 metric tons CO_2
CH_4 Tons of CO_2e	=	0.03347 metric tons CH_4	x	21 (GWP)	=	0.70287 metric tons CO_2e
N_2O Tons of CO_2e	=	0.01644 metric tons N_2O	x	310 (GWP)	=	5.0964 metric tons CO_2e
				Total	=	1,252.63 metric tons CO_2e

GLOBAL CLIMATE CHANGE AND CALIFORNIA

In Support of the *2005 Integrated Energy Policy Report*

Susan Brown
Fuels and Transportation Division
California Energy Commission

STAFF FINAL PAPER

DISCLAIMER

This paper was prepared as the result of work by a member of the staff of the California Energy Commission. The paper has been revised from an earlier version to reflect 2002 data now available for the statewide emissions inventory. It does not necessarily represent the views of the Energy Commission, its employees, or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this paper; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This paper has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this paper.

June 2005
CEC-600-2005-007-SF

their GHG emissions, pledging to reduce emission levels to five percent below 1990 levels by 2012.[5]

In its December 2004 Report to the Congress, the National Commission on Energy recommended that the United States establish a mandatory, economy-wide trading system to curb the nation's increasing GHG emissions, and that the United States should join efforts with other countries to reduce global GHG emissions.[6]

The Intergovernmental Panel on Climate Change (IPCC), an international scientific body which periodically assesses the state of the climate change science, found in 2000 that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."[7]

In May 2001, President George W. Bush asked the National Academy of Science (NAS) to assess the veracity of the IPCC findings. According to the NAS, the IPCC assessment "accurately reflects the current thinking of the scientific community on this issue." In addition, the NAS reported that "GHG are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Temperatures are, in fact, rising." [8]

A 2004 study by a team of leading California scientists, *Climate Change in California: Choosing Our Future*, predicts substantial increases in temperatures in both the summer and winter months as a result of climate change.[9] Using scenarios of lower and higher future emissions, and state-of-the-art climate models, the authors report significant changes in California's natural resources could result, including:

- Rising sea levels along the California coastline, especially in San Francisco and the San Joaquin Delta.

- Extreme-heat conditions, such as heat waves and very high temperatures, which will last longer and become more commonplace.

- An increase in heat-related human deaths, infectious diseases and a higher risk of respiratory problems caused by deteriorating air quality.

- Reduced snow pack and stream flow in the Sierra Nevada Mountains, affecting winter recreation and water supplies.

- Rising temperatures that can affect California agriculture, causing variations in crop quality and yield.

- Changes in the distribution of vegetation from projected increases in temperature and high fire risk.

These changes in California's climate and ecosystems are occurring at a time when the state's population is projected to grow from 34 million people to 59 million by the year 2040. Population growth and the demand for vital natural resources will compound the effects of climate change on water resources, human health and the environment.

Purpose of the Paper

This paper builds upon prior work carried out in numerous public forums, including the *2003 Integrated Energy Policy Report (Energy Report),* the *2004 Energy Report Update*, the California Climate Action Registry, the California Public Utilities Commission (CPUC) decisions related to climate change, and the California Energy Commission's (Energy Commission) Climate Change Advisory Committee. The paper also highlights coordinated efforts by state government agencies to address global climate change through the Joint Agency Climate Team in California, the West Coast Governors' Global Warming Initiative, and the Regional GHG Initiative in the Northeastern and Mid-Atlantic states.

This paper provides background and context to guide the formulation of policy options for reducing GHG emissions in California. Following a summary of state legislation on global climate change, the paper discusses the science of climate change, the impacts of climate change on California, emerging trends in GHG emissions, existing state policies and programs, options for addressing climate change, and recommended next steps.

Legislative Background

In 1988, the California Legislature first recognized the potential adverse effects of climate change when it enacted a state law [AB 4420 (Sher), Chapter 1506, Statutes of 1988] directing the Energy Commission to assess the impacts of climate change on energy supply and demand as well as the state's economy, environment, agriculture, and water supplies. The law also directed the Energy Commission to identify potential GHG reducing strategies. In response, the Energy Commission published *"Global Climate Change: Potential Impacts and Policy Recommendations"* in December, 1991.

Since then, numerous statutes have been enacted that have shaped California's climate change policies and programs. In 2004, the Legislature enacted budget control language which gave authority to the Secretary for Environmental Protection to coordinate greenhouse gas emission reductions and climate change activity in state government. (SB 1107, Chapter 230, Statutes of 2004)

CALIFORNIA ENERGY COMMISSION

INVENTORY OF CALIFORNIA GREENHOUSE GAS EMISSIONS AND SINKS: 1990 TO 2004

STAFF FINAL REPORT

December 2006
CEC-600-2006-013-SF

Arnold Schwarzenegger, *Governor*

EXECUTIVE SUMMARY

This report updates California's statewide inventory of greenhouse gas (GHG) emissions to support evaluation of state policies that address climate change and climate variability or more commonly known as global warming. Information in this report extends the inventory period through 2004, which is the most recent year that data are available from the California Energy Commission (Energy Commission) or the United States Department of Energy's (DOE's) Energy Information Administration. This inventory reports GHG emissions from out-of-state electricity used in California along with in-state generation GHG emissions and estimates future emissions trends using fuel demand and other forecast data from the Energy Commission's *2005 Integrated Energy Policy Report*.

California's economy experienced the second largest percentage growth in terms of gross state product (in dollars, not adjusted for inflation) of any state in the country from 1990 to 2003.[1] During that period, California's GSP grew 83 percent while its GHG emissions grew more slowly at 12 percent. This demonstrates the potential for uncoupling economic trends from GHG emissions trends.

Nonetheless, California's GHG emissions are large and growing. As the second largest emitter of GHG emissions in the United States and twelfth to sixteenth largest in the world,[2] the state contributes a significant quantity of GHGs to the atmosphere.

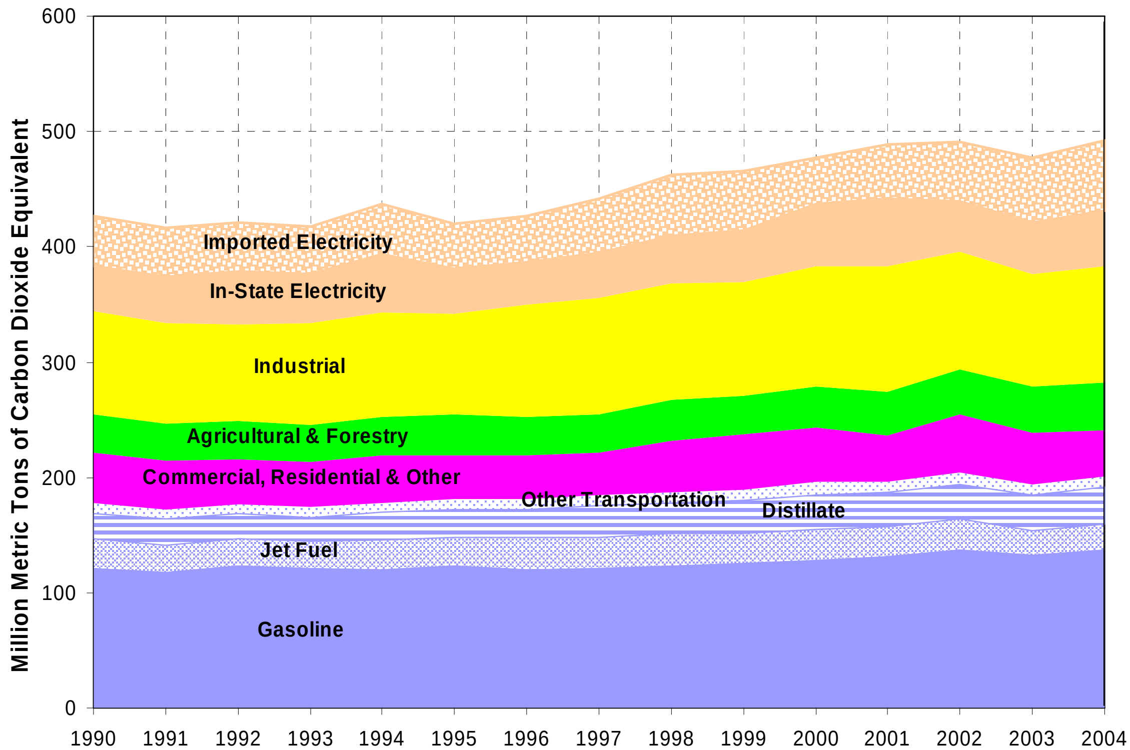
California's ability to slow the rate of growth of GHG emissions is largely due to the success of its energy efficiency and renewable energy programs and a commitment to clean air and clean energy. In fact, the state's programs and commitments lowered its GHG emissions rate of growth by more than half of what it would have been otherwise.[3] Moreover, California's energy programs and policies have had multiple benefits that include not only reducing GHG emissions, but reducing energy demand and improving air quality and public health.

Although California's total GHG emissions are larger than every state but Texas, California has relatively low carbon emission intensity. In 2001, California ranked fourth lowest of the 50 states in carbon dioxide emissions per capita from fossil fuel combustion and fifth lowest of the 50 states in carbon dioxide emissions from fossil fuel combustion per unit of gross state product. Emission trends per unit of gross state product are encouraging; most states have reduced their emissions per unit of gross state product over the 1990 to 2001 period.

In 2004, California produced 492 million gross metric tons of carbon dioxide-equivalent[4] GHG emissions, including imported electricity and excluding combustion of international fuels and carbon sinks or storage.

Figure 1 shows year-by-year trends in GHG emissions for the major energy sectors. Values differ yearly due to changes in fuel uses, meteorological variations, and other factors.

Figure 1 -- California's Gross GHG Emissions Trends



Source: California Energy Commission

The transportation sector is the single largest category of California's GHG emissions, producing 41 percent of the state's total emissions in 2004. Most of California's emissions, 81 percent, are carbon dioxide produced from fossil fuel combustion.

This California GHG emissions inventory excludes all international fuel uses, reporting them separately. Including these international emissions would increase total emissions by 27 to 40 million metric tons of carbon dioxide–equivalent GHG emissions, depending on the year.

Electricity generation is the second largest category of GHG emissions (behind transportation). In particular, out-of-state electricity generation has higher carbon intensity than in-state generation. While imported electricity is a relatively small methods being used by the EPA. An update[21] to this inventory was prepared and published in June 2005 to incorporate newer information and to allow policy makers to use the most current information and data available.

Summary of California's 2004 GHG Emissions

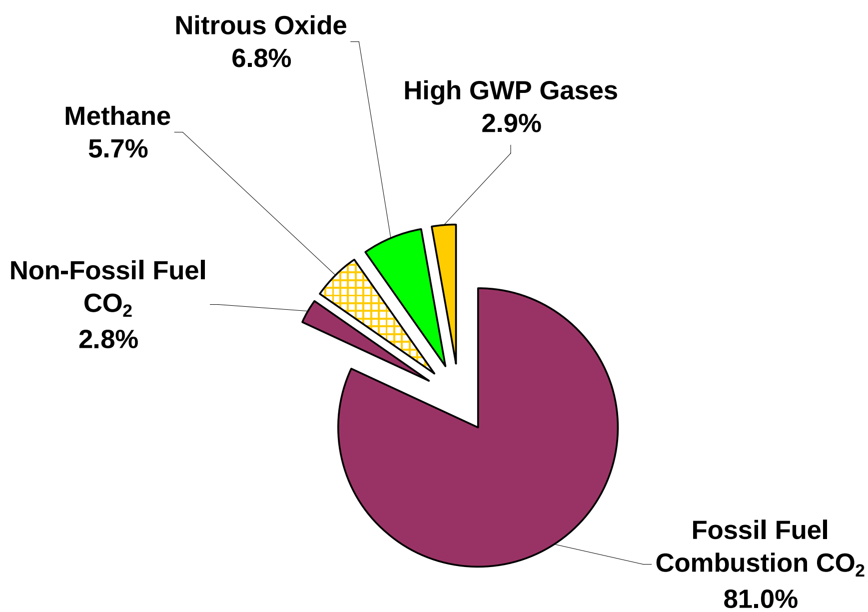
In 2004 California produced 492 million metric tons of CO_2-equivalent GHG emissions, including emissions associated with imported electricity. As shown in Figure 2, 81 percent were emissions of CO_2 from fossil fuel combustion, 2.8 percent were from other sources of CO_2, 5.7 percent were from methane, and 6.8 percent were from nitrous oxide. The remaining source of GHG emissions was high GWP gases, 2.9 percent.

The percentage of climate change associated with each specific gas is similar for each year over the 1990 to 2004 period. However, high GWP gas percentages are rising somewhat.

Composition of California's GHG Emissions

CO_2 emissions represent about 84 percent of California's total GHG emissions in 2004. CO_2 emissions are mainly associated with carbon-bearing fossil fuel combustion with a portion of these emissions attributed to out-of-state fossil fuel used for electricity consumption within California. Other activities that produce CO_2 emissions include mineral production, waste combustion, and land use and forestry changes. Some anthropogenic activities lead to a reduction in atmospheric concentration of CO_2. These are called "CO_2 sinks."

Figure 2 -- California GHG Composition by Type of Gas in 2004
(Includes electricity imports and excludes international bunker fuels)



Source: California Energy Commission

Methane emissions also contribute to global warming and they represented 5.7 percent of total GHG emissions in 2004. Methane emissions are reported in CO_2-equivalent units to reflect their GWP compared to CO_2. Agricultural activities (enteric fermentation and manure management) and landfills compose the major sources of these emissions.

Another gas that contributes to global warming is nitrous oxide (N_2O). Agricultural soil management activities and mobile source fuel combustion compose the major sources of these emissions. After using the appropriate GWP adjustment, N_2O emissions comprised 6.8 percent of California's overall GHG emissions in 2004.

A class of gases called "high GWP gases" makes up the final set of gases that contribute to global warming,[22] composing about 2.9 percent of total emissions in 2004. These are composed mostly of gases used in industrial applications to replace gases associated with ozone depletion over the Earth with an additional modest contribution from sulfur hexafluoride (SF_6) used as insulating materials in electricity transmission and distribution.

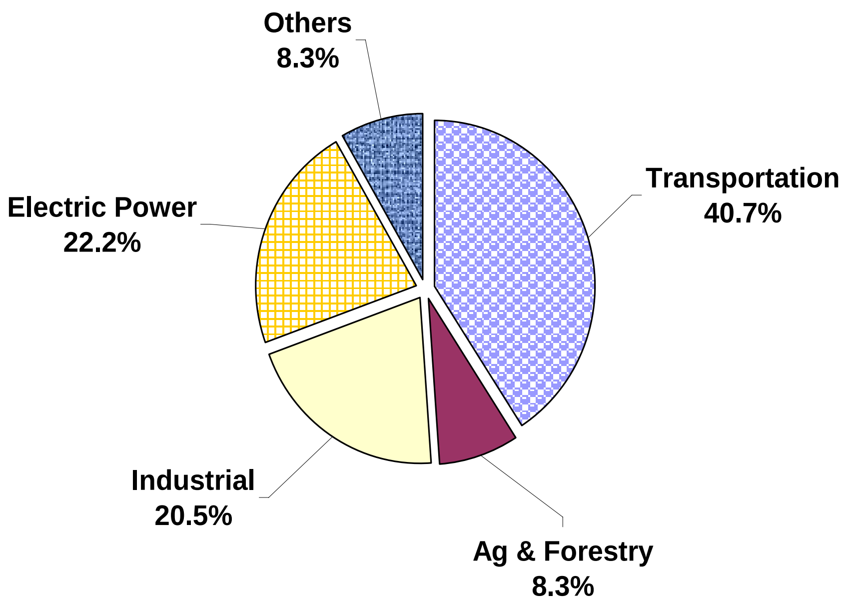
High GWP gases compose a low percentage of overall GHG emissions over this time period, although the estimated emissions are difficult to quantify and are less certain than other emissions categories. Although small in magnitude, emissions of these gases are increasing at a faster rate than other GHGs. In California, high GWP gases are largely composed of refrigerants, although electric utility transmission and distribution equipment are also sources.

End-Use Sectors Contributing to California's GHG Emissions

As shown in Figure 3, fossil fuel consumption in the transportation[23] sector was the single largest source of California's GHG emissions in 2004, with electric power from both in-state and out-of-state sources second, and the industrial[24] sector as the third largest source category. Agriculture,[25] forestry,[26] commercial,[27] and residential[28] activities composed the balance of California's GHG emissions.

Care must be exercised when looking at emissions from different sectors of the economy. For example, the GHG inventory identifies cement production from clinker manufacturing in a stand-alone category and fuel used to heat the cement production process within the industrial fuel category. Thus, CO_2 from clinker production does not represent total GHG emissions from cement production. Likewise, the GHG inventory reports landfill methane emissions in the methane portion of the inventory and CO_2 sinks associated with landfills in the CO_2 portion of the inventory. Taken together, the landfill CO_2 sinks approximately offset the landfill methane emissions. However, there are additional fuel related GHG emissions from transporting wastes to landfills, and these emissions are included in transportation fuels.

Figure 3 -- Sources of California's 2004 GHG Emissions (By End-Use Sector) (Includes electricity imports and excludes international bunker fuels)



Source: California Energy Commission

Historical GHG Emissions Trends

This section discusses historical trends in California's gross GHG emissions. The values discussed in this section do not account for CO_2 sinks from forest, rangelands, or landfill and yard trimming disposal.

This section also excludes international aviation and marine vessel uses of jet fuel, residual oil,[29] and distillate oil because they are international fuel uses and the standard GHG emissions inventory protocol excludes them. Domestic aviation gasoline, jet fuel, residual oil, and distillate oil uses are included in the analysis.

The trends discussed in this section include carbon emissions from imported electricity, including out-of-state coal-fired power plants owned by California electric utility companies that provide electricity to California.

California's GHG emissions are large and growing as a result of population and economic growth and other factors. From 1990 to 2004 total gross GHG emissions rose 14.3 percent; they are expected to continue to increase in the future under "business-as-usual" unless California implements programs to reduce emissions.

Arnold Schwarzenegger
Governor

REFINING ESTIMATES OF WATER-RELATED ENERGY USE IN CALIFORNIA

PIER FINAL PROJECT REPORT

Prepared For:

California Energy Commission
Public Interest Energy Research Program

Prepared By:
Navigant Consulting, Inc.

NAVIGANT CONSULTING

December 2006
CEC-500-2006-118

(MG) of water, and the number of kWh needed to treat and dispose of the same quantity of wastewater.

Inasmuch as water-energy is a new area of study, data were not readily available that directly related energy use to portions of the water-use cycle. Consequently, the team adjusted the existing data sets to prepare refined estimates.

Project Outcomes

Through detailed reviews of work papers and interviews with stakeholders, the study team identified a number of recommended adjustments to the water-energy relationship proxies for energy embedded in water for Northern and Southern California. Some of the recommended adjustments addressed a number of minor errors and inconsistencies in allocations made during the preparation of the WER. Others addressed adjustments needed to ensure consistency. In addition, the team recommends adjusting the estimates by segment of the water-use cycle for losses.

The type of water use determines whether wastewater treatment and disposal will be required. In general, outdoor water use, such as landscape irrigation, typically either flows into storm drains or recharges groundwater or natural waterways, bypassing need for wastewater treatment and disposal. Indoor water use typically discharges to sanitary sewers, consuming energy for wastewater treatment and disposal. To simplify application of the proxies, we recommend further breaking down the northern and southern proxies into indoor and outdoor use.

Table ES-1. Recommended revised water-energy proxies

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

The bases for the recommended adjustments are provided in Section 2 and the appendices to this report.

Index No.	Author	Study Title	Date	Water-Related Energy Use Data Item	Comments
19	MWDSC	N/A	October 2006	1,400 kWh/ac-ft (4,298 kWh/MG)	Third-party data, via e-mail
20	Wolff (NRDC)	"Energy Down the Drain"	August 2004	1,700 kWh/ac-ft (5,219 kWh/MG) for Chino Desalter Facility	Pg. 12
21	Wolff (NRDC)	"Energy Down the Drain"	August 2004	405 kWh/ac-ft (1,243 kWh/MG) for Reynolds treatment plant in San Diego County	Pg. 13
				Water Supply—Groundwater	
22	Anderson	"Energy Use in the …"	1999	175 kWh/ac-ft (537 kWh/MG) for Tulare Lake	Pg. 4; Citing DWR; equals 1.45 kWh/ac-ft per foot of depth for cited depth of 120 feet
23	Anderson	"Energy Use in the …"	1999	292 kWh/ac-ft (896 kWh/MG) for San Joaquin River and Central Coast	Pg. 4; Citing DWR; equals 1.45 kWh/ac-ft per foot of depth for cited depth of 200 feet
24	Burt (ITRC)	"California Agricultural…"	December 2003	335 kWh/ac-ft (1,028 kWh/MG) for irrigation district pumping	Calculated from statewide energy and water total estimates, Table 1 (Pg. vii) and Table 2 (Pg. xi)
25	Goldstein (EPRI)	"Water & Sustainability…"	March 2002	197 kWh/ac-ft (605 kWh/MG) average for municipal groundwater wells	Pg. 4-5
26	SCVWD	N/A	Forthcomin g	650 kWh/ac-ft (1,996 kWh/MG)	Per telephone conversation

California Energy Consumption Database

The California Energy Commission has created this on-line database for informal reporting purposes using numerous electricity and natural gas consumption data sources.

Users can generate reports showing the amount of energy consumed by geographical area, sector (residential, commercial, industrial) classifications. The database also provides easy downloading of energy consumption data into Microsoft Excel (XLS) and comma-separated values (CSV) file formats.

For further information about, or problems with this database, please contact Steven Mac at steven.mac@energy.state.ca.us or call 916-651-1468. Members of the news media please call the Media and Public Communications Office at 916-654-4989.

Electricity Consumption

- Electricity Consumption by Entity
- Electricity Consumption by County
- Electricity Consumption by Planning Area

Natural Gas Consumption

- Gas Consumption by Entity
- Gas Consumption by County
- Gas Consumption by Planning Area

Forest Project Protocol

Version 3.0

September 1, 2009

The derived estimate of biomass must be multiplied by 0.5 to calculate the mass (kg) in carbon. This product must be multiplied by 0.001 tonnes/kg to convert the mass to metric tonnes of carbon.

Because of the difficulties associated with measuring the below-ground carbon component of trees, the Reserve allows for the estimation of this component of tree carbon through the use of a regression equation (Cairns, Brown, Helmer, & Baumgardner, 1997). This equation provides a practical and cost-effective approach that estimates below-ground biomass of standing live trees using the sampling-based calculation of above-ground biomass of standing live trees only:

$$BBD = \exp(-0.7747 + 0.8836 * \ln(ABD))$$

Where:

BBD = below-ground biomass density of standing live trees in tonnes per hectare
ABD = above-ground biomass density of standing live trees in tonnes per hectare

This equation must be applied at the plot level, after estimates of above-ground biomass have been calculated as described above.

Example A.1. Quantification Example (Part III – Tree Biomass)

The chart below displays summary data for tree biomass for the first plot in Strata 1.

Tree Biomass								
1	2	3	4	5	6	7	8	9
Plot	Tree Number	Species	DBH (cm)	Total Height (m)	Status	Biomass (kg)	Weight (Expansion per Hectare)	Biomass (kg per Hectare)
1	1	Redwood	65	32	L	2,560	21	53,768
1	2	Douglas-fir	65	29	L	2,007	21	42,152
1	3	Tanoak	28	14	L	280	112	31,402
1	4	Redwood	68	30	L	2,677	19	50,858
1	5	Redwood	76	27	L	3,086	15	46,287
1	6	Douglas-fir	65	34	L	2,310	21	48,501
1	7	Tanoak	42	17	L	729	50	36,442
1	8	Tanoak	46	18	L	914	41	37,464
							Total	346,874

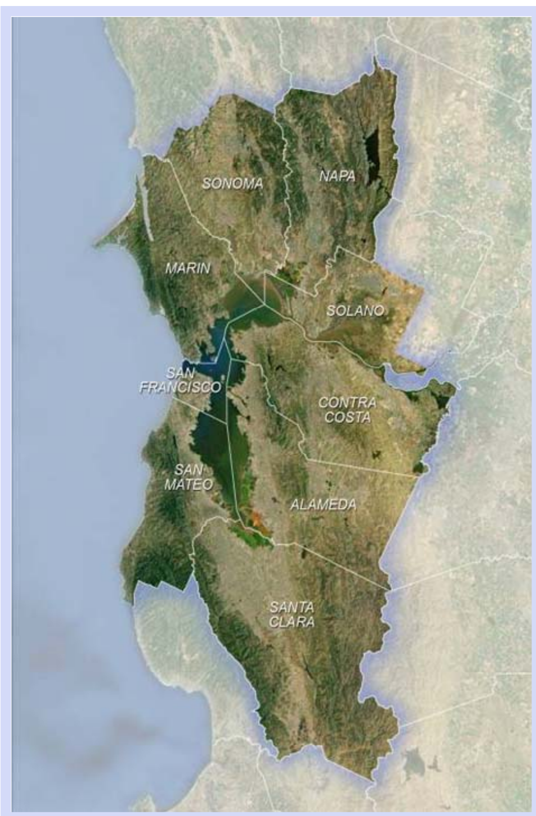
The plot in this example was measured using a 30 square foot basal area factor prism. The plot number is entered in column 1. All ‘in’ trees (trees on the plot) are measured and input consecutively starting at North and proceeding clockwise (this facilitates check cruising, quality control). Each tree is numbered (column 2), the species documented (column 3), the DBH measurements entered as centimeters in column 4, and the total height entered as meters in column 5.

The status of the tree goes in column 6. The status codes are shown below.

BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

California Environmental Quality Act

Air Quality Guidelines



December 2009

BAY AREA AIR QUALITY MANAGEMENT DISTRICT

California Environmental Quality Act

Air Quality Guidelines

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December 2009

Once all emission reductions are scaled by their applicable sector and land use, they should be added together for the total sum of emission reductions.

The following tables list feasible mitigation measures for consideration in projects. The estimated emission reductions are a work in progress and the Air District will continue to improve guidance on quantifying the mitigation measures.

URBEMIS Mitigation Measures for Operational Mobile Source Emissions

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
Mix of Uses	-3% to 9%	CAPs, GHGs	Mobile sources	-3 when no housing or employment centers within 1/2 mile	Residential: % reduction is taken from base trips (9.57) and subtracted from ITE trip generation; Nonresidential: % reduction from ITE trip generation
Local serving retail within 1/2 mile of project	2%	CAPs, GHGs	Mobile sources	Uses lower end of reported research to avoid double counting with mix of uses measure	
Transit Service	0% to 15%	CAPs, GHGs	Mobile sources		
Bike & Pedestrian	0%–9%	CAPs, GHGs	Mobile sources	Credit is given based on intersection density, sidewalk completeness, and bike network completeness; No reduction if entire area within 1/2 mile is single use	
Affordable Housing	0%–4%	CAPs, GHGs	Mobile sources		
Transportation Demand Management Parking, Transit Passes					
Daily Parking Charge	0%–25%	CAPs, GHGs	Only resident/ employee trips, no visitor/ shopper trips		
Parking Cash-Out	0%–12.5%	CAPs, GHGs		Shoup, Donald. 2005. Parking Cash Out. American Planning Association. Chicago, IL.	
Free Transit Passes	25% of Transit Service Reduction	CAPs, GHGs			
Telecommuting					
Employee Telecommuting Program	1%–100%	CAPs, GHGs	Mobile sources, Worker Trips only		
Compressed Work Schedule 3/36	1%–40%	CAPs, GHGs			
Compressed Work Schedule 4/40	1%–20%	CAPs, GHGs			
Compressed Work Schedule 9/80	1%–10%	CAPs, GHGs			

URBEMIS Mitigation Measures for Operational Mobile Source Emissions

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
Other Transportation Demand Measures					
Secure Bike Parking (at least 1 space per 20 vehicle spaces)	At least 3 elements: 1% reduction, plus 5% of the reduction for transit and pedestrian/bike friendliness; At least 5 elements: 2% reduction, plus 10% of the reduction for transit and pedestrian/bike friendliness	CAPs, GHGs	Mobile sources, Worker Trips only		
Showers/Changing Facilities Provided					
Guaranteed Ride Home Program Provided					
Car-Sharing Services Provided					
Information Provided on Transportation Alternatives (Bike Schedules, Maps)					
Dedicated Employee Transportation Coordinator					
Carpool Matching Program					
Preferential Carpool/Vanpool Parking					
Parking Supply	0%–50%	CAPs, GHGs	Mobile sources		
On Road Trucks	As input by user in URBEMIS	CAPs, GHGs	Mobile sources		

URBEMIS Mitigation Measures for Operational Area-Source Emissions

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes
Increase Energy Efficiency Beyond Title 24	Same as % improvement over Title 24	CAPs, GHGs	Natural gas sector in URBEMIS for applicable land use only	User should specify baseline year for the Title 24 standards
Electrically powered landscape equipment and outdoor electrical outlets	Same as % of landscape equipment emissions	CAPs, GHGs	Landscape emissions: residential only	
Low VOC architectural coatings	Same as % VOC reduction in applicable coatings (Interior/Exterior)	ROG only	Architectural coating	

NON-URBEMIS Energy Efficiency Mitigation Measures

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
Plant shade trees within 40 feet of the south side or within 60 feet of the west sides of properties.	30%	GHGs	R,C A/C Electricity	USDA Forest Service, Pacific Northwest Research Station. "California Study Shows Shade Trees Reduce Summertime Electricity Use." Science Daily 7 January 2009. 20 February 2009 <http://www.sciencedaily.com/releases/2009/01/090105150831.htm>.	Electricity-related measures reduce CAPs off-site, but they are not typically quantified as part of a CEQA analysis.
Require cool roof materials (albedo >= 30)	34%	GHGs	C A/C Electricity	U.S. EPA Cool Roof Product Information, Available: <http://www.epa.gov/heatisland/resources/pdf/CoolRoofsCompendium.pdf>	
	69%	GHGs	R A/C Electricity		
Install green roofs	1%	GHGs	R,C A/C Electricity	Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that a vegetated roof is installed on a least 50% of the roof area or that a combination high albedo and vegetated roof surface is installed that meets the following standard: (Area of SRI Roof/0.75)+(Area of vegetated roof/0.5) >= Total Roof Area.	
Require smart meters and programmable thermostats	10%	CAPs, GHGs	R, C electricity and natural gas space heating	U. S. Environmental Protection Agency. 2009. Programmable Thermostat. http://www.energystar.gov/ia/new_homes/features/ProgThermostats1-17-01.pdf	

NON-URBEMIS Energy Efficiency Mitigation Measures

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
Meet GBC standards in all New construction	17%	GHGs	R electricity	California Energy Commission [CEC] 2007. Impact Analysis 2008 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings	
	7%	GHGs	C electricity		
	9%	CAPs, GHGs	R natural gas		
	3%	CAPs, GHGs	C natural gas		
Retrofit existing buildings to meet CA GBC standards	38%	GHGs	R electricity	California Energy Commission [CEC] 2003. Impact Analysis 2005 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings; California Energy Commission [CEC] 2007. Impact Analysis 2008 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings	
	12%	GHGs	C electricity		
	18%	CAPs, GHGs	R natural gas		
	12%	CAPs, GHGs	C natural gas		
Install solar water heaters	70%	CAPs, GHGs	R natural gas water heating	Energy Star. 2009. Solar Water Heater. http://www.energystar.gov/ia/new_homes/features/WaterHtrs_062906.pdf; Department of Energy. California Energy Commission [CEC] 2007. Impact Analysis 2008 Update to the California Energy Efficiency Standards for Residential and Nonresidential Buildings	Cannot take credit for both solar and tank-less water heater measures
	70%	CAPs, GHGs	C natural gas water heating		
Install tank-less water heaters	35%	CAPs, GHGs	R natural gas water heating	Tankless Water Heater. 2008. Available: <http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820>	
	35%	CAPs, GHGs	C natural gas water heating		
Install solar panels on residential and commercial buildings	100%	GHGs	R, C electricity		

NON-URBEMIS Energy Efficiency Mitigation Measures

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
100% increase in diversity of land use mix	5%	CAPs, GHGs	Mobile sources	Ewing, Reid, et al. 2001. *Travel and the Built Environment: A Synthesis.* Transportation Research Record 1780. Paper No. 01-3515 as cited in Urban Land Institute. 2008. *Growing Cooler.* ISBN: 978-0-87420-082-2. Washington, DC	
Jobs housing balance	Trip reduction = (1 – (ABS (1.5 * HH – E)/(1.5 * HH + E)) – 0.25) / 0.25 * 0.03; where ABS = absolute value; HH = study area households; E = study area employment	CAPs, GHGs	Mobile sources	*Nelson/Nygaard Consultants. 2005. Crediting Low-Traffic Developments: Adjusting Site-Level Vehicle Trip Generation Using URBEMIS. Pg 12, (adapted from Criterion and Fehr & Peers, 2001)*	
100% increase in design (i.e., presence of design guidelines for transit oriented development, complete streets standards)	3%	CAPs, GHGs	Mobile sources	Ewing, Reid, et al. 2001. *Travel and the Built Environment: A Synthesis.* Transportation Research Record 1780. Paper No. 01-3515 as cited in Urban Land Institute. 2008. *Growing Cooler.* ISBN: 978-0-87420-082-2. Washington, DC	

NON-URBEMIS Energy Efficiency Mitigation Measures

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
100% increase in density	5%	CAPs, GHGs	Mobile sources	Ewing, Reid, et al. 2001. *Travel and the Built Environment: A Synthesis.* Transportation Research Record 1780. Paper No. 01-3515 as cited in Urban Land Institute. 2008. *Growing Cooler.* ISBN: 978-0-87420-082-2. Washington, DC	
HVAC duct sealing	30%	GHGs	R,C A/C electricity	Sacramento Metropolitan Utilities District. 2008. Duct Sealing. Available: <http://www.pge.com/myhome/saveenergymoney/rebates/coolheat/duct/index.shtml>.	
Provide necessary infrastructure and treatment to allow use of 50% greywater/ recycled water in residential and commercial uses for outdoor irrigation	SFR: 74%*50% = 37.5% MFR: 58% * 50% = 29%	GHGs	R electricity (water consumption)	Department of Water Resources. 2001. Statewide Indoor/Outdoor Split. Accessed December 2, 2008. Available at: <http://www.landwateruse.water.ca.gov/annualdata/urbanwateruse/2001/landuselevels.cfm?use=8>.	
	Commercial: 12% * 50% = 6%		C electricity (water consumption)		
Complete streets (i.e., bike lanes and pedestrian sidewalks on both sides of streets, traffic calming features such as pedestrian bulb-outs, cross-walks, traffic circles, and elimination of physical and psychological barriers (e.g., sound walls and large arterial roadways, respectively).)	1-5%	CAPs, GHGs	Mobile sources	Dierkers, G., E. Silsbe, S. Stott, S. Winkelman, an M. Wubben. 2007. *CCAP Transportation Emissions Guidebook*. Center for Clean Air Policy. Washington, D.C. Available: <http://www.ccap.org/safe/guidebook.php>. as cited in California Air Pollution Control Officers Association (CAPCOA) 2008. *CEQA and Climate Change.*	
Maximize interior day light		GHGs	R, C, M		
Increase roof/ceiling insulation		CAPs, GHGs	R, C, M		
Create program to encourage efficiency improvements in rental units		CAPs, GHGs	R		
Install rainwater		GHGs	R,C,M		

NON-URBEMIS Energy Efficiency Mitigation Measures

Measure	Sector Reductions	Applicable Pollutants	Sector	Notes	Additional comments
collection systems in residential and Commercial Buildings					
Install low-water use appliances and fixtures		GHGs	R,C,M	California Air Pollution Control Officers Association (CAPCOA) 2008. CEQA and Climate Change.	
Restrict the use of water for cleaning outdoor surfaces/Prohibit systems that apply water to non-vegetated surfaces		GHGs	R,C,M	California Attorney General's Office GHG Reduction Measures	
Implement water-sensitive urban design practices in new construction		GHGs	R,C,M		
NON-URBEMIS Waste Reduction Mitigation Measures					
Provide composting facilities at residential uses		GHGs	R		
Create food waste and green waste curb-side pickup service		GHGs	R,C,M		
Require the provision of storage areas for recyclables and green waste in new construction		GHGs	R,C,M		

Notes: CAPs = Criteria Air Pollutants; GHGs = Greenhouse Gases; ROG = Reactive Organic Gases; R = Residential Development; C = Commercial Development; M = Mixed Use Development; A/C = Air Conditioning; and VOC = Volatile Organic Compounds.
Source: Information compiled by EDAW 2009.

Energy Information Administration
Official Energy Statistics from the U.S. Government

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Glossary

Emissions of Greenhouse Gases Report

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Report #: DOE/EIA-0573(2007)
Released Date: December 3, 2008
Next Release Date: December 2009
Previous reports

Overview

Total Emissions

- Total U.S. greenhouse gas emissions in 2007 were 1.4 percent above the 2006 total.
- Total emissions growth—from 7,179.7 million metric tons carbon dioxide equivalent ($MMTCO_2e$) in 2006 to 7,282.4 $MMTCO_2e$ in 2007—was largely the result of a 75.9-$MMTCO_2e$ increase in carbon dioxide (CO_2) emissions. There were larger percentage increases in emissions of other greenhouse gases, but their absolute contributions to total emissions growth were relatively small: 13.0 $MMTCO_2e$ for methane (CH_4), 8.2 $MMTCO_2e$ for nitrous oxide, and 5.6 $MMTCO_2e$ for the man-made gases with high global warming potentials (high-GWP gases) (Table 1 below).
- The increase in U.S. carbon dioxide emissions in 2007 resulted primarily from two factors: unfavorable weather conditions, which increased demand for heating and cooling in buildings; and a drop in hydropower availability that led to greater reliance on fossil energy sources (coal and natural gas) for electricity generation, increasing the carbon intensity of the power supply.
- Methane emissions totaled 699.9 $MMTCO_2e$ in 2007 (Figure 1 at right), up by 13.0 $MMTCO_2e$ from 2006, with increases in emissions from energy sources, waste management, and agriculture.
- U.S. emissions of high-GWP gases, which totaled 176.9 $MMTCO_2e$ in 2007, were 5.6 $MMTCO_2e$ above the 2006 total. The increase resulted mainly from higher emissions levels for hydrofluorocarbons (HFCs, up by 4.1 $MMTCO_2e$) and perfluorocarbons (PFCs, up by 2.0 $MMTCO_2e$). Emissions of sulfur hexafluoride (SF_6) were down by 0.5 $MMTCO_2e$.

Figure 1. U.S. Greenhouse Gas Emissions by Gas, 2007

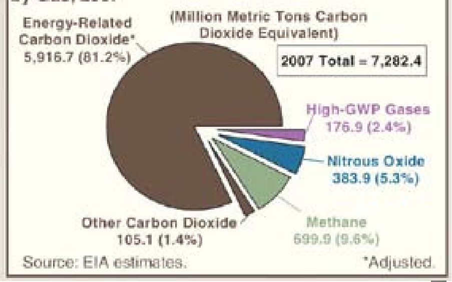


figure data

Table 1. U.S. Emissions of Greenhouse Gases, Based on Global Warming Potential, 1990, 1995, and 2000-2007
(Million Metric Tons Carbon Dioxide Equivalent)

Gas	1990	1995	2000	2001	2002	2003	2004	2005	2006	P2007
Carbon Dioxide	5,021.4	5,348.4	5,892.6	5,806.9	5,880.5	5,938.7	6,023.9	6,032.3	5,945.8	6,021.8
Methane	782.1	752.6	685.7	670.1	674.2	676.5	679.7	679.4	686.9	699.9
Nitrous Oxide	336.0	359.7	344.6	339.3	335.4	334.6	361.5	370.8	375.7	383.9
High-GWP Gases[a]	102.4	114.6	152.1	141.4	153.6	149.0	165.0	174.5	171.3	176.9
Total	6,241.8	6,575.2	7,075.0	6,957.7	7,043.7	7,098.8	7,230.1	7,256.9	7,179.7	7,282.4

[a]Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).
P = preliminary data.
Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2006*, DOE/EIA-0573(2006) (Washington, DC, November 2007). Totals may not equal sum of components due to independent rounding.
Sources: **Emissions:** EIA estimates. **Global Warming Potentials:** Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis* (Cambridge, UK: Cambridge University Press, 2007), web site www.ipcc.ch/ipccreports/ar4-wg1.htm.

Data for all years 1990-2007

U.S. Anthropogenic Greenhouse Gas Emissions, 1990, 2006, and 2007

	1990	2006	2007
Estimated Emissions (Million Metric Tons CO_2e)	6,241.8	7,179.7	7,282.4
Change from 1990 (Million Metric Tons CO_2e)		937.9	1,040.6
(Percent)		*15.0%*	*16.7%*
Average Annual Change from 1990 *(Percent)*		*0.9%*	*0.9%*
Change from 2006 (Million Metric Tons CO_2e)			102.7
(Percent)			*1.4%*

Greenhouse Gas Intensity

- From 2006 to 2007, the greenhouse gas intensity of the U.S. economy—measured as metric tons carbon dioxide equivalent ($MTCO_2e$) emitted per million dollars of gross domestic product (GDP)—fell by 0.6 percent, the smallest annual decrease since 2002.
- Economic growth of 2.0 percent in 2007, coupled with a 1.4-percent increase in total greenhouse gas emissions, accounted for the relatively slow rate of decrease (improvement) in U.S. greenhouse gas intensity from 2006 to 2007 (Table 2 below).
- Since 2002, the base year for the Bush Administration's emissions intensity reduction goal of 18 percent in a decade, U.S. greenhouse gas intensity has fallen by an average of 2.1 percent per year, resulting in a total reduction of 9.8 percent from 2002 to 2007.
- The steady decrease in carbon intensity (carbon/GDP) has resulted mainly from reductions in energy use per unit of GDP (energy/GDP) rather than increased use of low-carbon fuels, as indicated by the carbon/energy ratio shown in Figure 2 at right.

Figure 2. Intensity Ratios: Carbon/Energy, Energy/GDP, and Carbon/GDP, 1980-2007

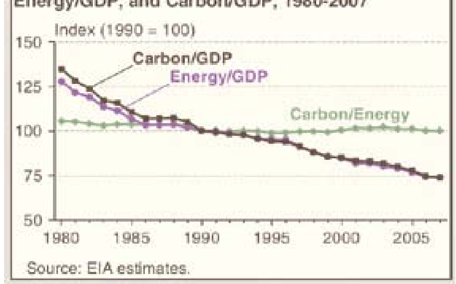


figure data

Table 2. U.S. Greenhouse Gas Intensity and Related Factors, 1990, 1995, and 2000-2007

	1990	1995	2000	2001	2002	2003	2004	2005	2006	P2007
Gross Domestic Product (Billion 2000 Dollars)	7,112.5	8,031.7	9,817.0	9,890.7	10,048.8	10,301.0	10,675.8	10,989.5	11,294.8	11,523.9
Greenhouse Gas Emissions ($MMTCO_2e$)	6,241.8	6,575.2	7,074.9	6,957.7	7,043.7	7,098.8	7,230.1	7,257.0	7,179.8	7,282.5
Greenhouse Gas Intensity ($MTCO_2e$ per Million 2000 Dollars)	877.6	818.7	720.7	703.5	701.0	689.1	677.2	660.4	635.7	631.9
Change from Previous Year (Percent)										
Gross Domestic Product	—	2.5	3.7	0.8	1.6	2.5	3.6	2.9	2.8	2.0
Greenhouse Gas Emissions	—	0.8	2.6	-1.7	1.2	0.8	1.8	0.4	-1.1	1.4
Greenhouse Gas Intensity	—	-1.7	-1.0	-2.4	-0.4	-1.7	-1.7	-2.5	-3.7	-0.6
Change from 2002 (Percent)[a]										
Cumulative	—	—	—	—	—	-1.7	-3.4	-5.8	-9.3	-9.8
Annual Average	—	—	—	—	—	-1.7	-1.7	-2.0	-2.4	-2.1

[a]The Bush Administration s emissions intensity goal calls for an 18-percent reduction between 2002 and 2012; achieving that goal would require an average annual reduction of slightly less than 2 percent over the entire period.

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2006*, DOE/EIA-0573(2006) (Washington, DC, November 2007).

Sources: **Emissions:** EIA estimates. **GDP:** U.S. Department of Commerce, Bureau of Economic Analysis, web site www.bea.gov.

U.S. Greenhouse Gas Intensity, 1990, 2006, and 2007

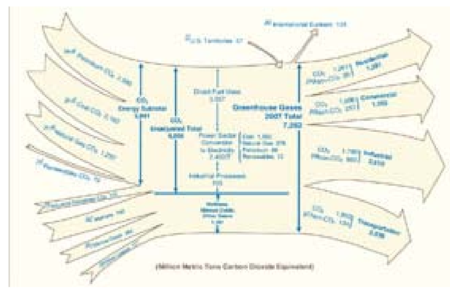
	1990	2006	2007
Estimated Intensity ($MTCO_2e$/GDP*)	877.6	635.7	631.9
Change from 1990 ($MTCO_2e$/GDP*)		-241.9	-245.6
(Percent)		*-27.6%*	*-28.0%*
Average Annual Change from 1990 *(Percent)*		*-2.0%*	*-1.9%*
Change from 2006 ($MTCO_2e$/GDP*)			-3.7
(Percent)			*-0.6%*

*U.S. gross domestic product (million 2000 dollars).

Data for all years 1990-2007

Greenhouse Gas Emissions in the U.S. Economy

The diagram on the right illustrates the flow of U.S. greenhouse gas emissions in 2007, from their sources to their distribution across the U.S. end-use sectors. The left side shows CO_2 by fuel sources and quantities and other gases by quantities; the right side shows their distribution by sector. The center of the diagram indicates the split between CO_2 emissions from direct fuel combustion and electricity conversion. Adjustments indicated at the top of the diagram for U.S. territories and international bunker fuels correspond to greenhouse gas reporting requirements developed by the United Nations Framework Convention on Climate Change (UNFCCC).



Click Chart to Enlarge

CO_2. CO_2 emission sources include energy-related emissions (primarily from fossil fuel combustion) and emissions from industrial processes. The energy subtotal (5,991 $MMTCO_2e$) includes petroleum, coal, and natural gas consumption and smaller amounts from renewable sources, including municipal solid waste and geothermal power generation. The energy subtotal also includes emissions from nonfuel uses of fossil fuels, mainly as inputs to other products. Industrial process emissions (105 $MMTCO_2e$) include cement manufacture, limestone and dolomite calcination, soda ash manufacture and consumption, carbon dioxide manufacture, and aluminum production. The sum of the energy subtotal and industrial processes equals unadjusted CO_2 emissions (6,096 $MMTCO_2e$). The energy component of unadjusted emissions can be divided into direct fuel use (3,557 $MMTCO_2e$) and fuel converted to electricity (2,433 $MMTCO_2e$).

Non-CO_2 Gases. Methane (700 $MMTCO_2e$) and nitrous oxide (384 $MMTCO_2e$) sources include emissions related to energy, agriculture, waste management, and industrial processes. Other, high-GWP gases (177 $MMTCO_2e$) include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These gases have a variety of uses in the U.S. economy, including refrigerants, insulators, solvents, and aerosols; as etching, cleaning, and firefighting agents; and as cover gases in various manufacturing processes.

Adjustments. In keeping with the UNFCCC, CO_2 emissions from U.S. Territories (57 $MMTCO_2e$) are added to the U.S. total, and CO_2 emissions from fuels used for international transport (both oceangoing vessels and airplanes) (131 $MMTCO_2e$) are subtracted to derive total U.S. greenhouse gas emissions (7,282 $MMTCO_2e$).

Emissions by End-Use Sector. CO_2 emissions by end-use sectors are based on EIA's estimates of energy consumption (direct fuel use and purchased electricity) by sector and on the attribution of industrial process emissions by sector. CO_2 emissions from purchased electricity are allocated to the end-use sectors based on their shares of total electricity sales. Non-CO_2 gases are allocated by direct emissions in those sectors plus emissions in the electric power sector that can be attributed to the end-use sectors based on electricity sales.

Residential emissions (1,281 $MMTCO_2e$) include energy-related CO_2 emissions (1,261 $MMTCO_2e$); and non-CO_2 emissions (20 $MMTCO_2e$). The non-CO_2 sources include direct methane and nitrous oxide emissions from direct fuel use. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Emissions in the commercial sector (1,355 $MMTCO_2e$) include both energy-related CO_2 emissions (1,098 $MMTCO_2e$) and non-CO_2 emissions (257 $MMTCO_2e$). The non-CO_2 emissions include direct emissions from landfills, wastewater treatment plants, commercial refrigerants, and stationary combustion emissions of methane and nitrous oxide. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Industrial emissions (2,610 $MMTCO_2e$) include CO_2 emissions (1,760 $MMTCO_2e$)—which can be broken down between combustion (1,655 $MMTCO_2e$) and process emissions (105 $MMTCO_2e$)—and non-CO_2 emissions (850 $MMTCO_2e$). The non-CO_2 direct emissions include emissions from agriculture (methane and nitrous oxide), coal mines (methane), petroleum and natural gas pipelines (methane), industrial process emissions (methane, nitrous oxide, HFCs, PFCs and SF_6), and direct stationary combustion emissions of methane and nitrous oxide. Non-CO_2 indirect emissions attributable to purchased electricity, including methane and nitrous oxide emissions from electric power generation and SF_6 emissions related to electricity transmission and distribution, are also included.

Transportation emissions (2,036 $MMTCO_2e$) include energy-related CO_2 emissions from mobile source combustion (1,902 $MMTCO_2e$); and non-CO_2 emissions (134 $MMTCO_2e$). The non-CO_2 emissions include methane and nitrous oxide emissions from mobile source combustion and HFC emissions from the use of refrigerants for mobile source air-conditioning units.

Distribution of Total U.S. Greenhouse Gas Emissions by End-Use Sector, 2007

Greenhouse Gas and Source	Sector				
	Residential	Commercial	Industrial	Transportation	Total
	Million Metric Tons Carbon Dioxide Equivalent				
Carbon Dioxide					
Energy-Related (adjusted)	1,261.3	1,097.7	1,655.2	1,902.5	**5,916.7**
Industrial Processes	—	—	105.1	—	**105.1**
Total CO_2	**1,261.3**	**1,097.7**	**1,760.3**	**1,902.5**	**6,021.8**
Methane					
Energy					
Coal Mining	—	—	71.1	—	**71.1**
Natural Gas Systems	—	—	176.6	—	**176.6**
Petroleum Systems	—	—	22.9	—	**22.9**
Stationary Combustion	10.4	0.1	0.6	—	**11.1**
Stationary Combustion: Electricity	0.1	0.1	0.1	—	**0.3**
Mobile Sources	—	—	—	5.1	**5.1**
Waste Management					
Landfills	—	169.0	—	—	**169.0**
Domestic Wastewater Treatment	—	17.4	—	—	**17.4**
Industrial Wastewater Treatment	—	—	9.3	—	**9.3**
Industrial Processes	—	—	2.6	—	**2.6**
Agricultural Sources					
Enteric Fermentation	—	—	138.5	—	**138.5**
Animal Waste	—	—	65.0	—	**65.0**
Rice Cultivation	—	—	9.7	—	**9.7**
Crop Residue Burning	—	—	1.4	—	**1.4**
Total Methane	**10.5**	**186.7**	**497.6**	**5.1**	**699.9**
Nitrous Oxide					
Agriculture					
Nitrogen Fertilization of Soils	—	—	229.6	—	**229.6**
Solid Waste of Animals	—	—	62.2	—	**62.2**
Crop Residue Burning	—	—	0.6	—	**0.6**
Energy Use					
Mobile Combustion	—	—	—	56.2	**56.2**
Stationary Combustion	0.9	0.3	4.4	—	**5.7**
Stationary Combustion: Electricity	3.4	3.3	2.6	—	**9.3**
Industrial Sources	—	—	14.0	—	**14.0**
Waste Management					
Human Sewage in Wastewater	—	6.0	—	—	**6.0**
Waste Combustion	—	—	—	—	**0.0**
Waste Combustion: Electricity	0.1	0.1	0.1	—	**0.4**
Total Nitrous Oxide	**4.5**	**9.8**	**313.5**	**56.2**	**383.9**
Hydrofluorocarbons (HFCs)					
HFC-23	—	—	22.0	—	**22.0**
HFC-32	—	0.5	—	—	**0.5**
HFC-125	—	22.8	—	—	**22.8**
HFC-134a	—	—	—	72.7	**72.7**
HFC-143a	—	23.9	—	—	**23.9**
HFC-236fa	—	3.0	—	—	**3.0**
Total HFCs	**0.0**	**50.2**	**22.0**	**72.7**	**144.9**
Perfluorocarbons (PFCs)					
CF_4	—	—	5.2	—	**5.2**
C_2F_6	—	—	4.2	—	**4.2**
NF_3, C_3F_8, and C_4F_8	—	—	0.7	—	**0.7**
Total PFCs	**0.0**	**0.0**	**10.1**	**0.0**	**10.1**
Other HFCs, PFCs/PFPEs	—	**6.1**	—	—	**6.1**
Sulfur Hexafluoride (SF_6)					
SF_6: Utility	4.6	4.4	3.4	—	**12.3**
SF_6: Other	—	—	3.4	—	**3.4**
Total SF_6	**4.6**	**4.4**	**6.8**	**0.0**	**15.8**
Total Non-CO_2	**19.5**	**257.2**	**849.9**	**133.9**	**1,260.6**
Total Emissions	**1,280.8**	**1,354.7**	**2,610.4**	**2,036.4**	**7,282.4**

U.S. Emissions in a Global Perspective

- In EIA's 2006 emissions inventory report, total U.S. energy-related carbon dioxide emissions in 2005 (including nonfuel uses of fossil fuels) were estimated at 5,982 MMT. With the 2005 world total for energy-related carbon dioxide emissions estimated at 28,051 MMT, U.S. emissions were about 21 percent of the world total (see Table 3 below).
- Carbon dioxide emissions related to energy use in the mature economies of countries that are members of the Organization for Economic Cooperation and Development (OECD)—including OECD North America, OECD Europe, Japan, and Australia/New Zealand—are estimated at 13,565 MMT, or 48 percent of the world total. With the remaining 52 percent of worldwide energy-related carbon dioxide emissions (14,486 MMT) estimated as having come from non-OECD countries, 2005 marked the first year in which emissions from the non-OECD economies were significantly greater than those from the OECD economies (Figure 3 at right).
- In EIA's *International Energy Outlook 2008* (*IEO2008*) reference case, projections of energy use and emissions

World Energy-Related Carbon Dioxide Emissions, 1990, 2005, and 2030

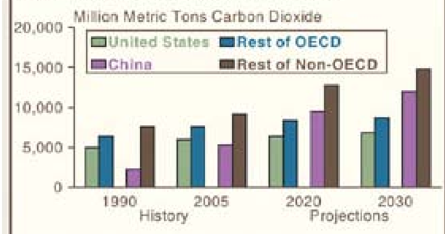
	1990	2005	2030*
Estimated Emissions (Million Metric Tons)	21,226	28,051	42,325
Change from 1990 (Million Metric Tons)		6,825	21,099
(Percent)		*32.2%*	*99.4%*
Average Annual Change from 1990 *(Percent)*		*1.9%*	*1.7%*
Change from 2005 (Million Metric Tons)			14,274
(Percent)			*50.9%*

*EIA, *International Energy Outlook 2008*.

are sensitive to economic growth rates and energy prices. Projections for a range of alternative growth and price scenarios are presented in *IEO2008*.

- U.S. energy-related carbon dioxide emissions are projected to increase at an average annual rate of 0.5 percent from 2005 to 2030 in the *IEO2008* reference case, while emissions from the non-OECD economies are projected to grow by 2.5 percent per year. As a result, the U.S. share of world carbon dioxide emissions is projected to fall to 16 percent in 2030 (6,851 MMT out of a global total of 42,325 MMT) (Figure 4 at right).
- China's share of global energy-related carbon dioxide emissions is projected to grow from 18 percent in 2005 to 28 percent in 2030. As a result, China is expected to be responsible for 47 percent of the projected increase in world emissions over the period. India is expected to account for the second-largest share of the projected increase, 8 percent.

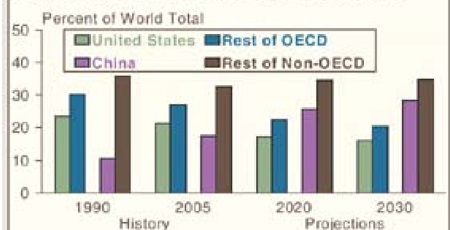
Figure 3. World Carbon Dioxide Emissions by Region, 1990, 2005, 2020, and 2030



Source: EIA, *International Energy Outlook 2008*.

figure data

Figure 4. Regional Shares of World Carbon Dioxide Emissions, 1990, 2005, 2020, and 2030



Source: EIA, *International Energy Outlook 2008*.

figure data

Table 3. World Energy-Related Carbon Dioxide Emissions by Region, 1990-2030
(Million Metric Tons Carbon Dioxide, Percent Share of World Emissions)

Region/Country	History[a] 1990	2004	2005	Projections[a] 2010	2015	2020	2025	2030	Average Annual Percent Change, 2005-2030[b]
OECD									
OECD North America	**5,754**	**6,959**	**7,008**	**7,109**	**7,408**	**7,653**	**7,928**	**8,300**	**0.7**
	(27.1%)	**(25.7%)**	**(25.0%)**	**(22.9%)**	**(21.6%)**	**(20.7%)**	**(20.0%)**	**(19.6%)**	**(9.1%)**
United States[c]	4,989	5,957	5,982	6,011	6,226	6,384	6,571	6,851	0.5
	(23.5%)	(22.0%)	(21.3%)	(19.3%)	(18.1%)	(17.2%)	(16.6%)	(16.2%)	(6.1%)
Canada	465	623	628	669	698	727	756	784	0.9
	(2.2%)	(2.3%)	(2.2%)	(2.2%)	(2.0%)	(2.0%)	(1.9%)	(1.9%)	(1.1%)
Mexico.	300	379	398	430	484	542	601	665	2.1
	(1.4%)	(1.4%)	(1.4%)	(1.4%)	(1.4%)	(1.5%)	(1.5%)	(1.6%)	(1.9%)
OECD Europe	**4,101**	**4,373**	**4,383**	**4,512**	**4,678**	**4,760**	**4,800**	**4,834**	**0.4**
	(19.3%)	**(16.2%)**	**(15.6%)**	**(14.5%)**	**(13.6%)**	**(12.9%)**	**(12.1%)**	**(11.4%)**	**(3.2%)**
OECD Asia	**1,541**	**2,148**	**2,174**	**2,208**	**2,287**	**2,322**	**2,357**	**2,403**	**0.4**
	(7.3%)	**(7.9%)**	**(7.8%)**	**(7.1%)**	**(6.7%)**	**(6.3%)**	**(6.0%)**	**(5.7%)**	**(1.6%)**
Japan	1,009	1,242	1,230	1,196	1,201	1,195	1,184	1,170	-0.2
	(4.8%)	(4.6%)	(4.4%)	(3.8%)	(3.5%)	(3.2%)	(3.0%)	(2.8%)	(-0.4%)
South Korea	241	488	500	559	612	632	656	693	1.3
	(1.1%)	(1.8%)	(1.8%)	(1.8%)	(1.8%)	(1.7%)	(1.7%)	(1.6%)	(1.4%)
Australia/New Zealand	291	418	444	454	474	495	517	540	0.8
	(1.4%)	(1.5%)	(1.6%)	(1.5%)	(1.4%)	(1.3%)	(1.3%)	(1.3%)	(0.7%)
Total OECD	**11,396**	**13,480**	**13,565**	**13,829**	**14,373**	**14,736**	**15,085**	**15,538**	**0.5**
	(53.7%)	**(49.8%)**	**(48.4%)**	**(44.5%)**	**(41.9%)**	**(39.8%)**	**(38.1%)**	**(36.7%)**	**(13.8%)**
Non-OECD									
Non-OECD Europe and Eurasia. . .	**4,198**	**2,797**	**2,865**	**3,066**	**3,330**	**3,508**	**3,625**	**3,811**	**1.1**
	(19.8%)	**(10.3%)**	**(10.2%)**	**(9.9%)**	**(9.7%)**	**(9.5%)**	**(9.2%)**	**(9.0%)**	**(6.6%)**
Russia	2,376	1,669	1,696	1,789	1,902	1,984	2,020	2,117	0.9
	(11.2%)	(6.2%)	(6.0%)	(5.8%)	(5.5%)	(5.4%)	(5.1%)	(5.0%)	(2.9%)
Other	1,822	1,128	1,169	1,278	1,428	1,524	1,606	1,694	1.5
	(8.6%)	(4.2%)	(4.2%)	(4.1%)	(4.2%)	(4.1%)	(4.1%)	(4.0%)	(3.7%)
Non-OECD Asia.	**3,613**	**7,517**	**8,177**	**10,185**	**12,157**	**13,907**	**15,683**	**17,482**	**3.1**
	(17.0%)	**(27.8%)**	**(29.2%)**	**(32.7%)**	**(35.4%)**	**(37.6%)**	**(39.6%)**	**(41.3%)**	**(65.2%)**
China.	2,241	4,753	5,323	6,898	8,214	9,475	10,747	12,007	3.3
	(10.6%)	(17.6%)	(19.0%)	(22.2%)	(23.9%)	(25.6%)	(27.1%)	(28.4%)	(46.8%)
India	565	1,127	1,164	1,349	1,604	1,818	2,019	2,238	2.6
	(2.7%)	(4.2%)	(4.1%)	(4.3%)	(4.7%)	(4.9%)	(5.1%)	(5.3%)	(7.5%)
Other Non-OECD Asia	807	1,637	1,690	1,938	2,338	2,614	2,917	3,237	2.6
	(3.8%)	(6.0%)	(6.0%)	(6.2%)	(6.8%)	(7.1%)	(7.4%)	(7.6%)	(10.8%)
Middle East	**700**	**1,290**	**1,400**	**1,622**	**1,802**	**1,988**	**2,120**	**2,250**	**1.9**
	(3.3%)	**(4.8%)**	**(5.0%)**	**(5.2%)**	**(5.2%)**	**(5.4%)**	**(5.4%)**	**(5.3%)**	**(6.0%)**
Africa	**649**	**943**	**966**	**1,090**	**1,244**	**1,366**	**1,450**	**1,515**	**1.8**
	(3.1%)	**(3.5%)**	**(3.4%)**	**(3.5%)**	**(3.6%)**	**(3.7%)**	**(3.7%)**	**(3.6%)**	**(3.8%)**
Central and South America	**669**	**1,042**	**1,078**	**1,308**	**1,429**	**1,531**	**1,628**	**1,729**	**1.9**
	(3.2%)	**(3.8%)**	**(3.8%)**	**(4.2%)**	**(4.2%)**	**(4.1%)**	**(4.1%)**	**(4.1%)**	**(4.6%)**
Brazil	216	350	356	451	498	541	582	633	2.3
	(1.0%)	(1.3%)	(1.3%)	(1.5%)	(1.5%)	(1.5%)	(1.5%)	(1.5%)	(1.9%)
Other Central/South America	453	692	722	857	931	990	1,046	1,097	1.7
	(2.1%)	(2.6%)	(2.6%)	(2.8%)	(2.7%)	(2.7%)	(2.6%)	(2.6%)	(2.6%)
Total Non-OECD	**9,830**	**13,589**	**14,486**	**17,271**	**19,962**	**22,299**	**24,506**	**26,787**	**2.5**
	(46.3%)	**(50.2%)**	**(51.6%)**	**(55.5%)**	**(58.1%)**	**(60.2%)**	**(61.9%)**	**(63.3%)**	**(86.2%)**
Total World	**21,226**	**27,070**	**28,051**	**31,100**	**34,335**	**37,035**	**39,591**	**42,325**	**1.7**

[a]Values adjusted for nonfuel sequestration.
[b]Values in parentheses indicate percent share of total world absolute change.
[c]Includes the 50 States and the District of Columbia.
Note: The U.S. numbers include carbon dioxide emissions attributable to renewable energy sources.
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (May-July 2007), web site www.eia.doe.gov/iea/; and data presented in this report. **Projections:** EIA, *Annual Energy Outlook 2008*, DOE/EIA-0383(2008) (Washington, DC, June 2008), Table 1, web site www.eia.doe.gov/oiaf/aeo; and *International Energy Outlook 2008*, DOE/EIA-0484(2008) (Washington, DC, September 2008), Table A10.

No data for all years

Recent U.S. and International Developments in Global Climate Change

United States

- ***Federal Actions***
  The Consolidated Appropriations Act of 2008, which became Public Law 110-161 on December 26, 2007, directed the U.S. Environmental Protection Agency (EPA) to develop a draft mandatory reporting rule for greenhouse gases by the end of September 2008; although the draft rule has not yet been released, the Final Rule is due to be completed by June 2009. The Rule is expected to require mandatory reporting of greenhouse gas emissions "above appropriate thresholds in all sectors of the economy," with thresholds and frequency of reporting to be determined by the EPA.
- In July 2008, the EPA released an Advance Notice of Proposed Rulemaking (ANPR) to implement the ruling of the U.S. Supreme Court case, Massachusetts v. the Environmental Protection Agency. On April 2, 2007, the Court ruled that Section 202(a)(1) of the Clean Air Act (CAA) gives the EPA authority to regulate tailpipe emissions of greenhouse gases. Four key issues for discussion in the ANPR include: descriptions of key provisions and programs in the CAA and advantages and disadvantages of regulating greenhouse gases under those provisions; how a decision to regulate GHG emissions under one section of the CAA could or would lead to regulation of GHG emissions under other sections of the Act, including sections establishing permitting requirements for major stationary sources of air pollutants; issues relevant for Congress to consider for possible future climate legislation and the potential for overlap between future legislation and regulation under the existing CAA; and scientific information relevant to, and the issues raised by, an endangerment analysis.
- ***Congressional Initiatives***
  Senate Bill 3036, the Lieberman-Warner Climate Security Act of 2008, came to the floor for debate in the Senate on June 2, 2008. The main purpose of the Act was to establish a Federal program that would substantially reduce U.S. greenhouse gas emissions between 2007 and 2050, in large part through a Federal cap-and-trade program.
- ***Regional and State Efforts***
  On September 25, 2008, the Regional Greenhouse Gas Initiative (RGGI) held its first auction. More than 12.6 million tons were sold at a clearing price of $3.07. New York, with 40 percent allowance allocation, did not participate in the first round of auctions; however, all 10 States are expected to participate in the second allowance auction on December 17, 2008, at which 31.5 million allowances will be available with a reserve price set at $1.86. RGGI is a cooperative effort by 10 Northeast and Mid-Atlantic States to limit greenhouse gas emissions from the electric power sector. Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont are signatory States to the RGGI agreement.
- On September 28, 2008, the Western Climate Initiative (WCI) released a detailed scoping plan for its regional market-based cap-and-trade program. The multi-sector program will be the most comprehensive carbon reduction strategy to date, covering nearly 90 percent of the region's emissions, including those from electricity, industry, transportation, and residential and commercial fuel use, and reducing greenhouse gas emissions to 15 percent below 2005 levels by 2020. On September 30, 2008, the WCI released its Second Draft of Reporting Requirements, which addresses the essential requirements for mandatory reporting. Participating U.S. States include Arizona, California, Montana, New Mexico, Oregon, Utah, and Washington. Canadian provinces participating include British Columbia, Manitoba, Ontario, and Quebec.
- Nine Midwestern governors and two Canadian premiers signed on to participate or observe in the Midwestern Greenhouse Gas Reduction Accord as first agreed to in November 2007. Member States have agreed to reduce greenhouse gas emissions, and a working group is to provide recommendations regarding the implementation of the Accord. In September 2008, the Advisory Group released an updated timeline that requires preliminary design recommendations to be released by November 2008, final recommendations by March 2009, and a draft model rule between May and September 2009. Member States include Iowa, Illinois, Kansas, Michigan, Minnesota, and Wisconsin, as well as the Canadian province of Manitoba. Observer States include Indiana, Ohio, and South Dakota, as well as the Canadian province of Ontario.
- On September 30, 2008, Governor Arnold Schwarzenegger of California signed S.B. 375 to integrate greenhouse gas emissions into California's transportation planning decisions. Under the law, the California Air Resources Board will work with California's 18 metropolitan planning organizations to align their regional transportation, housing, and land-use plans and prepare a "sustainable communities strategy" to reduce vehicle-miles traveled in their respective areas and demonstrate the region's ability to meet its greenhouse gas reduction targets.[1]

International: United Nations Framework Convention on Climate Change and the Kyoto Protocol

COP-13 and CMP

In December 2007, the Thirteenth Conference of the Parties to the United Nation's Framework Convention on Climate Change (COP-13) and the Third Meeting of the Parties to the Kyoto Protocol (CMP-3) were held in Nusa Dua, Bali. Key areas included:

- Launch of a negotiating process with the expectation of reaching a comprehensive post-2012 agreement in 2009 (COP-13 and CMP-3)
- Agreement by developing countries to consider taking "measurable, reportable, and verifiable" mitigation actions, while receiving technological and financial support from developed countries (COP-13)
- Agreement by developed countries to consider making "commitments or actions, quantified emission limitation and reduction objectives," including making binding targets an option (COP-13)
- Reconstitution of the Expert Group on Technology Transfer for 5 more years, with a new mandate to evaluate technology transfer efforts and develop recommendations for strengthening the efforts in a post-2012 agreement (COP-13)
- Adoption of a decision encouraging countries with tropical forests to undertake demonstration activities, particularly the development of national emission baselines, and provide indicative guidance for such projects (COP-13)
- Setting of parameters for a thorough review of the Kyoto Protocol for CMP-4, including the scope and

effectiveness of the flexibility mechanisms, progress by developed countries in implementing their commitments on finance and technology for developing countries, and the possibility of extending to the other flexibility mechanisms the levy now applied to clean development mechanism (CDM) transactions to support the Protocol's Adaptation Fund(CMP-3)

- Resolution of long-standing differences on the governance of the Adaptation Fund, including establishing a 16-member Adaptation Fund Board to manage the fund on behalf of CMP (CMP-3).

COP-14 and CMP-4

Poland will host COP-14 and CMP-4 in Poznañ, December 1-12, 2008. Parties are expected to:

- Agree on a plan of action and programs of work for the final year of negotiations after a year of comprehensive and extensive discussions on crucial issues relating to future commitments, actions, and cooperation
- Make significant progress on several issues required to enhance further the implementation of the Convention and the Kyoto Protocol
- Advance understanding and commonality of views on a “shared vision” for a new climate change regime beyond the Kyoto Protocol
- Strengthen momentum and commitment to the process and the agreed timeline
- Discuss capacity-building for developing countries, reducing emissions from deforestation, and technology transfer and adaptation.

Units for Measuring Greenhouse Gases

Emissions data are reported here in metric units, as favored by the international scientific community. Metric tons are relatively intuitive for users of U.S. measurement units, because 1 metric ton is only about 10 percent heavier than a short ton.

Throughout this report, emissions of carbon dioxide and other greenhouse gases are given in carbon dioxide equivalents. In the case of carbon dioxide, emissions denominated in the molecular weight of the gas or in carbon dioxide equivalents are the same. Carbon dioxide equivalent data can be converted to carbon equivalents by multiplying by 12/44.

Emissions of other greenhouse gases (such as methane) can also be measured in carbon dioxide equivalent units by multiplying their emissions (in metric tons) by their global warming potentials (GWPs). Carbon dioxide equivalents are the amount of carbon dioxide by weight emitted into the atmosphere that would produce the same estimated radiative forcing as a given weight of another radiatively active gas.

Carbon dioxide equivalents are computed by multiplying the weight of the gas being measured (for example, methane) by its estimated GWP (which is 25 for methane). In 2007, the Intergovernmental Panel on Climate Change (IPCC) Working Group I released its Fourth Assessment Report, *Climate Change 2007: The Physical Science Basis*.[2] Among other things, the Fourth Assessment Report updated a number of the GWP estimates that appeared in the IPCC's Third Assessment Report.[3] The GWPs published in the Fourth Assessment Report were used for the calculation of carbon dioxide equivalent emissions for this report. Table 4 below summarizes the GWP values from the Second, Third, and fourth Assessment Reports.

Table 4. Greenhouse Gases and 100-Year Net Global Warming Potentials

Greenhouse Gas	Chemical Formula	Global Warming Potential		
		SAR[a]	TAR[b]	AR4[c]
Carbon Dioxide	CO_2	1	1	1
Methane	CH_4	21	23	25
Nitrous Oxide	N_2O	310	296	298
Hydrofluorocarbons				
HFC-23 (Trifluoromethane)	CHF_3	11,700	12,000	14,800
HFC-32 (Difluoromethane)	CH_2F_2	650	550	675
HFC-41 (Monofluoromethane)	CH_3F	150	97	—
HFC-125 (Pentafluoroethane)	CHF_2CF_3	2,800	3,400	3,500
HFC-134 (1,1,2,2-Tetrafluoroethane)	CHF_2CHF_2	1,000	1,100	—
HFC-134a (1,1,1,2-Tetrafluoroethane)	CH_2FCF_3	1,300	1,300	1,430
HFC-143 (1,1,2-Trifluoroethane)	CHF_2CH_2F	300	330	—
HFC-143a (1,1,1-Trifluoroethane)	CF_3CH_3	3,800	4,300	4,470
HFC-152 (1,2-Difluoroethane)	CH_2FCH_2F	—	43	—
HFC-152a (1,1-Difluoroethane)	CH_3CHF_2	140	120	124
HFC-161 (Ethyl Fluoride)	CH_3CH_2F	—	12	—
HFC-227ea (Heptafluoropropane)	CF_3CHFCF_3	2,900	3,500	3,220
HFC-236cb (1,1,1,2,2,3-Hexafluoropropane)	$CH_2FCF_2CF_3$	—	1,300	—
HFC-236ea (1,1,1,2,3,3-Hexafluoropropane)	CHF_2CHFCF_3	—	1,200	—
HFC-236fa (1,1,1,3,3,3-Hexafluoropropane)	$CF_3CH_2CF_3$	6,300	9,400	9,810
HFC-245ca (1,1,2,2,3-Pentafluoropropane)	$CH_2FCF_2CHF_2$	560	640	—
HFC-245fa (1,1,1,3,3-Pentafluoropropane)	$CHF_2CH_2CF_3$	—	950	1,030
HFC-365mfc (Pentafluorobutane)	$CF_3CH_2CF_2CH_3$	—	890	794
HFC-43-10mee (Decafluoropentane)	$CF_3CHFCHFCF_2CF_3$	1,300	1,500	1,640
Perfluorocarbons				
Perfluoromethane	CF_4	6,500	5,700	7,390
Perfluoroethane	C_2F_6	9,200	11,900	12,200
Perfluoropropane	C_3F_8	7,000	8,600	8,830
Perfluorobutane (FC 3-1-10)	C_4F_{10}	7,000	8,600	8,860
Perfluorocyclobutane	$c\text{-}C_4F_8$	8,700	10,000	10,300
Perfluoropentane	C_5F_{12}	7,500	8,900	9,160
Perfluorohexane (FC 5-1-14)	C_6F_{14}	7,400	9,000	9,300
Sulfur Hexafluoride	SF_6	23,900	22,200	22,800

Sources: [a]Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996). [b]Intergovernmental Panel on Climate Change, *Climate Change 2001: The Scientific Basis* (Cambridge, UK: Cambridge University Press, 2001), web site www.ipcc.ch/ipccreports/tar/wg1/index.htm. [c]Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis* (Cambridge, UK: Cambridge University Press, 2007), web site www.ipcc.ch/ipccreports/ar4-wg1.htm.

Methodology Updates for This Report

Carbon Dioxide

EIA has begun using a separate carbon coefficient for net imports of metallurgical coke, based on IPCC guidelines. The new coefficient more accurately reflects the carbon content of imported coke. The carbon in coke that is domestically produced, and the carbon dioxide emissions from that coke, are counted in the amount of domestic coking coal consumed. For net coke imports, however, it was decided that the new, higher carbon coefficient should be used. Although the difference between the two coefficients is about 14 percent, the amount of coke imported is relatively small. Thus, the increase in calculated carbon dioxide emissions resulting from the change in coefficients is in the range of 1 to 3 million metric tons for most years over the 1990-2007 period.

Estimates of carbon dioxide emissions from natural gas combustion have been adjusted upward, to reflect increasing concentrations of carbon dioxide in the natural gas produced in the United States in recent years. As a result of the change, the estimates of carbon dioxide emissions from natural gas combustion for recent years are about 1 million metric tons higher than those in last year’s report.

Because of a change in methodology, the estimate of carbon dioxide emissions from waste combustion (included in “Other Sources”) has been adjusted downward, as most of those emissions are accounted for by grid-connected waste-to-energy plants in the electric power sector, which are captured in EIA’s surveys. The result of this change is a reduction of 3 to 4 million metric tons per year from 1990 to 2007.

An error in the calculation code caused emissions from industrial lubricants to be omitted from total emissions in EIA’s emissions inventory reports for 2005 and 2006. Although lubricants are a nonfuel use, there are emissions associated with their use. Emissions from this source are again included in total emissions in this year’s report. As a result of the correction, the estimates of total U.S. carbon dioxide emissions are higher by about 6 to 7 million metric tons per year from 1990 to 2007 than those in the 2005 and 2006 data reports.

Other changes reflect revisions in the underlying activity data. For example, in the 2006 data report, the amount of natural gas consumed in the United States in 2005 was estimated at 22,241 billion cubic feet, whereas in this year’s report the estimate for 2005 is 22,011 billion cubic feet. As a result, the estimate for carbon dioxide emissions from natural gas combustion in 2005 is about 10 million metric tons lower in this year’s report than in last year’s report.

Methane

In its Fourth Assessment Report (AR4),[4] the IPCC developed revised global warming potential factors (GWPs) for selected gases. The GWP for methane was revised from the previously published value of 23 in the IPCC’s Third

Assessment Report[5] to 25 in the Fourth Assessment Report. The revised GWP for methane is used in this report. In addition, this report incorporates an increase in the density of methane from 42.28 to 42.37 pounds per thousand cubic feet, in order to provide consistent temperature and pressure values for methane in all EIA data.

Nitrous Oxide

The IPCC also updated the GWP for nitrous oxide in its Fourth Assessment Report, to 298, up from 296 in the IPCC's Third Assessment Report. The revised GWP for nitrous oxide is used in this report.

High-GWP Gases

The IPCC also updated GWPs for most of the high-GWP emissions sources in its Fourth Assessment Report. The revised GWPs are included in Table 4 on page 11, under "Units for Measuring Greenhouse Gases."

Land Use

Forest Land Remaining Forest Land is the major source of change in net carbon dioxide flux resulting from land use. In this report, the addition of newly available forest inventory data, as well as some refinements to previous data, involved the following major changes: incorporating and updating State and sub-State inventory data; and including a portion of Alaskan forest for the first time. In addition, minor refinements to the calculation of flux from harvested wood products included: a shorter half-life for decay in dumps; and separation of decay in dumps from decay in landfills. Overall, these changes, in combination with adjustments in the other sources/sinks within the land-use category, resulted in an average annual increase of 20.1 million metric tons carbon dioxide equivalent (2.5 percent) in net carbon flux to the atmosphere from Land Use, Land-Use Change, and Forestry for the years 1990 through 2005.

Report Chapters

Notes and Sources

Number of Natural Gas Consumers

Area: California   Period: Annual

Download Series History   Definitions, Sources & Notes

Show Data By: Data Series / Area	2002	2003	2004	2005	2006	2007	View History
Residential							
Number of Consumers	9,726,642	9,803,311	9,957,412	10,124,433	10,329,224	10,439,220	1986-2007
Sales	9,701,323	9,765,276	9,921,331	10,092,466	10,299,984	10,412,700	1997-2007
Transported	25,319	38,035	36,081	31,967	29,240	26,520	1997-2007
Commercial							
Number of Consumers	420,690	431,795	432,367	434,899	442,052	446,120	1986-2007
Sales	414,851	424,689	425,341	427,226	426,379	421,449	1998-2007
Transported	5,839	7,106	7,026	7,673	15,673	24,671	1998-2007
Average Consumption per Consumer (Thousand Cubic Ft.)	566	539	536	536	553	562	1967-2007
Industrial							
Number of Consumers	33,725	34,617	41,487	40,226	38,637	39,134	1986-2007
Sales	31,867	32,636	39,426	38,150	35,889	35,814	1998-2007
Transported	1,858	1,981	2,061	2,076	2,748	3,320	1998-2007
Average Consumption per Consumer (Thousand Cubic Ft.)	21,948	22,506	20,147	19,425	18,947	18,871	1973-2007

- = No Data Reported; -- = Not Applicable; NA = Not Available; W = Withheld to avoid disclosure of individual company data.

Notes: Sales consumers buy their gas from the company that delivered it to them. Transported consumers buy their gas from a company other than the one that delivered it to them.

Beginning in 1996, consumption of natural gas for agricultural use was classified as industrial use. In 1995 and earlier years, agricultural use was classified as commercial use. See Definitions, Sources, and Notes link above for more information on this table.

Release Date: 10/30/2009
Next Release Date: 11/30/2009

Natural Gas Consumption by End Use

(Million Cubic Feet)

Area: California Period: Annual

Download Series History Definitions, Sources & Notes

Show Data By: Data Series / Area	2003	2004	2005	2006	2007	2008	View History
Total Consumption	2,269,405	2,406,889	2,248,256	2,315,721	2,394,930		1997-2007
Lease and Plant Fuel							1967-1998
Lease Fuel	39,452	37,337	37,865	57,234	56,936		1983-2007
Plant Fuel	2,568	2,760	2,875	2,475	2,540		1983-2007
Pipeline & Distribution Use	8,670	12,969	10,775	7,023	8,994		1997-2007
Volumes Delivered to Consumers	2,167,037	2,349,984	2,187,330	2,239,099	2,316,040	NA	1997-2008
Residential	497,955	512,046	483,699	491,777	492,378	489,296	1967-2008
Commercial	232,912	231,597	233,082	244,432	250,874	NA	1967-2008
Industrial	779,085	835,824	781,381	732,054	738,501	763,745	1997-2008
Vehicle Fuel	3,419	3,839	9,411	9,889	10,421		1988-2007
Electric Power	705,343	770,517	689,169	770,836	834,286	850,836	1997-2008

- = No Data Reported; -- = Not Applicable; NA = Not Available; W = Withheld to avoid disclosure of individual company data.

Notes: Gas volumes delivered for use as vehicle fuel are included in the State annual totals through 2007 but not in the State monthly components. See Definitions, Sources, and Notes link above for more information on this table.

Release Date: 10/30/2009
Next Release Date: 11/30/2009

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MEMORANDUM

Date: October 8, 2009

To: Rob Brueck, Hauge Brueck Associates, LLC

From: Katy Cole, P.E., Fehr & Peers
Marissa Harned, Fehr & Peers

SUBJECT: Homewood Mountain Resort Existing Volumes and Trip Generation

RN08-0403

This memorandum addresses the trip generation, pass-by, and internal capture rates used in the analysis of the Homewood Mountain Resort (HMR). A discussion of both the summer and winter trip generation is provided.

EXISTING HOMEWOOD VOLUMES

The existing HMR consists of a small, day-use ski resort that primarily serves locals of the Lake Tahoe area. No lodging is available on site, so skiers must arrive in the morning and leave at the end of the day. During the summer, HMR is not in operation on a regular basis.

The Friday PM peak hour was analyzed for the summer and winter seasons. During the summer, the Friday PM peak hour is typically evaluated, as it is generally when peak traffic volumes occur on the roadways. Three analysis periods were considered for winter – Friday, Saturday, and Sunday. The Friday PM peak hour is expected to have the biggest change in operations compared to existing conditions and was therefore studied. A more detailed explanation of the selection process for the winter analysis period is provided in the Winter Trip Generation section of this memo.

Summer

The existing HMR does not have any regular summer uses on site. The Lake Tahoe Music Festival holds one or two concerts per summer at Homewood. Since the event only occurs twice a summer, at most, it was not included when analyzing the existing summer trip generation of the site.

Winter

Existing winter traffic volumes generated by HMR were developed using traffic counts and parking data collected by the applicant. The existing winter trip generation (shown in **Table 1**) was developed based on the following steps:

1.) Counts were collected by a consultant hired by the applicant at all of the driveways and access roads to HMR during the AM and PM peak periods on Saturday, December 30, 2006. The PM peak hour volumes at the driveways are shown in the table, as well as the total two-way volume during the count periods (8:15 – 10:00AM and 2:15-5:00PM).

2.) HMR collects daily peak parking data on a regular basis. This data shows that on the day the traffic counts were collected at the driveways, 789 parking spaces were occupied. Parking data collected during the 2007-2008 and 2008-2009 ski seasons (including holidays) was reviewed to determine the peak Friday attendance at the existing site. The five highest Fridays of parking space occupancy for each of the 2007-2008 and 2008-2009 ski seasons were averaged. The results show that on a typical peak Friday, approximately 532 parking spaces are occupied.

3.) The ratio of average peak Friday parking space occupancy over occupied parking spaces on the day of the traffic counts (532 / 789 = 0.67) was used to factor the two-way volume during the count period, and estimate PM peak hour traffic volumes on a peak Friday.

4.) Data collected at Heavenly Ski Resort in Lake Tahoe provided the hourly variation of ski area traffic over the course of a day. This information was used to determine the total daily traffic volumes based on the peak period volumes collected at HMR.

5.) Fawn Drive and Tahoe Ski Bowl Way provide access for residential units (permanently occupied and recreational homes), as well as the ski resort. Trip generation estimates were calculated (using ITE *Trip Generation, Eighth Edition*) for the units and subtracted from the ski area trip generation estimates.

TABLE 1
EXISTING WINTER FRIDAY TRIP GENERATION SUMMARY

	Calculation Factors	Daily Trips	PM Peak Hour Trips	
			In	Out
Traffic Volumes Counted at Driveways (Saturday - 12/30/06)			194	550
Total Two-Way Volume in Count Periods (8:15-10:00 AM, 2:15-5:00 PM)	2,347			
Ski Area Parking Count on Date of Count	789			
Average Peak Friday Parking for 2007-2008 and 2008-2009 Ski Seasons	532			
Ratio of Friday Parking vs. Parking on Date of Count	0.67			
Estimated Traffic Volume on Peak Friday	1,572		130	369
Ratio of Total Daily Traffic to Traffic During Count Period	1.79			
Total Daily Traffic on Peak Friday		2,815		
Traffic Generated by Other Land Uses in Count Area		(-280)	(-15)	(-12)
Total Estimated Friday Traffic Generation of Existing Ski Area		2,535	115	357

Source: Fehr & Peers, 2009

The existing HMR generates 2,535 daily trips on the typical peak Friday, and 472 PM peak hour trips.

TYPICAL TRIP GENERATION RATES

Vehicle trips were generated for the HMR development using trip generation rates from *Trip Generation, Eighth Edition* (Institute of Transportation Engineers (ITE), 2008) and the TRPA Trip Table (Tahoe Regional Planning Agency, 2004).

A daily trip generation rate is not provided by TRPA or ITE for a Miniature Golf Course (summer only land use). It is a typical practice methodology to assume that the PM peak hour rate is 10% of the daily rate; therefore, this assumption was used to determine the daily trip generation rate for the Miniature Golf Course.

Standard trip generation rates are not available for a destination ski resort; therefore, the foundation for winter season trip generation calculations in this analysis is resort occupancy, maximum carrying capacity of the mountain, and the fluctuation or "turnover" of resort residents and guests.

Pass-By, Internal Capture, and Mode Split

Pass-by trips are made as intermediate stops on the way from an origin to a primary trip destination without a route diversion. For example, someone who regularly drives on SR 89 to go home from work stops at the retail use and then continues on their regular route would be considered a pass-by trip. No additional vehicle trips are added to the external roadway network.

In a mixed use development it is expected that trips will be made internally within the development. For example, people who live in the residential units on-site will travel to the retail or restaurant uses, and then return home. Their trip making activity never ventures to the external roadway network. By applying an internal capture reduction rate to the overall project trip generation, the number of estimated vehicle trips added to the surrounding roadway network is reduced.

Alternative modes of travel are also considered when analyzing project sites that are located near accessible bicycle and pedestrian paths and transit stops. Alternative mode reduction rates account for trips that are made by means other than a vehicle.

SUMMER TRIP GENERATION (ALTERNATIVE 1)

Assumed Accessory Uses

The ITE description of the hotel land use category includes accessory uses such as restaurants, cocktail lounges, meeting and banquet rooms or convention facilities, limited recreational facilities (pool, fitness room), and/or other retail and service shops. Based on this definition, the restaurant, bar, meeting space, and fitness center/spa uses were included as accessory uses to the hotel for analysis purposes.

Land Uses

The following land uses were included in the trip generation analysis of the proposed project (Alternative 1):

<u>North Base</u>

- Hotel - 75 rooms
  - Accessory uses include:
    - Meeting Space – 3,005 square feet
    - Fitness Center/Spa –10,590 square feet
    - Restaurant – 1,800 square feet
    - Bar – 1,260 square feet
- Condo/Hotel Rooms – 60 units (40 units, 20 with lock-offs)
- Penthouse Condos – 30 units

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- Residential Condos – 36 units
- Fractional Condos (Timeshares) - 20 units
- Townhomes – 16 units
- Apartment (Workforce Housing) – 13 units
- Retail – 25,000 square feet (CFA)*
- Miniature Golf Course – 12 holes
- North Base Lodge/Skier Services – 30,000 square feet (winter only)
- Outdoor Amphitheater – 1,500 seats (special events only – infrequent use)

<u>South Base</u>

- Residential Condos – 99 units
- Skier Services – 2,000 square feet (winter only)

<u>Mid Mountain</u>

- Day Lodge – 15,000 square feet (winter only)

* Note: The applicant has indicated the 25,000 square feet of commercial floor area (CFA) at the North Base may be reduced or split between the North Base and Mid Mountain Day Lodge. Further analysis will incorporate any changes.

Analysis Methodology

Trip generation estimates for HMR were developed through comprehensive evaluation of the variety of land uses within the resort, the internal interaction of these uses, and the interaction between the project and the surrounding community.

The foundation for summer trip generation calculations in this analysis is resort occupancy and the fluctuation or "turnover" of resort residents and guests. This study takes a conservative approach and assumes that 100% of the lodging units are occupied on peak weekends. Monday and Thursday occupancy rates are estimated at 50% with mid-week occupancies around 35%.

The following steps were taken to develop summer trip generation estimates for the proposed project:

- Based on the information discussed above, it was assumed that 50% of the lodging guests will arrive at the resort on Friday. To present a conservative analysis, it was further assumed that all 50% of the lodging guests will arrive during the PM peak hour. It was also estimated that an average of 1.5 vehicles will arrive per lodging unit.
- Trips were generated for the remaining 50% of lodging units and the residential units using typical TRPA and ITE trip generation rates. Trips were also generated for the retail uses using these rates.
- The North Base Lodge, Mid Mountain Day Lodge, and other skier services buildings are generally winter-only uses. Any summer operation of these uses is expected to be 100% internalized. The purpose of these uses is to accommodate skiers (in the winter) and resort guests.

Internal Capture, Mode Split, and Pass-By Reductions

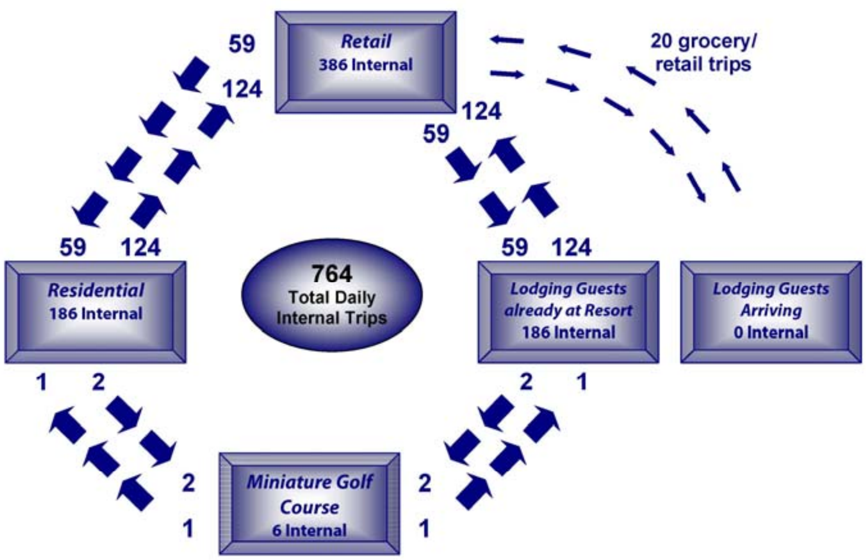
Internal Capture

The ITE *Trip Generation Handbook* provides procedures and data for estimating internal capture at mixed use project sites. The ITE information was used, however some of the defaults in the calculations spreadsheet were modified to reflect local information. U.S. Census data was utilized to determine the number of households in the vicinity of the project. Daily trips were estimated for the households and compared to the number of daily trips generated by the residential and hotel uses of the project. The comparison was used to modify the internal interaction between the residential and retail uses of the project.

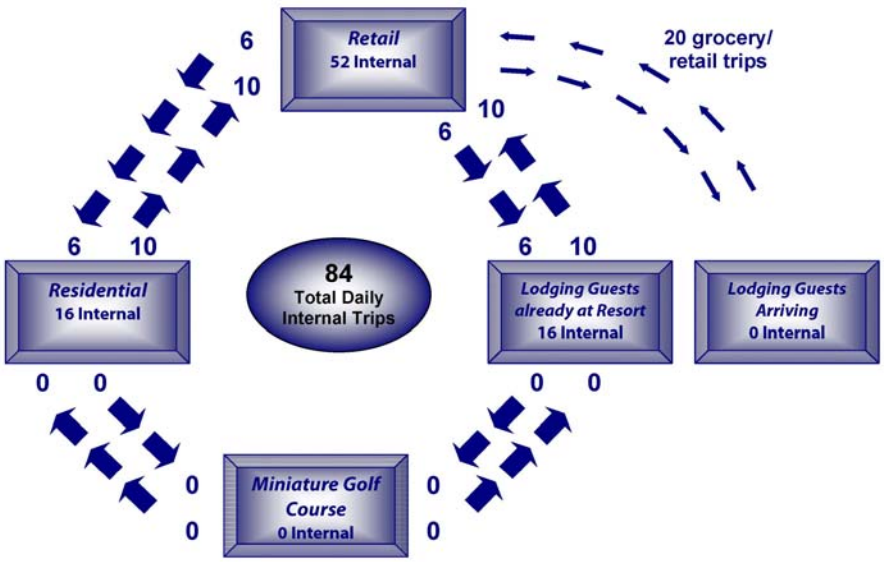
The internal trips between the retail, residential and lodging guests already at the resort were calculated using ITE methodology and are shown in the figures below. The internal trips between the retail and lodging guests arriving on Friday were also calculated, using ITE methodology, to account for guests who stop at the grocery store/retail to stock up on supplies during their stay at the resort upon their arrival. Therefore, the trips entering and exiting the retail as lodging guests arrive were counted as internal trips to the retail uses.

The figures below provide a visual representation of the internal interaction between the proposed project uses for the daily and PM peak hour analysis periods.

Daily



PM Peak



Alternative Modes of Travel

Fehr & Peers has completed considerable research to develop a series of trip generation equations that are used to evaluate the potential for alternative modes of travel to a development. The data used to develop the Fehr & Peers mixed use equations has been validated through comparison to field data and accounts for project land uses and sizes, population and employment created by the project, number of transit stops and intersections within the project site, employment within one mile of the project site, employment within a 30 minute transit trip, and the regional jobs to housing ratio.

The analysis estimates that 6% of trips generated by HMR will use alternative modes of travel.

Pass-By

The following pass-by rate, presented in *Trip Generation Handbook* (ITE, 2004), was used for the project:

- Shopping Center – 34%

Transit/Shuttle Service Provided by Homewood Mountain Resort

HMR is proposing to provide a shuttle service between Homewood and Tahoe City, and a Dial-A-Ride service, during the summer season. The HMR shuttle service will operate hourly from 7:00AM – 11:00PM. Trips generated at the HMR driveways by the shuttle service (32 daily trips, 2 PM peak hour trips) were added to the trip generation estimates.

A Dial-A-Ride service will be provided and will include up to 10 vans. It is estimated that 20 calls can be served during the peak hour (40 total PM peak hour trips) on a busy day. During off-peak hours, it is assumed that 10 calls will be served each hour (20 trips per hour), during a 16 hour service day. Assuming two peak hours during the day (80 peak hour trips), and 14 off-peak hours (280 trips), the daily trip generation of the Dial-A-Ride service is 360 daily trips.

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Trip Generation Summary

Table 2 presents a summary of the trip generation for the proposed project including internal capture, mode splits, and pass-by reductions. Please see the attachments for the complete trip generation spreadsheet.

TABLE 2
PROPOSED PROJECT (ALTERNATIVE 1) SUMMER TRIP GENERATION SUMMARY

Land Use (ITE Code)	Density[1]	Rates[2]				Trips[3]			
		Daily	PM	PM In	PM Out	Daily	PM	PM In	PM Out
North Base									
*50% of lodging guests arrive on Friday **									
Hotel	38 rooms	1.5	1.5	100%	0%	57	57	57	0
Condo/Hotel	30 rooms	1.5	1.5	100%	0%	45	45	45	0
Penthouse Condos	15 units	1.5	1.5	100%	0%	23	23	23	0
Timeshare	10 units	1.5	1.5	100%	0%	15	15	15	0
Remaining 50% of lodging units, all residential units, and retail use analyzed using typical TRPA and ITE trip generation rates									
Hotel (310)	37 rooms	8.92	0.70	49%	51%	330	26	13	13
Condo/Hotel (310)	30 rooms	8.92	0.70	49%	51%	268	21	10	11
Penthouse Condos (230)	15 units	5.86	0.52	67%	33%	88	8	5	3
Timeshare (265)	10 units	10.1	0.79	40%	60%	101	8	3	5
Residential Condos/Townhomes (230)	52 units	5.86	0.52	67%	33%	305	27	18	9
Apartment (220)	13 units	6.72	0.62	65%	35%	87	8	5	3
Shopping Center (820)	25 ksf	42.94	3.75	48%	52%	1,074	95	45	49
Meeting Space	3.005 ksf	Accessory Use to Hotel							
Fitness Center/Spa	10.59 ksf	Accessory Use to Hotel							
Restaurant	1.80 ksf	Accessory Use to Hotel							
Bar	1.26 ksf	Accessory Use to Hotel							
Miniature Golf Course (431)	12 holes	3.30	0.33	33%	67%	40	4	1	3
South Base									
Residential Condos (230)	99 units	5.86	0.52	67%	33%	580	51	34	17
Total "Raw" Trip Generation						3,011	386	275	111
Internal Capture Trips						(-764)	(-84)	(-42)	(-42)
External Project Trips						*2,247*	*302*	*233*	*69*
Alternative Mode Trips [4] (6%)						(-135)	(-18)	(-14)	(-4)
External Vehicle Trips						*2,112*	*284*	*219*	*65*
Pass-By Trips [4] (Shopping Center – 34%)						(-220)	(-25)	(-12)	(-13)
HMR Shuttle Trips						32	2	1	1
Dial-A-Ride Trips						360	80	40	40
Total Net New External Roadway Trips						**2,284**	**341**	**248**	**93**

Notes: [1] ksf = 1,000 square feet

[2] Daily rates are from the TRPA Trip Table and PM rates are from ITE. ITE Daily rates were used where the TRPA Trip Table did not provide rates.

[3] Numbers may differ slightly from the trip generation spreadsheet due to rounding.

[4] Alternative Mode trips (6%) were subtracted from the external project trips. Pass-By trips were subtracted from the external vehicle trips.

The proposed project (Alternative 1) is expected to generate 2,284 net new daily trips and 341 Friday PM peak hour trips on the external roadway network during the summer season.

WINTER TRIP GENERATION (ALTERNATIVE 1)

Winter Study Period

Typically, traffic volumes in the Lake Tahoe Basin are highest during the summer months; therefore, traffic analysis is usually performed for the summer condition. However, the proposed project is a major winter trip generator due to the ski operation. Therefore, the winter trip generation was evaluated. Three winter study periods were considered for analysis of the proposed HMR – Friday, Saturday, and Sunday. Each study period was qualitatively evaluated to determine which period would result in the highest net new trip generation (accounting for the existing ski resort operation).

- Friday - The Friday PM peak hour is expected to have the biggest change in operations compared to existing conditions. Currently the resort is primarily occupied by day skiers who arrive in the morning and leave in the afternoon/evening. The proposed project will include skier accommodations, residential and lodging units, and retail uses. These uses will change the distribution of vehicle trips in to and out of the project site. Currently, the majority of vehicle trips exit the resort during the PM peak hour; however, with the proposed project, the day skiers will still leave at the end of the day, but a large portion of the lodging guests will arrive during the Friday PM peak hour.
- Saturday - The proposed project is expected to generate fewer trips than the existing HMR on Saturday. The skier capacity of the mountain is not expected to change, and the number of day skier parking spaces will be reduced by approximately 70%. The remaining skier capacity of the mountain is expected to be filled with the residents and hotel guests. Since the residents already live at the project site, they will not be generating new trips to the resort, and the majority of hotel guests will likely arrive and leave, prior to and after, Saturday.
- Sunday – As mentioned, the skier capacity of the mountain will not change, just the mix of attendees. Currently, a majority of the skiers are day skiers who leave the resort at the end of the day. With the proposed project, the smaller number of day skiers will still be leaving during the Sunday peak hour, as well as the people who are lodging at the site. The trip generation on a winter Sunday will be similar for the proposed project and the existing facility; therefore, the proposed project will not result in new trips to the roadway network.

Based on this qualitative assessment, we propose to analyze winter Friday PM peak hour conditions.

Assumed Accessory Uses

The ITE description of the hotel land use category includes accessory uses such as restaurants, cocktail lounges, meeting and banquet rooms or convention facilities, limited recreational facilities (pool, fitness room), and/or other retail and service shops; therefore, the restaurant, bar, meeting space, and fitness center/spa uses were included as accessory uses to the hotel for analysis purposes.

Land Uses

The following land uses were included as part of the proposed project (Alternative 1):

<u>North Base</u>

- Hotel - 75 rooms
  - Accessory uses include: Meeting Space – 3,005 square feet
    Fitness Center/Spa –10,590 square feet
    Restaurant – 1,800 square feet
    Bar – 1,260 square feet
- Condo/Hotel Rooms – 60 units (40 units, 20 with lock-offs)
- Penthouse Condos – 30 units
- Residential Condos – 36 units
- Fractional Condos (Timeshares) - 20 units
- Townhomes – 16 units
- Apartment (Workforce Housing) – 13 units
- Retail – 25,000 square feet
- Miniature Golf Course – 12 holes (summer only)
- North Base Lodge/Skier Services – 30,000 square feet
- Outdoor Amphitheater – 1,500 seats (summer only)
- Day Skier Parking – 270 spaces

<u>South Base</u>

- Residential Condos – 99 units
- Skier Services – 2,000 square feet

<u>Mid Mountain</u>

- Day Lodge – 15,000 square feet

Analysis Methodology

Winter trip generation estimates for HMR were developed through comprehensive evaluation of the variety of land uses within the resort, the internal interaction of these uses, and the interaction between the project and the surrounding community. Standard trip generation rates are not available for a destination ski resort, therefore land use specific trip analysis, considering internal trip making, is necessary for the proposed project.

The foundation for trip generation calculations in this analysis is resort occupancy, maximum carrying capacity of the mountain, and the fluctuation or “turnover” of resort residents and guests. This study takes a conservative approach and assumes that 100% of the lodging units are occupied on peak weekends. Monday and Thursday occupancy rates are estimated at 50% with mid-week occupancies around 35%. Based on data collected by the Park City Chamber of Commerce, the length of a typical stay at a ski resort is 3 to 5 days, with most arrivals on Fridays and the majority of departures on Sundays.

The maximum carrying capacity of the mountain is not going to change, however the number of day skier parking spaces will be reduced to 270 (approximately 70% of existing). This indicates that the majority of skiers at the proposed project site will also be lodging at the resort, or residents on the property.

The following steps were taken to develop winter trip generation estimates for the proposed project:

- Friday parking data collected by HMR during the 2007-2008 and 2008-2009 ski seasons (including holidays) was reviewed to determine the peak Friday attendance at the existing site. The five highest Fridays of parking space occupancy for each of the 2007-2008 and 2008-2009 ski seasons were averaged. The results showed that on a typical peak Friday, the day skier parking spaces are approximately 56% occupied. This factor was applied to the 270 proposed day skier parking spaces to determine the number of occupied spaces on a peak Friday at the proposed project (270 x 56% = 151 occupied spaces). It was assumed that all occupied spaces will be vacated during the PM peak hour for analysis purposes. Daily trip generation was determined by doubling the number of occupied spaces (to account for the entering trip and exiting trip made by each vehicle).
- Based on the information discussed previously, it was assumed that 50% of the lodging guests will arrive at the resort on Friday. To present a conservative analysis, it was further assumed that all 50% of the lodging guests will arrive during the PM peak hour. It was also estimated that an average of 1.5 vehicles will arrive per lodging unit.
- Trips were generated for the remaining 50% of lodging units and the residential units using typical TRPA and ITE trip generation rates. Trips were also generated for the retail uses using these rates.
- Trips generated by the North Base Lodge, Mid Mountain Day Lodge, and other skier services buildings are expected to be 100% internalized. The purpose of these uses is to accommodate skiers and resort guests.
- The same methodology used for summer trip generation was used to determine the internal capture, alternative mode, and pass-by reductions for the winter analysis.

Internal Capture, Mode Split, and Pass-By Reductions

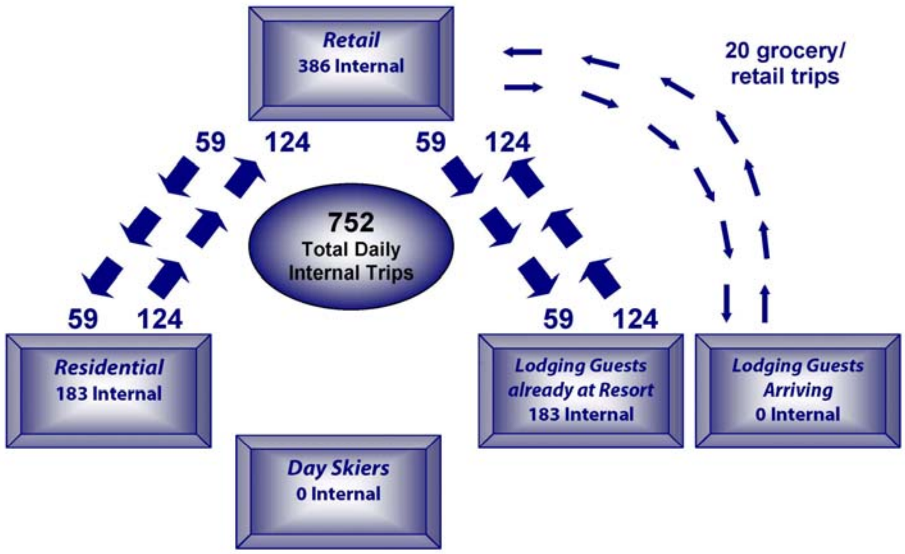
<u>Internal Capture</u>

The internal trips between the retail, residential and lodging guests already at the resort were calculated using ITE methodology and are shown in the figures below. The internal trips between the retail and lodging guests arriving on Friday were also calculated, using ITE methodology, to account for guests who stop at the grocery store/retail to stock up on supplies during their stay at the resort upon their arrival. Therefore, the trips entering and exiting the retail, as lodging guests arrive, were counted as internal trips to the retail uses.

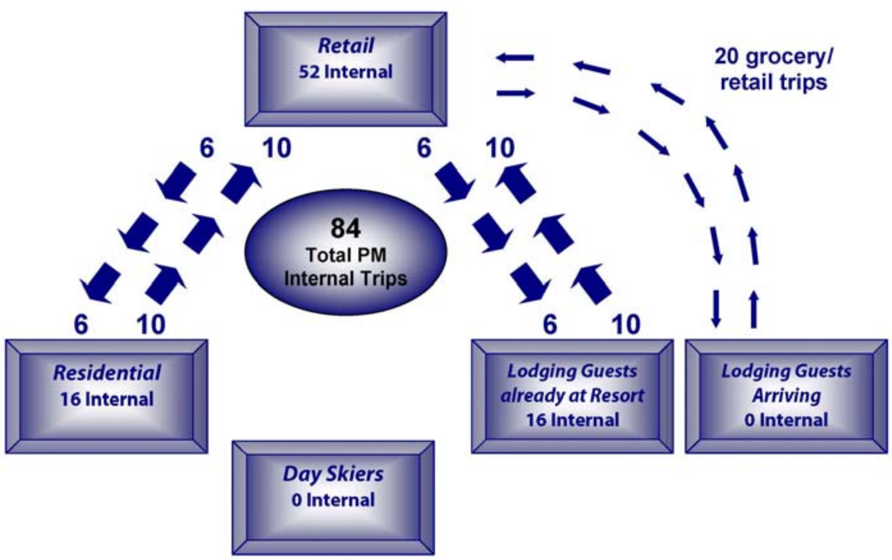
Note that the estimate of internal trips is conservative because no internal capture was applied to the day skiers, and they will likely go to the retail uses.

The figures below provide a visual representation of the internal interaction between the proposed project uses for the daily and PM peak hour analysis periods.

Daily



PM Peak



Alternative Modes of Travel

The Fehr & Peers mixed use equations were used to determine the alternative mode reduction rate of the project. The analysis estimates that 6% of trips generated by HMR will use alternative modes of travel.

Pass-By

The following pass-by rate, presented in *Trip Generation Handbook* (ITE, 2004), was used for the project:

- Shopping Center – 34%

Transit/Shuttle Service Provided by Homewood Mountain Resort and Skier Drop Off and Pick Up

Transit/Shuttle Service

HMR is proposing to provide skier shuttles to and from HMR. Each shuttle will have a 12 skier capacity, but to provide a conservative analysis, it is assumed that each shuttle is only half full. It is assumed that 100 skiers will use the shuttle daily. During the PM peak hour it is estimated that 17 buses (to accommodate all 100 skiers) will enter and exit HMR. The total daily trip generation of the skier shuttles is 68 trips.

A Dial-A-Ride service will be provided and will include up to 10 vans. It is estimated that 20 calls can be served during the peak hour (40 total PM peak hour trips) on a busy day. During off-peak hours, it is assumed that 10 calls will be served each hour (20 trip per hour), during a 16 hour service day. Assuming two peak hours during the day (80 peak hour trips), and 14 off-peak hours (280 trips), the daily trip generation of the Dial-A-Ride service is 360 daily trips.

Skier Drop Off and Pick Up

For analysis purposes it was assumed that 100 day use skiers will be dropped off and picked up from HMR. Assuming a vehicle occupancy of 2.5 skiers per vehicle, drop off/pick up trips will account for 80 PM peak hour trips and 160 daily trips.

Trip Generation Summary

Table 3 presents a summary of the trip generation for the proposed project including internal capture, mode splits, and pass-by reductions. Please see the attachments for the complete trip generation spreadsheet.

FEHR & PEERS
TRANSPORTATION CONSULTANTS

TABLE 3
PROPOSED PROJECT (ALTERNATIVE 1) WINTER TRIP GENERATION SUMMARY

Land Use (ITE Code)	Density[1]	Rates[2]				Trips[3]			
		Daily	PM	PM In	PM Out	Daily	PM	PM In	PM Out
North Base									
*50% of lodging guests arrive on Friday **									
Hotel	38 rooms	1.5	1.5	100%	0%	57	57	57	0
Condo/Hotel	30 rooms	1.5	1.5	100%	0%	45	45	45	0
Penthouse Condos	15 units	1.5	1.5	100%	0%	23	23	23	0
Timeshare	10 units	1.5	1.5	100%	0%	15	15	15	0
All occupied day skier parking spaces vacate during PM peak hour									
Day Skier Parking	270 spaces	1.12	0.56	0%	100%	302	151	0	151
Remaining 50% of lodging units, all residential units, and retail use analyzed using typical TRPA and ITE trip generation rates									
Hotel (310)	37 rooms	8.92	0.70	49%	51%	330	26	13	13
Condo/Hotel (310)	30 rooms	8.92	0.70	49%	51%	268	21	10	11
Penthouse Condos (230)	15 units	5.86	0.52	67%	33%	88	8	5	3
Timeshare (265)	10 units	10.1	0.79	40%	60%	101	8	3	5
Residential Condos/Townhomes (230)	52 units	5.86	0.52	67%	33%	305	27	18	9
Apartment (220)	13 units	6.72	0.62	65%	35%	87	8	5	3
Shopping Center (820)	25 ksf	42.94	3.75	48%	52%	1,074	94	45	49
Meeting Space	3.005 ksf	Accessory Use to Hotel							
Fitness Center/Spa	10.59 ksf	Accessory Use to Hotel							
Restaurant	1.80 ksf	Accessory Use to Hotel							
Bar	1.26 ksf	Accessory Use to Hotel							
South Base									
Residential Condos (230)	99 units	5.86	0.52	67%	33%	580	51	34	17
Total "Raw" Trip Generation						3,275	534	274	260
Internal Capture Trips						(-752)	(-84)	(-42)	(-42)
External Project Trips						*2,523*	*450*	*232*	*218*
Alternative Mode Trips [4] (6%)						(-151)	(-27)	(-14)	(-13)
External Vehicle Trips						*2,372*	*423*	*218*	*205*
Pass-By Trips [4] (Shopping Center – 34%)						(-220)	(-13)	(-6)	(-7)
Skier Drop Off and Pick Up						160	40	20	20
HMR Shuttle Service						68	34	17	17
Dial-A-Ride						360	80	40	40
Total New Project Trips						**2,740**	**564**	**289**	**275**
Existing Homewood Volumes						(-2,535)	(-472)	(-115)	(-357)
Total Net New External Roadway Trips						**205**	**92**	**174**	**(-82)**

Notes: * An average of 1.5 vehicles per unit was assumed.
[1] ksf = 1,000 square feet
[2] Daily rates are from the TRPA Trip Table and PM rates are from ITE. ITE Daily rates were used where the TRPA Trip Table did not provide rates.
[3] Numbers may differ slightly from the trip generation spreadsheet due to rounding.
[4] Alternative Mode trips (6%) were subtracted from the external project trips. Pass-By trips were subtracted from the external vehicle trips.

The proposed project (Alternative 1) is expected to generate 205 net new daily trips, and 92 net new Friday PM peak hour trips on the external roadway network during the winter season.

However, the directional split of trips during the Friday PM peak hour will change. The number of trips entering HMR will increase by 174, and the number exiting trips will decrease by 82 compared to existing conditions.

TRIP DISTRIBUTION

Vehicle trips generated by the project were distributed to the roadway network based on travel patterns in the study area and locations of complementary land uses. The trip distribution and assignment for the proposed project is described below:

- 11% enter/exit from/to the south on SR 89
- 89% enter/exit from/to the north on SR 89
    - 45% enter/exit from/to the west on SR 89
    - 55% enter/exit from/to the east on SR 28
- Vehicle trips entering and exiting the driveway access points of the project site were distributed based on the locations of the land uses and parking facilities on site.

Alternative 1 (Summer)

ITE Land Use & Code	Project Land Use	Density	Measure	Daily Rate	Friday PM Peak Rate	Friday PM Peak In	Friday PM Peak Out	Daily Trips	Friday PM Peak Trips	In	Out
NORTH BASE											
*50% of lodging guests arrive on Friday **											
310 - Hotel	Hotel Rooms	38	occupied rooms	1.5	1.5	100%	0%	57	57	57	0
310 - Hotel	*2-bedroom condo/hotel	30	occupied rooms	1.5	1.5	100%	0%	45	45	45	0
230 - Residential Condos	Penthouse Condos	15	rooms	1.5	1.5	100%	0%	23	23	23	0
265 - Timeshare	Fractional Ownership	10	units	1.5	1.5	100%	0%	15	15	15	0
Remaining 50% of lodging units, residential units, and retail use analyzed using typical TRPA and ITE trip generation rates											
310 - Hotel	Hotel Rooms	37	occupied rooms	8.92	0.70	49%	51%	330	26	13	13
310 - Hotel	*2-bedroom condo/hotel	30	occupied rooms	8.92	0.70	49%	51%	268	21	10	11
230 - Residential Condos	Penthouse Condos	15	rooms	5.86	0.52	67%	33%	88	8	5	3
265 - Timeshare	Fractional Ownership	10	units	10.1	0.79	40%	60%	101	8	3	5
230 - Residential Condos	Residential Condos & Townhomes	52	units	5.86	0.52	67%	33%	305	27	18	9
220 - Apartment	Employee Housing	13	units	6.72	0.62	65%	35%	87	8	5	3
820 - Shopping Center	Commercial	25	ksf	42.94	3.75	48%	52%	1074	94	45	49
Restaurant	**Hotel Accessory	1.8	ksf								
Bar	**Hotel Accessory	1.26	ksf								
Meeting Space	**Hotel Accessory	3.005	ksf								
Fitness Center/Spa	**Hotel Accessory	10.59	ksf								
Base Lodge		30	ksf	Winter Only							
431 - Miniature Golf Course	Miniature Golf Course	12	holes	3.30	0.33	33%	67%	40	4	1	3
							RAW Trip Generation	**2431**	**335**	**241**	**94**
SOUTH BASE											
230 - Residential Condos	Residential Condos	99	units	5.86	0.52	67%	33%	580	51	34	17
							RAW Trip Generation	**580**	**51**	**34**	**17**
MID MOUNTAIN											
Base Lodge		15	ksf	Winter Only							
ADDITIONAL RECREATION											
Outdoor Amphitheater		1500	seats	Special Events only - not typical							
							Total RAW Trip Generation	3011	386	275	111
							Internal Capture	764	84	42	42
					Alternative Mode Reduction		6%	135	18	14	4
					Shopping Center Pass-By		34%	220	25	12	13
							HMR Shuttle trips	32	2	1	1
							Dial-A-Ride	360	80	40	40
							Total External Trip Generation	**2285**	**341**	**248**	**93**

*40 condo units, 20 with lock-offs

** Hotel definition includes accessory uses.

DAILY

Analyst: **MH**
Date: **10/8/2009**
Project #: **RN08-0403**

MULTI-USE DEVELOPMENT
TRIP GENERATION
AND INTERNAL CAPTURE SUMMARY

Name of Development/Tile: **Homewood - Summer**
Time Period: **Daily**

LAND USE ID:	A	Residential	
ITE LU Code:	0	Residential	
Size:	0.00	0	
	Total	Internal	External
Enter	486	60	426
Exit	486	126	360
Total	972	186	786
%	100%	19%	81%

Enter from External: 426
Exit to External: 360

LAND USE ID:	B	Office	
ITE LU Code:	0	Lodging	
Size:	0.00	0	
	Total	Internal	External
Enter	394	60	333
Exit	394	126	268
Total	787	186	601
%	100%	24%	76%

Enter from External: 333
Exit to External: 268

A–B:
Demand 0% 0 | Balanced 0 | Demand 0% 0
Demand 0% 0 | Balanced 0 | Demand 0% 0

A–C:
Demand 38% 185 | Balanced 124 | Demand 23% 124
Demand 33% 160 | Balanced 59 | Demand 11% 59

A–D:
Demand 19% 92 | Balanced 2 | Demand 12% 2
Demand 17% 80 | Balanced 1 | Demand 6% 1

B–C:
Demand 38% 150 | Balanced 124 | Demand 23% 124
Demand 33% 130 | Balanced 59 | Demand 11% 59

B–D:
Demand 19% 75 | Balanced 2 | Demand 12% 2
Demand 17% 65 | Balanced 1 | Demand 6% 1

C–D:
Demand 10% 54 | Balanced 1 | Demand 5% 1
Demand 10% 54 | Balanced 2 | Demand 10% 2

LAND USE ID:	C	Retail	
ITE LU Code:	0	Shopping Center	
Size:	0.00	0	
	Total	Internal	External
Enter	537	248	289
Exit	537	120	417
Total	1074	368	706
%	100%	34%	66%

Enter from External: 289
Exit to External: 417

LAND USE ID:	D	Misc	
ITE LU Code:	0	Schools and Parks	
Size:	0.00	0	
	Total	Internal	External
Enter	20	7	13
Exit	20	3	17
Total	40	10	30
%	100%	25%	76%

Enter from External: 13
Exit to External: 17

Net External Trips for Multi-Use Development

Land Use ID	A	B	C	D	Total	
Enter	426	333	289	13	1062	
Exit	360	268	417	17	1062	
Total	786	601	706	30	2123	***INTERNAL CAPTURE***
Single-Use Trip Gen. Est.	972	787	1074	40	2873	**26%**

PM

Analyst: **MH**
Date: **10/8/2009**
Project #: **RN08-0403**

MULTI-USE DEVELOPMENT
TRIP GENERATION
AND INTERNAL CAPTURE SUMMARY

Name of Development/Tile: **Homewood - Summer**
Time Period: **PM Peak Hour**

LAND USE ID:	A	Residential	
ITE LU Code:	0	Residential	
Size:	0.00	0	
	Total	Internal	External
Enter	58	6	52
Exit	29	10	19
Total	87	17	70
%	100%	19%	81%

Enter from External: 52
Exit to External: 19

LAND USE ID:	B	Office	
ITE LU Code:	0	Lodging	
Size:	0.00	0	
	Total	Internal	External
Enter	31	6	25
Exit	32	10	22
Total	63	17	46
%	100%	26%	74%

Enter from External: 25
Exit to External: 22

A–B: Demand 0% 0; Balanced 0; Demand 0% 0
B–A: Demand 0% 0; Balanced 0; Demand 0% 0

A–C: Demand 53% 15; Balanced 10; Demand 23% 10
C–A: Demand 31% 18; Balanced 6; Demand 12% 6

A–D: Demand 27% 8; Balanced 0; Demand 12% 0
D–A: Demand 16% 9; Balanced 6; Demand 12% 6

B–C: Demand 53% 17; Balanced 10; Demand 23% 10
C–B: Demand 31% 10; Balanced 6; Demand 12% 6

B–D: Demand 27% 8; Balanced 0; Demand 12% 0
D–B: Demand 16% 5; Balanced 0; Demand 6% 0

C–D (lower diagonal boxes): Demand 12% 0; Balanced 0; Demand 6% 0

LAND USE ID:	C	Retail	
ITE LU Code:	0	Shopping Center	
Size:	0.00	0	
	Total	Internal	External
Enter	45	21	24
Exit	49	12	37
Total	94	33	61
%	100%	35%	65%

Enter from External: 24
Exit to External: 37

LAND USE ID:	D	Misc	
ITE LU Code:	0	Schools and Parks	
Size:	0.00	0	
	Total	Internal	External
Enter	1	0	1
Exit	3	1	2
Total	4	1	3
%	100%	25%	75%

Enter from External: 1
Exit to External: 2

C–D: Demand 10% 5; Balanced 0; Demand 10% 0
D–C: Demand 10% 5; Balanced 0; Demand 10% 0

Net External Trips for Multi-Use Development					
Land Use ID	A	B	C	D	Total
Enter	52	25	24	1	102
Exit	19	22	37	2	80
Total	70	46	61	3	181
Single-Use Trip Gen. Est.	87	63	94	4	248

INTERNAL CAPTURE
27%

Alternative 1 (Winter)

ITE Land Use & Code	Project Land Use	Density	Measure	Daily Rate	Friday PM Peak Rate	Friday PM Peak In	Friday PM Peak Out	Daily Trips	Friday PM Peak Trips	Friday PM Peak In	Friday PM Peak Out
NORTH BASE											
*50% of lodging guests arrive on Friday **											
310 - Hotel	Hotel Rooms	38	occupied rooms	1.5	1.5	100%	0%	57	57	57	0
310 - Hotel	*2-bedroom condo/hotel	30	occupied rooms	1.5	1.5	100%	0%	45	45	45	0
230 - Residential Condos	Penthouse Condos	15	rooms	1.5	1.5	100%	0%	23	23	23	0
265 - Timeshare	Fractional Ownership	10	units	1.5	1.5	100%	0%	15	15	15	0
All occupied day skier parking spaces vacate during PM peak hour											
Skier Parking Spaces	Ski Resort	270	spaces	1.12	0.56	0%	100%	302	151	0	151
Remaining 50% of lodging units, residential units, and retail use analyzed using typical TRPA and ITE trip generation rates											
310 - Hotel	Hotel Rooms	37	occupied rooms	8.92	0.70	49%	51%	330	26	13	13
310 - Hotel	*2-bedroom condo/hotel	30	occupied rooms	8.92	0.70	49%	51%	268	21	10	11
230 - Residential Condos	Penthouse Condos	15	rooms	5.86	0.52	67%	33%	88	8	5	3
265 - Timeshare	Fractional Ownership	10	units	10.1	0.79	40%	60%	101	8	3	5
230 - Residential Condos	Residential Condos & Townhomes	52	units	5.86	0.52	67%	33%	305	27	18	9
220 - Apartment	Employee Housing	13	units	6.72	0.62	65%	35%	87	8	5	3
820 - Shopping Center	Commercial	25	ksf	42.94	3.75	48%	52%	1074	94	45	49
Restaurant	**Hotel Accessory	1.8	ksf								
Bar	**Hotel Accessory	1.26	ksf								
Meeting Space	**Hotel Accessory	3.005	ksf								
Fitness Center/Spa	**Hotel Accessory	10.59	ksf								
Base Lodge		30	ksf	Internal Trips Only							
							RAW Trip Generation	**2694**	**482**	**239**	**243**
SOUTH BASE											
230 - Residential Condos	Residential Condos	99	units	5.86	0.52	67%	33%	580	51	34	17
							RAW Trip Generation	**580**	**51**	**34**	**17**
MID MOUNTAIN											
Base Lodge		15	ksf	Internal Trips Only							
ADDITIONAL RECREATION											
Outdoor Amphitheater		1500	seats	Summer Only							

		Daily Trips	Trips	In	Out
Total RAW Trip Generation		3274	534	274	260
Internal Capture		751	86	43	43
Alternative Mode Reduction	6%	151	27	14	13
Shopping Center Pass-By	34%	220	13	6	7
Skier Drop Off and Pick Up		160	40	20	20
HMR Shuttle Service		68	34	17	17
Dial-A-Ride		360	80	40	40
Total External Trip Generation		**2740**	**562**	**288**	**274**

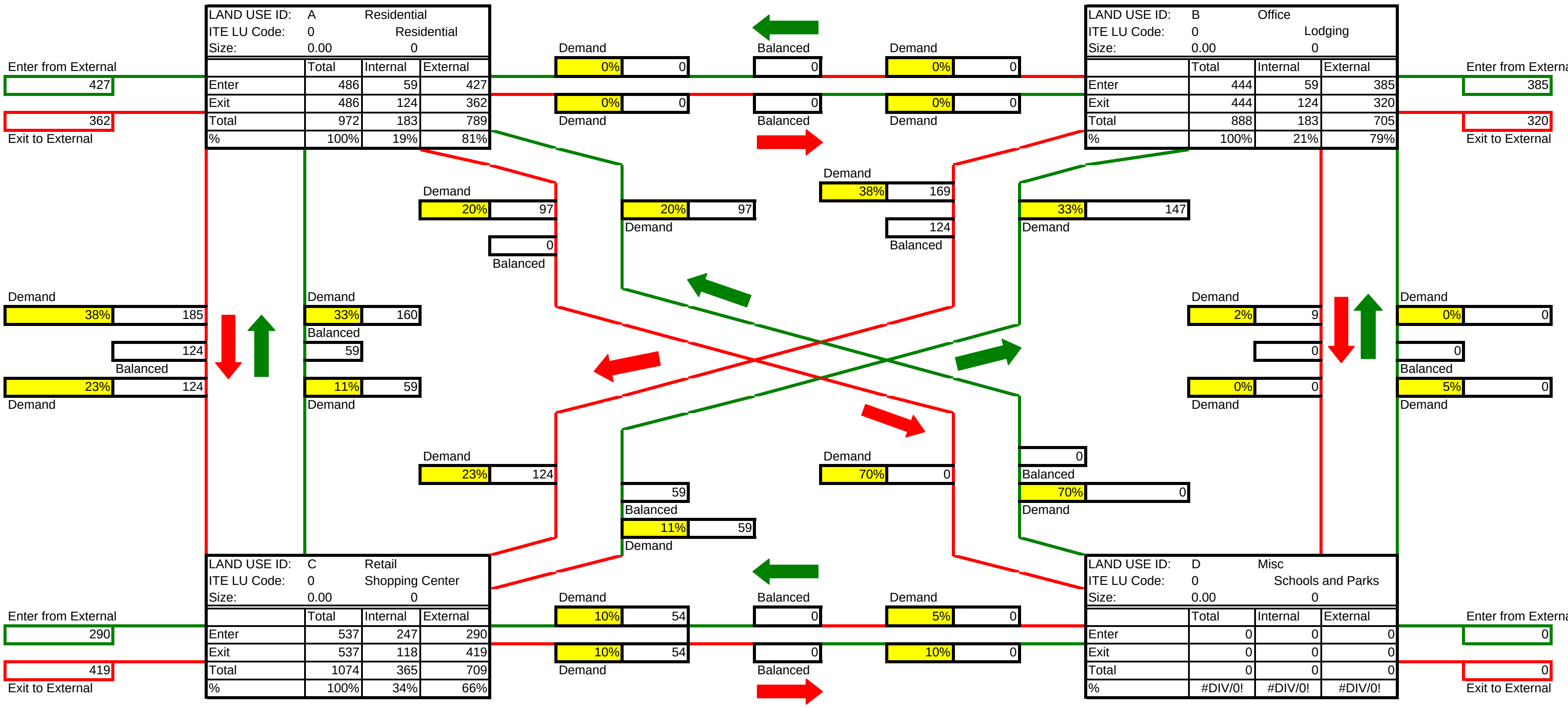
*40 condo units, 20 with lock-offs
** Hotel definition includes accessory uses.

DAILY

Analyst: **MH**
Date: **10/8/2009**
Project #: **RN08-0403**

MULTI-USE DEVELOPMENT
TRIP GENERATION
AND INTERNAL CAPTURE SUMMARY

Name of Development/Tile: **Homewood**
Time Period: **Daily**



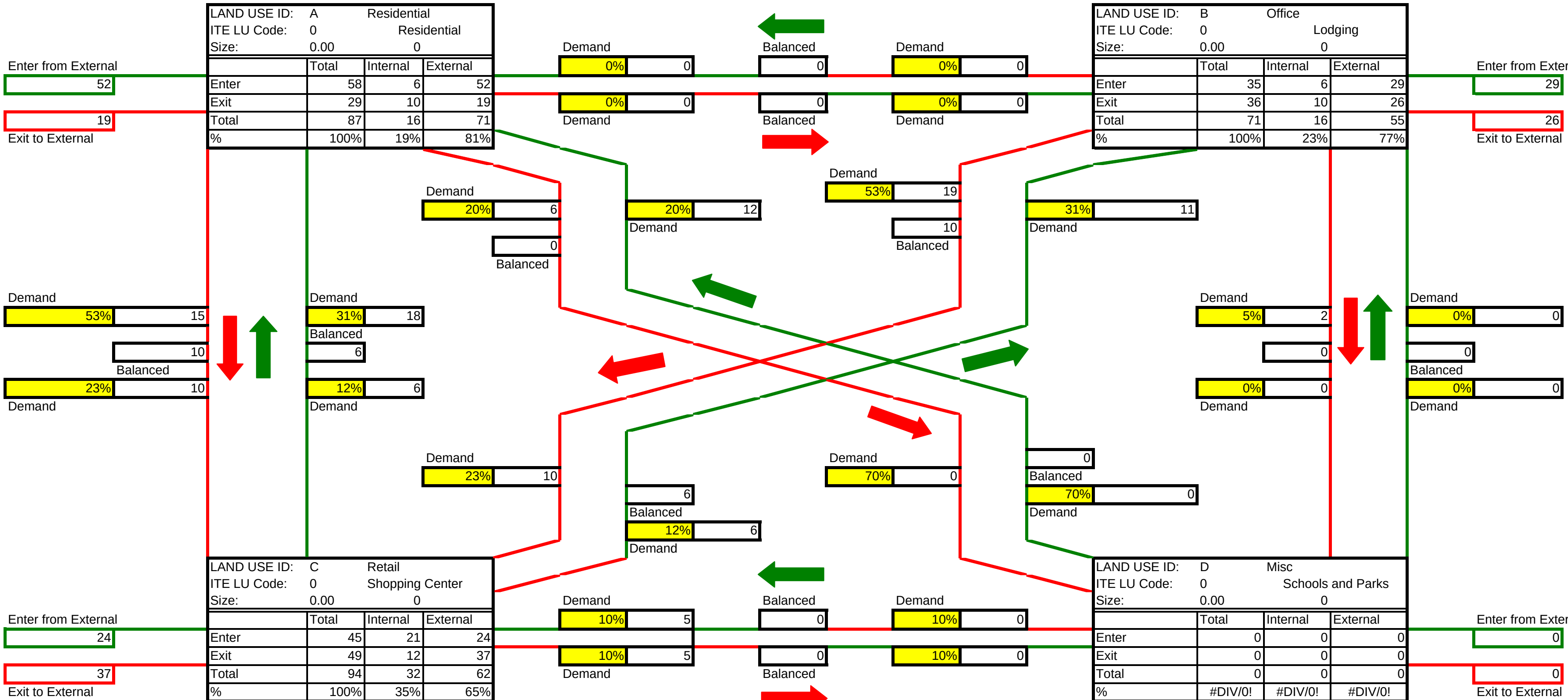
Net External Trips for Multi-Use Development						
Land Use ID	**A**	**B**	**C**	**D**	**Total**	
Enter	427	385	290	0	1102	
Exit	362	320	419	0	1102	
Total	789	705	709	0	2204	***INTERNAL CAPTURE***
Single-Use Trip Gen. Est.	972	888	1074	0	2934	**25%**

PM

Analyst: **MH**
Date: **10/8/2009**
Project #: **RN08-0403**

MULTI-USE DEVELOPMENT
TRIP GENERATION
AND INTERNAL CAPTURE SUMMARY

Name of Development/Tile: **Homewood**
Time Period: **PM Peak Hour**



LAND USE ID:	A	Residential	
ITE LU Code:	0	Residential	
Size:	0.00	0	
	Total	Internal	External
Enter	58	6	52
Exit	29	10	19
Total	87	16	71
%	100%	19%	81%

LAND USE ID:	B	Office	
ITE LU Code:	0	Lodging	
Size:	0.00	0	
	Total	Internal	External
Enter	35	6	29
Exit	36	10	26
Total	71	16	55
%	100%	23%	77%

LAND USE ID:	C	Retail	
ITE LU Code:	0	Shopping Center	
Size:	0.00	0	
	Total	Internal	External
Enter	45	21	24
Exit	49	12	37
Total	94	32	62
%	100%	35%	65%

LAND USE ID:	D	Misc	
ITE LU Code:	0	Schools and Parks	
Size:	0.00	0	
	Total	Internal	External
Enter	0	0	0
Exit	0	0	0
Total	0	0	0
%	#DIV/0!	#DIV/0!	#DIV/0!

Net External Trips for Multi-Use Development

Land Use ID	A	B	C	D	Total	
Enter	52	29	24	0	106	
Exit	19	26	37	0	82	
Total	71	55	62	0	187	***INTERNAL CAPTURE***
Single-Use Trip Gen. Est.	87	71	94	0	252	**26%**

Technical Advisory

CEQA AND CLIMATE CHANGE: Addressing Climate Change Through California Environmental Quality Act (CEQA) Review

This technical advisory is one in a series of advisories provided by the Governor's Office of Planning and Research (OPR) as a service to professional planners, land use officials and CEQA practitioners. OPR issues technical guidance from time to time on issues that broadly affect the practice of CEQA and land use planning. The emerging role of CEQA in addressing climate change and greenhouse gas emissions has been the topic of much discussion and debate in recent months. This document provides OPR's perspective on the issue.

I. PURPOSE

General scientific consensus and increasing public awareness regarding global warming and climate change have placed new focus on the California Environmental Quality Act (CEQA) review process as a means to address the effects of greenhouse gas (GHG) emissions from proposed projects on climate change. Many public agencies—along with academic, business, and community organizations—are striving to determine the appropriate means by which to evaluate and mitigate the impacts of proposed projects on climate change. Approaches and methodologies for calculating GHG emissions and addressing the environmental impacts through CEQA review are rapidly evolving and are increasingly available to assist public agencies to prepare their CEQA documents and make informed decisions.

JUNE 19, 2008

STATE OF CALIFORNIA
Arnold Schwarzenegger, Governor

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The Governor's Office of Planning and Research (OPR) will develop, and the California Resources Agency (Resources Agency) will certify and adopt amendments to the Guidelines implementing the California Environmental Quality Act ("CEQA Guidelines"), on or before January 1, 2010, pursuant to Senate Bill 97 (Dutton, 2007). These new CEQA Guidelines will provide regulatory guidance on the analysis and mitigation of GHG emissions in CEQA documents. In the interim, OPR offers the following informal guidance regarding the steps lead agencies should take to address climate change in their CEQA documents. This guidance was developed in cooperation with the Resources Agency, the California Environmental Protection Agency (Cal/EPA), and the California Air Resources Board (ARB).

II. BACKGROUND

Climate change refers to any significant change in measures of climate, such as average temperature, precipitation, or wind patterns over a period of time. Climate change may result from natural factors, natural processes, and human activities that change the composition of the atmosphere and alter the surface and features of the land. Significant changes in global climate patterns have recently been associated with global warming, an average increase in the temperature of the atmosphere near the Earth's surface, attributed to accumulation of GHG emissions in the atmosphere. Greenhouse gases trap heat in the atmosphere, which in turn heats the surface of the Earth. Some GHGs occur naturally and are emitted to the atmosphere through natural processes, while others are created and emitted solely through human activities. The emission of GHGs through the combustion of fossil fuels (i.e., fuels containing carbon) in conjunction with other human activities, appears to be closely associated with global warming.

State law defines GHG to include the following: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (Health and Safety Code, section 38505(g).) The most common GHG that results from human activity is carbon dioxide, followed by methane and nitrous oxide.

Requirements of AB 32 and SB 97

Assembly Bill 32 (AB 32), the California Global Warming Solutions Act of 2006 (Nunez, 2006), recognizes that California is the source of substantial amounts of GHG emissions. The statute begins with several legislative findings and declarations of intent, including the following:

> Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snow pack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems. (Health and Safety Code, section 38501.)

In order to avert these consequences, AB 32 establishes a state goal of reducing GHG emissions to 1990 levels by the year 2020 (a reduction of approximately 25 percent from forecast emission levels) with further reductions to follow. The law requires the ARB to establish a program to track and report GHG emissions; approve a scoping plan for achieving the maximum technologically feasible and cost effective reductions from sources of GHG emissions; adopt early reduction measures to begin moving forward; and adopt, implement and enforce regulations – including market mechanisms such as "cap-and-trade" programs – to ensure the required reductions occur. The ARB recently adopted a statewide GHG emissions limit and an emissions inventory, along with requirements to measure, track, and report GHG emissions by the industries it determined to be significant sources of GHG emissions.

CEQA requires public agencies to identify the potentially significant effects on the environment of projects they intend to carry out or approve, and to mitigate significant effects whenever it is feasible to do so. While AB 32 did not amend CEQA to require new analytic processes to account for the environmental impacts of GHG emissions from projects subject to CEQA, it does acknowledge that such emissions cause significant adverse impacts to human health and the environment.

Senate Bill 97, enacted in 2007, amends the CEQA statute to clearly establish that GHG emissions and the effects of GHG emissions are appropriate subjects for CEQA analysis. It directs OPR to develop draft CEQA Guidelines "for the mitigation of greenhouse gas emissions or the effects of greenhouse gas emissions" by July 1, 2009 and directs the Resources Agency to certify and adopt the CEQA Guidelines by January 1, 2010.

Requirements of CEQA

CEQA is a public disclosure law that requires public agencies to make a good-faith, reasoned effort, based upon available information, to identify the potentially significant direct and indirect environmental impacts—including cumulative impacts— of a proposed project or activity. The CEQA process is intended to inform the public of the potential environmental effects of proposed government decisions and to encourage informed decision-making by public agencies. In addition, CEQA obligates public agencies to consider less environmentally-damaging alternatives and adopt feasible mitigation measures to reduce or avoid a project's significant impacts.

The lead agency is required to prepare an Environmental Impact Report (EIR), a Mitigated Negative Declaration, or equivalent document, when it determines that the project's impacts on the environment are potentially significant. This determination of significance must be based upon substantial evidence in light of all the information before the agency.

Although the CEQA Guidelines, at Appendix G, provide a checklist of suggested issues that should be addressed in an EIR, neither the CEQA statute nor the CEQA Guidelines prescribe thresholds of significance or particular methodologies for performing an impact analysis. This is left to lead agency judgment and discretion, based upon factual data and guidance from regulatory agencies and other sources where available and applicable. A threshold of significance is essentially a regulatory standard or set of criteria that represent the level at which a lead agency finds a particular environmental effect of a project to be significant. Compliance with a given threshold means the effect normally will be considered less than significant. Public agencies are encouraged but not required to adopt thresholds of significance for environmental impacts. Even in the absence of clearly defined thresholds for GHG emissions, the law requires that such emissions from CEQA projects must be disclosed and mitigated to the extent feasible whenever the lead agency determines that the project contributes to a significant, cumulative climate change impact.

We realize that perhaps the most difficult part of the climate change analysis will be the determination of significance. Although lead agencies typically rely on local or regional definitions of significance for most environmental issues, the global nature of climate change warrants investigation of a statewide threshold of significance for GHG emissions. To this end, OPR has asked ARB technical staff to recommend a method for setting thresholds which will encourage consistency and uniformity in the CEQA analysis of GHG emissions throughout the state. Until such time as state guidance is available on thresholds of significance for GHG emissions, we recommend the following approach to your CEQA analysis.

III. RECOMMENDED APPROACH

Each public agency that is a lead agency for complying with CEQA needs to develop its own approach to performing a climate change analysis for projects that generate GHG emissions. A consistent approach should be applied for the analysis of all such projects, and the analysis must be based on best available information. For these projects, compliance with CEQA entails three basic steps: identify and quantify the GHG emissions; assess the significance of the impact on climate change; and if the impact is found to be significant, identify alternatives and/or mitigation measures that will reduce the impact below significance.

Lead agencies should determine whether greenhouse gases may be generated by a proposed project, and if so, quantify or estimate the GHG emissions by type and source. Second, the lead agency must assess whether those emissions are individually or cumulatively significant. When assessing whether a project's effects on climate change are "cumulatively considerable" even though its GHG contribution may be individually limited, the lead agency must consider the impact of the project when viewed in connection with the effects of past, current, and probable future projects. Finally, if the lead agency determines that the GHG emissions from the project as proposed are potentially significant, it must investigate and implement ways to avoid, reduce, or otherwise mitigate the impacts of those emissions. Although the scientific knowledge and understanding of how best to perform this analysis is rudimentary and still evolving, many useful resources are available (see Attachment 1).

Until such time as further state guidance is available on thresholds of significance, public agencies should consider the following general factors when analyzing whether a proposed project has the potential to cause a significant climate change impact on the environment.

Identify GHG Emissions

- Lead agencies should make a good-faith effort, based on available information, to calculate, model, or estimate the amount of CO_2 and other GHG emissions from a project, including the emissions associated with vehicular traffic, energy consumption, water usage and construction activities.
- Technical resources, including a variety of modeling tools, are available to assist public agencies to quantify GHG emissions. OPR recognizes that more sophisticated emissions models for particular types of projects are continually being developed and that the state-of-the-art quantification

models are rapidly changing. OPR will periodically update the examples of modeling tools identified in Attachment 2.

- There is no standard format for including the analysis in a CEQA document. A GHG/climate change analysis can be included in one or more of the typical sections of an EIR (e.g., air quality, transportation, energy) or may be provided in a separate section on cumulative impacts or climate change.

Determine Significance

- When assessing a project's GHG emissions, lead agencies must describe the existing environmental conditions or setting, without the project, which normally constitutes the baseline physical conditions for determining whether a project's impacts are significant.
- As with any environmental impact, lead agencies must determine what constitutes a significant impact. In the absence of regulatory standards for GHG emissions or other scientific data to clearly define what constitutes a "significant impact", individual lead agencies may undertake a project-by-project analysis, consistent with available guidance and current CEQA practice.
- The potential effects of a project may be individually limited but cumulatively considerable. Lead agencies should not dismiss a proposed project's direct and/or indirect climate change impacts without careful consideration, supported by substantial evidence. Documentation of available information and analysis should be provided for any project that may significantly contribute new GHG emissions, either individually or cumulatively, directly or indirectly (e.g., transportation impacts).
- Although climate change is ultimately a cumulative impact, not every individual project that emits GHGs must necessarily be found to contribute to a significant cumulative impact on the environment. CEQA authorizes reliance on previously approved plans and mitigation programs that have adequately analyzed and mitigated GHG emissions to a less than significant level as a means to avoid or substantially reduce the cumulative impact of a project.

Mitigate Impacts

- Mitigation measures will vary with the type of project being contemplated, but may include alternative project designs or locations that conserve energy and water, measures that reduce vehicle miles traveled

(VMT) by fossil-fueled vehicles, measures that contribute to established regional or programmatic mitigation strategies, and measures that sequester carbon to offset the emissions from the project.

- The lead agency must impose all mitigation measures that are necessary to reduce GHG emissions to a less than significant level. CEQA does not require mitigation measures that are infeasible for specific legal, economic, technological, or other reasons. A lead agency is not responsible for wholly eliminating all GHG emissions from a project; the CEQA standard is to mitigate to a level that is "less than significant".
- If there are not sufficient mitigation measures that the lead agency determines are feasible to achieve the less than significant level, the lead agency should adopt those measures that are feasible, and adopt a Statement of Overriding Considerations that explains why further mitigation is not feasible. A Statement of Overriding Considerations must be prepared when the lead agency has determined to approve a project for which certain impacts are unavoidable. These statements should explain the reasons why the impacts cannot be adequately mitigated in sufficient detail, and must be based on specific facts, so as not to be conclusory.
- Agencies are encouraged to develop standard GHG emission reduction or mitigation measures that can be applied on a project-by-project basis. Attachment 3 contains a preliminary menu of measures that lead agencies may wish to consider. This list is by no means exhaustive or prescriptive. Lead agencies are encouraged to develop their own measures and/or propose project alternatives to reduce GHG emissions, either at a programmatic level or on a case-by-case review.
- In some cases GHG emission reduction measures will not be feasible or may not be effective at a project level. Rather, it may be more appropriate and more effective to develop and adopt program-level plans, policies and measures that will result in a reduction of GHG emissions on a regional level.

IV. ADDITIONAL LAND USE CONSIDERATIONS

CEQA can be a more effective tool for GHG emissions analysis and mitigation if it is supported and supplemented by sound development policies and practices that will reduce GHG emissions on a broad planning scale and that can provide the basis for a programmatic approach to project-specific CEQA analysis and mitigation.

Local governments with land use authority are beginning to establish policies that result in land use patterns and practices that will result in less energy use and reduce GHG emissions. For example, some cities and counties have adopted general plans and policies that encourage the development of compact, mixed-use, transit-oriented development that reduces VMT; encourage alternative fuel vehicle use; conserve energy and water usage; and promote carbon sequestration. Models of such developments exist throughout the state (see OPR climate change website for examples of city and county plans and policies, referenced in Attachment 1).

For local government lead agencies, adoption of general plan policies and certification of general plan EIRs that analyze broad jurisdiction-wide impacts of GHG emissions can be part of an effective strategy for addressing cumulative impacts and for streamlining later project-specific CEQA reviews.

International, national, and statewide organizations such as ICLEI (Local Governments for Sustainability), the Cities for Climate Protection, and the Clean Cities Coalition —to name just a few — have published guidebooks to help local governments reduce GHG emissions through land use planning techniques and improved municipal operations. Links to these resources are provided at the end of this advisory.

Regional agencies can also employ a variety of strategies to reduce GHG emissions through their planning processes. For example, regional transportation planning agencies adopt plans and programs that address congestion relief, jobs-to-housing balance, reduction of vehicle miles traveled (VMT), and other issues that have implications for GHG emission reductions.

State agencies are also tackling the issue of climate change. Some have adopted or support policies and programs that take climate change into account, including the Department of Water Resources' State Water Plan; the Department of Transportation's State Transportation Plan; and the Business, Housing and Transportation Agency's Regional Blueprint Planning Program. These efforts not only raise public awareness of climate change and how the State can reduce GHG emissions, but also offer specific information and resources for lead agencies to consider.

V. NEXT STEPS

OPR has asked ARB technical staff to recommend a method for setting a threshold of significance for GHG emissions. OPR has requested that the ARB identify a range of feasible options, including qualitative and quantitative options.

OPR is actively seeking input from the public and stakeholder groups, as it develops draft CEQA Guidelines for GHG emissions. OPR is engaged with the Resources Agency and other expert state agencies, local governments, builders and developers, environmental organizations, and others with expertise or an interest in the development of the Guidelines.

OPR will conduct public workshops later this year to receive input on the scope and content of the CEQA Guidelines amendments. It is OPR's intent to release a preliminary draft of the CEQA Guidelines amendments for public review and comment in the fall. This will enable OPR to deliver a proposed package of CEQA Guidelines amendments to the Resources Agency as early as January 2009, well before the statutory due date of July 1, 2009.

We encourage public agencies and the public to refer to the OPR website at www.opr.ca.gov for information about the CEQA Guidelines development process and to subscribe to OPR's notification system for announcements and updates.

For more information about this technical advisory and assistance in addressing the impacts of GHG emissions on the environment, please contact:

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ATTACHMENTS

1. References and Information Sources
2. Technical Resources/Modeling Tools to Estimate GHG Emissions
3. Examples of GHG Reduction Measures

Attachment 1

References and Information Sources

The following is a list of websites of organizations that can offer additional information regarding methods to characterize, quantify, assess and reduce GHG emissions. In addition, a list of useful resources and reference materials is provided on the subject of climate change and greenhouse gases.

ORGANIZATIONS

- Governor's Office of Planning and Research
  http://www.opr.ca.gov
- California Climate Action Team
  http://www.climatechange.ca.gov/climate_action_team/
- California Climate Change Portal
  http://www.climatechange.ca.gov
- California Air Resources Board Climate Change Website
  http://www.arb.ca.gov/cc/cc.htm
- California Climate Action Registry
  http://www.climateregistry.org/
- California Department of Water Resources, Climate Change and California Water Plan Website
  http://www.waterplan.water.ca.gov/climate/
- California Energy Commission Climate Change Proceedings
  http://www.energy.ca.gov/global_climate_change/index.html
- California Public Utilities Commission, Climate Change Website
  http://www.cpuc.ca.gov/static/energy/electric/climate+change/_index.htm
- Green California Website
  http://www.green.ca.gov/default.htm
- Western Climate Initiative
  http://www.westernclimateinitiative.org

- California Air Pollution Control Officers Association
  http://www.capcoa.org
- Local Governments for Sustainability (ICLEI)
  http://www.iclei.org/
- ICLEI Cities for Climate Protection (CCP)
  http://www.iclei.org/index.php?id=800
- United Nations Framework Convention on Climate Change
  http://unfccc.int/2860.php
- Intergovernmental Panel on Climate Change
  http://www.ipcc.ch
- United States Environmental Protection Agency
  http://www.epa.gov/climatechange/
- City of Seattle U.S. Mayors Climate Protection Agreement
  http://www.seattle.gov/mayor/climate/
- Mayors for Climate Protection
  http://www..coolmayors.com
- U.S. Conference of Mayors Climate Protection Web Page
  http://usmayors.org/climateprotection
- Institute for Local Government California Climate Action Network
  http://www.ca-ilg.org/climatechange

STATUTES, REGULATIONS, AND EXECUTIVE ORDERS

- SB 97
  http://opr.ca.gov/ceqa/pdfs/SB_97_bill_20070824_chaptered.pdf
- SB 97 Governor's Signing Message
  http://opr.ca.gov/ceqa/pdfs/SB-97-signing-message.pdf
- AB 32
  http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf
- AB 1493
  http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_1451-1500/ab_1493_bill_20020722_chaptered.pdf

- Regulations implementing AB 1493

  http://www.arb.ca.gov/regact/grnhsgas/revfro.pdf and http://www.arb.ca.gov/regact/grnhsgas/revtp.pdf

- SB 1368

  http://www.leginfo.ca.gov/pub/05-06/bill/sen/sb_1351-1400/sb_1368_bill_20060929_chaptered.pdf

- Executive Order S-01-07 regarding low carbon standard for transportation fuels

  http://gov.ca.gov/index.php?/executive-order/5172/

- Executive Order S-20-06 regarding implementation of AB 32

  http://gov.ca.gov/index.php?/executive-order/4484/

- Executive Order S-3-05 regarding greenhouse gas goals

  http://gov.ca.gov/index.php?/executive-order/1861/

- Executive Order S-20-04 regarding energy conservation by state

  http://gov.ca.gov/index.php?/executive-order/3360/

REPORTS

- OPR List of Environmental Documents Addressing Climate Change

  http://opr.ca.gov/ceqa/pdfs/Environmental_Assessment_Climate_Change.pdf

- OPR List of Local Plans Addressing Climate Change

  http://opr.ca.gov/ceqa/pdfs/City_and_County_Plans_Addressing_Climate_Change.pdf

- *Climate Action Team Proposed Early Action Measures to Mitigate Climate Change in California*, April 2007

  http://www.climatechange.ca.gov/climate_action_team/reports/2007-04-20_CAT_REPORT.PDF

- California Air Resources Board, *Early Action Items to Mitigate Climate Change in California*, October 2007

  http://www.arb.ca.gov/cc/ccea/meetings/ea_final_report.pdf

- California Air Resourced Board, *Draft Greenhouse Gas Inventory*, November 2007

  http://www.arb.ca.gov/cc/inventory/data/tables/rpt_Inventory_IPCC_All_2007-11-19.pdf

- *Climate Action Team Report to the Governor and Legislature*, March 2006, http://www.climatechange.ca.gov/climate_action_team/reports/index.html

- California Climate Change Center*, Our Changing Planet: Assessing the Risks to California - Summary Report*

  http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF

  Detailed reports available at: http://www.climatechange.ca.gov/biennial_reports/2006report/index.html
- California Energy Commission, *2007 Integrated Energy Policy Report Update*

  http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF
- California Department of Water Resources, *Progress on Incorporating Climate Change into Management of California's Water Resources*

  http://baydeltaoffice.water.ca.gov/climatechange/DWRClimateChangeJuly06.pdf - pagemode=bookmarks&page=1
- *Climate Action Program at Caltrans*, December 2006

  http://www.dot.ca.gov/docs/ClimateReport.pdf
- California Air Pollution Control Officers Association, *CEQA & Climate Change,* January 2008

  http://www.capcoa.org/ceqa/CAPCOA%20White%20Paper%20-%20CEQA%20and%20Climate%20Change.pdf
- West Coast Governors' Global Warming Initiative, November 2004

  http://www.climatechange.ca.gov/westcoast/documents/2004-11_final_report/2004-11-18_STAFF_RECOMMENDS.PDF
- Western Climate Initiative Work Plan, October 2007

  http://www.westernclimateinitiative.org/ewebeditpro/items/O104F13792.pdf
- California Climate Change Center, University of California at Berkeley, *Managing Greenhouse Gas Emissions in California,* 2007

  http://calclimate.berkeley.edu/managing_GHGs_in_CA.html
- U.S. Conference of Mayors, *Energy & Environment Best Practices*

  http://www.usmayors.org/climateprotection/AtlantaEESummitCDROMVersion.pdf
- *U.S. Mayors Climate Protection Agreement Climate Action Handbook*, 2006

  http://www.seattle.gov/climate/docs/ClimateActionHandbook.pdf
- Natural Capitalism Solutions *Climate Protection Manual for Cities*, June 2007

  http://www.climatemanual.org

- National Governor's Association Center for Best Practices *Growing with Less Greenhouse Gases*, November 2002

  http://www.nga.org/cda/files/112002ghg.pdf

- National Governor's Association Center for Best Practices *State and Regional Greenhouse Gas* Initiatives, October 2006

  http://www.nga.org/Files/pdf/0610GREENHOUSE.PDF

- United States Climate Change Program *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*, May 2008

  http://www.usda.gov/oce/global_change/sap_2007_FinalReport.htm

Attachment 2

Technical Resources/Modeling Tools to Estimate GHG Emissions

TOOL	AVAILABILITY	SCOPE LOCAL/ REGIONAL	SCOPE TRANSPORTATION/ BUILDINGS	DATA INPUT REQUIREMENTS	DATA OUTPUT
URBEMIS	• Download • Public domain (free)	• Local project level	• Transportation • Some building (area source) outputs • Construction	• Land use information • Construction, area source, and transportation assumptions	• CO2 (pounds per day) • Mitigation impacts
Clean Air and Climate Protection (CACP) Software	• Download • Available to public agencies (free)	• Local project level	• Buildings • Communities • Governments	• Energy usage • Waste generation and disposal • Transportation fuel usage or VMT	• CO2e (tons per year)
Sustainable Communities Model (SCM)	• Custom model	• Regional • Scalable to site level	• Transportation • Buildings • Neighborhoods • Master planned communities	• Location and site specific information • Transportation assumptions • On-site energy usage	• CO2e (tons per year)
Internet-accessed Planning for Community Energy, Economic and Environmental Sustainability I-PLACE^{3}S	• Web-based • Small access fee • Full model now available in eight CA counties	• Regional • Scalable to site level	• Transportation • Housing • Land Use • Buildings • Energy • Economics	• Parcel level land use data (ability to work with less data) • Project-level data for alternative comparisons	• CO2 (any quantity over any time)

Climate Action Registry Reporting On-Line Tool (CARROT)	• Web-based
	• Available to Registry members
	• General public can view entity reports
		• Regional, scalable to entity and facility level	• General Reporting and Certification Protocols
			  o Transportation
			  o Buildings/facilities
			• Specific protocols for some sectors
				• Mobile source combustion (VMT or fuel usage)
				• Stationary combustion (fuel usage)
				• Indirect emissions (electricity usage)
					• Each GHG and CO2e (tons per year)

EMFAC	• Download • Public domain (free)	• Statewide • Regional (air basin level)	• Transportation emission factors	• Travel activity data to calculate CO2 from projects.	• CO2 and methane (grams per mile) emission factors

VMT = Vehicle miles traveled
eCO2 = Carbon dioxide equivalent emissions
Note: This is not meant to be a definitive list of modeling tools to estimate climate change emissions impacts. Other tools may be available.

Description of Modeling Tools

URBEMIS

The Urban Emissions Model is used extensively during the CEQA process by local air districts and consultants to determine the impacts of projects on criteria pollutants. It was recently updated to calculate CO2 emissions as well. Future updates will include additional greenhouse gases. URBEMIS uses the ITE Trip Generation Rate Manual and the Air Resources Board's (ARB) motor vehicle emissions model (EMFAC) to calculate transportation-related CO2 emissions and ARB's OFFROAD2007 model for CO2 emissions from off-road equipment. Area source outputs include natural gas use, landscaping equipment, consumer products, architectural coatings, and fireplaces. It also estimates construction impacts and impacts of mitigation options. Web site: http://www.urbemis.com.

Clean Air and Climate Protection (CACP) Software

This tool is available to state and local governments and members of ICLEI, NACAA, NASEO and NARUC to determine greenhouse gas and criteria pollutant emissions from government operations and communities as a whole. The user must input aggregate information about energy (usage), waste (quantity and type generated, disposal method, and methane recovery rate) and transportation (VMT) for community analyses. CACP uses emission factors from EPA, DOE, and DOT to translate the energy, waste and transportation inputs into greenhouse gas (in carbon dioxide equivalents) and criteria air pollutant emissions. If associated energy, waste and transportation reduction are provided, the model can also calculate emission reductions and money saved from policy alternatives. Web site: http://cacpsoftware.org.

Sustainable Communities Model (SCM)

This model quantifies total CO2e emissions allowing communities the ability to optimize planning decisions that result in the greatest environmental benefit for the least cost. Total CO2e emissions are based on emissions from energy usage, water consumption and transportation. The model provides an interactive comparison of various scenarios to provide environmental performance, economic performance, and cost benefit analysis.

Web site: www.ctg-net.com/energetics/documents/doc_SCM_070731.pdf

I-PLACE^{3}S

This model is an internet-accessed land use and transportation model designed specifically for regional and local governments to help understand how their growth and development decisions can contribute to improved sustainability. It estimates CO2, criteria pollutant and energy impacts on a neighborhood or regional level for existing, long-term baseline and alternative land use plans. The data input requirements are extensive and require a fiscal commitment from the Metropolitan Planning Organization and its member local governments. Once the data is available, the IPLACES tool can be developed for that region relatively quickly, in approximately one week. The benefits include a multifunctional tool that provides immediate outputs to compare alternatives during public meetings, multilevel password protected on-line access, as well as providing access for local development project CEQA analyses. This tool also supports regional travel models and integrated land use and transportation assessments. Web site: http://www.sacregionblueprint.org/sacregionblueprint/the_project/technology.cfm and http://www.places.energy.ca.gov/places

CARROT

The California Climate Action Registry offers the Climate Action Registry Reporting On-Line Tool (CARROT) for Registry members to calculate and report annual greenhouse gas (GHG) emissions. CARROT calculates direct and indirect GHG emissions for the following emission categories by source: stationary combustion, process emissions, mobile source combustion, fugitive emissions and electricity use by source. It calculates emissions using entity collected data such as fuel purchase records, VMT and utility bills. While reporting and certification through CARROT is only available to members, the public may access entity reports online. Reporting protocols are also available to the public, including the General Reporting Protocol (www.climateregistry.org/docs/PROTOCOLS/GRP%20V2-March2007_web.pdf) and cement, forestry and power/utility sector protocols. Additional sector protocols are under development. Website: www.climateregistry.org/CARROT/

EMFAC

The Air Resources Board's EMission FACtors (EMFAC) model is used to calculate emission rates from all motor vehicles in California. The emission factors are combined with data on vehicle activity (miles traveled and average speeds) to assess emission impacts. The URBEMIS model described above uses EMFAC to calculate the transportation emission impacts of local projects. Web site: http://www.arb.ca.gov/msei/onroad/onroad.htm

Attachment 3

Examples of GHG Reduction Measures

The following are examples of measures that have been employed by some public agencies to reduce greenhouse gas emissions, either as general development policies or on a project-by-project basis. These are provided for illustrative purposes only.

LAND USE AND TRANSPORTATION

- Implement land use strategies to encourage jobs/housing proximity, promote transit-oriented development, and encourage high density development along transit corridors. Encourage compact, mixed-use projects, forming urban villages designed to maximize affordable housing and encourage walking, bicycling and the use of public transit systems.
- Encourage infill, redevelopment, and higher density development, whether in incorporated or unincorporated settings
- Encourage new developments to integrate housing, civic and retail amenities (jobs, schools, parks, shopping opportunities) to help reduce VMT resulting from discretionary automobile trips.
- Apply advanced technology systems and management strategies to improve operational efficiency of transportation systems and movement of people, goods and services.
- Incorporate features into project design that would accommodate the supply of frequent, reliable and convenient public transit.
- Implement street improvements that are designed to relieve pressure on a region's most congested roadways and intersections.
- Limit idling time for commercial vehicles, including delivery and construction vehicles.

URBAN FORESTRY

- Plant trees and vegetation near structures to shade buildings and reduce energy requirements for heating/cooling.
- Preserve or replace onsite trees (that are removed due to development) as a means of providing carbon storage.

GREEN BUILDINGS

- Encourage public and private construction of LEED (Leadership in Energy and Environmental Design) certified (or equivalent) buildings.

ENERGY CONSERVATION POLICIES AND ACTIONS

- Recognize and promote energy saving measures beyond Title 24 requirements for residential and commercial projects
- Where feasible, include in new buildings facilities to support the use of low/zero carbon fueled vehicles, such as the charging of electric vehicles from green electricity sources.
- Educate the public, schools, other jurisdictions, professional associations, business and industry about reducing GHG emissions.
- Replace traffic lights, street lights, and other electrical uses to energy efficient bulbs and appliances.
- Purchase Energy Star equipment and appliances for public agency use.
- Incorporate on-site renewable energy production, including installation of photovoltaic cells or other solar options.
- Execute an Energy Savings Performance Contract with a private entity to retrofit public buildings. This type of contract allows the private entity to fund all energy improvements in exchange for a share of the energy savings over a period of time.
- Design, build, and operate schools that meet the Collaborative for High Performance Schools (CHPS) best practices.
- Retrofit municipal water and wastewater systems with energy efficient motors, pumps and other equipment, and recover wastewater treatment methane for energy production.
- Convert landfill gas into energy sources for use in fueling vehicles, operating equipment, and heating buildings.
- Purchase government vehicles and buses that use alternatives fuels or technology, such as electric hybrids, biodiesel, and ethanol. Where feasible, require fleet vehicles to be low emission vehicles. Promote the use of these vehicles in the general community.
- Offer government incentives to private businesses for developing buildings with energy and water efficient features and recycled materials. The incentives can include expedited plan checks and reduced permit fees.
- Offer rebates and low-interest loans to residents that make energy-saving improvements on their homes.

- Create bicycle lanes and walking paths directed to the location of schools, parks and other destination points.

PROGRAMS TO REDUCE VEHICLE MILES TRAVELED

- Offer government employees financial incentives to carpool, use public transportation, or use other modes of travel for daily commutes.
- Encourage large businesses to develop commute trip reduction plans that encourage employees who commute alone to consider alternative transportation modes.
- Develop shuttle systems around business district parking garages to reduce congestion and create shorter commutes.
- Create an online ridesharing program that matches potential carpoolers immediately through email.
- Develop a Safe Routes to School program that allows and promotes bicycling and walking to school.

PROGRAMS TO REDUCE SOLID WASTE

- Create incentives to increase recycling and reduce generation of solid waste by residential users.
- Implement a Construction and Demolition Waste Recycling Ordinance to reduce the solid waste created by new development.
- Add residential/commercial food waste collection to existing greenwaste collection programs.

CEQA GUIDELINES

SECTIONS PROPOSED TO BE ADDED OR AMENDED

PROPOSED AMENDMENTS TO 14 SECTIONS

OF THE CEQA GUIDELINES

ARE INDICATED BY REDLINE/STRIKEOUT TEXT

OPR proposes that the Resources Agency amend or add the following fourteen (14) sections of the State CEQA Guidelines. The complete text of each section is provided below with strikeouts to indicate deletions and underlines to indicate additions.

15064. Determining the Significance of the Environmental Effects Caused by a Project

(a) Determining whether a project may have a significant effect plays a critical role in the CEQA process.

(1) If there is substantial evidence, in light of the whole record before a lead agency, that a project may have a significant effect on the environment, the agency shall prepare a draft EIR.

(2) When a final EIR identifies one or more significant effects, the Lead Agency and each Responsible Agency shall make a finding under Section 15091 for each significant effect and may need to make a statement of overriding considerations under Section 15093 for the project.

(b) The determination of whether a project may have a significant effect on the environment calls for careful judgment on the part of the public agency involved, based to the extent possible on scientific and factual data. An ironclad definition of significant effect is not always possible because the significance of an activity may vary with the setting. For example, an activity which may not be significant in an urban area may be significant in a rural area.

(c) In determining whether an effect will be adverse or beneficial, the Lead Agency shall consider the views held by members of the public in all areas affected as expressed in the whole record before the lead agency. Before requiring the preparation of an EIR, the Lead Agency must still determine whether environmental change itself might be substantial.

(d) In evaluating the significance of the environmental effect of a project, the Lead Agency shall consider direct physical changes in the environment which may be caused by the project and reasonably foreseeable indirect physical changes in the environment which may be caused by the project.

(1) A direct physical change in the environment is a physical change in the environment which is caused by and immediately related to the project. Examples of direct physical changes in the environment are the dust, noise, and traffic of heavy equipment that would result from construction of a sewage treatment plant and possible odors from operation of the plant.

(2) An indirect physical change in the environment is a physical change in the environment which is not immediately related to the project, but which is caused indirectly by the project. If a direct physical change in the environment in turn causes another change in the environment, then the other change is an indirect physical change in the environment. For example, the construction of a new sewage treatment plant may facilitate population growth in the service area due to the increase in sewage treatment capacity and may lead to an increase in air pollution.

(3) An indirect physical change is to be considered only if that change is a reasonably foreseeable impact which may be caused by the project. A change which is speculative or unlikely to occur is not reasonably foreseeable.

(e) Economic and social changes resulting from a project shall not be treated as significant effects on the environment. Economic or social changes may be used, however, to determine that a physical change shall be regarded as a significant effect on the environment. Where a physical change is caused by economic or social effects of a project, the physical change may be regarded as a significant effect in the same manner as any other physical change resulting from the project. Alternatively, economic and social effects of a physical change may be used to determine that the physical change is a significant effect on the environment. If the physical change causes adverse economic or social effects on people, those adverse effects may be used as a factor in determining whether the physical change is significant. For example, if a project would cause overcrowding of a public facility and the overcrowding causes an adverse effect on people, the overcrowding would be regarded as a significant effect.

(f) The decision as to whether a project may have one or more significant effects shall be based on substantial evidence in the record of the lead agency.

(1) If the lead agency determines there is substantial evidence in the record that the project may have a significant effect on the environment, the lead agency shall prepare an EIR (Friends of B Street v. City of Hayward (1980) 106 Cal.App.3d 988). Said another way, if a lead agency is presented with a fair argument that a project may have a significant effect on the environment, the lead agency shall prepare an EIR even though it may also be presented with other substantial evidence that the project will not have a significant effect (No Oil, Inc. v. City of Los Angeles (1974) 13 Cal.3d 68).

(2) If the lead agency determines there is substantial evidence in the record that the project may have a significant effect on the environment but the lead agency determines that revisions in the project plans or proposals made by, or agreed to by, the applicant would avoid the effects or mitigate the effects to a point where clearly no significant effect on the environment would occur and there is no substantial evidence in light of the whole record before the public agency that the project, as revised, may have a significant effect on the environment then a mitigated negative declaration shall be prepared.

(3) If the lead agency determines there is no substantial evidence that the project may have a significant effect on the environment, the lead agency shall prepare a negative declaration (Friends of B Street v. City of Hayward (1980) 106 Cal.App. 3d 988).

(4) The existence of public controversy over the environmental effects of a project will not require preparation of an EIR if there is no substantial evidence before the agency that the project may have a significant effect on the environment.

(5) Argument, speculation, unsubstantiated opinion or narrative, or evidence that is clearly inaccurate or erroneous, or evidence that is not credible, shall not constitute substantial evidence.

Substantial evidence shall include facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts.

(6) Evidence of economic and social impacts that do not contribute to or are not caused by physical changes in the environment is not substantial evidence that the project may have a significant effect on the environment.

(7) The provisions of sections 15162, 15163, and 15164 apply when the project being analyzed is a change to, or further approval for, a project for which an EIR or negative declaration was previously certified or adopted (e.g. a tentative subdivision, conditional use permit). Under case law, the fair argument standard does not apply to determinations of significance pursuant to sections 15162, 15163, and 15164.

(g) After application of the principles set forth above in Section 15064(f)(g), and in marginal cases where it is not clear whether there is substantial evidence that a project may have a significant effect on the environment, the lead agency shall be guided by the following principle: If there is disagreement among expert opinion supported by facts over the significance of an effect on the environment, the Lead Agency shall treat the effect as significant and shall prepare an EIR.

(h)(1) When assessing whether a cumulative effect requires an EIR, the lead agency shall consider whether the cumulative impact is significant and whether the effects of the project are cumulatively considerable. An EIR must be prepared if the cumulative impact may be significant and the project's incremental effect, though individually limited, is cumulatively considerable. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.

(2) A lead agency may determine in an initial study that a project's contribution to a significant cumulative impact will be rendered less than cumulatively considerable and thus is not significant. When a project might contribute to a significant cumulative impact, but the contribution will be rendered less than cumulatively considerable through mitigation measures set forth in a mitigated negative declaration, the initial study shall briefly indicate and explain how the contribution has been rendered less than cumulatively considerable.

(3) A lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable if the project will comply with the requirements in a previously approved plan or mitigation program (including, but not limited to, water quality control plan, air quality attainment or maintenance plan, integrated waste management plan, habitat conservation plan, natural community conservation plan, plans or regulations for the reduction of greenhouse gas emissions) which provides specific requirements that will avoid or substantially lessen the cumulative problem ~~(e.g., water quality control plan, air quality attainment or maintenance plan, integrated waste management plan)~~ within the geographic area in which the project is located. Such plans or programs must be specified in law or adopted by the public agency with jurisdiction over the affected resources through a public review process to implement, interpret, or make specific the law enforced or administered by the public agency. When relying on a plan

or program, the lead agency should explain how the particular requirements in the plan or program ensure that the project's incremental contribution to the cumulative effect is not cumulatively considerable. If there is substantial evidence that the possible effects of a particular project are still cumulatively considerable notwithstanding that the project complies with the specified plan or mitigation program addressing the cumulative problem, an EIR must be prepared for the project.

(4) The mere existence of significant cumulative impacts caused by other projects alone shall not constitute substantial evidence that the proposed project's incremental effects are cumulatively considerable.

Note: Authority cited: Section 21083, Public Resources Code. Reference: Sections 21003, 21065, 21068, 21080, 21082, 21082.1, 21082.2, 21083 and 21100, Public Resources Code; No Oil, Inc. v. City of Los Angeles (1974) 13 Cal.3d 68; San Joaquin Raptor/Wildlife Center v. County of Stanislaus (1996) 42 Cal.App.4th 608; Gentry v. City of Murrieta (1995) 36 Cal.App.4th 1359; Laurel Heights Improvement Assn. v. Regents of the University of California (1993) 6 Cal.4th 1112; and Communities for a Better Environment v. California Resources Agency (2002) 103 Cal.App.4th 98.

15064.4. Determining the Significance of Impacts from Greenhouse Gas Emissions

(a) The determination of the significance of greenhouse gas emissions calls for a careful judgment by the lead agency consistent with the provisions in section 15064. A lead agency should make a good-faith effort, based on available information, to describe, calculate or estimate the amount of greenhouse gas emissions resulting from a project. A lead agency shall have discretion to determine, in the context of a particular project, whether to:

(1) Use a model or methodology to quantify greenhouse gas emissions resulting from a project, and which model or methodology to use. The lead agency has discretion to select the model it considers most appropriate provided it supports its decision with substantial evidence. The lead agency should explain the limitations of the particular model or methodology selected for use; or

(2) Rely on a qualitative analysis or performance based standards.

(b) A lead agency may consider the following when assessing the significance of impacts from greenhouse gas emissions on the environment:

(1) The extent to which the project may increase or reduce greenhouse gas emissions as compared to the existing environmental setting;

(2) Whether the project emissions exceed a threshold of significance that the lead agency determines applies to the project.

(3) The extent to which the project complies with regulations or requirements adopted to implement a statewide, regional, or local plan for the reduction or mitigation of greenhouse gas emissions. Such regulations or requirements must be adopted by the relevant public agency

through a public review process and must include specific requirements that reduce or mitigate the project's incremental contribution of greenhouse gas emissions. If there is substantial evidence that the possible effects of a particular project are still cumulatively considerable notwithstanding compliance with the adopted regulations or requirements, an EIR must be prepared for the project.

15064.7. Thresholds of Significance

(a) Each public agency is encouraged to develop and publish thresholds of significance that the agency uses in the determination of the significance of environmental effects. A threshold of significance is an identifiable quantitative, qualitative or performance level of a particular environmental effect, non-compliance with which means the effect will normally be determined to be significant by the agency and compliance with which means the effect normally will be determined to be less than significant.

(b) Thresholds of significance to be adopted for general use as part of the lead agency's environmental review process must be adopted by ordinance, resolution, rule, or regulation, and developed through a public review process and be supported by substantial evidence.

(c) When adopting thresholds of significance, a lead agency may consider thresholds of significance previously adopted or recommended by other public agencies, or recommended by experts, provided the decision of the lead agency to adopt such thresholds is supported by substantial evidence.

Note: Authority: Section 21083, Public Resources Code. Reference: Sections 21082 and 21083, Public Resources Code.

15065. Mandatory Findings of Significance

(a) A lead agency shall find that a project may have a significant effect on the environment and thereby require an EIR to be prepared for the project where there is substantial evidence, in light of the whole record, that any of the following conditions may occur:

(1) The project has the potential to: substantially degrade the quality of the environment; substantially reduce the habitat of a fish or wildlife species; cause a fish or wildlife population to drop below self-sustaining levels; threaten to eliminate a plant or animal community; substantially reduce the number or restrict the range of an endangered, rare or threatened species; or eliminate important examples of the major periods of California history or prehistory.

(2) The project has the potential to achieve short-term environmental goals to the disadvantage of long-term environmental goals.

(3) The project has possible environmental effects that are individually limited but cumulatively considerable. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.

(4) The environmental effects of a project will cause substantial adverse effects on human beings, either directly or indirectly.

(b)(1) Where, prior to the commencement of ~~preliminary~~ public review of an environmental document, a project proponent agrees to mitigation measures or project modifications that would avoid any significant effect on the environment specified by subdivision (a) or would mitigate the significant effect to a point where clearly no significant effect on the environment would occur, a lead agency need not prepare an environmental impact report solely because, without mitigation, the environmental effects at issue would have been significant.

(2) Furthermore, where a proposed project has the potential to substantially reduce the number or restrict the range of an endangered, rare or threatened species, the lead agency need not prepare an EIR solely because of such an effect, if:

(A) the project proponent is bound to implement mitigation requirements relating to such species and habitat pursuant to an approved habitat conservation plan or natural community conservation plan;

(B) the state or federal agency approved the habitat conservation plan or natural community conservation plan in reliance on an environmental impact report or environmental impact statement; and

(C) 1. such requirements avoid any net loss of habitat and net reduction in number of the affected species, or

2. such requirements preserve, restore, or enhance sufficient habitat to mitigate the reduction in habitat and number of the affected species to below a level of significance.

(c) Following the decision to prepare an EIR, if a lead agency determines that any of the conditions specified by subdivision (a) will occur, such a determination shall apply to:

(1) the identification of effects to be analyzed in depth in the environmental impact report or the functional equivalent thereof,

(2) the requirement to make detailed findings on the feasibility of alternatives or mitigation measures to substantially lessen or avoid the significant effects on the environment,

(3) when found to be feasible, the making of changes in the project to substantially lessen or avoid the significant effects on the environment, and

(4) where necessary, the requirement to adopt a statement of overriding considerations.

Note: Authority cited: Section 21083, Public Resources Code. Reference: Sections 21001(c), 21082.2, and 21083, Public Resources Code; San Joaquin Raptor/Wildlife Center v. County of Stanislaus (1996) 42 Cal.App.4th 608; Los Angeles Unified School District v. City of Los

Angeles (1997) 58 Cal.App.4th 1019, 1024; and Communities for a Better Environment v. California Resources Agency (2002) 103 Cal.App.4th 98.

15086. Consultation Concerning Draft EIR

(a) The Lead Agency shall consult with and request comments on the draft EIR from:

(1) Responsible Agencies,

(2) Trustee agencies with resources affected by the project, and

(3) Any other state, federal, and local agencies which have jurisdiction by law with respect to the project or which exercise authority over resources which may be affected by the project, including water agencies consulted pursuant to section 15083.5.

(4) Any city or county which borders on a city or county within which the project is located.

(5) For a project of statewide, regional, or areawide significance, the transportation planning agencies and public agencies which have transportation facilities within their jurisdictions which could be affected by the project. "Transportation facilities" includes: major local arterials and public transit within five miles of the project site, and freeways, highways and rail transit service within 10 miles of the project site.

(6) For a state lead agency when the EIR is being prepared for a highway or freeway project, the ~~State~~ California Air Resources Board as to the air pollution impact of the potential vehicular use of the highway or freeway and if a non-attainment area, the local air quality management district for a determination of conformity with the air quality management plan.

(7) For a subdivision project located within one mile of a facility of the State Water Resources Development System, the California Department of Water Resources.

(b) The lead agency may consult directly with:

(1) Any person who has special expertise with respect to any environmental impact involved.

(2) Any member of the public who has filed a written request for notice with the lead agency or the clerk of the governing body.

(3) Any person identified by the applicant whom the applicant believes will be concerned with the environmental effects of the project.

(c) A responsible agency or other public agency shall only make substantive comments regarding those activities involved in the project that are within an area of expertise of the agency or which are required to be carried out or approved by the responsible agency. Those comments shall be supported by specific documentation.

(d) Prior to the close of the public review period, a responsible agency or trustee agency which has identified what that agency considers to be significant environmental effects shall advise the lead agency of those effects. As to those effects relevant to its decision, if any, on the project, the responsible or trustee agency shall either submit to the lead agency complete and detailed performance objectives for mitigation measures addressing those effects or refer the lead agency to appropriate, readily available guidelines or reference documents concerning mitigation measures. If the responsible or trustee agency is not aware of mitigation measures that address identified effects, the responsible or trustee agency shall so state.

Note: Authority cited: Section 21083, Public Resources Code; Reference: Sections 21081.6, 21092.4, 21092.5, 21104 and 21153, Public Resources Code.

15093. Statement of Overriding Considerations

(a) CEQA requires the decision-making agency to balance, as applicable, the economic, legal, social, technological, or other benefits of a proposed project against its unavoidable environmental risks when determining whether to approve the project. If the specific economic, legal, social, technological, or other benefits of a proposed project outweigh the unavoidable adverse environmental effects, the adverse environmental effects may be considered "acceptable."

(b) When the lead agency approves a project which will result in the occurrence of significant effects which are identified in the final EIR but are not avoided or substantially lessened, the agency shall state in writing the specific reasons to support its action based on the final EIR and/or other information in the record. The statement of overriding considerations shall be supported by substantial evidence in the record.

(c) If an agency makes a statement of overriding considerations, the statement should be included in the record of the project approval and should be mentioned in the notice of determination. This statement does not substitute for, and shall be in addition to, findings required pursuant to Section 15091.

(d) When an agency makes a statement of overriding considerations, the agency may consider adverse environmental effects in the context of region-wide or statewide environmental benefits.

Note: Authority cited: Section 21083, Public Resources Code; Reference: Sections 21002 and 21081, Public Resources Code; San Francisco Ecology Center v. City and County of San Francisco (1975) 48 Cal.App.3d 584; City of Carmel-by-the-Sea v. Board of Supervisors (1977) 71 Cal.App.3d 84; Sierra Club v. Contra Costa County (1992) 10 Cal.App.4th 1212; Citizens for Quality Growth v. City of Mount Shasta (1988) 198 Cal.App.3d 433.

15125. Environmental Setting

(a) An EIR must include a description of the physical environmental conditions in the vicinity of the project, as they exist at the time the notice of preparation is published, or if no notice of preparation is published, at the time environmental analysis is commenced, from both a local and regional perspective. This environmental setting will normally constitute the baseline physical conditions by which a lead agency determines whether an impact is significant. The description of the environmental setting shall be no longer than is necessary to an understanding of the significant effects of the proposed project and its alternatives.

(b) When preparing an EIR for a plan for the reuse of a military base, lead agencies should refer to the special application of the principle of baseline conditions for determining significant impacts contained in Section 15229.

(c) Knowledge of the regional setting is critical to the assessment of environmental impacts. Special emphasis should be placed on environmental resources that are rare or unique to that region and would be affected by the project. The EIR must demonstrate that the significant environmental impacts of the proposed project were adequately investigated and discussed and it must permit the significant effects of the project to be considered in the full environmental context.

(d) The EIR shall discuss any inconsistencies between the proposed project and applicable general plans, specific plans and regional plans. Such regional plans include, but are not limited to, the applicable air quality attainment or maintenance plan or State Implementation Plan, area-wide waste treatment and water quality control plans, regional transportation plans, regional housing allocation plans, regional blueprint plans, greenhouse gas reduction plans, habitat conservation plans, natural community conservation plans and regional land use plans for the protection of the Coastal Zone, Lake Tahoe Basin, San Francisco Bay, and Santa Monica Mountains.

(e) Where a proposed project is compared with an adopted plan, the analysis shall examine the existing physical conditions at the time the notice of preparation is published, or if no notice of preparation is published, at the time environmental analysis is commenced as well as the potential future conditions discussed in the plan.

Note: Authority cited: Section 21083, Public Resources Code; Reference: Sections 21061 and 21100, Public Resources Code; E.P.I.C. v. County of El Dorado (1982) 131 Cal.App.3d 350; San Joaquin Raptor/Wildlife Rescue Center v. County of Stanislaus (1994) 27 Cal.App.4th 713; Bloom v. McGurk (1994) 26 Cal.App.4th 1307.

15126.2. Consideration and Discussion of Significant Environmental Impacts.

(a) The Significant Environmental Effects of the Proposed Project. An EIR shall identify and focus on the significant environmental effects of the proposed project. In assessing the impact of a proposed project on the environment, the lead agency should normally limit its examination to changes in the existing physical conditions in the affected area as they exist at the time the notice of preparation is published, or where no notice of preparation is published, at the time environmental analysis is commenced. Direct and indirect significant effects of the project on the environment shall be clearly identified and described, giving due consideration to both the short-term and long-term effects. The discussion should include relevant specifics of the area, the resources involved, physical changes, alterations to ecological systems, and changes induced in population distribution, population concentration, the human use of the land (including commercial and residential development), health and safety problems caused by the physical changes, and other aspects of the resource base such as water, historical resources, scenic quality, and public services. The EIR shall also analyze any significant environmental effects the project might cause by bringing development and people into the area affected. For example, an EIR on a subdivision astride an active fault line should identify as a significant effect the seismic hazard to future occupants of the subdivision. The subdivision would have the effect of attracting people to the location and exposing them to the hazards found there.

(b) Significant Environmental Effects Which Cannot be Avoided if the Proposed Project is Implemented. Describe any significant impacts, including those which can be mitigated but not reduced to a level of insignificance. Where there are impacts that cannot be alleviated without imposing an alternative design, their implications and the reasons why the project is being proposed, notwithstanding their effect, should be described.

(c) Significant Irreversible Environmental Changes Which Would be Caused by the Proposed Project Should it be Implemented. Uses of nonrenewable resources during the initial and continued phases of the project may be irreversible since a large commitment of such resources makes removal or nonuse thereafter unlikely. Primary impacts and, particularly, secondary impacts (such as highway improvement which provides access to a previously inaccessible area) generally commit future generations to similar uses. Also irreversible damage can result from environmental accidents associated with the project. Irretrievable commitments of resources should be evaluated to assure that such current consumption is justified. (See Public Resources Code section 21100.1 and Title 14, California Code of Regulations, section 15127 for limitations to applicability of this requirement.)

(d) Growth-Inducing Impact of the Proposed Project. Discuss the ways in which the proposed project could foster economic or population growth, or the construction of additional housing, either directly or indirectly, in the surrounding environment. Included in this are projects which would remove obstacles to population growth (a major expansion of a waste water treatment plant might, for example, allow for more construction in service areas). Increases in the population may tax existing community service facilities, requiring construction of new facilities that could cause significant environmental effects. Also discuss the characteristic of some projects which may encourage and facilitate other activities that could significantly affect the environment, either individually or cumulatively. It must not be assumed that growth in any area is necessarily beneficial, detrimental, or of little significance to the environment.

Note: Authority cited: Section 21083, Public Resources Code. Reference: Sections 21002, 21003, and 21100, Public Resources Code; Citizens of Goleta Valley v. Board of Supervisors, (1990) 52 Cal.3d 553; Laurel Heights Improvement Association v. Regents of the University of California, (1988) 47 Cal.3d 376; Gentry v. City of Murrieta (1995) 36 Cal.App.4th 1359; and Laurel Heights Improvement Association v. Regents of the University of California (1993) 6 Cal.4th 1112; Goleta Union School Dist. v. Regents of the Univ. Of Calif (1995) 37 Cal. App.4th 1025.

15126.4. Consideration and Discussion of Mitigation Measures Proposed to Minimize Significant Effects.

(a) Mitigation Measures in General.

(1) An EIR shall describe feasible measures which could minimize significant adverse impacts, including where relevant, inefficient and unnecessary consumption of energy.

(A) The discussion of mitigation measures shall distinguish between the measures which are proposed by project proponents to be included in the project and other measures proposed by the lead, responsible or trustee agency or other persons which are not included but the lead agency determines could reasonably be expected to reduce adverse impacts if required as conditions of approving the project. This discussion shall identify mitigation measures for each significant environmental effect identified in the EIR.

(B) Where several measures are available to mitigate an impact, each should be discussed and the basis for selecting a particular measure should be identified. Formulation of mitigation measures should not be deferred until some future time. However, measures may specify performance standards which would mitigate the significant effect of the project and which may be accomplished in more than one specified way.

(C) Energy conservation measures, as well as other appropriate mitigation measures, shall be discussed when relevant. Examples of energy conservation measures are provided in Appendix F.

(D) If a mitigation measure would cause one or more significant effects in addition to those that would be caused by the project as proposed, the effects of the mitigation measure shall be discussed but in less detail than the significant effects of the project as proposed. (Stevens v. City of Glendale(1981) 125 Cal.App.3d 986.)

(2) Mitigation measures must be fully enforceable through permit conditions, agreements, or other legally-binding instruments. In the case of the adoption of a plan, policy, regulation, or other public project, mitigation measures can be incorporated into the plan, policy, regulation, or project design.

(3) Mitigation measures are not required for effects which are not found to be significant.

(4) Mitigation measures must be consistent with all applicable constitutional requirements, including the following:

(A) There must be an essential nexus (i.e. connection) between the mitigation measure and a legitimate governmental interest. (Nollan v. California Coastal Commission, 483 U.S. 825 (1987)); and

(B) The mitigation measure must be "roughly proportional" to the impacts of the project. Dolan v. City of Tigard, 512 U.S. 374 (1994). Where the mitigation measure is an ad hoc exaction, it must be "roughly proportional" to the impacts of the project. (Ehrlich v. City of Culver City (1996) 12 Cal.4th 854).

(5) If the lead agency determines that a mitigation measure cannot be legally imposed, the measure need not be proposed or analyzed. Instead, the EIR may simply reference that fact and briefly explain the reasons underlying the lead agency's determination.

(b) Mitigation Measures Related to Impacts on Historical Resources.

(1) Where maintenance, repair, stabilization, rehabilitation, restoration, preservation, conservation or reconstruction of the historical resource will be conducted in a manner consistent with the Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Buildings (1995), Weeks and Grimmer, the project's impact on the historical resource shall generally be considered mitigated below a level of significance and thus is not significant.

(2) In some circumstances, documentation of an historical resource, by way of historic narrative, photographs or architectural drawings, as mitigation for the effects of demolition of the resource will not mitigate the effects to a point where clearly no significant effect on the environment would occur.

(3) Public agencies should, whenever feasible, seek to avoid damaging effects on any historical resource of an archaeological nature. The following factors shall be considered and discussed in an EIR for a project involving such an archaeological site:

(A) Preservation in place is the preferred manner of mitigating impacts to archaeological sites. Preservation in place maintains the relationship between artifacts and the archaeological context. Preservation may also avoid conflict with religious or cultural values of groups associated with the site.

(B) Preservation in place may be accomplished by, but is not limited to, the following:

1. Planning construction to avoid archaeological sites;

2. Incorporation of sites within parks, greenspace, or other open space;

3. Covering the archaeological sites with a layer of chemically stable soil before building tennis courts, parking lots, or similar facilities on the site.

4. Deeding the site into a permanent conservation easement.

(C) When data recovery through excavation is the only feasible mitigation, a data recovery plan, which makes provisions for adequately recovering the scientifically consequential information from and about the historical resource, shall be prepared and adopted prior to any excavation being undertaken. Such studies shall be deposited with the California Historical Resources Regional Information Center. Archeological sites known to contain human remains shall be treated in accordance with the provisions of Section 7050.5 Health and Safety Code. If an artifact must be removed during project excavation or testing, curation may be an appropriate mitigation.

(D) Data recovery shall not be required for an historical resource if the lead agency determines that testing or studies already completed have adequately recovered the scientifically consequential information from and about the archaeological or historical resource, provided that the determination is documented in the EIR and that the studies are deposited with the California Historical Resources Regional Information Center.

(c) Mitigation Measures Related to Greenhouse Gas Emissions.

Consistent with section 15126.4(a), lead agencies shall consider feasible means of mitigating greenhouse gas emissions that may include, but not be limited to:

(1) Measures in an existing plan or mitigation program for the reduction of emissions that are required as part of the lead agency's decision;

(2) Reductions in emissions resulting from a project through implementation of project features, project design, or other measures, such as those described in Appendix F;

(3) Off-site measures, including offsets, to mitigate a project's emissions;

(4) Measures that sequester greenhouse gases; and

(5) In the case of the adoption of a plan, such as a general plan, long range development plan, or greenhouse gas reduction plan, mitigation may include the identification of specific measures that may be implemented on a project-by-project basis. Mitigation may also include the incorporation of specific measures or policies found in an adopted ordinance or regulation that reduces the cumulative effect of emissions.

Note: Authority: Section 21083, Public Resources Code. Reference: Sections 5020.5, 21002, 21003, 21100 and 21084.1, Public Resources Code; Citizens of Goleta Valley v. Board of Supervisors (1990) 52 Cal.3d 553; Laurel Heights Improvement Association v. Regents of the University of California (1988) 47 Cal.3d 376; Gentry v. City of Murrieta (1995) 36 Cal.App.4th 1359; Laurel Heights Improvement Association v. Regents of the University of California (1993) 6 Cal.4th 1112; and Sacramento Old City Assn. v. City Council of Sacramento (1991) 229 Cal.App.3d 1011.

15130. Discussion of Cumulative Impacts

(a) An EIR shall discuss cumulative impacts of a project when the project's incremental effect is cumulatively considerable, as defined in section 15065(a)(3). Where a lead agency is examining a project with an incremental effect that is not "cumulatively considerable," a lead agency need not consider that effect significant, but shall briefly describe its basis for concluding that the incremental effect is not cumulatively considerable.

(1) As defined in Section 15355, a cumulative impact consists of an impact which is created as a result of the combination of the project evaluated in the EIR together with other projects causing related impacts. An EIR should not discuss impacts which do not result in part from the project evaluated in the EIR.

(2) When the combined cumulative impact associated with the project's incremental effect and the effects of other projects is not significant, the EIR shall briefly indicate why the cumulative impact is not significant and is not discussed in further detail in the EIR. A lead agency shall identify facts and analysis supporting the lead agency's conclusion that the cumulative impact is less than significant.

(3) An EIR may determine that a project's contribution to a significant cumulative impact will be rendered less than cumulatively considerable and thus is not significant. A project's contribution is less than cumulatively considerable if the project is required to implement or fund its fair share of a mitigation measure or measures designed to alleviate the cumulative impact. The lead agency shall identify facts and analysis supporting its conclusion that the contribution will be rendered less than cumulatively considerable.

(b) The discussion of cumulative impacts shall reflect the severity of the impacts and their likelihood of occurrence, but the discussion need not provide as great detail as is provided for the effects attributable to the project alone. The discussion should be guided by standards of practicality and reasonableness, and should focus on the cumulative impact to which the identified other projects contribute rather than the attributes of other projects which do not contribute to the cumulative impact. The following elements are necessary to an adequate discussion of significant cumulative impacts:

(1) Either:

(A) A list of past, present, and probable future projects producing related or cumulative impacts, including, if necessary, those projects outside the control of the agency, or

(B) A summary of projections contained in an adopted ~~general plan or related planning document, or in a prior environmental document which has been adopted or certified, which described or evaluated regional or areawide conditions contributing to the cumulative impact~~ local, regional or statewide plan, or related planning document, that describes or evaluates conditions contributing to the cumulative effect. Such plans may include: a general plan, regional transportation plan, or greenhouse gas reduction plan. A summary of projections may also be contained in an adopted or certified prior environmental document for such a plan. Such projections may be supplemented with additional information such as a regional modeling program. Any such ~~planning~~ document shall be referenced and made available to the public at a location specified by the lead agency.

(2) When utilizing a list, as suggested in paragraph (1) of subdivision (b), factors to consider when determining whether to include a related project should include the nature of each environmental resource being examined, the location of the project and its type. Location may be important, for example, when water quality impacts are at issue since projects outside the

watershed would probably not contribute to a cumulative effect. Project type may be important, for example, when the impact is specialized, such as a particular air pollutant or mode of traffic.

(3) Lead agencies should define the geographic scope of the area affected by the cumulative effect and provide a reasonable explanation for the geographic limitation used.

(4) A summary of the expected environmental effects to be produced by those projects with specific reference to additional information stating where that information is available; and

(5) A reasonable analysis of the cumulative impacts of the relevant projects. An EIR shall examine reasonable, feasible options for mitigating or avoiding the project's contribution to any significant cumulative effects.

(c) With some projects, the only feasible mitigation for cumulative impacts may involve the adoption of ordinances or regulations rather than the imposition of conditions on a project-by-project basis.

(d) Previously approved land use documents including, but not limited to, general plans, specific plans, regional transportation plans, greenhouse gas reduction plans, and local coastal plans may be used in cumulative impact analysis. A pertinent discussion of cumulative impacts contained in one or more previously certified EIRs may be incorporated by reference pursuant to the provisions for tiering and program EIRs. No further cumulative impacts analysis is required when a project is consistent with a general, specific, master or comparable programmatic plan where the lead agency determines that the regional or areawide cumulative impacts of the proposed project have already been adequately addressed, as defined in section 15152(f), in a certified EIR for that plan.

(e) If a cumulative impact was adequately addressed in a prior EIR for a community plan, zoning action, or general plan, and the project is consistent with that plan or action, then an EIR for such a project should not further analyze that cumulative impact, as provided in Section 15183(j).

(f) An EIR shall analyze greenhouse gas emissions resulting from a proposed project when the incremental contribution of those emissions may be cumulatively considerable.

Note: Authority cited: Section 21083, Public Resources Code. Reference: Sections 21083(b), 21093, 21094 and 21100, Public Resources Code; Whitman v. Board of Supervisors, (1979) 88 Cal. App. 3d 397; San Franciscans for Reasonable Growth v. City and County of San Francisco (1984) 151 Cal.App.3d 61; Kings County Farm Bureau v. City of Hanford (1990) 221 Cal.App.3d 692; Laurel Heights Homeowners Association v. Regents of the University of California (1988) 47 Cal.3d 376; Sierra Club v. Gilroy (1990) 220 Cal.App.3d 30; Citizens to Preserve the Ojai v. County of Ventura (1985) 176 Cal.App.3d 421; Concerned Citizens of South Cent. Los Angeles v. Los Angeles Unified Sch. Dist. (1994) 24 Cal.App.4th 826; Las Virgenes Homeowners Fed'n v. County of Los Angeles (1986) 177 Cal.App.3d 300; San Joaquin Raptor/Wildlife Rescue Ctr v. County of Stanislaus (1994) 27 Cal.App.4th 713; Fort Mojave Indian Tribe v. Cal. Dept. Of Health Services (1995) 38 Cal.App.4th 1574; and Communities for a Better Environment v. California Resources Agency (2002) 103 Cal.App.4th 98.

15150. Incorporation by Reference

(a) An EIR or Negative Declaration may incorporate by reference all or portions of another document which is a matter of public record or is generally available to the public. Where all or part of another document is incorporated by reference, the incorporated language shall be considered to be set forth in full as part of the text of the EIR or Negative Declaration.

(b) Where part of another document is incorporated by reference, such other document shall be made available to the public for inspection at a public place or public building. The EIR or Negative Declaration shall state where the incorporated documents will be available for inspection. At a minimum, the incorporated document shall be made available to the public in an office of the Lead Agency in the county where the project would be carried out or in one or more public buildings such as county offices or public libraries if the Lead Agency does not have an office in the county.

(c) Where an EIR or Negative Declaration uses incorporation by reference, the incorporated part of the referenced document shall be briefly summarized where possible or briefly described if the data or information cannot be summarized. The relationship between the incorporated part of the referenced document and the EIR shall be described.

(d) Where an agency incorporates information from an EIR that has previously been reviewed through the state review system, the state identification number of the incorporated document should be included in the summary or designation described in subdivision (c).

(e) Examples of materials that may be incorporated by reference include but are not limited to:

(1) A description of the environmental setting from another EIR.

(2) A description of the air pollution problems prepared by an air pollution control agency concerning a process involved in the project.

(3) A description of the city or county general plan that applies to the location of the project.

(4) A description of the effects of greenhouse gas emissions on the environment.

(f) Incorporation by reference is most appropriate for including long, descriptive, or technical materials that provide general background but do not contribute directly to the analysis of the problem at hand.

Note: Authority cited: Section 21083, Public Resources Code; Reference Sections 21003, 21061, and 21100, Public Resources Code.

15183. Projects Consistent with a Community Plan or Zoning

(a) CEQA mandates that projects which are consistent with the development density established by existing zoning, community plan, or general plan policies for which an EIR was certified shall not require additional environmental review, except as might be necessary to examine whether there are project-specific significant effects which are peculiar to the project or its site. This streamlines the review of such projects and reduces the need to prepare repetitive environmental studies.

(b) In approving a project meeting the requirements of this section, a public agency shall limit its examination of environmental effects to those which the agency determines, in an initial study or other analysis:

(1) Are peculiar to the project or the parcel on which the project would be located,

(2) Were not analyzed as significant effects in a prior EIR on the zoning action, general plan, or community plan, with which the project is consistent,

(3) Are potentially significant off-site impacts and cumulative impacts which were not discussed in the prior EIR prepared for the general plan, community plan or zoning action, or

(4) Are previously identified significant effects which, as a result of substantial new information which was not known at the time the EIR was certified, are determined to have a more severe adverse impact than discussed in the prior EIR.

(c) If an impact is not peculiar to the parcel or to the project, has been addressed as a significant effect in the prior EIR, or can be substantially mitigated by the imposition of uniformly applied development policies or standards, as contemplated by subdivision (e) below, then an additional EIR need not be prepared for the project solely on the basis of that impact.

(d) This section shall apply only to projects which meet the following conditions:

(1) The project is consistent with:

(A) A community plan adopted as part of a general plan,

(B) A zoning action which zoned or designated the parcel on which the project would be located to accommodate a particular density of development, or

(C) A general plan of a local agency, and

(2) An EIR was certified by the lead agency for the zoning action, the community plan, or the general plan.

(e) This section shall limit the analysis of only those significant environmental effects for which:

(1) Each public agency with authority to mitigate any of the significant effects on the environment identified in the planning or zoning action undertakes or requires others to undertake mitigation measures specified in the EIR which the lead agency found to be feasible, and

(2) The lead agency makes a finding at a public hearing as to whether the feasible mitigation measures will be undertaken.

(f) An effect of a project on the environment shall not be considered peculiar to the project or the parcel for the purposes of this section if uniformly applied development policies or standards have been previously adopted by the city or county with a finding that the development policies or standards will substantially mitigate that environmental effect when applied to future projects, unless substantial new information shows that the policies or standards will not substantially mitigate the environmental effect. The finding shall be based on substantial evidence which need not include an EIR. Such development policies or standards need not apply throughout the entire city or county, but can apply only within the zoning district in which the project is located, or within the area subject to the community plan on which the lead agency is relying. Moreover, such policies or standards need not be part of the general plan or any community plan, but can be found within another pertinent planning document such as a zoning ordinance. Where a city or county, in previously adopting uniformly applied development policies or standards for imposition on future projects, failed to make a finding as to whether such policies or standards would substantially mitigate the effects of future projects, the decisionmaking body of the city or county, prior to approving such a future project pursuant to this section, may hold a public hearing for the purpose of considering whether, as applied to the project, such standards or policies would substantially mitigate the effects of the project. Such a public hearing need only be held if the city or county decides to apply the standards or policies as permitted in this section.

(g) Examples of uniformly applied development policies or standards include, but are not limited to:

(1) Parking ordinances.

(2) Public access requirements.

(3) Grading ordinances.

(4) Hillside development ordinances.

(5) Flood plain ordinances.

(6) Habitat protection or conservation ordinances.

(7) View protection ordinances.

(8) Requirements for reducing greenhouse gas emissions, as set forth in an adopted land use plan, policy or regulation.

(h) An environmental effect shall not be considered peculiar to the project or parcel solely because no uniformly applied development policy or standard is applicable to it.

(i) Where the prior EIR relied upon by the lead agency was prepared for a general plan or community plan that meets the requirements of this section, any rezoning action consistent with the general plan or community plan shall be treated as a project subject to this section.

(1) "Community plan" is defined as a part of the general plan of a city or county which applies to a defined geographic portion of the total area included in the general plan, includes or references each of the mandatory elements specified in Section 65302 of the Government Code, and contains specific development policies and implementation measures which will apply those policies to each involved parcel.

(2) For purposes of this section, "consistent" means that the density of the proposed project is the same or less than the standard expressed for the involved parcel in the general plan, community plan or zoning action for which an EIR has been certified, and that the project complies with the density-related standards contained in that plan or zoning. Where the zoning ordinance refers to the general plan or community plan for its density standard, the project shall be consistent with the applicable plan.

(j) This section does not affect any requirement to analyze potentially significant offsite or cumulative impacts if those impacts were not adequately discussed in the prior EIR. If a significant offsite or cumulative impact was adequately discussed in the prior EIR, then this section may be used as a basis for excluding further analysis of that offsite or cumulative impact.

Note: Authority cited: Section 21083, Public Resources Code; Reference: Section 21083.3, Public Resources Code.

15183.5 Tiering and Streamlining the Analysis of Greenhouse Gas Emissions

(a) Lead agencies may analyze and mitigate the effects of greenhouse gas emissions at a programmatic level, such as in a general plan, a long range development plan, or a separate plan to reduce greenhouse gas emissions. Later project-specific environmental documents may tier and/or incorporate by reference that existing programmatic review. Project-specific environmental documents may rely on an EIR containing a programmatic analysis of greenhouse gas emissions as provided in section 15152 (tiering), 15168 (program EIRs), 15175-15179.5 (Master EIRs), 15182 (EIRs Prepared for Specific Plans), and 15183 (EIRs Prepared for General Plans, Community Plans, or Zoning).

(b) Greenhouse Gas Reduction Plans. Public agencies may choose to analyze and mitigate greenhouse gas emissions in a greenhouse gas reduction plan or similar document. A plan to reduce greenhouse gas emissions may be used in a cumulative impacts analysis as set forth below. Pursuant to sections 15064(h)(3) and 15130(d), a lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable if the project complies with the requirements in a previously adopted plan or mitigation program under specified circumstances.

(1) Plan Elements. A greenhouse gas emissions reduction plan may:

(A) Quantify greenhouse gas emissions, both existing and projected over a specified time period, resulting from activities within a defined geographic area;

(B) Establish a level, based on substantial evidence, below which the contribution to greenhouse gas emissions from activities covered by the plan would not be cumulatively considerable;

(C) Identify and analyze the greenhouse gas emissions resulting from specific actions or categories of actions anticipated within the geographic area;

(D) Specify measures or a group of measures, including performance standards, that substantial evidence demonstrates, if implemented on a project-by-project basis, would collectively achieve the specified emissions level;

(E) Establish a mechanism to monitor the plan's progress toward achieving the level and to require amendment if the plan is not achieving specified levels;

(F) Be adopted in a public process following environmental review.

(2) Use with Later Activities. A greenhouse gas reduction plan, once adopted following certification of an EIR, may be used in the cumulative impacts analysis of later projects. An environmental document that relies on a greenhouse gas reduction plan for a cumulative impacts analysis must identify those requirements specified in the plan that apply to the project, and, if those requirements are not otherwise binding and enforceable, incorporate those requirements as mitigation measures applicable to the project. If there is substantial evidence that the effects of a particular project may be cumulatively considerable notwithstanding the project's compliance with the specified requirements in the greenhouse gas reduction plan, an EIR must be prepared for the project.

(c) Special Situations. Consistent with Public Resources Code sections 21155.2 and 21159.28, certain residential and mixed use projects, and transit priority projects, as defined in section 21155, that are consistent with the general use designation, density, building intensity, and applicable policies specified for the project area in an applicable sustainable communities strategy or alternative planning strategy accepted by the California Air Resources Board need not analyze global warming impacts resulting from cars and light duty trucks. A lead agency should consider whether such projects may result in greenhouse gas emissions resulting from other sources, however, consistent with these Guidelines.

15364.5. Greenhouse Gas (Definition)

"Greenhouse gas" or "greenhouse gases" includes but is not limited to: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride. (Reference: Health and Safety Code section 38505(g).)

CEQA GUIDELINES

APPENDIX F

ENERGY CONSERVATION

PROPOSED AMENDMENTS TO APPENDIX F

ARE INDICATED BY REDLINE/STRIKEOUT TEXT

CEQA Guidelines

Appendix F

ENERGY CONSERVATION

I. Introduction

The goal of conserving energy implies the wise and efficient use of energy. The means of achieving this goal include:

(1) decreasing overall per capita energy consumption,

(2) decreasing reliance on natural gas and oil, and

(3) increasing reliance on renewable energy sources.

In order to assure that energy implications are considered in project decisions, the California Environmental Quality Act requires that EIRs include a discussion of the potential energy impacts of proposed projects, with particular emphasis on avoiding or reducing inefficient, wasteful and unnecessary consumption of energy (see Public Resources Code section 21100(b)(3)). Energy conservation implies that a project's cost effectiveness be reviewed not only in dollars, but also in terms of energy requirements. For many projects, ~~lifetime~~ costs~~s~~ effectiveness may be determined more by energy efficiency than by initial dollar costs. A lead agency may consider the extent to which an energy source serving the project has already undergone environmental review that adequately analyzed and mitigated the effects of energy production.

II. EIR Contents

Potentially significant energy implications of a project ~~should~~ shall be considered in an EIR to the extent relevant and applicable to the project. The following list of energy impact possibilities and potential conservation measures is designed to assist in the preparation of an EIR. In many instances, specific items may not apply or additional items may be needed. Where items listed below are applicable or relevant to the project, they should be considered in the EIR.

A. Project Description may include the following items:

1. Energy consuming equipment and processes which will be used during construction, operation, and/or removal of the project. If appropriate, this discussion should consider the energy intensiveness of materials and equipment required for the project.

2. Total energy requirements of the project by fuel type and end use.

3. Energy conservation equipment and design features.

4. Identification of ~~Initial and lifecycle~~ energy ~~costs or~~ supplies that would serve the project.

5. Total estimated daily vehicle trips to be generated by the project and the additional energy consumed per trip by mode.

B. Environmental Setting may include existing energy supplies and energy use patterns in the region and locality.

C. Environmental Impacts may include:

1. The project's energy requirements and its energy use efficiencies by amount and fuel type for each stage of the project~~'s lifecycle~~ including construction, operation, maintenance and/or removal. If appropriate, the energy intensiveness of materials may be discussed.

2. The effects of the project on local and regional energy supplies and on requirements for additional capacity.

3. The effects of the project on peak and base period demands for electricity and other forms of energy.

4. The degree to which the project complies with existing energy standards.

5. The effects of the project on energy resources.

6. The project's projected transportation energy use requirements and its overall use of efficient transportation alternatives.

D. Mitigation Measures may include:

1. Potential measures to reduce wasteful, inefficient and unnecessary consumption of energy during construction, operation, maintenance and/or removal. The discussion should explain why certain measures were incorporated in the project and why other measures were dismissed.

2. The potential of siting, orientation, and design to minimize energy consumption, including transportation energy, water conservation and solid-waste reduction.

3. The potential for reducing peak energy demand.

4. Alternate fuels (particularly renewable ones) or energy systems.

5. Energy conservation which could result from recycling efforts.

E. Alternatives should be compared in terms of overall energy consumption and in terms of reducing wasteful, inefficient and unnecessary consumption of energy. F. Unavoidable Adverse

Effects may include wasteful, inefficient and unnecessary consumption of energy during the project construction, operation, maintenance and/or removal that cannot be feasibly mitigated.

G. Irreversible Commitment of Resources may include a discussion of how the project preempts future energy development or future energy conservation.

H. Short-Term Gains versus Long-Term Impacts can be compared by calculating the project's energy costs over the project's lifetime ~~of the project~~.

I. Growth Inducing Effects may include the estimated energy consumption of growth induced by the project.

CEQA GUIDELINES

APPENDIX G

INITIAL STUDY CHECKLIST

PROPOSED AMENDMENTS TO APPENDIX G

ARE INDICATED BY REDLINE/STRIKEOUT TEXT

CEQA Guidelines

Appendix G

Environmental Checklist Form

NOTE: The following is a sample form and may be tailored to satisfy individual agencies' needs and project circumstances. It may be used to meet the requirements for an initial study when the criteria set forth in the CEQA Guidelines have been met. Substantial evidence of potential impacts that are not listed on this form must also be considered. The sample questions in this form are intended to encourage thoughtful assessment of impacts, and do not necessarily represent thresholds of significance.

1. Project title: ____
2. Lead agency name and address:

____
____
____

3. Contact person and phone number: ____________________________
4. Project location: _______________________________________
5. Project sponsor's name and address:

____
____
____

6. General plan designation: ____________________
7. Zoning: __________________________
8. Description of project: (Describe the whole action involved, including but not limited to later phases of the project, and any secondary, support, or off-site features necessary for its implementation. Attach additional sheets if necessary.)

____
____
____

9. Surrounding land uses and setting: Briefly describe the project's surroundings:

____
____
____

10. Other public agencies whose approval is required (e.g., permits, financing approval, or participation agreement.)

____
____

ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:

The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a "Potentially Significant Impact" as indicated by the checklist on the following pages.

Aesthetics
Agriculture and Forest Resources
Air Quality
Biological Resources
Cultural Resources
Geology/Soils
Greenhouse Gas Emissions
Hazards & Hazardous Materials
Hydrology/Water Quality
Land Use/Planning
Mineral Resources
Noise
Population/Housing
Public Services
Recreation
Transportation/Traffic
Utilities/Service Systems
Mandatory Findings of Significance

DETERMINATION: (To be completed by the Lead Agency)

On the basis of this initial evaluation:

I find that the proposed project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because revisions in the project have been made by or agreed to by the project proponent. A MITIGATED NEGATIVE DECLARATION will be prepared.

I find that the proposed project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

I find that the proposed project MAY have a "potentially significant impact" or "potentially significant unless mitigated" impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An ENVIRONMENTAL IMPACT REPORT is required, but it must analyze only the effects that remain to be addressed.

I find that although the proposed project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier EIR or NEGATIVE DECLARATION pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier EIR or NEGATIVE DECLARATION, including revisions or mitigation measures that are imposed upon the proposed project, nothing further is required.

Signature
Date
Printed Name

EVALUATION OF ENVIRONMENTAL IMPACTS:

1) A brief explanation is required for all answers except "No Impact" answers that are adequately supported by the information sources a lead agency cites in the parentheses following each question. A "No Impact" answer is adequately supported if the referenced information sources show that the impact simply does not apply to projects like the one involved (e.g., the project falls outside a fault rupture zone). A "No Impact" answer should be explained where it is based on project-specific factors as well as general standards (e.g., the project will not expose sensitive receptors to pollutants, based on a project-specific screening analysis).

2) All answers must take account of the whole action involved, including off-site as well as on-site, cumulative as well as project-level, indirect as well as direct, and construction as well as operational impacts.

3) Once the lead agency has determined that a particular physical impact may occur, then the checklist answers must indicate whether the impact is potentially significant, less than significant with mitigation, or less than significant. "Potentially Significant Impact" is appropriate if there is substantial evidence that an effect may be significant. If there are one or more "Potentially Significant Impact" entries when the determination is made, an EIR is required.

4) "Negative Declaration: Less Than Significant With Mitigation Incorporated" applies where the incorporation of mitigation measures has reduced an effect from "Potentially Significant Impact" to a "Less Than Significant Impact." The lead agency must describe the mitigation measures, and briefly explain how they reduce the effect to a less than significant level (mitigation measures from "Earlier Analyses," as described in (5) below, may be cross-referenced).

5) Earlier analyses may be used where, pursuant to the tiering, program EIR, or other CEQA process, an effect has been adequately analyzed in an earlier EIR or negative declaration. Section 15063(c)(3)(D). In this case, a brief discussion should identify the following:

a) Earlier Analysis Used. Identify and state where they are available for review.

b) Impacts Adequately Addressed. Identify which effects from the above checklist were within the scope of and adequately analyzed in an earlier document pursuant to applicable legal standards, and state whether such effects were addressed by mitigation measures based on the earlier analysis.

c) Mitigation Measures. For effects that are "Less than Significant with Mitigation Measures Incorporated," describe the mitigation measures which were incorporated or refined from the earlier document and the extent to which they address site-specific conditions for the project.

6) Lead agencies are encouraged to incorporate into the checklist references to information sources for potential impacts (e.g., general plans, zoning ordinances). Reference to a previously prepared or outside document should, where appropriate, include a reference to the page or pages where the statement is substantiated.

7) Supporting Information Sources: A source list should be attached, and other sources used or individuals contacted should be cited in the discussion.

8) This is only a suggested form, and lead agencies are free to use different formats; however, lead agencies should normally address the questions from this checklist that are relevant to a project's environmental effects in whatever format is selected.

9) The explanation of each issue should identify:

a) the significance criteria or threshold, if any, used to evaluate each question; and

b) the mitigation measure identified, if any, to reduce the impact to less than significance

SAMPLE QUESTIONS

I. AESTHETICS -- Would the project:

a) Have a substantial adverse effect on a scenic vista?

b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?

c) Substantially degrade the existing visual character or quality of the site and its surroundings?

d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?

II. AGRICULTURE AND FOREST RESOURCES: In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Dept. of Conservation as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts to forest resources, including timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and the Forest Legacy Assessment project; and the forest carbon measurement methodology provided in the Forest Protocols adopted by the California Air Resources Board. Would the project:

a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?

b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?

c) Conflict with existing zoning for, or cause rezoning of, forest land (as defined in Public Resources Code section 12220(g)) or timberland (as defined in Public Resources Code section 4526)?

d) Result in the loss of forest land or conversion of forest land to non-forest use?

e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland to non-agricultural use or conversion of forest land to non-forest use?

III. AIR QUALITY -- Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:

a) Conflict with or obstruct implementation of the applicable air quality plan?

b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?

c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?

d) Expose sensitive receptors to substantial pollutant concentrations?

e) Create objectionable odors affecting a substantial number of people?

IV. BIOLOGICAL RESOURCES -- Would the project:

a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?

b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, regulations or by the California Department of Fish and Game or US Fish and Wildlife Service?

c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?

d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?

e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?

f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?

V. CULTURAL RESOURCES -- Would the project:

a) Cause a substantial adverse change in the significance of a historical resource as defined in § 15064.5?

b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to § 15064.5?

c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?

d) Disturb any human remains, including those interred outside of formal cemeteries?

VI. GEOLOGY AND SOILS -- Would the project:

a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.

ii) Strong seismic ground shaking?

iii) Seismic-related ground failure, including liquefaction?

iv) Landslides?

b) Result in substantial soil erosion or the loss of topsoil?

c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?

d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?

e) Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?

VII. GREENHOUSE GAS EMISSIONS -- Would the project:

a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?

b) Conflict with any applicable plan, policy or regulation of an agency adopted for the purpose of reducing the emissions of greenhouse gases?

VIII. HAZARDS AND HAZARDOUS MATERIALS -- Would the project:

a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?

b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?

c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?

d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?

e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?

f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?

g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?

h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?

~~VIII~~IX. HYDROLOGY AND WATER QUALITY -- Would the project:

a) Violate any water quality standards or waste discharge requirements?

b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?

c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site?

d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?

e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?

f) Otherwise substantially degrade water quality?

g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?

h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?

i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?

j) Inundation by seiche, tsunami, or mudflow?

~~I~~X. LAND USE AND PLANNING - Would the project:

a) Physically divide an established community?

b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?

c) Conflict with any applicable habitat conservation plan or natural community conservation plan?

XI. MINERAL RESOURCES -- Would the project:

a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?

b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?

XII. NOISE -- Would the project result in:

a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?

b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?

c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?

d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?

e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?

f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?

XIII. POPULATION AND HOUSING -- Would the project:

a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?

b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?

c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?

~~XIII~~XIV. PUBLIC SERVICES

a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services:

Fire protection?
Police protection?
Schools?
Parks?
Other public facilities?

~~XIV~~XV. RECREATION

a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?

b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?

XVI. TRANSPORTATION/TRAFFIC -- Would the project:

a) ~~Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume to capacity ratio on roads, or congestion at intersections)?~~ Exceed the capacity of the existing circulation system, based on an applicable measure of effectiveness (as designated in a general plan policy, ordinance, etc.), taking into account all relevant components of the circulation system, including but not limited to intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?

b) ~~Exceed, either individually or cumulatively, a~~ Conflict with an applicable congestion management program, including, but not limited to level of service standards and travel demand measures, or other standards established by the county congestion management agency for designated roads or highways?

c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?

d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?

e) Result in inadequate emergency access?

~~f) Result in inadequate parking capacity?~~

~~g~~f) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?

XVII. UTILITIES AND SERVICE SYSTEMS -- Would the project:

a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?

b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?

c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?

d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?

e) Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?

f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?

g) Comply with federal, state, and local statutes and regulations related to solid waste?

XVIII. MANDATORY FINDINGS OF SIGNIFICANCE

a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?

b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?

c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?

Note: Authority cited: Sections 21083 and 21087, Public Resources Code. Reference: Sections 21080(c), 21080.1, 21080.3, 21082.1, 21083, 21083.3, 21093, 21094, 21151, Public Resources Code; Sundstrom v. County of Mendocino, 202 Cal.App.3d 296 (1988); Leonoff v. Monterey Board of Supervisors, 222 Cal.App.3d 1337 (1990).

GSA Public Buildings Service
Office of Applied Science
Applied Research

ASSESSING GREEN BUILDING PERFORMANCE

A POST OCCUPANCY EVALUATION OF 12 GSA BUILDINGS

SUSTAINABILITY

The Office of Applied Science supports GSA's Public Buildings Service by generating research findings and recommending business improvements that can be directly applied to real world situations. The mission of the Public Buildings Service is to provide superior workplaces for federal customer agencies at the best value to the American taxpayer.

Produced by GSA Public Buildings Service,
Office of Applied Science
June 2008

This document is printed on post-consumer recycled paper.

National Park Service,
Omaha, Nebraska

Photo Credit: Kessler Photography

INTRODUCTION

SUSTAINABLE DESIGN DELIVERS

To answer the question, ‘does sustainable design deliver?’ GSA evaluated 12 sustainably designed buildings in its national portfolio. The evaluation of these buildings was comprehensive—measuring environmental performance, financial metrics, and occupant satisfaction. No previous analysis has taken such a holistic view. The buildings studied all incorporated sustainable design criteria to varying degrees, with seven receiving LEED ratings. The results of GSA's evaluation show that sustainably designed buildings outperform the national average for buildings of their type by a substantial margin.

INTEGRATED DESIGN YIELDS EVEN BETTER PERFORMANCE

The best performing buildings in the study were those that took a fully integrated approach to sustainable design—addressing site development, water savings, energy efficiency, materials selection, and indoor environmental quality. As America’s largest public real estate organization, GSA has a special responsibility to lead in building sustainably and meet federal mandates, including energy policies and Executive Orders. What the evaluation shows is that a fully integrated approach to sustainable design is helping GSA to meet its mandates by delivering buildings that use substantially less energy, cost less to operate and maintain, and lead to greater occupant satisfaction.

NEEDED NEXT: NATIONAL SUSTAINABLE BUILDING DATA

This study is an important first step in a much-needed national assessment of sustainable building performance in the public, private, and institutional sectors. GSA's evaluation establishes a new benchmark for comprehensiveness using a protocol that others can follow, both in the federal and private sectors.

RESEARCH OVERVIEW

Integration Means High Performance

"This study breaks new ground by comparing GSA's sustainably designed buildings against US commercial buildings, using the latest performance data. Its findings will be relevant to building owners and developers, public and private, across the country."

-DAVID WINSTEAD
Commissioner, Public Buildings Service

The US General Services Administration (GSA) commissioned a comprehensive post-occupancy evaluation of 12 of its sustainably designed buildings.[1] The measures studied included environmental performance, financial metrics, and occupant satisfaction. No previous US study has taken such a holistic approach to building performance. The LEED buildings evaluated represented one-third of the total LEED buildings in GSA's national portfolio at the time the study was conducted.

The study compared the energy performance, operating cost, and water use of the 12 GSA buildings against the average performance of US commercial buildings, using the following sources of data:

Measurement	Data Source[2]
EUI	CBECS National Survey of Commercial Buildings constructed between 1990 and 2003[3]
CO_2	ENERGY STAR[4]
Maintenance Costs:	IFMA[5] and BOMA[6] 2006/2007 Surveys reporting 2003-2005 data
Water Use:	Federal Water Use Index[7]
Occupant Satisfaction:	Center for the Built Environment, UC Berkeley[8]

The study found that GSA's green buildings outperform national averages in all measured performance areas—energy, operating costs, water use, occupant satisfaction, and carbon emissions. The study also found that GSA's LEED Gold buildings, which reflect a fully integrated approach to sustainable design—addressing environmental, financial, and occupant satisfaction issues in aggregate—achieve the best overall performance.

KEY FINDINGS:

Compared to national averages, buildings in this study have:

26%
Less energy use
(65 kBtu/sf/yr vs. 88 kBtu/sf/yr).

13%
Lower aggregate maintenance costs ($2.88/sf vs. $3.30/sf)

27%
Higher occupant satisfaction

33%
Fewer CO_2 emissions
(19lbs/sf/yr vs. 29lbs/sf/yr)

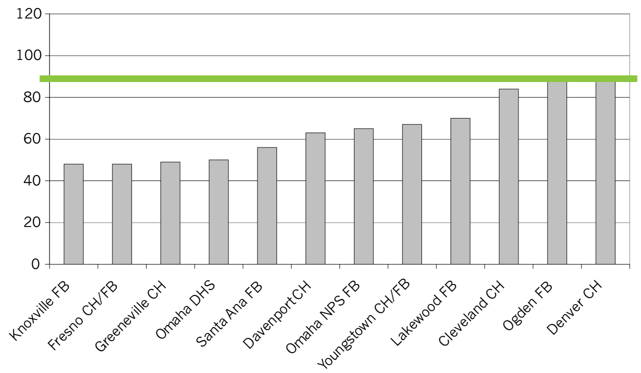
GSA STUDY BUILDINGS

Figure 1: Performance Metrics

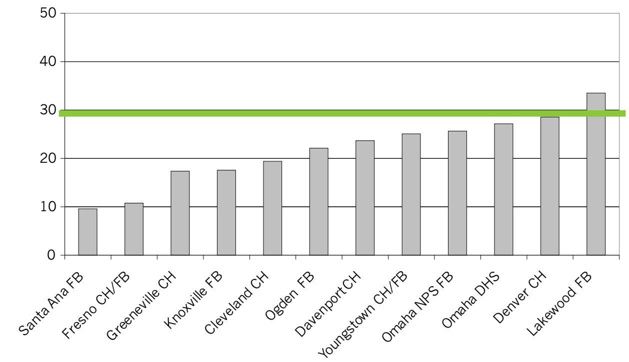
On average the 12 sustainably designed buildings in the study outperformed US commercial buildings.

Indicates National Average

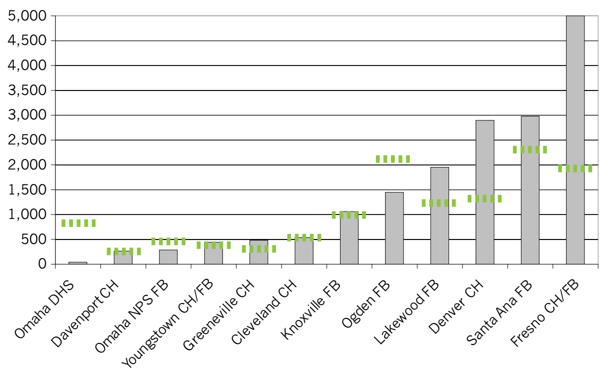
Indicates Building Baseline



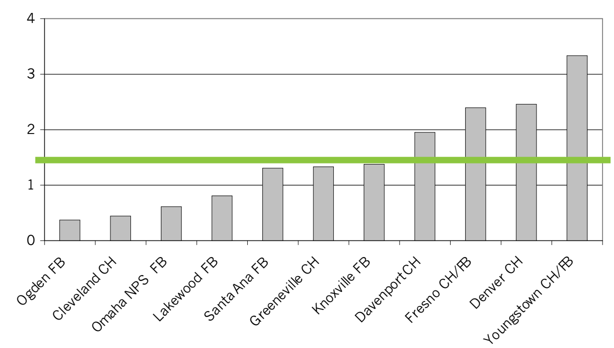
ENERGY USE INTENSITY
(kBtu/sf/yr)



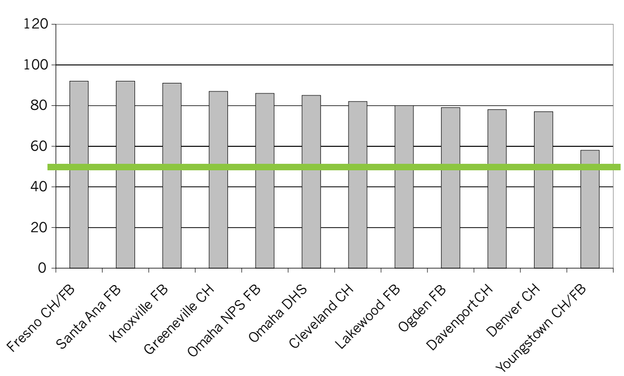
CO_2 EMISSIONS
(lbs/sf/yr)



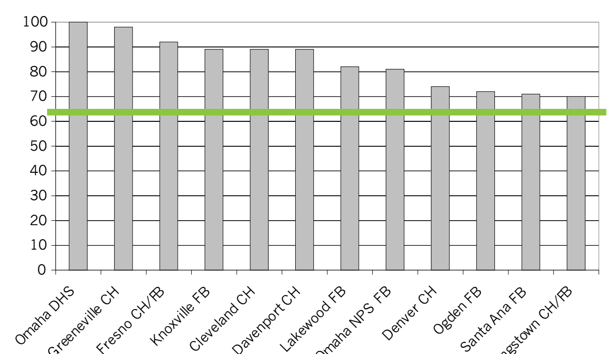
WATER USE
(Thousand gallons/yr)



MAINTENANCE COSTS
($/sf)



ENERGY STAR
SCORE



OCCUPANT SATISFACTION
(% Satisfaction)

RESEARCH CONTEXT

A Comprehensive Evaluation

"We believe that 'green' building and sustainable design and operation has a very positive impact on the people that work in our buildings, in terms of their morale and productivity. 'Green' building is the right thing to do, and it's also the right business thing to do."

DAVID BIBB
Acting Administrator, GSA

GSA asked Pacific Northwest National Laboratory (PNNL) to evaluate 12 of GSA's sustainably designed buildings, and answer this question:

While sustainably designed buildings promise higher performance, do they deliver?

The study evaluated actual, not modeled, building performance, so the results are reliable and objective. Successes and shortcomings were identified, along with areas requiring further research, to provide best practices to emulate and actions to take to improve performance.

The 12 buildings selected reflect different US regional climates, a mix of uses (courthouses and offices), and a mix of build-to-suit leases and federally owned buildings. Land ports of entry were excluded because, as a building type, they are too different to allow meaningful comparisons. Eight of these buildings were designed to meet or exceed basic LEED certification. The other four were designed to meet the requirements of other programs, including ENERGY STAR and the California Title 24 energy standard.

The research team used a consistent evaluation process for every building studied:

- Obtaining and reviewing one year of operating data
- Surveying building occupants
- Interviewing the building manager
- Conducting an expert walkthrough

To make the study useful to a larger audience, the team compared each performance measure with the national average for US commercial buildings. The latest available benchmark data comes from widely accepted industry and government standards.

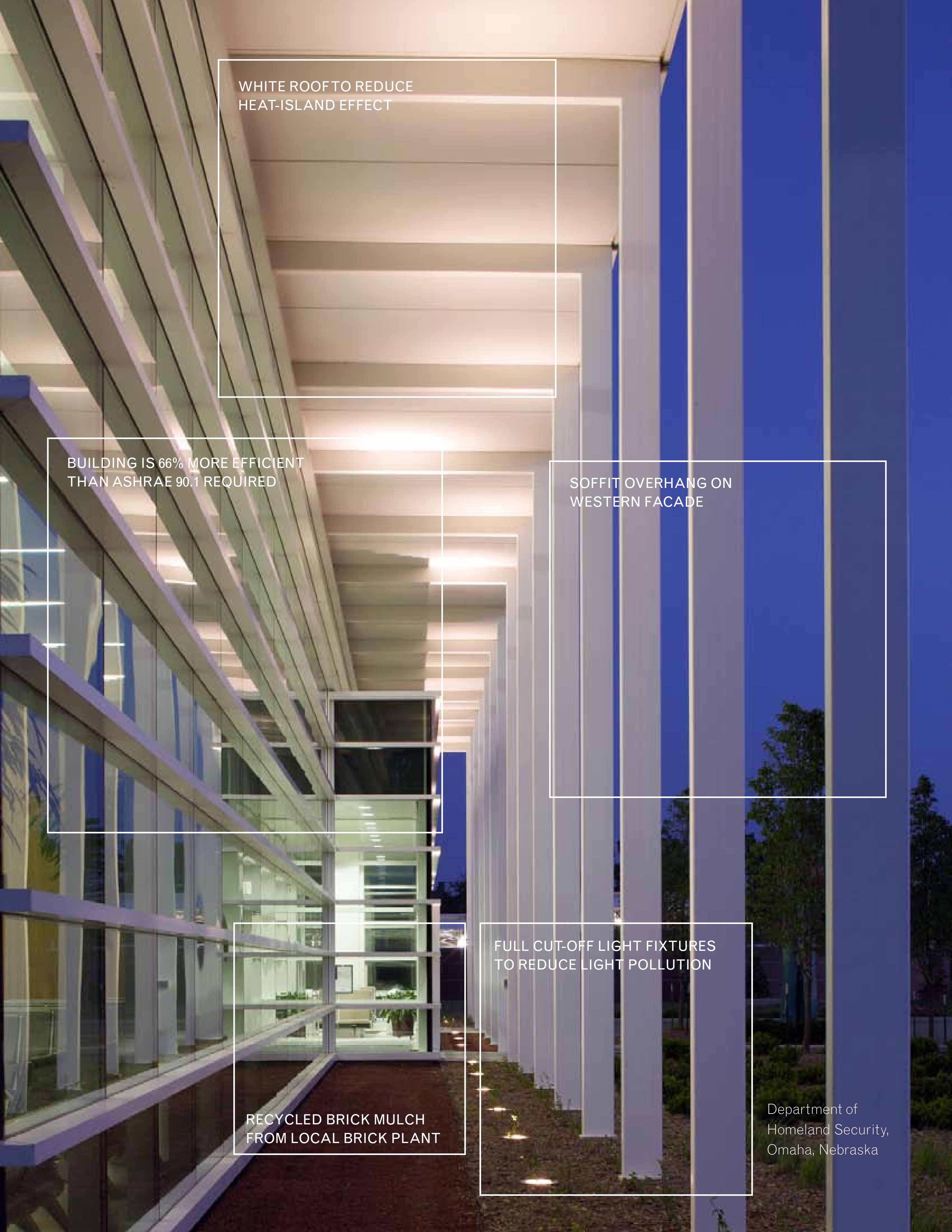
ABOUT THE LEED GREEN BUILDING RATING SYSTEM

The US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Rating System is a nationally accepted third party certification program for green building design, construction, and operation. As the USGBC puts it, "LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality." LEED closely approximates GSA's holistic approach to sustainable building development and operation.

The LEED Rating System addresses new construction and renovation, operations and maintenance of existing buildings, design of commercial interiors, building core and shell development, as well as neighborhood development and homes.

LEED provides four measures of performance: basic certification, Silver, Gold, and Platinum, based on a set of prerequisites and credits in the five major categories listed above. Each measure represents an incremental step toward integrating the different components of sustainable design, construction, and operation to achieve optimal performance.

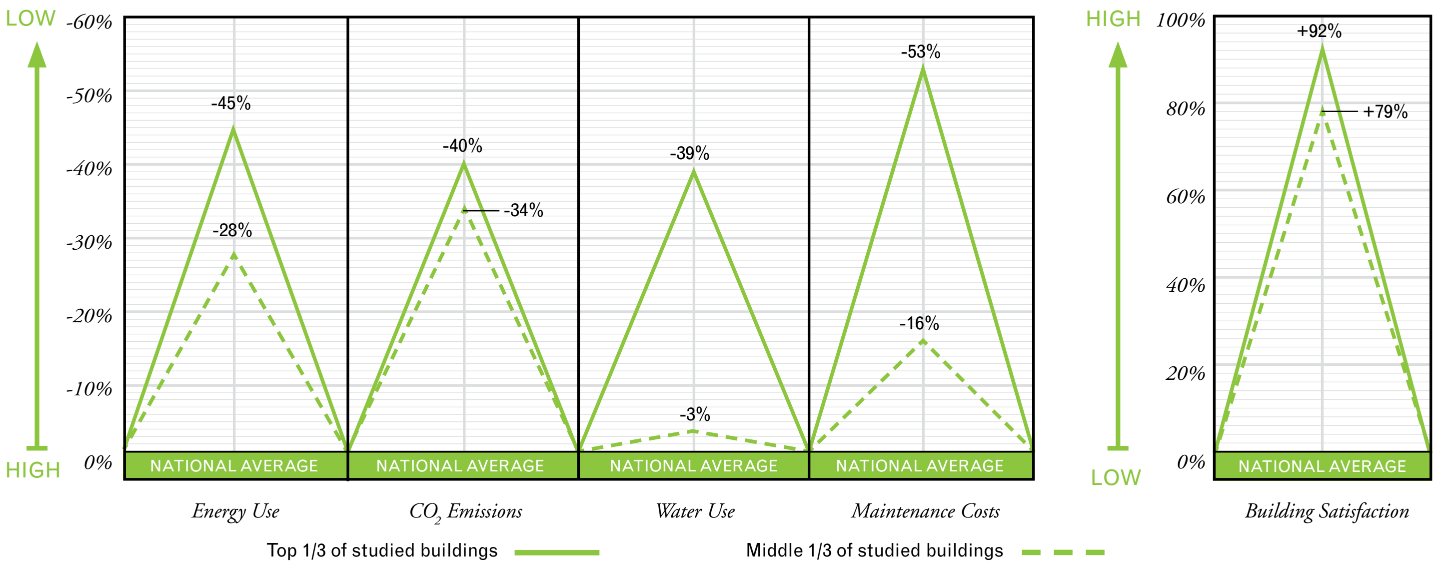
Learn more:
For more information on the LEED Rating System: www.usgbc.org



Department of
Homeland Security,
Omaha, Nebraska

HOW THE GSA STUDY BUILDINGS PERFORM

Figure 2: Comparison Against National Averages



THE TOP PERFORMING BUILDINGS IN EACH METRIC DELIVER SIGNIFICANTLY BETTER RESULTS THAN THE NATIONAL AVERAGE.

GSA STUDY BUILDINGS: FAST FACTS

Year Built: 1910
Year Renov: 2005
Employees: 105
Energy Star: 82
CO_2e: 2,440 mt
LEED-NC Certified

CLEVELAND

The Metzenbaum Courthouse is on the National Register of Historic Places. The renovations preserved 96% of the existing shell and 59% of the interior elements.

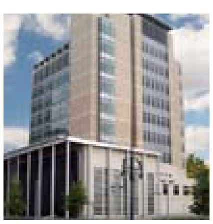
The courthouse won GSA's Environmental Award for recycling because of its seven-material collection system and green housekeeping practices.

Year Built: 1933
Year Renov: 2005
Employees: 45
Energy Star: 78
CO_2e: 945 mt
LEED Registered

DAVENPORT

The Davenport Courthouse is on the National Register of Historic Places. The renovation maintained the integrity of the historic space, while updating the mechanical systems in the building.

The courtrooms incorporate techniques to bring in daylight and the mechanical systems use variable speed drives. The HVAC system consists of water-cooled chillers, boilers, and air handling units.

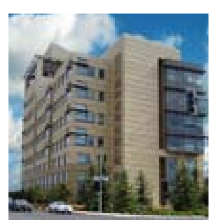


Year Built: 2002
Employees: 170
Energy Star: 77
CO_2e: 4,668 mt

DENVER

The Arraj Courthouse was designed as a green courthouse prior to the completion of the LEED rating system. It is currently seeking LEED for Existing Buildings Certification.

Denver employs a hybrid underfloor air distribution system, HVAC and lighting sensors, as well as photovoltaic panels.



Year Built: 2001
Employees: 85
Energy Star: 92
CO_2e: 2,666 mt
CA Energy Standard Title 24

FRESNO

The Coyle Courthouse and Federal Building houses 14 courtrooms and is the tallest building in the city (11 floors high).

Designed under California's Title 24 energy standard, the building includes high efficiency lighting, underfloor air distribution systems, water-cooled chillers, and natural gas boilers.

Year Built: 2001
Employees: 85
Energy Star: 87
CO_2e: 1,397 mt

GREENEVILLE

The Quillen Courthouse replaced a smaller courthouse from which the occupants reclaimed quality historic furniture.

Some of the energy-efficiency features include a well-insulated white roof and an Energy Management Control System of lighting and occupancy sensors. It also scores the highest occupant satisfaction for air quality, acoustics, and lighting.

Year Built: 1986
Year Renov: 2005
Employees: 285
Energy Star: 91
CO_2e: 1,516 mt
LEED-EB Silver

KNOXVILLE

Located in downtown Knoxville, the Duncan Federal Building currently houses a range of services including the FBI, US Customs, and HUD.

Alterations to the building incorporate high-efficiency lighting, enhanced metering techniques, and low-flow fixtures. The roof design reduces the heat island effect, as well as housing photovoltaic panels.

Year Built: 2001
Employees: 252
Energy Star: 80
CO_2e: 2,150 mt
LEED-NC Silver

LAKEWOOD

The facility at Lakewood for the Department of Transportation is a LEED Silver-leased building.

Some features include low-emitting material selection, and daylight and views in 91% of regularly occupied spaces. In addition, all building occupants receive a booklet about the design and operations of the building.

Year Built: 2001
Employees: 252
Energy Star: 79
CO_2e: 1,161 mt
LEED-NC Silver

OGDEN

Renovations transformed the historic Scowcroft Federal Building into usable office space meeting the IRS's specific needs.

The space incorporates earthquake prevention upgrades, improved roof insulation, radiant baseboard heating, and an underfloor air distribution system coupled with indirect/direct evaporative cooling.

Year Built: 2001
Employees: 252
Energy Star: 85
CO_2e: 1,168 mt
LEED-NC Gold

OMAHA DHS

The Omaha Department of Homeland Security was designed to house multiple DHS agencies, and recently won the 2007 American Council of Engineering Award for its design.

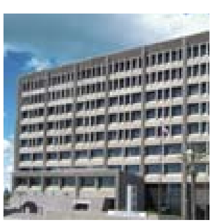
As a LEED Gold building, the facility incorporates daylight and rainwater-harvesting systems, a ground source heat pump, and Green Seal janitorial products.

Year built: 2004
Employees: 125
Energy Star: 86
CO_2e: 872 mt
LEED-NC Gold

OMAHA NPS

The Curtis National Park Service building was built on a brownfield as part of an urban redevelopment effort.

The building showcases passive solar design, daylight harvesting and HVAC sensors, as well as underfloor air distribution. Use of native and adaptive vegetation eliminated the need for irrigation. Operations also include green housekeeping practices.

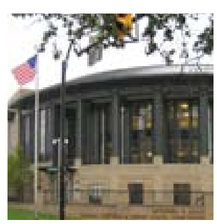


Year Built: 1975
Year Renov: 2005
Employees: 409
Energy Star: 92
CO_2e: 1,344 mt
CA Energy Standard Title 24

SANTA ANA

Renovated in 2005, the Santa Ana Federal Building lies in the heart of the civic center district and accommodates a large flow of visitors to the building each day.

This building features high-efficiency lighting and HVAC systems, a new roof, energy-efficient elevators, and lighting sensors.



Year Built: 2002
Employees: 45
Energy Star: 58
CO_2e: 655 mt
LEED-NC Certified

YOUNGSTOWN

The Jones Federal Building and Courthouse facility was built on a brownfield, and was part of the city's urban revitalization.

Youngstown incorporates building controls and daylighting to over 75% of occupied spaces. Unique features include a storm water management demonstration, a white membrane roof, and light-colored pavement.

FINDING 1:

Fully Integrated Design Delivers Higher Performance

GSA's sustainably designed green buildings have 26% lower energy use compared to the National Average.

(65 kBTu/sf/yr vs. 88 kBtu/sf/yr)
Source of National Average: CBECS

To achieve LEED Gold certification, credits must be obtained in all five rating areas, requiring a completely integrated approach to sustainable building design. The two LEED Gold buildings in this study clearly show that a comprehensive approach yields broad, holistic performance benefits. While neither building led in every category, these two buildings were the only ones studied that achieved consistently high levels of performance on all measures.

The **Curtis National Park Service (NPS) building,** Omaha, Nebraska, performed well in all categories. Its ENERGY STAR rating (86) is in the top third for the group. Its water costs are 91% below the BOMA/IFMA baseline. Its domestic water use is 50% below baseline. Its CO_2 emissions are 34% under baseline, putting it in the top half. Its emissions from occupants' commutes, 1.7 metric tons per person, put it in the top one-third.

The **Omaha Department of Homeland Security (DHS) building,** Omaha, Nebraska, performed well across all categories. Its ENERGY STAR rating (85) is also in the top third for the group. Its water costs are 66% below the BOMA/IFMA baseline, achieved using rainwater harvesting and low-flow and auto-flow lavatory fixtures to offset its greater public use. DHS has 65 regular occupants and 360 occupant visitors while NPS has 125 regular occupants and 134 occupant visitors. DHS's domestic water use is 58% below baseline.

LESSON LEARNED

Across all buildings studied, building performance tracks design intent. Buildings designed with a strong energy focus—compliance with California's demanding Title 24 energy code or ENERGY STAR—had outstanding energy performance, although with a lesser achievement in terms of water use intensity. One LEED certified building did not pursue energy efficiency during design. As a result, it achieved no LEED energy optimization credits, and had the lowest ENERGY STAR rating in the study.

NATIONAL BUILDING FACTS

31%
projected increase in energy consumption by the year 2030 despite dramatic gains in energy efficiency.[9]

20%
of U.S. drinking water supply is consumed by commercial buildings.[10]

2 trillion
gallons of water a year would be saved if commercial buildings reduced their water consumption by 10%.[11]

Figure 3: Top Performers by CO_2 Emissions (lbs/sf/yr)

Source of National Average: Energy Star

ALL BUILDINGS IN THIS STUDY PRODUCE A SMALLER CARBON FOOTPRINT THAN THE NATIONAL AVERAGE.

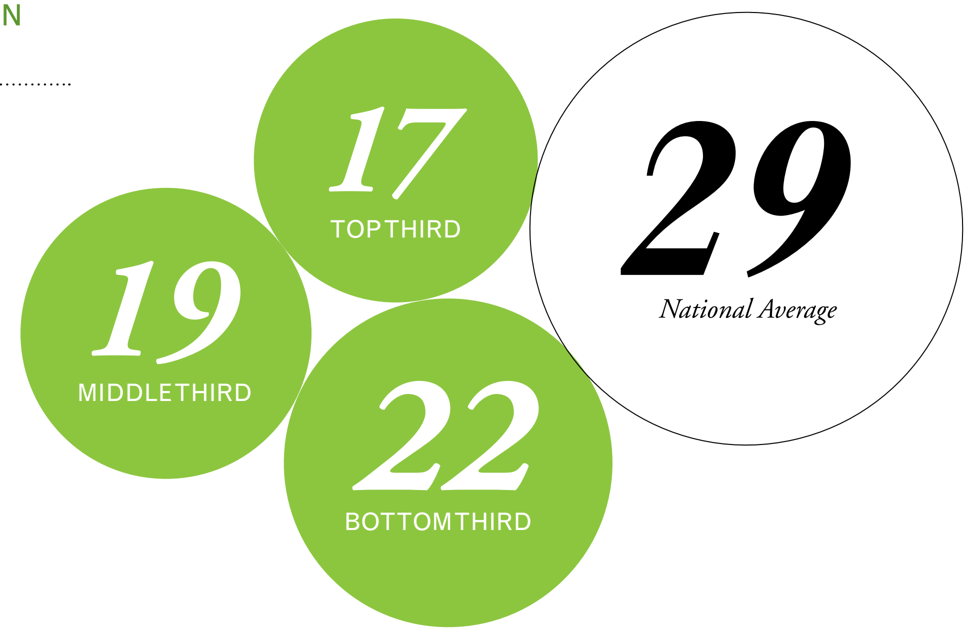
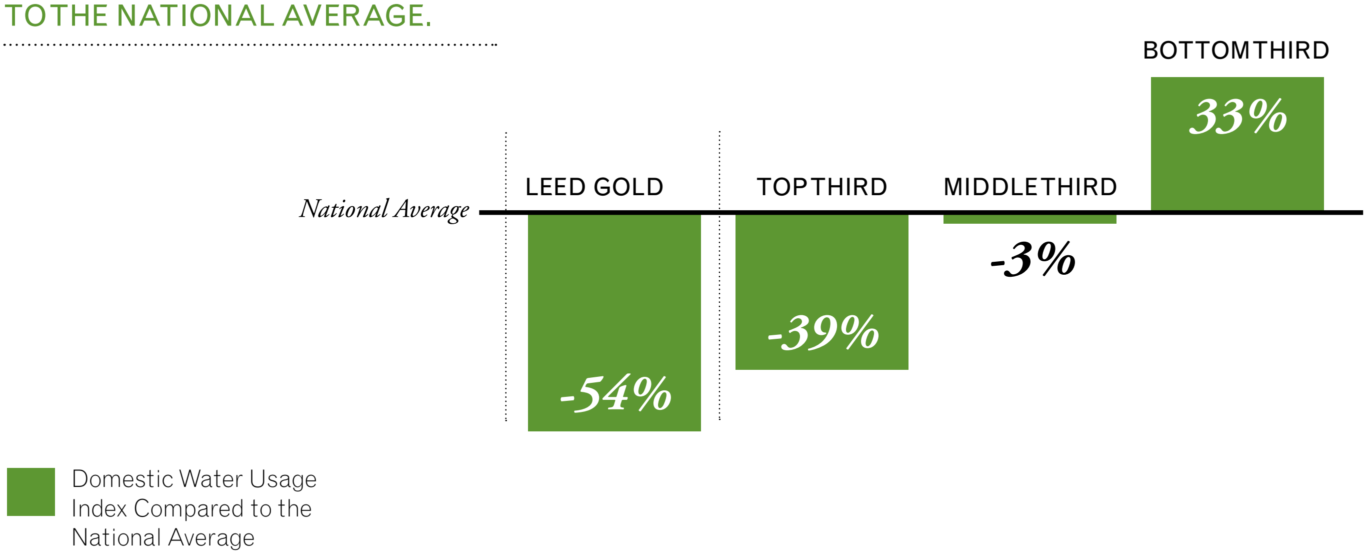


Figure 4: Top Performers by Water Use (thousand gallons/yr)

Source of National Average: Federal Water Use Index

LEED GOLD BUILDINGS IN THIS STUDY HAVE SIGNIFICANTLY LOWER WATER USE COMPARED TO THE NATIONAL AVERAGE.



FINDING 2:
GSA's Green Buildings Cost Less to Operate

The five top-performing buildings studied spent 14% to 45% less on energy than the National Average.

Source of National Average: BOMA/IFMA

Why do operations and maintenance (O&M) costs matter? Considered in aggregate, they approximate the consumption side of overall sustainable performance. As a group, the 12 buildings studied performed only slightly better than the national average for US commercial buildings: 7% below that baseline. However, the top-performing one-third of the group did much better, at 41% below.

The two LEED Gold buildings were among the best performers from an O&M cost perspective. Lower utility and janitorial costs and savings from recycling resulted in top scores for the Curtis National Park Service building and the Omaha Department of Homeland Security building. The use of green cleaning practices enhanced their performance.

On average, the bottom quartile of the buildings studied had considerably higher costs than the industry baseline: 45% above the national average for US commercial buildings. These buildings had unusually high maintenance costs and, in one case, an operating emergency.

LESSON LEARNED

The best practice lesson here is that O&M costs are lowest when sustainability is integral to every aspect of a building, including cleaning and recycling. Building and systems efficiency alone isn't enough. Upfront investments in sustainable measures need to be matched by sustainable O&M practices.

NATIONAL BUILDING FACTS

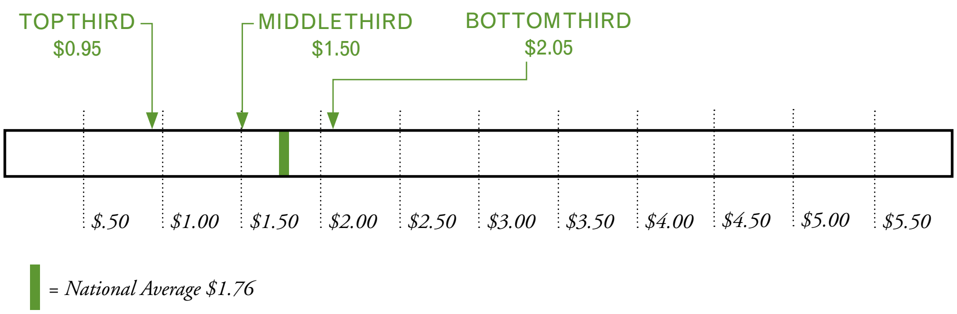
18%
of total U.S. energy use consumption comes from commercial buildings.[12]

Why water efficiency?
Between 1950 and 2000, the US population nearly doubled. In that same period, however, public demand for water nearly tripled. Americans now use an average of 100 gallons of water per day—enough to fill 1,600 drinking glasses![13]

Figure 5: Top Performers by Energy Cost ($/sf/yr)

Source of National Average: BOMA/IFMA

THE TOP-PERFORMING SUSTAINABLE BUILDINGS STUDIED SHOWED CONSISTENTLY LOWER ENERGY COSTS THAN NATIONAL AVERAGES.



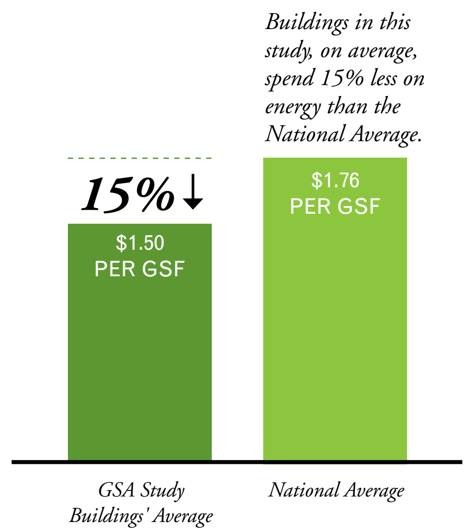
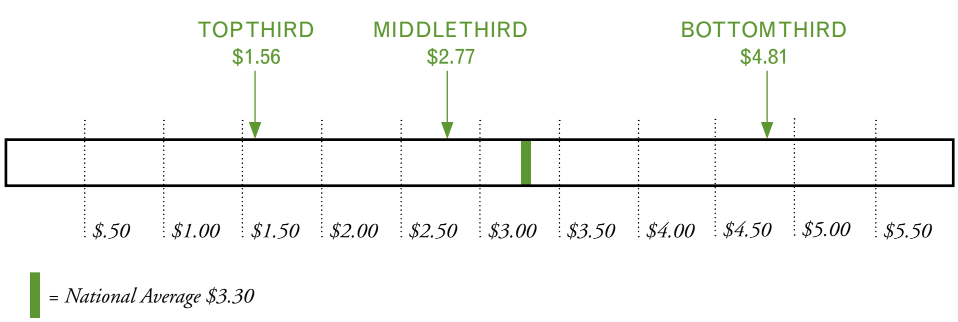
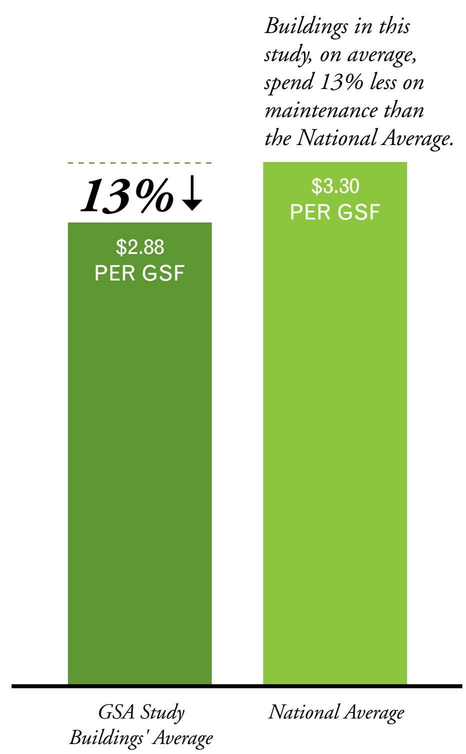


Figure 6: Top Performers by Aggregate Maintenance Cost ($/sf)

Source of National Average: BOMA/IFMA

THE TOP-PERFORMING SUSTAINABLE BUILDINGS STUDIED SHOWED CONSISTENTLY LOWER AGGREGATE MAINTENANCE COSTS THAN THE NATIONAL AVERAGE.





FINDING 3:

GSA's Green Buildings have Satisfied Occupants

GSA's sustainably designed green buildings demonstrate a 27% higher occupant satisfaction than the National Average.

Source for National Average: CBE, UC Berkeley[14]

This study provides important new evidence that occupant satisfaction is higher in sustainably designed buildings. Occupant satisfaction is important because it correlates with personal and team performance. That often means higher productivity and creativity for an organization.

As a group, the 12 sustainable buildings studied scored better in occupant satisfaction than the national average for US commercial buildings. Half of the buildings studied scored in the top quartile for occupant satisfaction. Significantly, their average scores in all categories were higher than those of LEED certified buildings in the private sector[14]. This suggests that GSA's integrated life cycle approach will be a valuable model for public and private organizations.

For the lower-performing buildings, the study found that occupant satisfaction is undermined by poor acoustics, lighting and maintenance problems. A low level of ambient noise, a lack of sound masking, and a perceived lack of privacy make acoustic quality worse. The poorly calibrated systems that turn lights on and off in response to daylight conditions may cause problems for some occupants. Mechanical failures and poor maintenance can drive down satisfaction scores.

LESSON LEARNED

GSA's sustainably designed buildings are scoring points with their occupants in terms of overall building and workplace quality, indoor air quality, cleanliness, and quality of maintenance. We also gained the following insights from the lower-performing buildings:

First, acoustic performance matters, and should be addressed by appropriate teaming and design criteria at the outset of every project.

Second, both change management and periodic fine-tuning may be needed to make automated systems work well for building occupants, at least until these systems are fully accepted.

Third, good building maintenance is a foundation stone of occupant satisfaction. Don't neglect it.

NATIONAL BUILDING FACTS

79%
of employees surveyed were willing to forgo income to work for a firm with a credible sustainable strategy.[15]

80%
of employees surveyed said they felt greater motivation and loyalty toward their company due to its sustainability initiatives.[16]

OCCUPANT SATISFACTION SURVEY

Figure 7: Comparison Against National Averages

Source of National Average: Center for the Built Environment, UC Berkeley

Air Quality Satisfaction

Top Third	79%
Middle Third	68%
Bottom Third	58%
National Average	46%

Cleanliness Satisfaction

Top Third	91%
Middle Third	86%
Bottom Third	74%
National Average	62%

Thermal Satisfaction

Top Third	63%
Middle Third	47%
Bottom Third	30%
National Average	39%

Acoustic Satisfaction

Top Third	62%
Middle Third	47%
Bottom Third	30%
National Average	38%

Lighting Satisfaction

Top Third	81%
Middle Third	75%
Bottom Third	67%
National Average	75%

FINDING 4:

Green Buildings Deliver on GSA's Mandates

New executive and legislative mandates raise the performance requirements for buildings in GSA's national real estate portfolio. (See chart to right)

To meet these new requirements, GSA will need to ensure that its future buildings, including both new construction and major renovation projects, achieve a consistently high standard of performance. The study found a strong positive correlation in that direction. Taken as a group, these 12 sustainably designed buildings use less energy and water, and have a smaller carbon footprint than the national average for US commercial buildings.

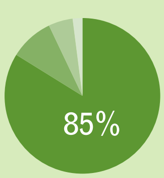
LESSON LEARNED

Although they were not designed to meet GSA's new legislative mandates, the top performing quartile of the buildings studied already meet 2015 requirements for reducing metered energy and water use. GSA can build on this strong foundation of achievable performance. GSA is and will continue to be an important benchmark for other public agencies and for companies and institutions as they plan and implement their building programs.

MANDATE	PERFORMANCE REQUIREMENT
EPAct 2005	• Modeled energy performance must be at least 30% better than ASHRAE 90.1-2004 by 2015
EO 13423	For entire GSA portfolio: • 3% per year metered energy use reduction • 30% metered energy use reduction by 2015 (an average of 54.6 kBtu per sf per year) • 16% metered water use reduction by 2015
EISA 2007	For new GSA buildings and major renovations, reduce fossil fuel generated energy consumption by: • 55% by 2010 • 100% by 2030

For additional information on EISA, EPAct 2005, and EO 13423:
www.wbdg.org/references/federal_mandates

NATIONAL BUILDING FACTS



CO_2 EMISSIONS

In the year 2004, the United States emitted over 7 billion metric tons of greenhouse gases. Carbon dioxide accounted for the largest percentage of greenhouse gases **(83%),** followed by methane **(9%),** nitrous oxide **(5%),** and high global warming potential gases **(2%).**[17]

GSA ON THE GROUND

Green Elements of the Omaha Department of Homeland Security

Although designed in 2004, the Omaha Department of Homeland Security already meets the latest federal mandates.

Landscaping captures storm water run-off

Bike racks encourage people to leave their cars behind

The building features access to windows and daylight

Skylights provide daylight where needed

Rainwater is stored and reused for landscape irrigation

A ground source heat pump reduces energy costs

TEST YOUR KNOWLEDGE:

QUESTION 1
How much of US total energy is used by commercial buildings?

QUESTION 2
How much of US energy is generated by coal?

QUESTION 3
How much of US electricity is used by commercial buildings?

QUESTION 4
Over the 30 year life-cycle cost of an office building, what percentage is dedicated to occupant salaries?

QUESTION 5
How much time does the average human spend indoors?

QUESTION 6
Compared to average US buildings, what is the aggregate reduction in energy use over the past year for the 12 buildings studied?

QUESTION 7
Compared to average US buildings, what is the aggregate reduction in domestic water use over the past year for the 12 buildings studied?

QUESTION 8
Compared to average US buildings, what is the aggregate reduction in carbon emissions over the past year for the 12 buildings studied?

QUESTION 9
Compared to average US buildings, how much did the 12 buildings studied save in aggregate maintenance costs over the past year?

ANSWERS

1. 18%
2. 49%
3. 35%
4. 88%
5. 90%
6. 616,000 BTUs
7. 313,000 gallons
8. 172,000 mt, equivalent to the annual emissions for 28,667 cars.
9. $1,175,707

RESOURCES

LESSONS LEARNED FROM CASE STUDIES OF SIX HIGH-PERFORMANCE BUILDINGS
National Renewable Energy Laboratory
2006

Analyzed the design, construction, and energy performance of six commercial buildings. All of the low-energy buildings used more energy than predicted, but those designed with a whole building approach and with the “strongest” energy goals had the best energy performance. Monitoring buildings to provide feedback improves their energy performance.

THE ENERGY CHALLENGE: A NEW AGENDA FOR CORPORATE REAL ESTATE
Rocky Mountain Institute / CoreNet
2007

Buildings use two-fifths of the world’s materials and energy and one-sixth of its fresh water. In the US, buildings make up 85% of all fixed US capital assets. In short, buildings are part of the problem and part of the solution. The Energy Challenge identifies barriers, documents successes, and recommends actions to achieve greater energy efficiency in US corporate real estate.

THE COST OF GREEN REVISITED
Davis Langdon
2007

Found no significant difference in the average costs between green and other buildings. The study also found that the construction industry has embraced sustainable design in most US regions, and no longer views sustainable design measures as an extra cost burden.

ENERGY PERFORMANCE OF LEED NC BUILDINGS
New Buildings Institute
2008

Compares design intent to energy performance in 121 LEED-rated buildings. Office buildings used 33% less energy and all buildings used 24% less energy than the CBECS average for US commercial buildings. Nearly half the buildings had an ENERGY STAR rating of at least 75; the average rating for all buildings was 68, with a quarter rated below 50.

GLOSSARY

BOMA
Building Owners and Managers Association International. This study used their research to obtain the national average for maintenance costs.

CBE
Center for the Built Environment. This study used their research as a basis for the occupant satisfaction surveys, as well as obtaining the national average for general building satisfaction, cleanliness, lighting, air quality, acoustic, and thermal satisfaction.

CALIFORNIA TITLE 24 ENERGY STANDARD
A California-specific building standard that compiles codes from three sources: standards from national model codes, adapted national model codes to meet California conditions, and new standards to address particular California concerns.

CBECS
Commercial Buildings Energy Consumption Survey. The survey gathers and compiles energy use and cost information for US commercial buildings. This study used their research to obtain the national average for energy use.

CH
Courthouse

ENERGY STAR
Energy Star is a rating to promote energy efficiency in products and buildings. This study used their research to obtain the national average for CO_2 emissions. It is a joint program between the US Environmental Protection Agency and the U.S. Department of Energy.

EUI
Energy Use Intensity.

FB
Federal Building

Federal Water Use Index
This study used the Department of Energy's research to obtain the national average for water use.

GSF
Gross square feet. Refers to a building's overall floor plate size, measuring from the outside of its exterior walls and including all vertical penetrations, such as walls and elevator shafts.

IFMA
International Facility Management Association. This study used their research to obtain the national average for energy costs.

kBtu
1000 British thermal units

mt
Metric ton

NOTES

1 This white paper summarizes research presented in the following report: KM Fowler and EM Rauch: Assessing Green Building Performance: A Post-Occupancy Evaluation of 12 GSA Buildings, PNNL-17393, Pacific Northwest National Laboratory, Richland, WA, 2008. www.gsa.gov/appliedresearch

2 See glossary above for abbreviations.

3 U.S. Department of Energy. Commercial Buildings Energy Consumption Survey (CBECS). 2003. Energy Information Administration. Washington, DC.

4 ENERGY STAR Portfolio Manager. www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

5 IFMA. 2007. Space and Project Management Benchmarks #28. IFMA. Houston, Texas.

6 Building Owners and Managers Association (BOMA) International Experience Exchange Report. 2006. Special Studies 2005, Agency Managed, Downtown all sizes, U.S. Government Sector. BOMA International, Washington, DC.

7 Federal Water Use Index, Department of Energy, Federal Energy Management Program.

8 Center for the Built Environment (CBE) Occupant Satisfaction Survey. UC Berkeley.

9 www.yourenergyfuture.org/energyFacts.htm, (accessed 23.04.2008).

10 www.energystar.gov/index.cfm?c=business.bus_water, (accessed 23.04.2008).

11 ibid.

12 goliath.ecnext.com/coms2/gi_0199-6408096/Section-2-Energy-consumption-by.html, (accessed 01.05.08)

13 www.epa.gov/watersense/water/why.htm, (accessed 23.04.08)

14 Center for the Built Environment (CBE) Occupant Satisfaction Survey. UC Berkeley.

15 Survey of 800 MBAs from 11 Top International Business Schools; Stanford Graduate School of Business, 2002 GlobeScan International Survey, MORI.

16 ibid.

17 www.pewclimate.org/global-warming-basics/facts_and_figures/us_emissions/usghgemgas.cfm, (accessed 01.05.08)

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3

Methodologies

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Contents

EXECUTIVE SUMMARY

The phase out of CFCs and HCFCs under the Montreal Protocol requires the selection of replacement technologies, and in many cases are these alternative fluids. These technologies have differing impacts on global climate change, health, safety and other environmental endpoints, and different private and social costs. Analyses that focus on one or more of these types of impacts can help decision-makers to make choices about competing replacement technologies. However the outcomes of such analyses are influenced by many factors not intrinsic to the technologies. Examples of these are the analytical approach (e.g., top-down compared with bottom-up), the degree of product or process optimization, service and disposal practices, regional circumstances and a wealth of other inputs and assumptions. Therefore in order to make informed choices, decision-makers need to be aware of the sensitivities, uncertainties and limitations inherent in each type of analysis, and must be able to evaluate whether the approach and assumptions used in an analysis are reasonable for the regions and time periods in which the competing technologies are to be applied.

The purpose of this chapter is to provide an overview of the different types of analyses as well as concise guidance on how to evaluate and apply these. For each type of analysis, the most important analytical approaches and variables are discussed, along with the associated sensitivities, uncertainties and limitations. The requirements and limitations of each method are explained. This provides a point of reference for the selection of assessment methods in the technical chapters of this report and gives a framework which helps to harmonize the reporting of results. Further the chapter provides an introduction to the technical chapters and to their subsequent application, non-application and specific-default macrodata. A description of the key methods used in these chapters is also given.

An overview is given of the key approaches used to compare the lifetime, and the direct and indirect emissions of different types of systems. These range from the modelling of partial or complete systems to measured values of individual systems or of representative equipment populations. There can be significant differences between the results from different approaches and therefore relevant policy comparisons can only be made if there is maximum transparency and a harmonization of assumptions. Reference values for emissions from energy consumption in the production of fluids and products are given along with values for CO_2 emissions from electricity generation for the national electricity grids. These values differ significantly over time and between regions, suggesting that great care should be taken if results of system comparisons based on total equivalent warming impact (TEWI) or Life Cycle Assessment (LCA) are transferred to related applications or other regions.

In any economic analysis, the cost of mitigation is calculated as the difference in costs (defined in monetary units) between a reference situation and a new one characterized by lower emissions. Both situations should, as far as possible, be defined such that the assessment can include all major economic and social impacts of the policies and the resulting impact on greenhouse-gas emissions. At the project level, the simplest cost assessment using cost-benefit analysis considers that a new technology requires capital investment to cover costs accounted in the project. Major categories of costs accounted in a project are labour, land, material, energy, investments, environmental services and foreign exchange. These costs are known as the direct engineering and financial costs. A more complete cost evaluation requires the inclusion of externalities, the costs not paid directly by the private commercial entity developing the project. External costs are paid by society and where available, these should be considered for wider policy assessments. In principle, the total cost to society (*social cost*) consists of both the *external cost* and the *private cost*. For the assessment of engineering-type measures relevant to this report, the focus is best placed on private costs, expressed in terms of their net present value (NPV) or as levelized costs to account for the time distribution of costs and investments during the project lifetime.

Health and safety issues are an integral aspect of decisions concerning the choice of fluids. These decisions can have far-reaching consequences for the workforce, the population, industry, the environment and the economy. The prevention of negative health and safety impacts requires methodologies such as risk assessment, risk management, and policy and regulatory controls. Health and safety issues are considered under the following criteria: Flammability, acute toxicity, chronic toxicity, carcinogenicity, acute ecotoxicity, chronic ecotoxicity, and persistence. Information on the substances covered by this report was drawn from several sources. The technical chapters provide detailed information on the substances and the products these are used in is provided in the subsequent technical chapters. The information is divided into general characteristics of a group of fluids followed by typical characteristics of certain fluids within the group. There are significant differences between the various fluid groups, and in some cases within the fluid groups, with respect to flammability, acute toxicity, ecotoxicity and persistence. The design of systems and processes should reflect the specific weaknesses of the fluids used.

A fairly wide range of assessment methods is described so that the impacts of different technologies on the environment and climate can be compared and understood. One significant problem identified is that methodologies like LCA and TEWI are installation-specific and therefore do not provide meaningful results for entire sectors. It is also demonstrated that the available assessment methodologies are not generic but have been developed for a specific purpose. Each of the methodologies can play a role in technology choices if used appropriately.

The use of fluorocarbons is specific to certain technical sectors. In these sectors, technology selection and product development are influenced by the customers and a number of other factors, such as the enforcement of legislation, of a local, national or regional nature. An overview of the regional factors that should be reflected in the inputs for analyses is given. These factors include climate, labour costs, the availability of capital, skilled labour and spare parts, the replacement rates of

systems, and disposal pathways. In this section a regional partitioning of developed and developing countries is used according to the Montreal Protocol.

For applications involving banked amounts of fluids, an overview is given of the available approaches and associated uncertainties for the modelling of process emissions compared to emissions in the usage phase and upon disposal. For both areas, the future usage pattern and emissions can be estimated using bottom-up and top-down approaches. The former ideally involves the modelling of the emissions of individual substances or substance classes from populations of equipment. The properties of these pieces of equipment will often be modelled differently for different years and in different regions so as to reflect anticipated technological changes. In contrast to these technology-rich approaches, top-down models rely on historically established relations between sales into certain sectors and economic growth. This approach is typically weakest in capturing long-term technological changes but is good for the appropriate capture of mid- to long-term growth and wealth effects. However for technologies involving the use of fluorinated greenhouse gases, uncertainties associated with both bottom-up and top-down models become so significant that projections beyond the year 2020 are unreliable.

In the past, too little attention was paid to ensuring the comparability and transferability of results from different technology assessments. The treatment of uncertainties is often incomplete and therefore the resulting recommendations are often not robust enough to be transferred across a sector. To address these concerns, analysts and decision-makers should ensure, wherever possible, that the assumptions and methods used to compare competing technologies are consistent and that uncertainties and sensitivities are identified and quantified. The development of simple and pragmatic standard methodologies and the respective quality criteria should be continued. It is recommended that future efforts should focus on increasing the involvement of relevant stakeholders and introducing additional measures to increase transparency for outside users, for example by providing more extensive documentation. For certain regions and policy questions the amount of resources needed for some of the assessment methods is prohibitive. There is a need for simple and pragmatic assessment methods that can also be used in regions with very limited resources.

3.1 Introduction

This chapter provides public and corporate decision-makers with an overview of assessment methodologies that can be used to support informed decisions on technologies to replace the use of ozone-depleting substances (ODSs). Such decisions are taken in the context of the phase out of ozone-depleting substances under the Montreal Protocol, and national and international policies aimed at reducing emissions of anthropogenic greenhouse gases. The latter include not only direct emissions of fluids during production, use and disposal but also energy-related emissions over the lifetime of products and equipment. Decisions on technology choices and the definition of appropriate practices will often take place at the level of individual projects but could also be important in designing policies. This chapter has therefore been designed as a toolbox for decision-makers. The intention is to give an overview of the most common assessment methodologies for evaluating competing technologies, including a description of how these are applied and their practical limitations. It also provides information used by several subsequent chapters in this report.

Fluorinated substances such as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are being widely used or are being considered for future use as refrigerants, blowing agents in foam production, propellants for aerosol applications, solvents, surfactants, fire-fighting agents and anaesthetics. These substances are used in many technical applications over a wide range of conditions. They are replacing the use of CFCs and HCFCs, which were and are being banned due to their significant impact as ODSs. In quantitative terms, stationary refrigeration and air conditioning, mobile air conditioning and foam blowing dominate usage and emissions in most countries.

As these substances are potent greenhouse gases, considerable efforts are underway to reduce the emissions of these from products or processes to well below the levels that can be obtained on the basis of current technical and economic drivers. The principal available emission reduction options – over the lifetime of the product equipment – for the aforementioned applications fall into five main groups:

a) Improved containment of fluorinated gases during the life cycle of a product or system (manufacture, use and decommissioning/disposal);
b) Use of technologies with a lower fluid charge;
c) Use of alternative fluids with a zero/low global-warming potential (GWP);
d) Use of not-in-kind (NIK) technologies;
e) Process modifications to avoid byproduct formation or emission.

The benefits of reducing emissions of fluorinated gases clearly need to be offset against potential changes in terms of energy efficiency, safety and costs or the impact on environmental categories such as air quality and the continuation of damage to the ozone layer (see Figure 3.1). The specific details of a sector – or even the application concerned – need to be taken into account when making decisions about technological options.

As a result of international concerted action, many of the sectors and applications covered in this report have undergone a rapid transition away from the use of ODSs. This mandated transition has also led to a significant increase in knowledge about technological alternatives to the use of ODSs and has resulted in increased innovation. This high rate of innovation has made it more difficult to appropriately characterize technology options and then to assess them in terms of their performance or costs. Therefore it is now more important than ever to apply consistent methodologies, as outlined in this chapter, for the purpose of producing valid comparisons upon which robust technology choices can be based.

The subsequent sections of this chapter cover the following aspects of technology assessment relevant to the sectors using fluorinated gases: Key performance characteristics such as direct and indirect emissions (3.2), categories of costs (3.3), consideration of health and safety issues (3.4), assessment of climate and environmental impacts (3.5), regional dimensions of technology choices (3.6), basics of emission projections (3.7) and future methodological developments (3.8).

3.2 Direct and indirect emissions

This section considers aspects related to emissions from products and equipment using HFCs or PFCs. Direct and indirect emissions need to be identified to account for the full inventory of such emissions. Indirect emissions are usually associated with the amount of energy consumed for the operation of equipment loaded with the fluid. Table 3.1 gives an overview of the relative contribution of direct HFC emissions to the total greenhouse-gas emissions associated with systems, for example, a domestic refrigerator, a refrigerated truck, a supermarket cooling system or the energy losses through an insulated area of building surface. The table shows that for several important technical systems (e.g. mobile air conditioners or supermarket refrigeration) direct and indirect emissions are of the same order of magnitude but that for several other applications, energy-related indirect emissions outweigh direct emissions by one or two orders of magnitude. The methodologies stated in Table 3.1 are described in greater detail in Section 3.5. Specific values are highly dependent on emission factors, end-of-life treatment of equipment, the GWP of the fluids used and the carbon intensity of the energy supply system.

3.2.1 Direct emissions

Emissions are possible throughout the lifetime of the fluid, from the initiation of fluid manufacture through use within the intended equipment, to its destruction. The following paragraphs describe key stages within the lifetime of the fluid where direct emissions occur. The identification of emissions from these various stages is necessary for both the environmental impact and safety assessments of applications that use any type of fluid.

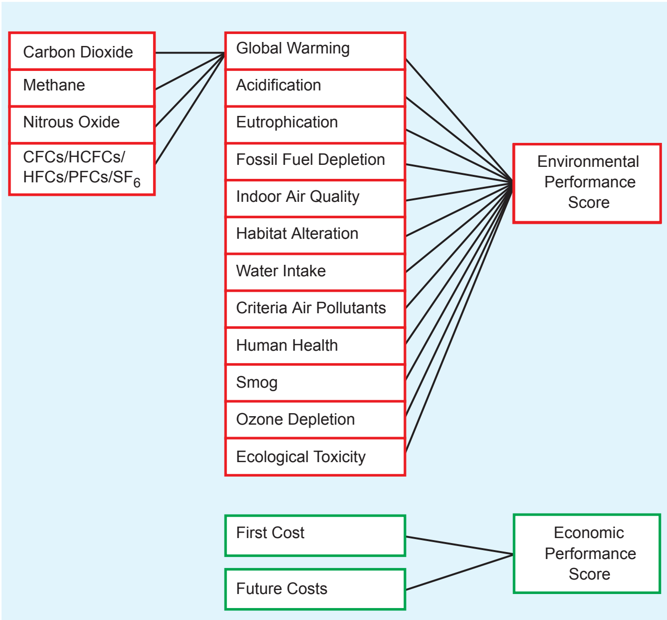

Figure 3.1. Example of impacts to be accounted when taking decisions about the introduction of new technologies or products (Lippiatt, 2002 adapted by authors).

3.2.1.1 Emissions by fluid life stage

Fluid manufacture [1]
The manufacture of fluids requires feedstock materials, which are sourced, produced and used worldwide. Emissions from these feedstock materials, their intermediates and the end substance can occur in chemical processing plants. For the production of many HFCs, these direct emissions can be significant in terms of CO_2 equivalent (on a GWP(100) basis – see Section 3.5.1). For example, the substances emitted during the production of HFC-227ea were estimated to amount to 120 kg CO_2-eq kg^{-1} of material manufactured (Banks *et al*., 1998), whereas for HFC-134a this figure was relatively low with estimates ranging from 2–40 kg CO_2-eq kg^{-1}. (McCulloch and Lindley, 2003 and Banks and Sharratt, 1996, respectively). These values are strongly dependent on the fluid manufacturing process and the integrity of the chemical plant. The good design and operation of the plant can lead to lower emissions. It should be noted that some of the intermediate substances might be ODSs (although these are converted into the end product without being emitted). For example CFC-114a, HCFC-133 and HFCF-124 are used in particular routes for the manufacture of HFC-134a (Frischknecht, 1999). The emissions of GHGs are significantly less for alternative fluids. HC-290, HC-600a and HC-1270 are generally extracted from natural gas mixtures and leakage from the process plant will generally comprise a variety of hydrocarbons. Gover *et al*. (1996) estimate 0.14 kg CO_2, 0.5 g HC and 0.7 g methane emissions per kg of propane/butane, which equates to 0.2 kg CO_2-eq kg^{-1}, and data from Frischknecht (1999) are lower than this. Ammonia is normally produced from natural gas and emissions of GHGs will only comprise methane and CO_2. Frischknecht (1999) estimates between 1.5 and 2.3 kg CO_2 kg^{-1} ammonia produced, consistent with the value in Campbell and McCulloch (1998). CO_2 is a slightly different case, as commodity CO_2 is generally a recovered byproduct from numerous other chemical manufacturing processes and it is therefore difficult to specifically attribute emissions to CO_2. Frischknecht (1999) reports emissions of CO_2 and methane, equivalent to 0.2 kg CO_2 kg^{-1} CO_2 produced.

Distribution of fluids
Once manufactured, fluids can be shipped nationally or internationally, often as bulk shipment or in individual cylinders. Typically, national or regionally organized distribution chains deliver bulk quantities to product manufacturers or transfer the substances into smaller containers for use by manufacturers and service companies, in the case of refrigerants and solvents. The distribution chain stops when the substance enters into the management or control of the 'user', such as a manufacturer or a service company. Losses normally occur during the transfer of fluids, connection and disconnection of hoses, and leakage from containers and pressure relief devices. These losses tend to be relatively small in relation to the large quantities of materials handled (Banks *et al*., 1998), as transfer operations take place under carefully-controlled conditions and are subject to international regulations for the prevention of releases (e.g. UN, 2002; IMO, 2000).

Manufacture and distribution of products
HFCs and alternative fluids are generally used in the manufacture of refrigeration systems, foams, aerosols and fire protection equipment, whereas solvent applications (e.g. cleaning) tend to apply fluids directly on-site during the in-use stage. The manufacture of refrigeration products requires transfer of the fluid. Losses normally occur due to the connection and disconnection of hoses and valves. Emissions also originate from storage vessels and the associated piping, but these are less frequent.

Some sources of emissions are specific to certain applications and products. For example, refrigerants are often used to rinse out air, moisture and other contaminants from refrigeration equipment to ensure internal cleanliness prior to charging. Moreover, the refrigerant may also be employed as a tracer for the detection of leaks. Equipment leaks may be found after charging of the refrigerant, in which case further emissions will occur during the recovery and evacuation process prior to repairing the leaks. During the manufacture of foams, fluids are used as blowing agents. The blowing-agent emissions during the preparation of foam formulations, when the blowing agent is mixed with other raw materials such as polyols, are low due to the use of closed systems. Depending on the type of foam

[1] Only direct emissions from the production process are considered here and not indirect emissions from electrical energy requirements.

Table 3.1. Percentage contribution of direct (HFC) emissions to total lifetime greenhouse-gas emissions in various applications (emissions associated to functional unit) – selected indicative examples.

Application	Method applied	HFC emissions as percentage of lifetime systemgreenhouse-gas emissions (using GWP-100)	Characterization of system and key assumptions	Publication
Mobile Air Conditioning	TEWI	**40–60%** – Current systems (gasoline engine) **50–70%** – Current systems (diesel engine)	Passenger vehicle; HFC-134a Sevilla (Spain)	Barrault *et al*. (2003)
Commercial Refrigeration	LCCP	**20–50%** – for a wide range of sensitivity tests on leakage rate, energy efficiency and energy supply	Direct Expansion Refrigeration Unit; Supermarket (1000m^2); HFC-404A; Germany	Harnisch *et al*. (2003)
Domestic Refrigeration	TEWI	**2–3%** – No recovery at end-of-life	European standard domestic refrigerator; HFC-134a; World average electricity mix	Chapter 4 of this report
Insulation Foam of Domestic Refrigerators	LCCP	**6%** – with 90% blowing agent recovered at disposal **17%** – with 50% blowing agent recovered at disposal	HFC-245 fa; Europe	Johnson (2004)
PU Insulation Foam in Refrigerated Truck	LCCP	**2%** – with full recovery of HFC at disposal **13%** – without recovery of HFC at disposal	Refrigerated Diesel truck; Germany	Harnisch *et al*. (2003)
PU Spray Foam Industrial Flat Warm Roof	LCA	**13%** – with full recovery of HFC at disposal **20%** – without recovery of HFC at disposal	4 cm thickness; HFC-365 mfc; Germany	Solvay (2000)
PU Boardstock in Private Building Cavity Wall	LCA	**4%** – with full recovery of HFC at disposal **17%** – without recovery of HFC at disposal	5 cm thickness; HFC-365 mfc; Germany	Solvay (2000)
PU Boardstock in Private Building Pitched Warm Roof	LCA	**10%** – with full recovery of HFC at disposal **33%** – without recovery of HFC at disposal	10 cm thickness; HFC-365 mfc; Germany	Solvay (2000)

and process, either a small fraction (rigid closed cell foam) or the entire blowing agent (flexible open cell foam) is emitted during the manufacturing process. The foaming usually takes place under ambient atmospheric conditions. The blowing agent emitted from the foaming process mixes with the air and is then vented or incinerated. Aerosols are generally charged in factory premises and, as for refrigerating systems, the disconnection of charging heads results in small releases. Cleaning machinery is occasionally filled with solvent, although emissions tend to be minimal at this stage because fluids with a low vapour pressure are generally used.

Use

The in-use stage of the product lifetime tends to result in the greatest emissions for most applications, particularly for refrigeration, aerosols, solvents and fire protection systems. For refrigeration and air-conditioning systems, for example, in-use emissions can vary widely depending on the service and disposal practices as well as other operational and environmental factors not intrinsic to the technology. Emissions from domestic, commercial and industrial refrigerating equipment generally originate from failures in system components or from the handling of refrigerant during servicing, with the size and frequency of leaks depending upon several factors. External factors include usage patterns, frequency of equipment relocation, weathering and aggressive environments, repair quality and frequency of preventative maintenance. Rapid fluctuations of temperature or pressure and excessive vibration of piping, joints and so forth, due to fan motors and compressors or other external sources are major causes of in-use leakage. Other integral aspects are associated with the design and construction of the equipment. The design quality of the equipment and the use of suitable components have a significant impact on leakage rates. Control systems are also responsible for emissions, such as pressure-relief devices. Most industry guidance on emissions focuses on leak prevention for the in-use stage (e.g., see Institute of Refrigeration, 1995; Butler, 1994; ETSU, 1997). The multiple factors contributing to emissions of refrigerant often lead to a fairly broad distribution of net leakage rates for individual pieces of equipment. Figure 3.2 shows an example

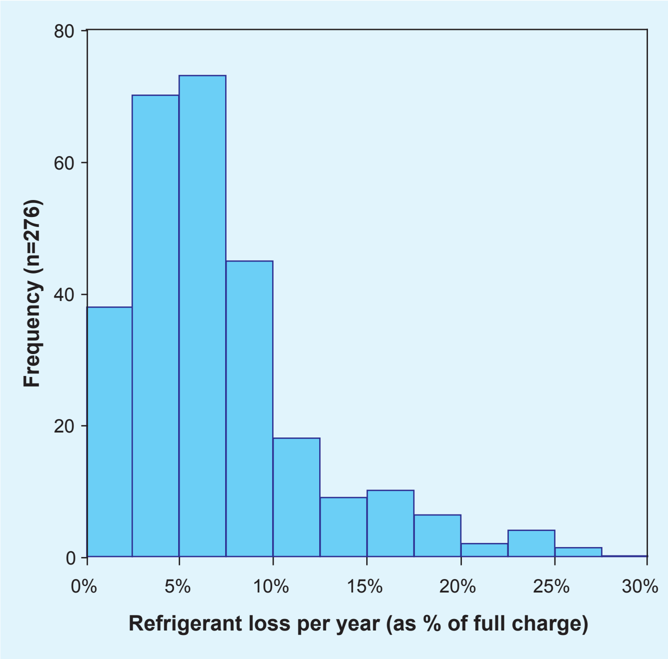

Figure 3.2. Distribution of annual leakage rates of mobile air conditioning systems in a fleet of 276 European passenger vehicles (after Schwarz & Harnisch, 2003.

from a survey carried out on mobile air-conditioning systems in Europe (Schwarz and Harnisch, 2003). A similar distribution is seen with supermarket systems (Radford, 1998). It is clear that the mean leakage rate for an equipment population can result from a broad distribution that includes many very tight, a large number of fairly tight and a small number of very leaky systems.

Decision-makers should realise that, in general, a leakage rate is not necessarily intrinsic to a certain technology but can also strongly depend on a number of environmental and operational factors. If properly understood, these factors can be systematically influenced to reduce emission levels. Whilst the quality of maintenance and repairs to equipment influence the leakage during operation, the actual handling of refrigerant may also lead to significant emissions, for example the removal of fluid from a system and the subsequent recharge. The degree of leakage is strongly dependent on the behaviour of the personnel and the tools they use, and will range from the minimum (that associated with residual gas within hoses and the system) up to quantities exceeding the system charge. Despite the legislation against venting in a number of countries, practices frequently prevail in which the whole system is vented, leak-tested with the fluid (possibly several times until all leaks are repaired) and flushed with the fluid before final recharging. Poorly connected hoses and fittings, and poor-quality recovery equipment can significantly contribute to high emissions.

The majority of emissions from aerosols, fire protection systems and solvents also occur during the in-use stage, although these are intentional since a release is part of the functionality of the equipment. Emissions from aerosols are simply a function of the amount of propellant used. Fire protection systems produce emissions upon demand, as is the intention, although undesired emissions occur from false alarms or faulty signals, or from mandatory system qualification tests that require full system discharge. Sometimes training also involves the operation of the fire protection system. Within the use phase of certain applications, such as fire protection systems, equipment servicing and maintenance may require the removal of fluid from a system and subsequent recharge, and emissions associated with this. Fire protection systems also exhibit slow passive emissions throughout the in-use stage, particularly in the case of high-pressure cylinder systems. Similarly systems that are being maintained can produce significant emissions if the system is accidentally initiated, or when servicing of the systems requires checking and confirmation of operation. Processes that use solvents generally lead to emissions as a result of residual fluid evaporation of treated items, and to a lesser extent whenever equipment is opened as part of its use.

Annual emissions from foams are generally minor during the in-use stage. The blowing agent in closed cell foams is released over time and typically only part of the blowing agent/insulant will be released during the useful life of the product. Caleb (2000) has calculated emission factors for different rigid foams based on a survey and the collection of data from emission factors reported in the literature. Lee and Mutton (2004) recently did the same for extruded polystyrene or XPS foam.

Decommissioning

Fluids may be vented or recovered during the decommissioning of refrigeration equipment, unexpelled fire protection systems and equipment using solvents. Over the past decade the price of recovery equipment has fallen significantly and the sales of such equipment have expanded, indicating that recovery has become much more widespread than was the case during the 1980s and first half of the 1990s. Blowing agents from foams and propellant from aerosols can also be recovered at end-of-life, but current methods have a low effectiveness. Emission levels of refrigeration and air-conditioning systems, and of foam applications are very sensitive to disposal practices.

For refrigerants, fluids from fire protection systems and solvents, the sources of emissions associated with removal at end-of-life are the same as those associated with normal handling, as discussed previously for the servicing aspect during the in-use stage. Fluids used to be vented when equipment was decommissioned but where legislation has been introduced, the expected practice is to recover the fluid. If the fluid is recovered, it may be re-used (in its recovered form), recycled (using on-site machinery) or taken back to the supplier or recycling centre for cleaning (and re-use) or disposal. Uncontaminated fluids can normally be reused and whether a fluid can be cleaned on-site or has to be returned to the supplier, depends on the type and degree of contamination and the process needed to return it to the purity of virgin fluid. However, in many situations, the resources required to clean up contaminated refrigerant rarely outweigh the risks and benefits to the service company. Therefore in most countries recovery rates have remained low if the chemical to be recovered is relatively inexpensive. Some suppliers or governments (e.g. Australia) have introduced cash incentives for the return of 'minimally-contaminated' refrigerant, but the success rate of such schemes is still unknown.

In the case of rigid insulating foams, the majority of blowing agents remain in the foam until end-of-life. Some rigid insulating foams such as 'board stock' and 'sandwich panels' can be recovered or re-used if they are not adhered to substrates or can be easily separated from these. A similar approach can be used with aerosol cans that contain residual propellant, although this procedure is not normally used.

Disposal

Following the recovery, and potentially recycling and reclamation, of refrigeration equipment, fluids meant for disposal are stored ready for destruction. The handling and storage of refrigerants and fire protection system fluids, solvents and recovered aerosol propellants prior to destruction can lead to emissions in the same way as in the distribution of fluids stage.

In the case of rigid insulating foams, the disposal is complicated because the foams are only a small part of overall systems such as a refrigerator or a building. Refrigerator foams can be shredded and incinerated to destroy all blowing agents. Alternatively they can be sent to landfills, where the blowing agents will slowly be emitted and/or decompose (Kjeldsen and Scheutz, 2003).

In general, destruction by incineration produces a small amount of emissions (of the original material). Destruction (or destruction and recovery) efficiencies are typically between 99% and 99.99%, resulting in 0.1−10 g released per kg of material (UNEP-TEAP, 2002). Gases such as CO_2, resulting from the combustion of fuel and fluid, are also emitted.

3.2.1.2 Types of emission

Table 3.2 identifies the types of emission common to the various applications in the subsequent technical chapters. These can be categorized into four general groups. Mitigation of emissions for each category requires attention for a particular process within the life of the equipment: Material selection (passive), mechanical design/construction (rupture), technician training (handling) and usage patterns (intentional/functional).

Passive

Passive emissions are generally small, 'seeping' leaks that occur constantly and are normally the result of permeation through construction materials and metal fatigue. This applies in particular to refrigerants, fire protection system fluids and aerosols when materials gasket, plastics and elastomers for seals and hosing are used. Emissions are minimized by selecting the correct materials for the fluids used. In making this choice, the influence of other fluids within the mixture such as refrigeration oils and aerosol fragrances, which can affect permeability, should also be considered. In rigid insulating foams, the passive emission of blowing agents occurs through diffusion. The diffusion coefficients of HFCs through the rigid insulating foams vary considerably, dependent on the type of blowing agent. The use of non-permeable facer materials such as aluminium foils and metal skins can significantly reduce the diffusion of blowing agents. Passive emissions typically occur throughout all stages of the fluid and foam life, but as they are relatively constant, they predominate during the in-use stage.

Table 3.2. Sources of emissions by type and application.

Application	Production				Use				Decommissioning				Disposal			
	Passive	Rupture	Handling	International	Passive	Rupture	Handling	International	Passive	Rupture	Handling	International	Passive	Rupture	Handling	International
Refrigeration		✓	✓	✓	✓	✓	✓	✓			✓	✓			✓	✓
Air conditioning		✓	✓	✓	✓	✓	✓	✓			✓	✓			✓	✓
Mobile air conditioning		✓	✓	✓	✓	✓	✓	✓			✓	✓			✓	✓
Foams			✓	✓	✓				✓		✓				✓	✓
Aerosols			✓	✓	✓	✓		✓			✓	✓		✓	✓	✓
Fire protection			✓	✓	✓	✓	✓	✓			✓	✓			✓	✓
Solvents			✓	✓	✓	✓		✓			✓	✓		✓	✓	✓

Note: Fluid manufacture and distribution are excluded from this table since they do not pertain to any one specific application.

Rupture

Ruptures are accidental breaks in pressure systems, such as fractures in pipework, vessels and components. These are normally associated with fluids under high pressure and therefore tend to occur throughout most stages of the fluid life. Ruptures can result from external forces applied to components, inherent material weaknesses, the influence of pressure and temperature changes, vibration, the ageing of materials and corrosion. Large ruptures are generally the most notable type of leaks and tend to cause rapid and often complete release of the fluid. Rupture leaks or emissions do not apply to foam because the pressure differential within and outside the foams is very small. Ruptures can be minimized by appropriately designing piping and components to account for anticipated stresses, protecting against external impact and avoiding a chemically aggressive environment.

Handling

Handling emissions are unintentional releases that occur with human intervention, for example, where a fluid is being transferred into or out of equipment and complete recovery is impractical. Residual amounts of fluid occur in transfer hoses, within components and systems following recovery, and absorbed in certain materials such as oil. The fluid will subsequently migrate to the atmosphere when hoses are disconnected or systems are opened following recovery. Such releases occur throughout the life of the fluid regardless of the application, but a lack of training and insufficient awareness of the environmental impact of fluids means that personnel are less likely to mitigate emissions when handling them.

Intentional/Functional

Intentional releases are determined by human activity and may be unnecessary or required because of the function of the application (e.g. aerosols, fire protection). Unnecessary intentional releases occur where the operator chooses to directly release the fluid to the atmosphere. Examples include venting where the fluid is not recovered following removal from an application, the fluid being released directly through opening valves or cutting into pipe work, or the operator employing the fluid for ulterior uses such as blowing dust from pipes, and so forth.

Functional emissions occur specifically with fire protection, aerosols and some solvent uses. In situations where the fluid is within storage facilities, or within pressure systems during the in-use stage, intentional releases can occur in response to uncontrolled circumstances, for example, when pressure relief devices vent in the event of fire. Similarly, fire protection systems may release fluid in response to false signals from heat, smoke or light detectors, thus discharging the whole system.

3.2.1.3 Measurement and estimation of emissions

Quantifying emissions from a specific application is useful for several purposes, including the retrospective environmental impact assessment or the evaluation of operating costs. Unfortunately for most applications it is difficult to measure the field leakage and even where this is possible, the measurement is imprecise. Laboratory studies are largely impractical for most applications, for example large supermarket refrigeration systems that are built and maintained by a number of different companies. However, emissions from foams are usually less sensitive to external conditions and so laboratory measurements are normally highly appropriate. Releases during fluid manufacture, fluid distribution and the manufacture/distribution of equipment would normally be measured by monitoring the mass flow of material into and out of facilities. The same applies at end-of-life, when recovered fluid is returned to suppliers and delivered to recycling or incineration facilities.

Since releases at the in-use stage tend to predominate, these are more frequently monitored. The problem with existing methods such as gas detection is that they do not measure the mass of fluid released; concentrations of leaked gas detected indicate the presence of a leak, but do not permit this to be quantified (Van Gerwen and Van der Wekken, 1995). Recent developments in leak detection for refrigerating systems include intrinsic detectors, where a reduction in refrigerant inventory is measured within the system (as opposed to measuring the presence of refrigerant outside it) (Peall, 2003, www.nesta.org.uk/ourawaardees/profiles/3763/index.html). Such an approach is particularly useful for accurately measuring the loss of charge but does not provide information on losses from handling activities. The most accurate method is to record the mass usage of the substance. For refrigerating equipment, fire protection systems and solvent use, this involves tracking the quantities of chemicals that are acquired, distributed and used to fill a net increase in the total mass (charge) of the equipment. Quantities not accounted for are assumed to have been emitted. Entities that contract equipment maintenance to service companies can estimate their emissions by requesting the service company to track the quantities of refrigerant recovered from and added to systems.

Different approaches can be used to prediction emissions associated with particular equipment or systems. The least accurate but most simplistic approach is to apply annual leak rates (% yr^{-1}) for the appropriate sector or equipment types to the mass of fluid used. However, these are generally approximated using bottom-up methods, combined with limited measured data and industry interviews (e.g. March, 1996). At best, leak rates may be found for equipment manufacture, aggregate in-use stage and end-of-life recovery. More detailed analyses may be conducted by calculating releases from each element throughout the equipment life. This also depends on good information about the flow of material throughout its life, data on component dimensions and knowledge about the behaviour of technician handling (US EPA, 1995). For example, Colbourne and Suen (1999) provide empirically-derived emission indexes for the leakage of different components and different servicing frequencies in order to estimate leakage for a whole system. With this more detailed approach, the actual design of systems and equipment can be more accurately assessed and 'emission optimization' can be applied to the design and operation.

Nevertheless, it is known that leakage rates are highly erratic and for two similar systems these may vary from 0% to over 100% yr^{-1}.

The emission of foam-blowing agents through diffusion can be derived from model calculations (Vo and Paquet, 2004; Albouy *et al*., 1998). Alternatively, the residual quantity of blowing agents can be determined analytically, although caution must be exercised when using these measurements to estimate in-use emissions. Although the emission of the blowing agent out of a well-defined foam system (e.g., a refrigerator or a piece of rigid foam) can be estimated, obtaining accurate emissions from the foam sector remains difficult due to the variety of foams, blowing-agent initial concentrations, diffusion rates of specific blowing agents, product thicknesses, densities, usage conditions and cell structures.

Direct measurement of greenhouse gas and other fluid emissions is only possible in a few cases and so the values described as 'real' data have to be calculated from secondary data. These calculations should conform to the standard methodologies already developed for emissions trading, which cover refrigeration and air-conditioning systems and chemical processes (DEFRA, 2003), and the standards and guidance for greenhouse-gas emissions inventories (IPCC, 1997; IPCC, 2000a).

The IPCC Good Practice Guidance on National Greenhouse Gas Inventories published in 2000 (IPCC, 2000a) includes three methods for estimating emissions of ODS substitutes. The tier 1 method that equates emissions to consumption (potential emissions), the tier 2a bottom-up method that applies country-specific emission factors to estimates of equipment stock at different life-cycle stages, and the tier 2b top-down method that uses a country-level, mass-balance approach. For sectors where the chemical is banked into equipment, the tier 1 method is significantly less accurate than the other two approaches. This is particularly the case where the equipment bank is being built up and this is precisely the current situation for air conditioning and refrigeration equipment during the transition from CFCs and HCFCs to HFCs. In this situation, most of the chemical consumed is used to fill new equipment volume (charge) rather than to replace emitted gas, and therefore the tier 1 method greatly overestimates emissions. To a lesser extent, the tier 2b country-level, mass-balance approach is also inaccurate during the period of bank building, but in this case, the error is an underestimate (see the discussion in Section 3.2.1.3 for an explanation of this underestimate). That is why the IPCC recommends supplementing the tier 2b approach with the tier 2a emission-factor based approach. The disadvantage of the tier 2a approach is that for the first few years of equipment life, the emission factors will necessarily be based on engineering estimates rather than empirical experience. However, when the first cohort of equipment is serviced, the emission factors can be corrected as necessary. Ultimately, when the HFC-using equipment starts to be retired, the tier 2b method can be used on its own with a high level of accuracy.

More detailed requirements for calculations are stated in IPCC (1997). IPCC (2000a) should be consulted for additional guidelines on emission estimation methods, particularly for the different sectors.

3.2.2 *Indirect emission*

This section examines aspects related to emissions arising from the energy consumption associated with the manufacturing of products and their components, the use of these products during their useful life and their disposal. The use phase is outlined for cooling applications, heat pumps and foams, as this phase usually dominates the energy consumption of these systems. More application-specific energy aspects are covered in the specific sections of Chapters 4 to 10 of this report.

3.2.2.1 Use phase

ODS substitutes are typically used in cooling applications and thermal insulation foams. For aerosols, solvents and fire protection, the energy consumption during the use phase is not relevant.

Cooling applications and heat pumps

The refrigeration, heat pump and air-conditioning sectors use different approaches to establish and compare energy efficiencies for various technologies:

- Modelled efficiencies based on modelled coefficients of performance (COP);
- Measured efficiencies of products in the research and development phase (established under standard test conditions)[2];
- Measured efficiencies of products in mass productions (established under standard test conditions);
- Measured consumption under representative real conditions.

The coefficient of performance (COP[3]) of a refrigerating plant, product or system is a key parameter for characterizing the energy efficiency of a process. It is the ratio of refrigerating capacity to the input power required to operate the compressor, pumps, fans and other ancillary components.

$$COP = Q_0 / P \qquad (3.1)$$

Where:

Q_0 is the refrigerating capacity (cooling mode) or heating capacity (heating mode) including an allowance for losses in any secondary circuit (kW), and

[2] It is important that the standard conditions represent the situation in which the equipment will be used; for example it would not be appropriate to use standard test results gained at an ambient temperature of 15°C when the real ambient temperature of operation of the equipment is 35°C.

[3] In European standards and some ISO standards the term EER (Energy Efficiency Ratio) is used for the cooling mode of the cycle and COP (Coefficient Of Performance) is used for the heating mode. For the purpose of this report only one term is used, COP. Where this term is used, it should be specified whether it relates to cooling or heating.

P is the total power consumption (kW) of the compressors, controls, fans and pumps required to deliver that capacity to the place where it is used.

The COP primarily depends on the working cycle and the temperature levels (evaporating/condensing temperature) but is also affected by the properties of the refrigerant and the design of the system. Energy consumption estimated from known models does not usually take into account the effects due to different ‘real-world’ handling practices, imperfect design, assembly, capacity control and maintenance. Small fluid leakage, for example, not only impacts direct emission but also indirect emission due to a decrease in the COP of equipment. Figure 3.3 gives an example of the real world spread of measured energy consumptions for a large group of homogenous refrigeration systems. Another typical example is the use of capacity control technologies to optimize the energy consumption. Good capacity control results in smaller pressure differences (evaporating/condensing temperature) leading to improvements of the overall energy efficiency of the system.

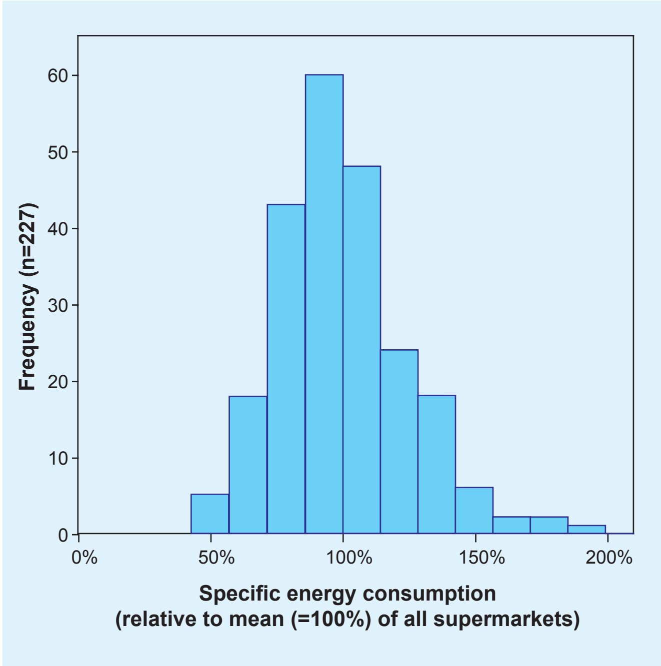

Figure 3.3. Distribution of measured specific energy consumptions (originally expressed as kWh d^{-1} m^{-1} of cooled display cases) expressed as percentage of the mean for 227 standard stores using standard HFC technology of a German supermarket chain – after Harnisch *et al.* (2003).

Insulation foams

There are two fundamental approaches to assess the effects on energy consumption of using insulation materials with differing insulation properties as a result of a changed blowing agent (Table 3.3).

Further the specific usage pattern of the system should be noted and addressed if it is material to the calculation. One example might be the effect of day to night temperature changes on a cold store that has traffic through it 24 hours per day as opposed to one that is shut up all night. Both approaches need to be documented with references to standard calculation methods and sources of information.

Approach B in Table 3.3 depends on more assumptions than approach A and is conceptually more challenging. However circumstances can arise in which thickness compensation is technically not possible due to space constraints and then approach B is the only feasible method. Even if partial thickness compensation is possible, the calculation of energy impacts will still require approach B.

In general these comparisons are limited to identical systems where only one element has been changed. Comparisons between completely different systems are much more difficult

Table 3.3. Comparison of two approaches for comparing the impact of blowing agent choice on energy consumption.

Approach A) Thickness compensation: The thickness is increased for any loss of insulation value so that unchanged energy consumption is assumed to be achieved by a material penalty. This may have an environmental impact due to increased direct emissions and the energy used for production. However, for the energy consumption during the usage phase, the key requirements are relatively simple and involve characterization of: • The functional unit and its desired service (e.g. required common additional heat resistance R value m^{-2} of application and time); • The insul respective thickness and density or mass); • The insulation properties of the foam(s) using a test appropriate to the duty (e.g. respective thermal conductivity values).
Approach B) Comparative energy modelling: Where it is not possible to com pensate for a change in insulation value, the energy consumption of the system in which the foam is used is calculated for both the reference case and alternative case. This is a more complex process and, in addition to the parameters outlined above, it will require definition of: • The type and efficiency of the process supplying heat or cold (to accommodate change in efficiency with temperature); • The appropriate ambient conditions and the internal temperature profile require or alternatively a description of an appropriate proxy (for example heating or cooling degree days); • Internal sources of heat or cold and how the demand will change with temperature.

to interpret. Examples of comparisons of different foam types, where the model assumptions are clear and do not compromise the results, are given in Caleb (1998, 1999), Enviros March (1999), ADL (1999), Krähling and Krömer (2000), Harnisch and Hendriks (2000) and Harnisch *et al*. (2003).

3.2.2.2 Production energy of fluids and fugitive emissions

Table 3.4 details the small number of estimates of production energy (also known as embodied energy) and fugitive emissions associated with the production of the materials used in systems covered by this report. These estimates are also summarized and applied in Frischknecht (1999a and 1999b) and Harnisch *et al*. (2003). It is worth noting that the newer study shows lower values for HFC-134a due to more widespread application of vent gas treatment to destroy 'fugitive' HFC streams (in previous studies these were emitted into the atmosphere). In-use emissions usually dominate environmental impact and production energy, whereas fugitive emissions only make small contributions.

3.2.2.3 Indirect emissions from energy use

Indirect emissions (of carbon dioxide) from the energy used to operate a system comprise those arising from the generation of the electricity consumed (for example by the compressor, controls, pumps and fans of a building air-conditioning system) and any fuel used directly by the system (e.g. gas used for gas-driven compressors, fuel used by absorption systems or the additional gasoline usage associated with automobile air conditioning). The total lifetime emission of carbon dioxide from the energy used to operate the system (E_I) is:

$$E_I = Q_E \text{ x } I_E + \sum(Q_{Fi} \text{ x } I_{Fi}) \qquad (3.2)$$

Where:
Q_E is the total lifetime use of electricity;
I_E is the carbon dioxide intensity of electricity production (from Table 3.5);
Q_{Fi} is the total lifetime use of fuel *i*, and
I_{Fi} is the carbon dioxide intensity of that fuel (from Table 3.5)

Carbon dioxide emissions associated with the generation of electricity vary greatly between countries depending on the specific mix of generation technologies and fuels (e.g. coal, natural gas, combined cycle systems, hydroelectricity, etc.) used. Increasingly complex calculations could be performed to define the minute details of energy-related emissions of carbon dioxide and other greenhouse gases. However for the generic approach described here, it is assumed that the most important emission is carbon dioxide and that the methods employed by the International Energy Agency (IEA) will give internationally consistent estimates. Accordingly, national and regional carbon dioxide intensities of electricity are shown in Table 3.5. These intensities are calculated as the ratio of national carbon dioxide emission from electricity generation, taken from IEA (2002b), to the quantity of electricity used nationally, obtained from IEA (2002a) or IEA (2003). The IEA statistics take into account electricity trading between countries, in the form of an annual average.

For those countries or regions not shown in Table 3.5, the national carbon dioxide intensity of their electrical power (I_E) may be calculated as the sum of the total of each fuel used in electricity generation, multiplied by its carbon dioxide intensity (also quoted in Table 3.5), divided by the total national quantity of electricity *delivered* to customers.

$$I_E = \sum (Q_{Fi} \text{ x } I_{Fi}) / D_E \qquad (3.3)$$

Where:
Q_{Fi} is the total annual quantity of fuel *i* used in electricity generation and I_{Fi} is the carbon dioxide intensity of that fuel (from Table 3.5), and

Table 3.4. Overview of production energy requirements and associated CO_2 emissions.

Material	Production Energy Requirement MJ kg^{-1}	Equivalent Production CO_2 Emissions kg CO_2-eq kg^{-1}	Reference
Aluminium	170	-	Lawson (1996)
		7.64	Ingots : SAEFL (1998)
		2.06–6.56	Pira (2001)
Steel/iron		2.95	Sheet: SAEFL (1998)
		1.60–2.78	Pira (2001)
Stainless Steel	38	-	Lawson (1996)
Copper	100	-	Lawson (1996)
Brass		2.97	Plate: SAEFL (1998)
		11.4–16.1	Norgate and Rankin (2000)
Glass	13	-	Lawson (1996)
HFC-134a (I)	64–105	6–9	Campbell and McCulloch (1998)
HFC-134a (II)	-	4.5	McCulloch and Lindley (2003)
Cyclopentane	24	1	Campbell and McCulloch (1998)
Ammonia	37	2	Campbell and McCulloch (1998)

Table 3.5. Carbon dioxide intensities of fuels and electricity for regions and countries.

Carbon Dioxide Intensity Of Electricity	kg CO_2 kWh^{-1}		Carbon Dioxide Intensity Of Electricity	kg CO_2 kWh^{-1}	
		Note			**Note**
Region		a	**Country**		
Africa	0.705	b	Argentina	0.319	b
Asia	0.772	b	Australia	0.885	c
EU	0.362	c	Austria	0.187	c
Europe (OECD)	0.391	c	Belgium	0.310	c
Europe (non-OECD)	0.584	b	Brazil	0.087	b
Latin America	0.189	b	Canada	0.225	c
Middle East	0.672	b	China	1.049	b
N America	0.567	c	Denmark	0.385	c
Pacific	0.465	c	Finland	0.222	c
Former USSR	0.367	c	France	0.078	c
			Germany	0.512	c
Carbon Dioxide Intensities Of			Greece	0.876	c
Fuels Used In The Calculations	g CO_2 MJ^{-1}		India	1.003	b
			Indonesia	0.715	b
Fuel			Ireland	0.722	c
Natural gas	56.1	d	Italy	0.527	c
Gasoline	69.3	d	Japan	0.389	c
Kerosene	71.5	d	Malaysia	0.465	b
Diesel Oil	74.1	d	Mexico	0.689	b
Liquefied Petroleum Gas	63.1	d	Netherlands	0.487	c
Residual Fuel Oil	77.4	d	New Zealand	0.167	c
Anthracite	98.3	d	Norway	0.003	c
Bituminous Coal	94.6	d	Pakistan	0.524	b
Sub-bituminous coal	96.1	d	Philippines	0.534	b
Lignite	101.2	d	Portugal	0.508	c
Oil Shale	106.7	d	Russia	0.347	b
Peat	106.0	d	S Africa	0.941	b
			Saudi Arabia	0.545	b
			Singapore	0.816	b
			Spain	0.455	c
			Sweden	0.041	c
			Switzerland	0.007	c
			UK	0.507	c
			USA	0.610	c

Notes:
a. Regions as defined in IEA (2002a) and IEA (2003).
b. Carbon dioxide from "Public Electricity and Heat Production"5 (units Mtonnes CO_2) in summary tables of IEA (2002b), divided by Total Final Consumption electricity and heat6 given as ktonne Oil Equivalent in IEA (2002a), further divided by 11.63 to convert to kg CO_2 kWh^{-1}.
c. Carbon dioxide as in 2 above, divided by Total Final Consumption[4] given as GWh in IEA (2003), multiplied by 1000 to convert to kg CO2 kWh^{-1}.
d. Values from Table 3 of IEA (2002b) multiplied by 44/12 to convert to mass of CO_2.
e. Using this category has the effect that all energy inputs to systems that generate electricity and heat are counted against both the electricity and heat generated.
f. Total Final Consumption is electricity or heat available at the consumer net of transmission and distribution losses.

D_E is the total annual national delivery of electricity. Table 3.6 shows examples of the application of this method.

Where there is a nationally agreed energy plan for the future, figures from this may be used for assumptions about future indirect emissions from energy use.

3.3 Categories of costs

The cost of climate change mitigation is an important input to decision-making about climate policy goals and measures. This section provides an oerview of key concepts and assumptions that can be applied to the assessment of policy options related

Table 3.6. Carbon dioxide intensity calculation for representative countries.

Fuel mix (for electricity generation only)												
	Coal			Fuel oil		LPG		Natural gas				
Type	Usage kt	Calorific value TJ/kt	*Emission factor* tCO_2/TJ	Usage kt	*Emission factor* tCO_2/TJ	Usage kt	*Emission factor* tCO_2/TJ	Usage kt	*Emission factor* tCO_2/TJ	**Total CO_2 emissions** $ktCO_2$	**Electricity generated less distribution losses** GWh_e	**Carbon intensity** $kgCO_2/kWh_e$
A	B	C	D	E	F	G	H	I	J	K	L	M
First Country Example												
Sub bituminous	112,775	18	*96.1*	118,712	*77.4*	0	*63.1*	127,574	*56.1*	21,0558	234,000	0.900
Second Country Example												
Bituminous	11,430	27	*94.6*	57,173	*77.4*	304	*63.1*	47,558	*56.1*	36,288	62,059	0.585
Third Country Example												
None				3,892	*77.4*	0	*63.1*	3,160	*56.1*	48	1,750	0.273

Notes:

Values in italics are constants available from standard tables (see Table 3.5 here)

A. Both the calorific value and the carbon content (and thus emission factor) vary with the quality of coal.

B. More than one quality of coal may be used (and separate rows should be used, then added together).

C. Calorific value varies between sources and should be determined by testing.

D, F, H, J. CO_2 emission factors are shown in Table 3.5

K. The value in K is equal to (B x C x D + E x F + G x H + I x J) divided by 1000.

L. This is the total electrical production minus only the amount lost in distribution.

M. The carbon intensity is equal to K divided by L.

to technologies and production processes using fluorinated gases. The use of consistent and well-defined cost concepts is recommended for the assessment of the various technologies and options described in detail in various parts of this Special Report, and for reporting the assumptions and concepts applied in mitigation studies in a thorough and transparent manner.

3.3.1 Introduction

Actions to abate emissions of fluorinated gases generally divert resources from other alternative uses, and the aim of a cost assessment is to measure the total value that society places on the goods and services foregone due to resources being diverted to climate protection. Where possible the assessment should include all resource components and implementation costs and should therefore take into account both the costs and benefits of mitigation measures.

A key question in cost analysis is whether all relevant dimensions (e.g. technical, environmental, social) can be measured in the same units as the costs (i.e. monetary). It is generally accepted that some impacts, such as avoided climate change, cannot be fully represented by monetary estimates and it is imperative that the cost methodology is supplemented by a broader assessment of impacts measured in quantitative and if needs be qualitative terms.

In any economic analysis of climate change mitigation, the cost of mitigation is calculated as a difference in costs and benefits between a baseline case and a policy case that implies lower emissions. Where possible, the definitions of the baseline and policy cases should include all major social, economic and environmental impacts (at minimum from GHG emissions and ODP emissions). In other words, the system boundary of the cost analysis should facilitate the inclusion of all major impacts. The system boundary can be a specific project, one or more sectors, or the entire economy.

The project, sector and macroeconomic levels can be defined as follows:

1. *Project*. A project level analysis considers a 'stand-alone' investment that is assumed not to have significant impacts on markets beyond the activity itself. The activity can be the implementation of specific technical facilities, demand-side regulations, technical standards, information efforts, and so forth. Methodological frameworks to assess the project level impacts include cost-benefit analysis, cost-effectiveness analysis and Life Cycle Assessment.

2. *Sector.* Sector level analysis considers sectoral policies in a 'partial equilibrium' context, for which all other sectors and the macroeconomic variables are assumed to be as given.

3. *Macroeconomic.* A macroeconomic analysis considers the impacts of policies across all sectors and markets.

Costs and benefits can be reported in present values or as levelized values (alternative ways to generate time-consistent values for flows of costs and benefits that occur at different points in time). Further details about these approaches can be found in Box 3.1.

This report focuses on project level cost analysis in particular because a); the scale of the mitigation policies analyzed can be considered small enough to exclude significant sectoral and economy-wide impacts; b) the basis for conducting a sectoral level cost analysis is weak since the literature does not include sectoral modelling studies for activities which involve the production and use of ODSs and their substitutes; c) and finally the current section is a first attempt to define consistent cost concepts applied to the assessment of climate change and ODS mitigation policies.

3.3.2 Direct engineering and financial cost approach

At the project level, the simplest cost assessment considers the financial costs of introducing a new technology or a production process that has lower emissions than the baseline case. Such practices can imply capital costs of new investments and changed operation and maintenance costs. When the system boundary is defined to include only the financial costs associated with the project implementation, some studies been termed this the direct engineering or financial cost approach.

Policy implementation can require upfront capital costs and changes (decreases or increases) in operation and maintenance costs compared with the baseline case over the lifetime of the project. Major categories of costs accounted in a financial cost assessment are capital, labour, land, materials, maintenance and administrative costs. The various costing elements need to be transformed into values that are comparable over the time frame and as such the cost assessment depends on assumptions about discount rates. The time dimension of costs can be dealt with using various policy evaluation approaches and an overview of some of those applied to the cost-effectiveness analysis of projects is given in Box 3.1.

3.3.2.1 Discounting

There are two approaches to discounting (IPCC, 1996b). One approach (known as ethical) gives special attention to the wealth of future generations and uses a social discounting rate. Another approach (known as descriptive) is based on the discount rates savers and investors actually apply on their day-to-day decisions and uses a higher, private cost discount rate. The former leads to relatively low rates of discount (around 2–3% in real terms) and the latter to relatively higher rates (at least 6% and in some case very much higher rates) (IPCC, 2001b, pp. 466).

For climate change, a distinction needs to be drawn between the assessment of mitigation programmes and the analysis of impacts caused by climate change. The discount rate applied in cost assessment depends on whether the social or private perspective is taken. The issues involved in applying discount rates in this context are addressed below. For mitigation effects, the

BOX 3.1 – The NPV and Levelized Cost Concepts

Guidelines for project assessment use a number of different concepts to compare the cost-effectiveness of projects. The most frequently used concepts are net present value (NPV) and levelized cost. These concepts basically provide similar project ranking.

The NPV concept
The NPV concept can be used to determine the present value of net costs, *NPVC*, incurred in a time period T, by discounting the stream of costs (C_t) back to the beginning of the base year (t = 0) at a discount rate I:

$$NPVC = \sum_{t=0}^{T} C_t / (1+i)^t$$

The levelized cost concept
The levelized cost represent a transformation of the *NPCV* into constant annual cost values, C_0, over the lifetime of the project. The levelized costs are calculated as a transformation of the *NPVC* using the formula:

$$C_0 = NPVC\left(i / \left(1-(1+i)^{-n}\right)\right)$$

where n is the time horizon over which the investment is evaluated.

The levelized costs can directly be compared with annual emission reductions if these are constant over the project lifetime.

The use of NPV and levelized costs as project ranking criteria is valid, given a number of assumptions:

NPV
An investment I_1 is more favourable than another investment I_2 if $NPVC_1$/*GHG reduction* < $NPVC_2$/*GHG reduction*. It should here be noticed that the use of NPVCs to compare the cost-efficiency of projects requires that some discounting criteria be applied to the annual greenhouse-gas emission reductions. The NPVC/GHG ratio can be used to rank investments with different time horizons.

Levelized cost
An investment I_1 is more favourable than another investment I_2 if the levelized cost of I_1 per unit of annual emission reduction is less than the levelized cost of I_2 per unit of annual emission reduction. The levelized costs should be calculated for similar investment lifetimes. The lifetimes of the investments if necessary can be made uniform by adding terminal values to investments with relatively long life time, or by replicating investments that have a relatively short lifetime.

country must base its decisions, at least in part, on discount rates that reflect the opportunity cost of capital. In developed countries, rates of around 4%–6% are probably justified (Watts, 1999). In developing countries the rate could be as high as 10–12%. These rates do not reflect private rates of return, which typically need to be considerably higher to justify the project, potentially between 10% and 25%.
For climate change impacts, the long-term nature of the problem is the key issue. The specific benefits of a GHG emission reduction depend on several factors such as the timing of the reduction, the atmospheric GHG concentration at the time of reduction and afterwards.. These are difficult to estimate. Any ‘realistic’ discount rate used to discount the impacts of increased climate change impacts would render the damages, which occur over long periods of time, very small.

3.3.3 Investment cycle and sector inertia

In the area of technologies associated with the manufacture and use of fluorinated gases, observations about replacement rates of old products have shown that it has been possible to undertake investments with a payback period as low as 1 to 5 years. This evidence suggests that from an economic and technical point of view[4], it is possible to rely on mitigation policies that are fully implemented over less than a decade. However, social structures and personal values also interact with society’s phys-

[4] There are some concerns about the capacity to maintain such fast technical transitions for future technical evolution in these sectors. Transition from CFCs to HCFCs was relatively easy because the chemistry was already known.

ical infrastructure, technology applications and institutions, and these combined systems have in many cases evolved relatively slowly. An example of such system inertia is seen in relation to the energy consumption for heating, cooling and transport, and the impacts of urban design and infrastructure. Markets sometimes tend to 'lock in' to specific technologies and practices that are economically and environmentally suboptimal, because the existing infrastructure makes it difficult to introduce alternatives. Similarly the diffusion of many innovations can be in conflict with people's traditional preferences and other social and cultural values (IPCC, 2001a, pp. 92-93).

At the same time, it should also be recognized that social and economic time scales are not fixed. They are sensitive to social and economic forces, and are influenced by policies as well as the choices made by individuals and institutions. In some cases behavioural and technological changes have occurred rapidly under severe economic conditions, for example during the oil crises of the 1970s (IPCC, 2001a, pp. 93). Apparently, the converse can also be true: In situations where the pressure to change is small, inertia is large.

Both of these issues should be considered when building scenarios about future GHG emissions from a sector. These lessons suggest that new policy approaches are needed. Instead of looking solely for least-cost policies given current preferences and social norms, policies could also aim at reshaping human behaviour and norms. This could support fast technology penetration and from a longer time perspective in particular, could imply cost reductions through learning and market development.

3.3.4 Wider costing methodologies – concepts

Up until now we have only considered the direct engineering and financial costs of specific technical measures. However, the implementation of policy options that mitigate climate change and ODSs will often imply a wider range of social and environmental impacts that need to be considered in a cost analysis.

3.3.4.1 Social and financial costs

In all work on costs, a basic distinction can be drawn between the social cost of any activity and the financial cost. Social cost is the full value of the scarce resources used in the activity measured from the point of view of society. Financial cost measures the costs from the perspective of a private company or an individual and bases its values on the costs that actually face these agents. A difference between social and financial costs arises when private agents do not take full account of the costs that they impose on other agents through their activities – such a cost is termed an external cost. Positive impacts which are not accounted for in the actions of the agent responsible, are referred to as external benefits.

External costs and benefits are distinct from the costs and benefits that companies or other private agents take into account when determining their outputs such as the prices of fuel, labour, transportation and energy, known as conventional company costs, and also from environmental costs usually accounted in more complete evaluations of company costs (see Table 3.7). Categories of costs that influence an individual's decision-making are referred to as private costs. The total cost to society is the sum of the external and private costs, which together are defined as social cost:

$$\text{Social Cost} = \text{External Cost} + \text{Private Cost} \qquad (3.4)$$

The scope of the social and private costs is illustrated in Figure 3.4.

External costs typically arise when markets fail to provide a link between the person who creates the 'externality' and the person who is affected by it, or more generally when property rights for the relevant resources are not well defined. Externalities do not necessarily arise when there are effects on third parties. In some cases, these effects may already be recognized, or 'internalized' and included in the price of goods and services. Figure 3.4 illustrates different subcategories of environmental costs, including external costs and private costs as faced by a private company. The centre box represents company costs that are typically considered in conventional decision-making. The next box (private costs) includes the typical costs plus other internal environmental costs that are potentially overlooked in decision-making, including regulatory, voluntary, up-front, operational, back-end, overhead, future, contingent and image/relationship costs. These 'private costs' include internal intangible costs (e.g., costs that could be experienced by a company related to delays in permitting, and so forth, and due to disputation with regulators and others). The box labelled societal includes environmental costs that are external to a company. These are costs incurred as a result of a company affecting the environment or human health, but for which the company is not currently held legally or fiscally responsible. These 'externalities' include environmental degradation and adverse effects on humans,

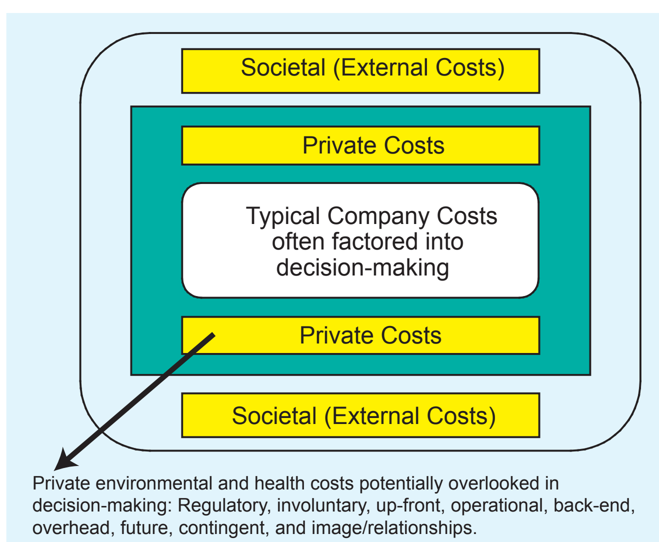

Figure 3.4. Scope of full costs (Adapted from US EPA, 1995).

Table 3.7. Examples of environmental costs incurred by firms.

Potential Hidden Costs		
Regulatory	**Upfront**	**Voluntary (Beyond Compliance)**
Notification	Site studies	Community relations/outreach
Reporting	Site preparation	Monitoring/testing
Monitoring/testing	Permitting	Training
Studies/Modelling	R&D	Audits
Remediation	Engineering at procurement	Qualifying suppliers
Record keeping	Installation	Reports (e.g., annual environmental reports)
Plans		Insurance
Training		Planning
Inspections	Conventional Costs	Feasibility Studies
Manifesting	Capital equipment	Remediation
Labelling	Materials	Recycling
Preparedness	Labour	Environmental studies
Protective equipment	Supplies	R&D
Medical surveillance	Utilities	Habitat and wetland protection
Environmental insurance	Structures	Landscaping
Financial assurance	Salvage Value	Other environmental projects
Pollution control		Financial support to environmental groups and/or
researchers		
Spill response	Back-End Costs	
Storm water management	Closure/decommissioning	
Waste management	Disposal of inventory	
Taxes/fees	Post-closure care	
	Site survey	
Contingent Costs		
Future compliance costs	Remediation	Legal expenses
Penalties/fines	Property damage	Natural resource damage
Response to future releases	Personal injury damage	Economic loss damages
Image and Relationship Costs		
Corporate image	Relationship with professional staff and workers	Relationship with lenders
Relationship with customers	Relationship with insurers	Relationship with communities
Relationship with investors	Relationship with suppliers	Relationship with regulators

Note. In upfront cost category, the centred box surrounded by dashed lines represents conventional costs, which are usually accounted.
Source: US EPA (1995).

property and welfare associated with emissions/activities that are performed in compliance with regulatory requirements. The figure does not directly portray the benefits that may be associated with alternative decisions.

3.3.4.2 Welfare basis of costs

The external effects described above cannot be valued directly from market data, because there are no 'prices' for the resources associated with the external effects (such as clean air or clean water). Indirect methods must therefore be used. Values have to be inferred from decisions of individuals in related markets, or by using questionnaires to directly determine the individuals' willingness to pay (WTP) to receive the resource or their willingness to accept payment (WTA) for the environmental good.

3.3.4.3 Ancillary costs and benefits

Projects or policies designed for GHG and ODS mitigation frequently have significant impacts on resource use efficiency, reductions in local and regional air pollution, and on other issues such as employment (IPCC, 2001b, pp. 462). When estimating the social costs of using technologies that impact climate change and/or ODS, all changes in cost arising from this activity have to be taken into account. If some of them imply a reduction (increase) in external costs, they are sometimes referred to as secondary, indirect benefits (costs) or ancillary benefits (costs).

3.3.5 Wider costing methodologies – cost categories

3.3.5.1 Project Costs

This item has already been discussed in the introduction of Section 3.3.2. However, the cost categories listed there may need to be adjusted when carrying out the wider cost methodology. Adjustments in land costs, labour, investments, materials, energy costs, environmental services and foreign exchange may be needed for private costs and external costs, and a detailed list is provided by Markandya and K. Halsnæs (2000).

3.3.5.2 Implementation cost

In addition to the above, the costs of implementation deserve special attention. Many aspects of implementation are not fully covered in conventional cost analyses (see Table 3.7). A lot of work needs to be done to quantify the institutional and other costs of programmes, so that the reported cost figures represent the full costs of policy implementation. As shown in Table 3.7, implementation costs depend on institutional and human capacities, information requirements, market size and the learning potential, as well as on market prices and regulations in the form of taxes and subsidies.

3.3.6 Key economic drivers and uncertainty

For various reasons cost estimates are shrouded by uncertainty and therefore any presentation of cost estimates should include transparent information about various keys to uncertainty that relate to both the baseline case and the new project case. Uncertainty in baseline cases is best dealt with by reporting cost estimates for multiple as opposed to single baselines. With this costs will not be given as single values, but as ranges based on the full set of plausible baselines (see for example IPCC, 2001b, pp. 30-37).

Uncertainties in cost estimates are related to both private and external cost components. Private cost figures tend to be less uncertain than external cost components, since the private costs primarily relate to market-based economic transactions. However, there is a particular uncertainty related to projections of future efficiency, and the costs and penetration rates of new technologies. One way to handle this uncertainty is to undertake a sensitivity analysis based on scenarios for high, low and medium case values (Markandya and Halsnæs, 2000). Another way of accounting is to consider some kind of 'learning curve', that is an expected cost reduction as a function of the increasing amount of products using the technology.

3.3.7 Other issues

3.3.7.1 Baseline Scenarios

Quite often the costs of a programme are evaluated against a situation where the programme is not implemented. This situation is defined by a baseline scenario, which tries to infer future conditions without the implementation of the programme. There are assumptions embedded in the baseline to forecast the future, for example, inefficient baseline, or 'business-as-usual' baseline. It is important to note that a programme's cost and benefit will vary according to this baseline scenario definition. For a mitigation programme, the cost will be larger if an economically efficient baseline is set rather than an inefficient one.

3.3.7.2 Macroeconomic costs

The cost of a programme can be measured using a macroeconomic analysis based on dynamic models of the economy. These models examine the impacts of a programme at an integrated level and allow for intersectoral effects. This means that they are more suitable for programmes large enough to produce impacts on other sectors of the economy.

On the other hand macroeconomic cost estimates generally provide less detail about technological options and externalities than project or sectoral cost estimates.

3.3.7.3 The equity issue

Equity considerations are concerned with the issues of how the costs and benefits of a programme are distributed and the climate change impacts avoided, as input to a more general discussion about the fairness of climate change policies. Equity concerns can be integrated in cost analysis by reporting the distribution of costs and benefits to individuals and society as a supplement to total cost estimates. Some authors also suggest applying income distribution weightings to the costs and benefits to reflect the prosperity of beneficiaries and losers (Ray, 1984; Banuri *et al*., 1996).

3.3.8 Conclusions

For most of the mitigation measures discussed in this Special Report, the specific measures (e.g. technical facilities, infrastructure, demand-side regulation, supply-side regulation, information efforts, technical standards) can be considered to have relatively small economic impacts outside of a narrow project border and can therefore be regarded as 'stand-alone' investments that are assessed using a project assessment approach. However, this does not imply that the cost assessment should solely limit itself to a consideration of the financial cost elements. A project system boundary allows a fairly detailed assessment of GHG emissions and the economic and social impacts generated by a specific project or policy. Accordingly various direct and indirect social costs and benefits of the GHG reduction policies under consideration should be included in the analysis.

Furthermore, it should be realized that as industrial competition increases, an increasing number of companies might become interested in using the most advanced production paradigms. For example, this was the case for lean production, an approach which evolved in Japan during the post-war period and implied greater flexibility in production and working partners. Many typical company features have included environmental concerns as well as broader issues of sustainable development as an evolving feature of the lean production paradigm.

In other words the companies have expanded the view about the boundaries of their own production.

Companies set boundaries around the activities they manage directly as well as those they do not control or manage. A distinctive feature of the lean production system has been an increasing transparency across firms that are dealing with different elements of the production chain. There has also been a tendency towards integrating management functions along the supply chain in order to examine the entire production chain for added value sources, irrespective of the current legal company boundaries along the chain. The application of information technology to business processes has facilitated the introduction of these new management systems. Without this the application of quantitative methods would have proved too complex (Wallace, 1996).

This new integrated management approach is illustrated in Figure 3.5. The figure shows a typical production chain, where the dotted line represents the boundary within the production process. Within that boundary, the management of the process may be integrated, irrespective of the number of companies involved or their exact legal relationship. This boundary might also include the extraction of raw materials, various product end-uses and even the disposal of the materials after use.

Every stage of production and consumption implies important environmental impacts. Companies are increasingly being required to explicitly manage these environmental impacts in response to formal regulations and pollution charges. Alternatively they might voluntarily adopt cleaner production technologies and tools, such as eco-auditing, in response to increasing expectations from society. Another driving force can be the increasing legislative liabilities of companies with respect to pollution. It is therefore useful for analysts to consider a system-wide company boundary that includes all stages of production in life cycle assessment, as shown in Figure 3.5.

3.4 Consideration of health and safety issues

Health and safety issues are an integral aspect of deciding the choice of fluids when alternatives are available, and the decisions can have far-reaching consequences for the workforce, domestic consumers, industry, the environment and the economy. Assessment methods for health and safety should first of all focus on minimizing negative health and safety impacts, and then consider risk management, policy and regulatory controls. This approach should be used for each step of the life cycle of the product including production, distribution, use, maintenance, repair and the end-of-life treatment such as destruction, re-use or recycling. Sometimes it can be wise to accept an increase in one life-cycle stage so as to arrive at an overall improvement in the impact accumulated over the life cycle. During the switch from ozone-depleting substances (CFCs and HCFCs) to HFCs, the health and safety risks of both groups of chemicals were similar. Here the main concern was energy efficiency and reliability. During the switch from higher GWP fluids to lower GWP fluids, health and safety often become a key issue. Some of the key considerations are examined in the following sections.

3.4.1 *Prevention of negative health and safety impacts*

Chemical exposure can cause or contribute to many serious health effects such as heart ailments, damage to the central nervous system, kidney and lungs, sterility, cancer, burns and rashes (US DoL, 1998). The impact of these effects includes lower productivity, absenteeism, increased health-care costs, litigation, and economic downturn at both the enterprise and national levels. Most countries have passed occupational health and safety laws in response to this, but the enforcement of such legislation is difficult, particularly in developing countries. This is borne out by the fact that only 5−10 % of workers in developing countries and 20–50 % of workers in industrialized countries (with a few exceptions) are estimated to have access to adequate occupational health services (Chemical Hazard communication: US Department of Labour (1998 revised). However, given the potential negative impacts in the absence

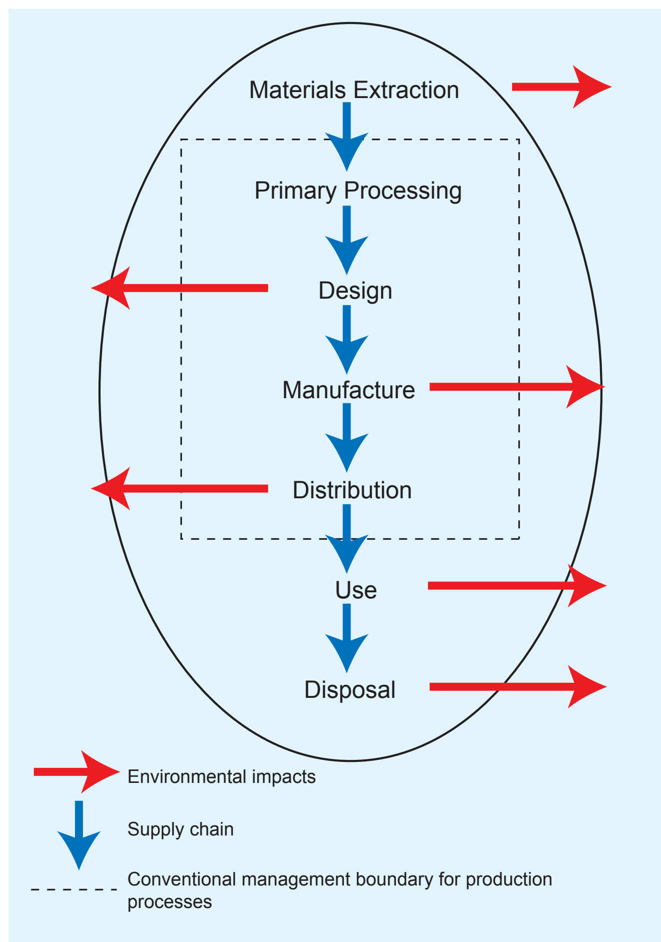

Figure 3.5. Environmental impacts along the supply chain (Wallace, 1996)

of adequate health and safety precautions, it is in the interest of both businesses and government to minimize these. Periods in which businesses are undergoing technological changes provide good opportunities to institute measures for preventing negative health and safety impacts on their workers and operations. They also provide governments with opportunities to implement measures to ensure that these matters are considered during the period of change.

3.4.2 Risk assessment of chemicals

Risk assessment is central to safety. It provides the scientifically sound basis for actions, including policy and regulatory actions to manage potential risks from the production, storage, transportation, use and disposal of chemicals. A number of parameters must be considered when undertaking risk assessments, such as chemical composition, stability and reactivity, hazards identification and classification, transportation, storage and handling, ecological impacts, physical and chemical properties, routes of exposure, effects of exposure, exposure limits, and toxicological information. As well as guiding the decision on the choice of a chemical to be used for a particular application, the assessment will also inform decisions on risk management as well as policy and regulatory controls.

3.4.3 Risk management of systems

Risk management is a broad term for the process that uses the outcomes of a scientific risk assessment to implement best practices, which are usually supported by appropriate policy and regulatory frameworks. A number of options are usually available for managing risk. These depend on the nature of the risk and the technological, economic and policy options available to address this. Effective risk management includes a wide range of measures such as information provision, training and/or retraining, risk assessment training, redesignated work practices, use of personal protective equipment, evaluation and monitoring of both the immediate and wider environments, redefinition of exposure limits and standards, and medical examinations.

3.4.4 Policy and regulatory controls

Most countries have occupational health and safety laws that require employers (as far as it is reasonable and practicable) to provide safe working environments and to develop and implement policies and measures to educate and protect their employees. In general, laws are developed on the principles of precaution and reasonableness, and these need to be adjusted when new processes, technologies or inputs are introduced into the economy that have health and safety implications not covered under the existing framework. Governments are responsible for ensuring that an appropriate regulatory and policy framework exists to protect human and ecological health and safety as well as property, and to ensure compliance. When such a framework and the associated legal requirements are compiled, the health and safety of the user, worker and those in the locality must be the main priorities. Product liability laws have been established in several areas of the world to protect users, workers and members of the public with respect to health and safety or any other damage. The liability legislation in a country is an important factor in the choice of the system and fluid chosen for the application, irrespective of what the safety standard specifies. When drawing up regulations, the combination of several regulatory requirements, including product liability, needs to be taken into account.

3.4.5 Health and safety criteria

For the purposes of this report, health and safety issues are considered under the following criteria:

Flammability: Ability to support combustion; a high capacity for combustion; burning velocity and expansion ratio.

Acute toxicity: Adverse effects are observed within a short time after exposure to a chemical. This exposure may be a single dose, a short period of continuous exposure, or multiple doses over a period of 24 hours or less.

Chronic toxicity: Adverse effects observed following repeated exposure to a chemical during a substantial fraction of an organism's lifespan. For human chronic toxicity typically means exposure over several decades; for experimental animals it is typically more than 3 months.

Carcinogenicity: The ability of a substance or agent to produce or provoke cancer.

Acute ecotoxicity: Adverse effect on ecosystems and/or the organisms within the ecosystem within a short period of time after exposure to a chemical.

Chronic ecotoxicity: Adverse effects to an ecosystem and/or the organisms within the ecosystem following exposure to a chemical during a substantial fraction of the ecosystem's or organism's lifespan.

Accumulation: The action or process of accumulating within biological tissues.

Persistence: Continued presence of a chemical or its effects in the environment after source or cause has stopped.

3.4.6 Health and safety data for relevant substances

The data for health and safety are extensive and this report only includes references to the databases. Most data can be found on the site of the International Programme on Chemical Safety (IPCS) (www.inchem.org), a collaborative venture of the World Health organization (WHO), the United Nations Environment Programme (UNEP) and the International Labour Organization

(ILO). The IPCS site refers to the ICSCs, CICADs, and EHCs. The International Chemical Safety Cards (ICSCs) (www.inchem.org/pages/icsc.html) provide a structured overview of the data for most of the substances under consideration. The Concise International Chemical Assessment Documents (CICADs) (www.inchem.org/pages/cicads.html) provide extensive data for a very limited number of substances. They are similar to the Environmental Health Criteria Monographs (EHC) (www.inchem.org/pages/ehc.html) which provide internationally accepted reviews on the effects of chemicals or combinations of chemicals on human health and the environment.

Additional data and substances can be found in the databases of the IPCS INTOX Programme, the US EPA, the US National Institute for Occupational Safety and Health (NIOSH), the University of Oxford Physical and Theoretical Chemistry Laboratory, the Programme for Alternative Fluorocarbon Toxicity Testing (www.afeas.org/paft/) and documents from ISO Technical Committees TC 86 "Refrigeration and air conditioning" and ISO TC 21 "Equipment for fire protection and fire fighting". If the data are not available from these sources, then national standards or the material safety data sheet from the supplier can be used as the source of information. Care is needed when using material safety data sheets from suppliers, as these data are not always peer reviewed. The most recent peer-reviewed data agreed at an international level (IPCS, PAFT or ISO) should be used in preference to other data.

The information required for health and safety considerations depend on the subsector and application involved. For example, the data required for refrigeration and air conditioning are different from that for fire protection and medical aerosols. Even within a sector, regional differences exist for detailed data. Each sector shall use the appropriate data valid for it to perform the risk assessment and management with respect to health and safety. For refrigeration and air conditioning an ISO work item has been approved to unify the data and resolve the regional differences (ISO TC 86/SC8/WG5). For fire protection this is handled by ISO TC 21.

3.5 Assessing climate and environmental impacts

This chapter describes approaches in which the environmental comparisons are made systematically using standardized procedures and factors. They are most suitably used for making comparisons between individual installations or items of equipment and do not provide 'generic' information. There is a hierarchy among the system-based approaches, which depends on the scope of treatment, but they all seek to apply data in the same rigorous manner. In every case, care should be taken to examine and clearly define the scope of the analysis, taking into account the requirements of those who commissioned the study.

3.5.1 Environmental impact categories and respective indicators including approaches for their ranking

A rational choice of systems, such as heating and cooling, to provide for societal needs should include an assessment of their environmental impact so that excessive demands on the environment can be identified and avoided. Environmental impact depends as much on the quantity of the material emitted as it does on the material's properties. Climate change and ozone depletion are clearly prioritized in this report. Within another framework, other impact categories such as energy-related acidification or resource depletion could be emphasized. An exhaustive list of potential impact parameters or a definition of the process of life cycle assessment fall outside of the scope of this report. However, the principal environmental impacts that may be considered for systems using HFCs, PFCs and other replacements for ozone-depleting substances are:

Climate Change The radiative effects of CFCs and their alternatives on climate is discussed in detail in Chapter 2 and, for the purposes of comparisons between climate impacts, the most important parameter is *global-warming potential*. This is a conversion factor that relates the climatic impact from an emission of particular greenhouse gas to that of an equivalent amount of emissions of carbon dioxide. It is calculated by integrating the radiative forcing from an emission of one kilogram of the greenhouse gas over a fixed time period (the *integration time horizon, ITH*) and comparing it to the same integral for a kilogram of carbon dioxide; units are (kg CO_2 equivalent)(kg emission)$^{-1}$. Commonly quoted integration time horizons are 20, 100 and 500 years with impacts beyond each ITH being ignored (see Table 2.1). The calculation has to be performed in this way because the reference gas, carbon dioxide, has a very long environmental lifetime; for example its impact up to 20 years is only 9% of that up to 500 years (IPCC, 1996a). The standard values for the emissions accounting required by the Kyoto Protocol are those in the Second Assessment Report of the IPCC (IPCC, 1996a) at the 100-year time horizon. The 20-year time scale does not meet the time criterion for judging sustainability; focusing on 20 years would ignore most of the effect on future generations (WCED, 1987). GWPs from the Second Assessment Report at the 100-year time horizon represent the standard for judging national performance. For the purpose of system comparisons the most recent IPCC GWPs could be used, for example, as presented earlier in this report. However, it should be noted that GWPs are parameters constructed to enable the ranking of emissions of greenhouse gases and do not reflect absolute environmental impact in the same way as, for example, the calculated future radiative forcing described in Chapter 2.

Ozone depletion gases that contain reactive halogens (chlorine, bromine and iodine) and are sufficiently unreactive to be transported to the stratosphere, can cause the halogen concentration in the ozone layer to rise. They are therefore *ozone-depleting substances*. For any given gas the efficiency of ozone depletion depends on the extent to which material released at ground level is transported into the stratosphere, how much halogen each molecule carries and the potency of that halogen for ozone depletion, and how the gas decomposes in the stratosphere and hence how much of its halogen content can affect the ozone layer. These factors are combined in mathematical models of the atmosphere to give relative *ozone depletion potentials (ODPs)* based on a scale where the ODP of CFC-11 (CCl_3F) is unity (Daniel *et al*., 1995; Albritton *et al*., 1999); values important for Life Cycle Assessments are shown in Table 1.1.

Acidification: The two groups principally involved in acidification are sulphur and nitrogen compounds and, with the exception of ammonia, neither the ODS nor their substitutes have a direct effect in this category. However, energy-related emissions can exhibit significant acidification potential, and degradation products of substances such as HF or HCl could have considerable acidification potential. Indicators for potential acid deposition onto the soil and in water have been developed with hydrogen ions as the reference substance. These factors permit computation of a single index for potential acidification (in grams of hydrogen ions[5] per functional unit of product), which represents the quantity of hydrogen ion emissions with the same potential acidifying effect:

$$\text{acidification index} = \sum i\ mi \times APi \qquad (3.5)$$

Where:
mi is the mass (in grams) of flow *i*, and
APi are the millimoles of hydrogen ions with the same potential acidifying effect as one gram of flow i, as listed in Table 3.8.

However, the acidification index may not be representative of the actual environmental impact, as this will depend on the susceptibility of the receiving systems (soil and water, in this case).

Photo-oxidant formation: The relative potencies of compounds in atmospheric oxidation reactions are characterized by their photochemical ozone creation potentials (POCP), on a scale where ethene is 100 (Derwent *et al*., 1998). The hydrocarbon substitutes for ODSs have POCPs ranging from 30 to 60 but HFCs and PFCs are not implicated in any significant photo-oxidant formation (Albritton *et al*., 1989) and are among the lowest priority category for volatile organic compound regulation (UN-ECE, 1991).

Resource depletion: The production of all of the chemicals considered in this report will deplete resources and the extent of this should become apparent in a Life Cycle Assessment. For example, an important consideration for fluorinated gases is the extraction of fluorspar mineral, as most of this is destined for the manufacture of fluorochemicals (Miller, 1999).

Eutrophication is the addition of mineral nutrients to soil or water. In both media, the addition of large quantities of mineral nutrients (such as ammonium, nitrate and phosphate ions) results in generally undesirable shifts in the number of species in ecosystems and a reduction in ecological diversity. In water it tends to increase algal growth, which can cause a depletion in oxygen and therefore the death of species such as fish.

Table 3.8. Acidification-potential characterization factors (Alternatively, in the literature sulphuric oxides are often used as reference).

Flow (i)	***AP_i (hydrogen-ion equivalents)***
Ammonia (NH_3)	95.49
Hydrogen chloride (HCl)	44.70
Hydrogen cyanide (HCN)	60.40
Hydrogen fluoride (HF)	81.26
Hydrogen sulphide (H_2S)	95.90
Nitrogen oxides (NO_x as NO_2)	40.04
Sulphur oxides (SO_x as SO_2)	50.79
Sulphuric acid (H_2SO_4)	33.30

Source: Lippiatt, 2002

Characterization factors for potential eutrophication have been developed, in a similar vein to those for the global-warming potential, with nitrogen as the reference substance. These factors permit the computation of separate indices for the potential eutrophication of soil and water (in grams of nitrogen per functional unit of product), which represent the quantity of nitrogen with the same potential nutrifying effect:

$$\text{eutrophication index (to water)} = \sum i\ mi \times EPi \qquad (3.6)$$

Where:
mi is the mass (in grams) of inventory flow *i*, to water, and
EPi are the grams of nitrogen with the same potential nutrifying effect as one gram of inventory flow i, as listed in Table 3.9.

The calculation for soil eutrophication is similar but, for both soil and water the actual impact will vary, dependent on the ability of the local environment to cope with an additional stress of this sort, as was the case for acidification.

Ecotoxicity is the introduction of a compound that is persistent, toxic and can accumulate in the biosphere (commonly shortened to PTB). All three attributes are required for environmental releases to accumulate to the point at which there is a toxic response. No such compounds are known to be directly associated with the production and use of any of the fluorocarbons considered in this report. An in-depth discussion of ecotoxicity issues can be found in Hauschild and Wenzel (1998), Heijungs (1992) and Goedkoop (1995).

3.5.2 System-based approaches

In these approaches the environmental comparisons are made systematically using standardized procedures and factors. They

[5] The hydrogen release potentials are criticized by some authors. They have proposed alternative factors based on UN-ECE-LRTAP models. See www.scientificjournals.com/sj/lca/pdf/aId/6924.

Table 3.9. Eutrophication Potential Characterization Factors. (Alternatively, in the literature PO4+ is often used as a reference).

Flow (i)	*EPi (nitrogen-equivalents)*
Ammonia (NH_3)	0.12
Nitrogen Oxides (NOx as NO_2)	0.04
Nitrous Oxide (N_2O)	0.09
Phosphorus to air (P)	1.12
Ammonia (NH_4^+, NH_3 as N)	0.99
BOD5 (Biochemical Oxygen Demand)	0.05
COD (Chemical Oxygen Demand)	0.05
Nitrate (NO_3^-)	0.24
Nitrite (NO_2^-)	0.32
Nitrogenous Matter (unspecified, as N)	0.99
Phosphates (PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, H_3PO_4, as P)	7.29
Phosphorus to water (P)	7.29

Source: Lippiatt, 2002

are best used for making comparisons between individual installations or items of equipment and do not provide 'generic' information. There is a hierarchy among the system-based approaches, which depends on the scope of treatment, but they all seek to apply data in the same rigorous manner. In every case, the scope of the analysis should be clearly examined and defined, taking into account the requirements of those who commissioned the study.

Life Cycle Assessment (LCA) is clearly the most comprehensive and formal approach to assessing and comparing the environmental impacts of technologies. The methodology for LCAs has been developed and formalized in the ISO 14040 series of international standards. On the other hand, TEWI (Total Equivalent Warming Impact) has the most limited scope, but has been applied most widely for the technologies within the remit of this report. It addresses the climatic impact of equipment operation and the disposal of operating fluids at end-of-life but, although it may be appropriate for most of the common systems, it does not consider the energy embodied in the fluid or equipment. This energy may be important in some cases and this consideration has led to the concept of LCCP (Life Cycle Climate Performance).

In LCCP a more complete climatic impact of the fluid is calculated and includes the impacts from its manufacture, the impacts from operating and servicing the system and finally those associated with disposal of the fluid at the system's end of useful life. However, both TEWI and LCCP consider just the climatic impact; this is reasonable for cases where the predominant environmental impact is on climate. Life cycle assessment (LCA) is the broadest-based approach and this includes the environmental impacts of other inputs and outputs to the system, in addition to those associated with energy.

LCCP can be seen as a submethod of LCA and TEWI as a submethod of LCCP. To a large extent the approach chosen will depend on the context. If the information required is the relative climate impacts of a number of alternative approaches for achieving a societal good, then TEWI or LCCP are likely to provide adequate information. However this will ignore all other environmental impacts that are addressed in LCA, assuming that these will be similar for the alternative technologies. Although the three approaches differ in their scope, all of data should be derived and all of the analyses performed with the same rigour.

3.5.2.1 Total equivalent warming impact (TEWI)

Arguably the largest environmental impact from many refrigeration and air-conditioning applications arises from their energy consumption and emissions during their operation. Similarly, the energy saved by thermal insulating foam is the principal offset for any effect due to fluid emissions. In order to help quantify these effects, TEWI sets out to standardize the calculation of climate-change impact in terms of emissions over the service life of the equipment, including emissions arising from the disposal of the fluids it contains. The units of TEWI are mass of CO_2 equivalent.

TEWI using generic or default data.

The analysis is performed by calculating the direct emissions of the fluids contained in each system from leakage during operation over its entire service lifetime. This includes servicing and the system's eventual decommissioning and disposal. In this context, the system does not cover the full life cycle (ISO, 1997) but includes the operation, decommissioning and disposal of the application.

The total mass emission of each greenhouse-gas component is converted to CO_2-equivalent emissions using GWP (see discussion in Section 3.5.1) as the conversion factor (see Table 2.1). These figures are then added to the emissions of actual carbon dioxide arising from the energy used during operation (see 3.2.2.3) to give a TEWI value for the lifetime of the equipment. Examples of 'equipment' are a refrigeration or air-conditioning system, or a building (particularly if it is insulated). There is often a combination of energy-consuming and energy-conserving parts, and different direct releases of greenhouse gases. Typically:

$$TEWI_S = \sum OR_i \text{ x } GWP_i + \sum DR_i \text{ x } GWP_i + E_I \qquad (3.7)$$

Where:

- $TEWI_S$ is the total equivalent warming impact from system S (for example, a particular refrigeration system or building installation) the units of which are mass of CO_2 equivalent;
- OR_i is the operational release of each greenhouse gas i (the mass total of the releases of each gas during the system's operating lifetime);
- GWP_i is the global-warming potential of greenhouse gas i (at the 100-year integration time horizon, as discussed below);

DR_i is the total mass of each greenhouse gas *i* released when the system is decommissioned, and

E_I is the indirect emission of carbon dioxide resulting from the energy used to operate the system (for its whole lifetime), already discussed in Section 3.2.1.3 and calculated according to Equation 3.2, above.

While this is apparently an absolute value, it can carry a high uncertainty associated with the assumptions and factors used in the calculation. TEWI is most effectively used to compare alternative ways of performing a service, where the same assumptions apply to all of the alternatives and the effect of these on relative ranking is minimized. A TEWI value calculated for one system using one methodology (i.e. set of assumptions, equations, procedures and source data) is not comparable with a TEWI value calculated for another system using another methodology. Then a comparison of TEWI is meaningless.

Depending on the quantity of information available and the needs of the study, there are several levels of complexity in the application of TEWI. At the simplest level, a default emission function could be used for the fluid release together with calculated energy requirements and regional carbon dioxide intensity. Default emission functions have been developed by AFEAS to calculate global emissions from refrigeration and closed-cell (insulating) foams (AFEAS, 2003). One feature of these functions is that all of the substance used is eventually released (in some cases after many years service) and this can have a profound effect on the application's impact.

In this case, the quantity released is equal to the amount originally charged into the system, plus any amount added during the system's period of service:

$$OR_i + DR_i = C_i + QA_i \qquad (3.8)$$

Where OR_i and DR_i are the operational and decommissioning releases of substance *i* as described above;
C_i is the mass of *i* originally charged into the system, and
QA_i is the mass of *i* added into the system during its service life.

For hermetic refrigeration systems (such as domestic refrigerators and window air conditioners), units are rarely, if ever, serviced and therefore QA_i is set at zero because of its insignificance. Yet for systems which require frequent servicing, such as mobile air conditioning, that default condition is not appropriate and a value for QA_i could be derived by analogy from the operation of similar systems.

Energy (either as power required to operate the system or the energy saved by thermal insulation) can be calculated using standard engineering methods. In many cases, electricity is used to power the equipment and this will have been produced by technologies that vary between countries and regions, with large differences in the fossil fuels used as primary sources (for more information see Section 3.2.1.3). Table 3.5 lists some regional and national carbon dioxide intensities for electricity. Such a calculation is only suitable for showing major differences (say within a factor of two) due to the extensive use of default factors. Nevertheless, it is useful for identifying the more important areas of the calculation that would repay further refinement (Fischer *et al*., 1991 and 1992; McCulloch, 1992 and 1994a). Uncertainties can be significantly reduced by using appropriate specific data.

GWP and integration time horizon

For the conversion of other greenhouse-gas emissions into their CO_2-equivalents, GWPs at the 100-year integration time horizon are usually used and the source of the GWP values must be clearly stated. For example, TEWI analyses are now usually performed using the most recent GWP values published by the IPCC, even though this is not the normative standard. To ensure that the results are as portable as possible and to facilitate intercomparisons, the standard values from the Second Assessment Report of the IPCC (IPCC, 1996a) as used in the emissions accounting reported under the Kyoto Protocol and UNFCCC, have frequently been used in existing TEWI analyses.

TEWI using specific data

The next level of complexity goes beyond the use of generic data. It requires real emission patterns obtained from field trials and operating experience and, preferably, the range of values obtained from such studies should be indicated and used in a sensitivity analysis (Fischer *et al*., 1994; ADL, 1994 and 2002; Sand *et al*., 1997; IPCC/TEAP, 1999). As the disposal of the fluid can have a significant impact, it is important to incorporate the real emissions on disposal. If the systems under consideration do not yet exist, the methods for calculating emissions patterns should have been verified against real operating systems.

Similarly, the actual energy consumption based on trials should be used in the more thorough analysis, together with the carbon dioxide intensity of the energy that would actually be used in the system. Many systems are powered electrically and therefore the procedures already discussed in Section 3.2.1.3 should be applied so as to facilitate comparisons between similar systems operated in different countries.

As in many cases electrical energy is the most important energy carrier, the sum of the other fuel usages and intensities can be neglected so that Equation 3.2 becomes:

$$E_I = Q_E \times I_E \qquad (3.9)$$

Where
E_I is the total indirect lifetime emission of carbon dioxide from the energy used to operate the system;
Q_E is the total lifetime use of electricity, and
I_E is the average carbon dioxide intensity of national electricity production (from Table 3.5)[6].

Uncertainty

When most of the impact arises from fluid emissions, the criterion for significance is set by the uncertainty of the GWP values and this is typically 35% (IPCC, 1996a). Where the impact is a combination of fluids and CO_2 from energy, the more common case, the total uncertainty should be assessed. A rigorous uncertainty analysis may not be meaningful in all cases or might not possible due to the poorly quantified uncertainties of emission factors, emissions from the energy supply systems, specific energy consumption and the like. However, the sensitivity of uncertainty in the data is valuable because the effort required to gather the information needed for increasingly detailed calculations, will only be repaid if these show significant differences.

Uses

TEWI is particularly valuable in making choices about alternative ways of performing a function in a 'new' situation but it also can be used to minimize climate impact in existing operations by providing information on the relative importance of sources, so that remedial actions can be prioritized. This is, however, methodologically restricted to those cases in which the original and alternative technologies remain reasonably similar throughout their life cycles.

A standard method of calculation which includes the concepts and arithmetic described here has been developed for refrigeration and air-conditioning systems, and the principles of this may be applied to other systems (BRA, 1996, consistent with EN378, 2000). TEWI can also be used to optimize the climate performance of existing installations and methods of working (McCulloch, 1995a; DETR, 1999). A particularly valuable application is in the construction or refurbishment of buildings, where TEWI can be used to facilitate the choice between different forms of insulation, heating and cooling. The affect of the design on both the TEWI and cost can be investigated, and significant greenhouse-gas emissions abated (DETR, 1999). The interaction between TEWI and cost is particularly useful when additional equipment is required to achieve an acceptable level of protection. For example, the cost of that safety equipment could have been invested in efficiency improvements (ADL, 2002; Hwang *et al*., 2004).

If sufficient information is available, TEWI can also be used to examine the climate and cost incentives of targeting operations at particular periods of the day or year when the carbon dioxide intensity of electrical power is lower (Beggs, 1996).

3.5.2.2 Life cycle climate performance (LCCP)

Like TEWI, this form of analysis concentrates on the greenhouse-gas emissions from direct emissions of operating fluids together with the energy-related CO_2 but, it also considers the fugitive emissions arising during the manufacture of the operating fluids and the CO_2 associated with their embodied energy. Like TEWI, LCCP is most effective when applied to individual installations, and a 'generic' LCCP will only be representative only if the data used to calculate it are representative of the types of installation being examined.

A comprehensive study has been made of representative LCCPs for alternative technologies in the areas of domestic refrigeration, automobile air conditioning, unitary air conditioning, large chillers, commercial refrigeration, foam building insulation, solvents, aerosols (including medical aerosols) and fire protection (ADL, 2002). The results were very similar to those of the TEWI analyses (see particularly Sand *et al.* (1997)). For example, the LCCP of domestic refrigerators was dominated by their energy use and there was no clear difference between the refrigerant fluids or blowing agents used in insulating foams. However the end-of-life disposal method has a significant impact on the LCCP (Johnson, 2003). As long as the disposal of all of the systems was treated in the same way, automobile air conditioning was most heavily influenced by the conditions under which it was operated (the climatic and social conditions of different geographical areas). Thus the highest LCCP values arose for vehicles in the southern USA, and this value was higher still if the fluid chosen did not allow for efficient operation (ADL, 2002).

LCCP is a useful addition to the TEWI methodology, even though in many cases the influence of fugitive emissions and embodied energy (which account for most of the difference between TEWI and LCCP results) can be small compared to the lifetime impact of using the system.

$$LCCP_S = TEWI_S + \sum OR_i \times (EE_i + FE_i) + \sum DR_i \times (EE_i + FE_i) \quad (3.10)$$

Where:

$LCCP_S$ is the system Life Cycle Climate Performance;

$TEWI_S$ is the system TEWI, as defined by Equation 3.5.1 above;

OR_i and DR_i are, respectively, the quantities of fluid i released from the system during operation and at decommissioning;

EE_i is the embodied energy of material i (the specific energy used during the manufacture of unit mass, expressed as CO_2 equivalent), and

FE_i is the sum of fugitive emissions of other greenhouse gases emitted during the manufacture of unit mass of i (expressed as their equivalent CO_2 mass), so that:

$$EE_i = \sum (EE_j \times I_{Fj}) \quad (3.11)$$

for j sources of energy used during the production of material i, each with a carbon dioxide intensity of I_{Fj} (see also Equation 3.2), and:

[6] The differing practice of using the carbon intensity of the most expensive fuel in an attempt to show the situation for an additional demand in a deregulated energy market, could be misleading. This carries unwarranted assumptions: the demand may not be additional, even if the system represents a new load. It is most probable that the effect of the new system on the energy balance would be, at least in part, to replace demand from elsewhere. And even if demand is additional, it may not result in the most expensive energy being used. That would depend on the daily, weekly and seasonal demand pattern, which is beyond the scope of this level of TEWI analysis.

$$FE_i = \sum (FE_j \times GWP_j) \quad (3.12)$$

for j greenhouse gases emitted during the production of material i, each with a global-warming potential at 100 years of GWP_j.

A comparison of Equations 3.7, 3.10, 3.11 and 3.12 shows that the difference between LCCP and TEWI is that the GWP of each greenhouse-gas component is augmented by the embodied energy and fugitive emissions of that component. However, the effect of these is now generally quite small as in much of the world the practice is to minimize or destroy process emissions (compare Section 3.2.1.1).

A relatively straightforward application for TEWI and LCCP analyses is the study of emissions attributable to a household refrigerator. In this case, either the refrigerant choice or the blowing agent choice may be studied, or both. Table 3.10 gives a summary of the items that would typically be considered in such studies.

3.5.2.3 Life Cycle Assessment (LCA)

LCA is a technique for assessing the environmental aspects of a means of accomplishing a function required by society (a 'product or service system' in LCA terminology) and their impacts. A life cycle assessment involves compiling an inventory of relevant inputs and outputs of the system itself and of the systems that are involved in those inputs and outputs (Life Cycle Inventory Analysis). The potential environmental impacts of these inputs and outputs are then evaluated. At each stage it is important to interpret the results in relation to the objectives of the assessment (ISO, 1997). Only an assessment which covers the full life cycle of the product system can be described as an 'LCA'. The methodology is also applicable to other forms of assessment, such as TEWI described above, provided that the scope of the assessment and its result are clearly defined. So whereas LCA studies describe the environmental impacts of product systems from raw material acquisition to final disposal, studies that are conducted to the same rigorous standards for

Table 3.10. Items considered in TEWI and LCCP studies for a refrigerator (Johnson, 2003).

	Considered in	
	TEWI	**LCCP**
Refrigerant		
Emissions of refrigerant:		
• During manufacturing of the refrigerant		X
• Fugitive emissions at the refrigerator factory	X	X
• Emissions during the life of the product (leaks and servicing)	X	X
• Emissions at the time of disposal of the product	X	X
Emissions of CO_2 due to energy consumption:		
• During manufacturing of the refrigerant		X
• During transportation of the refrigerant		X
Blowing agent		
Emissions of blowing agent:		
• During manufacturing of the blowing agent		X
• At the refrigerator factory	X	X
Emissions of blowing agent from the foam:		
• During the life of the product	X	X
• At the time of disposal of the product	X	X
• After disposal of the product	X	X
Emissions of CO_2 due to energy consumption:		
• During manufacturing of the blowing agent		X
• During transportation of the blowing agent		X
The refrigerator		
Emissions of CO_2 due to energy consumption related to the product:		
• During manufacturing of components		X*
• During assembly of the refrigerator		X*
• During transportation of the refrigerator		X*
• By the refrigerator during its useful life	X	X
• During transportation of the refrigerator for disposal		X*
• During disposal of the refrigerator (usually shredding)		X*

* These items are relatively small in comparison with emissions related to the power consumed by the refrigerator and those related to emission of the blowing agent, and are independent of the refrigerant and blowing agent. They may therefore be neglected in some LCCP studies.

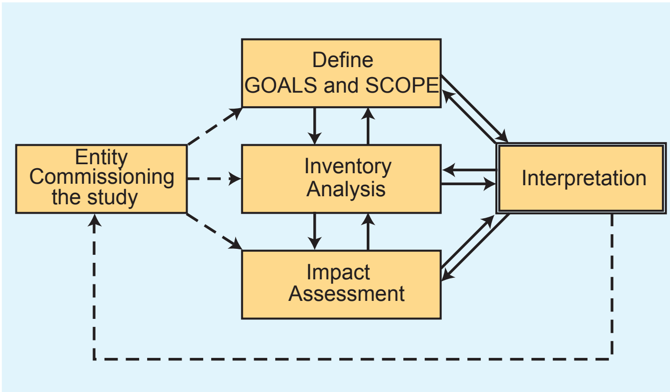

Figure 3.6. Outline phases of a Life Cycle Assessment and interactions with the commissioning entity.

subdivisions of the product chain (for example up to the sale of a unit to a customer) or subdivisions of the environmental impact (for example LCCP and TEWI) are just as valid, and may better meet the requirements of those commissioning the study. Indeed as the use phase usually dominates the environmental impact of the CFC substitutes, the LCA will be application-specific. However, attempts to provide 'generic' LCA results can help to identify the most relevant life-cycle stages and impact categories. These attempts will also tend to be tests of the extent to which the assumptions made about this use phase actually match the real performance of the application.
Figure 3.6 shows the steps in the general methodology.

For any given analysis it is essential that the objective is clearly defined. This should include the application, reasons for the study and the intended recipients of the results. To meet this objective, the scope of the study needs to specify the performance characteristics of the product and to define a 'functional unit' that will be used to quantify these characteristics (ISO, 1997 and 1998). This is a particularly important step and is best illustrated with examples:

Once a functional unit that is practical and meets the needs of those commissioning the assessment has been defined, a reference flow can be established from which all of the ancillary inputs and outputs may be calculated. For example, in a cold store this could be the annual throughput of foodstuff from which the number of receipts and deliveries, the energy load, and so forth can be estimated. In any LCA it is essential that the system boundaries are clearly and unambiguously defined. This includes not only the boundaries of the primary physical system under assessment (in this example the cold store) but also the extent to which inputs and outputs will be traced back to elementary flows (material drawn from or placed into the environment). The documentation for the decisions on system boundaries should be sufficient to judge whether or not more detailed examination is desirable and to permit subsequent changes to the assessment if new information becomes available.

Once the system has been defined, it should then be described in terms of its unit processes and their interrelationships. Each of these unit processes has its own set of inputs and outputs, enabling a matrix of flows, based on the reference flow, to be constructed. This constitutes the Life Cycle Inventory. In the subsequent stages of LCA, the environmental impacts of the inputs and outputs identified in the inventory are assessed. For the materials addressed in this report, the most obvious impact categories are climate change and ozone depletion but some or all of the additional categories described in 3.5.1 above may be important (ISO, 2000a and 2000b). The end product is a description of the environmental impacts of a defined product system in terms of the effects on the most appropriate individual categories, together with an indication of how significant that impact is for each category. There is no scientific basis for reducing LCA results to a single overall score or number (ISO, 1997) and, similarly, there is little justification for closely ranking impacts (although it is worth noting when one impact, such as that on climate change, clearly outweighs the rest). A data documentation format for Life Cycle Assessments has been developed (ISO, 2002) to facilitate common input. Data collection formats have also been developed for specific applications, such as motor vehicle manufacture (Finkbeiner *et al*., 2003) and plastics (O'Neill, 2003) and, similarly, large consistent databases are now sold (for example at www.ecoinvent.ch/).

It is difficult to characterize the uncertainty in LCA; there are a large number of variables with varying degrees of autocorrelation and for which formal uncertainty analyses may not exist. However, it should be possible to perform sensitivity analyses with comparatively little effort so as to provide a commentary on the significance of the impacts determined in the assessment (Ross *et al.,* 2002). The requirements for data quality assessment are described in ISO (1997, 1998, 2000b).

In order to facilitate complete LCA studies involving refrigerants and foam blowing agents, several studies have been performed to characterize the environmental impacts of fluid manufacture. The general conclusion was that the impact from producing the fluids was small compared to that arising from their use during service and their eventual disposal (Banks *et al*., 1998; Campbell and McCulloch, 1998; McCulloch and Campbell, 1998; McCulloch and Lindley, 2003). The most significant contribution to the impact for producing fluids comes from material, such as other fluorocarbons, released during the manufacturing process and there is a wide variation in the values used. The highest values were calculated by Banks *et al.* (1998) who used maximum permitted emissions rather than real values. The other studies used actual process records so that the amount of material released was not only lower but also decreased substantially in recent years as the treatment of vent gases to avoid their release to the atmosphere became more commonplace, particularly in the new plants to manufacture HFCs (Campbell and McCulloch, 1998; McCulloch and Campbell, 1998; McCulloch and Lindley, 2003).

As for studies of complete systems, Yanagitani and Kawahari (2000) confirmed that for air-conditioning systems the largest source of environmental impact arose from energy use, but that proper waste management at end-of-life could significantly reduce the impact. The predominant influence of energy production on the impact on global warming, acidification, aquatic ecotoxicity, photochemical ozone creation, terrestrial toxicity and the proliferation of radionuclides was demonstrated by Frischknecht (1999) in LCA studies of generic heat pumps, building air conditioning, and industrial and commercial refrigeration.

3.5.2.4 Other system-based approaches

Environmental burden
Environmental burden is a method for assessing the environmental impact of a production facility. Mass emissions of individual compounds released from the site are multiplied by a 'potency' that characterizes the impact of the compound on a particular environmental end-point (for example ozone depletion or global warming). The sum of these values in each impact category is the environmental burden of the facility (Allen *et al.,* 1996). The resulting site-specific review of environmental impact can be used in environmental management (as described in ISO 14001).

Eco-efficiency
This combines Life Cycle Assessment of similar products or processes with a total cost determination of each alternative. Economic and ecological data are plotted on an x/y graph, with costs shown on the horizontal axis and the environmental impact on the vertical axis. The graph reveals the eco-efficiency of a product or process compared to other products or processes, with alternatives that have high cost and high impact occupying the upper right-hand quadrant. Similarly, those with low impact and low-cost occupy the lower left-hand quadrant, close to the origin. (BASF, 2003). However, such analyses demand a great deal of accurate data.

3.6 Regional dimensions

The use of fluorocarbons is specific to certain technical sectors. The technology selection in these sectors, their customers and product developments are influenced by a number of factors, which are of a local, national or regional nature (e.g. EU regulation (COM(2003)0492), under preparation). In addition to technical requirements, those factors can also include cost, environmental considerations, legal requirements, health and safety issues, energy inputs and costs and market characteristics. Therefore prescriptions on how to arrive at these decisions are not possible, as each country, and each enterprise within it, must make its own decision. Against this background, this section presents some of the more general characteristics and considerations that will influence the choice of technology at both the national and enterprise levels.

This section also highlights some of the regional differences that influence technology choice. For these purposes, countries are considered in groupings recognized under the Montreal Protocol, namely:

- Latin America and the Caribbean;
- Africa and the Indian Ocean;
- Asia/Pacific region;
- Countries with economies in transition; and
- Developed countries.

Table 3.11 gives an overview of regional variations in key methodological issues.

3.6.1 Sector characteristics

3.6.1.1 Refrigeration and air conditioning
Growth in the demand for refrigeration has paralleled the demand for food preservation, processing, freezing, storage, transport and display, as well as final storage in homes. The more centralized food production becomes, and thus further removed from the consumer, the greater the amount of refrigeration. Consequently, societies with a more complex food supply structure and countries with a higher urban population will have a higher demand for refrigeration than countries supplying food from more local sources.

Large air-conditioning systems with capacities of about 1 MW cooling capacity upwards, are used in most of the large commercial buildings, hospitals and hotels around the globe, irrespective of the local climate (UNEP, 2003c). The occurrence of such systems roughly matches the occurrence of the type of buildings described. Smaller air-conditioning systems are largely desired in countries with warm climates (UNEP, 2003c), but there is an increasing market for these in areas with a more moderate climate, for example Central and Northern Europe. Therefore, the influencing factors for the spread of such systems are the occurrence of high ambient temperatures, and high humidity, as well as available income.

There is an almost universal preference for mobile air conditioning, even in colder climates. The only limiting factor is the cost of the system, which typically has to be covered when purchasing the vehicle. Certain types of systems – refrigerators, unitary air conditioning products and water chillers – have universal usage characteristics and can therefore be manufactured in centralized facilities. This simplifies quality control and reduces the likelihood of leaks, and thus the need for service. Nevertheless, since high ambient temperatures create an increased demand for servicing due to higher mechanical stress on the systems and longer periods of operation, and considering that most repairs currently lead to emissions of the refrigerant, hot climates tend to have higher levels of refrigerant emissions than cooler climates. In other sectors, for example most commercial refrigeration systems, the installations are too custom- or location-specific to be manufactured in a centralized facility, although research is underway to change this (UNEP, 2003c).

Maintenance philosophies which encourage preventive maintenance of refrigeration equipment, have lower emissions and maintain a stable energy-efficiency performance. The decision to have preventive maintenance or to request service

Table 3.11. Overview of regions and specific methodological dimensions.

Region **Dimension**	**Latin America and Caribbean**	**Africa and Indian Ocean**	**Asia-Pacific**	**Countries with economies in transition**	**Developed countries**
3.2 Key Technical Performance Indicators					
3.2.1 lifetime perspectives	No specific differences with the exception that the more expensive equipment generally has a longer lifetime. Such expensive equipment is sold more in developed countries, where standards are higher, and enforced.				
3.2.2 Fluid emission rates	Some care during fluid production. Frequent maintenance requirement due to high ambient temperature, yielding more fluid emissions. Poor care for fluid emissions at service and disposal, but this is being addressed under initiatives funded by the Multilateral Fund of the Montreal Protocol.	Frequent maintenance requirement due to high ambient temperature, yielding more fluid emissions. Poor care for fluid emissions at service and disposal, but this is being addressed under initiatives funded by the Multilateral Fund of the Montreal Protocol.	Some care during fluid production. Poor care for fluid emissions at service and disposal, but this is being addressed under initiatives funded by the Multilateral Fund of the Montreal Protocol.		Significant care during fluid production. Significant care during servicing and some during disposal of equipment.
3.2.3 Energy aspects	The energy aspect is not the driving factor when buying new equipment and material. Main factor is initial cost.				High concern with use of highly-efficient equipment.
	Significant share (72%)[1] of renewable electricity. Some concern about energy efficiency.	Moderate share (19%)1 of renewable electricity.	Significant use of fossil fuel (79%)[1] for electricity. Some concern about energy efficiency.	Average use (63%)[1] of fossil fuel for electricity	Average use (60%)[1] of fossil fuels for electricity.
3.3 Categories Of Cost					
3.3.2 Direct engineering and financial cost	Always considered. Focus on manufacturing, mostly assembly.		Always considered. Some R&D and component manufacturing.	Always considered Some component manufacturing.	Includes liability provision. Significant R&D and component manufacturing.
3.3.2.1 The time dimension in cost 3.3.2.2 Discounting	High interest rate.	High interest rate.	Average interest rate.	Average interest rate.	Low interest rate.
3.3.3 Investment cycle and Sector Inertia	Shortage of capital. Large inertia due to unavailability of resources for transition away from HCFC.		High economic development/ modest inertia. Little emphasis on transition away from HCFC.	Shortage of capital/large inertia. Transition away from HCFC according to Montreal Protocol schedule.	Strong pressure from legislation/low inertia.

Table 3.11. Continued

Region / Dimension	Latin America and Caribbean	Africa and Indian Ocean	Asia-Pacific	Countries with economies in transition	Developed countries
3.3.4 Wider costing Methodologies-Concepts	Not accounted.				Modest consideration.
3.3.5 Wider costing methodologies- cost categories	Life Cycle Cost (LCC) generally not considered.				LCC used as a marketing tool.
3.3.6 Economic Key drivers and technology uncertainty	Montreal Protocol Fund; Growing domestic and export markets; Low uncertainty since technology is generally imported; High uncertainty on HCFC future price. Large fluid producer.		Montreal Protocol Fund; Growing equipment market (domestic and export) Medium uncertainty due to fast transition. Large fluid producer.	GEF support for transition based on Montreal Protocol schedule, but some difficulties to achieve targets. Large fluid producer.	Market Leadership; Medium uncertainty due to fast transition.
3.3.7 Other issues	Increasing legislative framework to control trade in ODSs and trade in related technologies under the Montreal Protocol.				National and regional legislation more restrictive than Montreal Protocol.
3.4 Health And Safety Issues					
3.4.1 Health and Safety considerations	Modest concern due to modest liability. Main influence is from the USA.	Modest concern due to modest liability. Mainly influenced by Europe.	Growing concerns in production facilities. Mainly influenced by Europe.	Growing concerns in production facilities. Mainly influenced by Europe.	These two issues are the driving factors in USA and Europe policy design.
3.5 Climate And Environmental Impacts	Modest contribution; Main driver is ozone layer protection.		Significant contribution; Main driver is ozone layer protection.		Large contribution. Europe and Japan are taking a leading role in mitigation.

[1] Assessments based on data from International Energy Agency database, and considers electricity production from fossil and non-fossil (including nuclear) fuels.

only in the case of system failures, is not only dependent on the labour costs but also the business culture and the use-specific importance of uninterrupted delivery of refrigeration capacity. Labour costs, business culture and the value of reliable services are country-specific.

The widespread use of refrigeration and air-conditioning technology, and the accompanying high demand for service and repairs, makes the diffusion of improved techniques important. However, the large number of servicing companies makes it difficult to introduce new maintenance practices and to ensure that these are adhered to (UNEP, 2003c). Through the Montreal Protocol, networks of service technicians have been established in several countries for the diffusion of information within the service sector enterprises, and in some cases there are also mechanisms in place to facilitate a certain maintenance quality. For low-cost, factory-manufactured equipment, such as refrigerators or small- and medium-sized, air-conditioning systems, high labour costs reduce the demand for servicing and instead favour early replacement. Although this results in lower emissions during maintenance, there is the potential of repair-worthy systems being dumped in countries with a lower level of income. This further complicates the situation in poorer countries as ageing refrigeration systems tend to have higher emissions and energy consumptions, and require more frequent repairs (UNEP, 2003c).

Methods of disposal at the end-of-life of the equipment also have implications for the life-cycle GHG emissions of the equipment. (IPCC, 2001b, Chapter 3 Appendix). Given the widespread ownership of refrigeration systems and the high costs associated with recycling, appropriate disposal at end-of-life is at present (2004) more the exception than the rule in most regions. However, several countries have established legislation requiring certain disposal practices, although enforcement is still generally a challenge. For example in Japan, a recent system of CFC coupons compulsorily acquired by car owners when the car reaches end-of-life and are transferred to car dismantlers as they recover the fluid, is not performing well (www.yomiuri.co.jp/newse/20030511wo12.htm). The need for enforcement is further amplified by the fact that users have purchased the equipment many years, if not decades, before the disposal takes place, making data availability and the link between the manufacturer and the user fairly weak.

Customs tariffs have, according to experience gained under the Montreal Protocol, not significantly hindered the spread of new technologies. A further complication is the adherence to different national or regional regulations and standards, which are often mandatory in nature. These might not be compatible with the use of alternative technologies and their characteristics, or might hinder supplies of refrigerants and spare parts. These difficulties can be both substantial and long-lasting, thereby delaying the introduction of new technologies by several years.

In the case of mass-produced refrigeration systems, in particular refrigerators and air-conditioning systems, high labour costs in some regions have made the migration of industrial production an issue. With decreasing freight tariffs, refrigerators are also being increasingly transported over long distances, although differences in local requirements mean that the product is less standardized than air conditioners.

Investment capacities and interest to invest are also significant drivers for technology diffusion, for both manufacturers and consumers. Typically, manufacturers invest in new technology in response to consumers' demands and/or legal requirements[7]. For small manufacturers and technicians in the informal sector, investments are very complicated, especially as there are often few options for obtaining loans in many less-developed countries.

3.6.1.2 Foam sector

During the implementation of the Montreal Protocol, the consumption of CFCs in foam manufacture was largely phased out, and these were replaced by different technologies. In closed-cell rigid insulating foams, hydrocarbons including cyclopentane, n-pentane, isopentane and blends have been widely used in foam subsectors, where energy efficiency, safety and product performance criteria can be met. In flexible foams, CO_2 (water) technology has been successfully introduced. Currently, the most significant uses of HCFCs (developing countries) and HFCs (mostly developed countries) are in rigid insulating foam subsectors, where safety, cost, product performance and energy conservation are important (UNEP-TEAP, 2003).

[7] See for example the EU regulation on Fluorinated Gases under discussion (COM(2003) 0492).

For closed-cell rigid insulating foams, a large portion of the blowing agent remains in the foam until the end of its useful life (UNEP, 2003b). Consequently, the disposal practice (landfill compared with incineration) has a large influence on the direct emissions from a system (i.e., a refrigerator or a building) insulated with foams blown with fluorocarbons. Foam disposal requires collection from a large number of individual users or retrieval from a large quantity of mixed solid waste such as demolished building rubble. This is further complicated by the fact that, in some cases, the foams are integrated with other materials, for example, when used as building material it is adhered to substrates. These factors will make collection a major logistical and legal undertaking, which has not been mastered except in certain subsectors like domestic refrigeration, and even there, only a few countries are implementing such measures (UNEP, 2003b). As most foam products are lightweight compared to their volume, transportation costs prohibit their transportation over long distances, unless the foam is only a small fraction of the final product or system (i.e., a refrigerator). Addition, the movement of foam products, in particular building insulating foams, is further hindered by building construction traditions and building code requirements, which differ significantly between countries.

3.6.1.3 Solvents

The solvent sector is characterized on the one hand by the small scale, open use of solvents and on the other hand by use in industrial processes or closed machines. Both industrial uses and closed machine uses have undergone significant improvements as part of the efforts to reduce the use of ODSs under the Montreal Protocol. A completely different issue is the open use of solvents. For some open uses in medium-size consuming operations, investments might lead to a transition towards closed uses with internal recycling of the solvents. In other uses, in particular cleaning in smaller workshops, the solvent will evaporate into the atmosphere. Low labour costs and, thus, less automated production tend to support the open use of solvents. As in the case of the refrigeration sector, the large number of users in non-homogenous solvent applications makes the spreading of know-how a complex and labour-intensive undertaking (UNEP, 2003d). There are no substantial technical barriers to phasing out ODSs in the solvent sector. Alternatives are available that will meet the needs of all solvent users with very few exceptions. The main barrier to overcoming the obstacles in developing countries is communication and education about suitable alternatives. (UNEP, 2003d).

3.6.1.4 Aerosols/MDIs

Since the beginning of the Montreal Protocol, most aerosol uses of fluorocarbons have been converted to other motive agents, particularly hydrocarbons (UNEP, 2003e). Even so in Japan alone, 1850 tonnes of HFCs were distributed in about 4.5 million cans in 2003. This is a considerable increase compared to the 1050 tonnes distributed in 1995. It is estimated that 80% of these cans are used to blow away dust. The fluid used (HFC-

134a) has a high GWP and measures adopted by the government to replace it with a fluid with a lower GWP (HFC-152a) are only slowly having an effect (www.asahi.com/english/business/TKY200405270126.html). Furthermore, certain critical technical and/or laboratory uses of CFCs remain that are not controlled under the Protocol. For the users of such specialised aerosols the associated costs are less important. In these specific sectors, the introduction of alternatives to fluorocarbons is very knowledge intensive. However, due to the limited number of manufacturers, the number of specialists needed for technology transfer is limited (UNEP, 2003e). National legislation with respect to imports and standards is important because several products, in particular pharmaceuticals, need to adhere to national or regional standards. Most countries require intensive testing of new pharmaceuticals before the lengthy approval process is initiated and this can delay the introduction of new technologies. For all specialized products, manufacturers will often face very significant investments for research and development, testing, licenses and approval. The cost of converting production facilities to utilize alternative technologies could also be high.

3.6.1.5 Fire protection

Fire protection is a knowledge-intensive sector, which only needs a few specialists to service the limited amount of facilities. The diffusion of new technologies can therefore be undertaken with a limited amount of effort. Appropriate servicing of fire protection equipment and, where applicable, the subsequent appropriate disposal and destruction are key elements in the overall climate impact of these applications. The specific nature of this sector provides good opportunities for implementing containment measures for remaining applications, for example the banking of halons under the Montreal Protocol. For the introduction of new technologies, fire protection has a similar characteristic requirement to pharmaceuticals. The safe and efficient use of the agents has to be proven before new technologies can be accepted. This can cause significant delays in technology transfer. The costs of the systems are, within certain limits, secondary for the user because fire protection systems are required and/or essential and form an integral part of the purchase of buildings, military equipment or aircraft.

3.7 Emission projections

HFC and PFC emissions arise from two distinct sources (process emissions and releases when the product is in use (including disposal)) that require different methodologies for accounting historic and current mass emissions or for projecting mass emissions in the future.

Process emissions that occur during chemical production are subject to pollution-control regulations in many countries. These originate from a relatively small number of large facilities and are potentially simple to monitor. For example, there are some thirteen companies throughout the world that produce HCFC-22 and hence could be sources of the HFC-23 byproduct (AFEAS, 2003; EU, 2003). Together with their subsidiaries and associates, and the other independent facilities in a small number of developing countries, these constitute a set of 50 potential emission sites, which are point sources. A standard methodology exists to monitor the release of HFC-23 from these facilities (DEFRA, 2003; IPCC, 2000a) and future emissions will depend on production activity and the extent to which byproducts are abated at the sources.

Emissions arising during use of a fluorocarbon, or on disposal of the system containing it, occur over a much wider geographical area than the point source emissions described above. Furthermore, the losses are spread out over the service lifetime of the system with system-dependent rates of release; for most applications this will result in an emissions pattern that covers several years after the system is charged. Future releases will therefore depend on the release pattern from the current deployment, future changes in the number of systems, how widespread the use of fluids is and the extent to which the fluids are contained during usage and disposal. Methodological guidance is available for monitoring current releases of HFCs and PFCs from refrigeration and air-conditioning systems, foam blowing, aerosols, solvents and fire-fighting applications (IPCC, 2000a) and there is a standard methodological protocol for calculating releases from refrigeration systems (DEFRA, 2003).

Almost all predictions of future emissions are extrapolations of current quantities and trends and, the primary difference in methodology is the extent to which this is based on either:
a) An appreciation of the details of the market for the systems and the way those, and the emission rates of fluids, will change in the future (bottom-up approach)[8], or b) A view of the economy as a whole and the emissions arising from the niches filled by HFCs and PFCs, so that trends are governed by overall economic parameters (top-down approach).

3.7.1 Process emissions

This category includes emissions of HFC-23 from the production of HCFC-22 which, in recent years, has been the largest fluorocarbon contribution to potential climate change. This release of HFC-23 is used to exemplify the requirements for forecasting emissions.

In general, process emissions can be related to process activity:

$$E_i = A_i \times F_i \qquad (3.12)$$

Where:
E_i is the annual emission in year i;
A_i is the activity in that year, and
F_i is a factor relating activity to emissions.

8 This terminology is widely applied but has a variety of meanings. In this part of the report, all predictions based on study of HFC and PFC markets will be called bottom-up. Top-down will be used only for predictions based on macroeconomic parameters.

In the case of HFC-23, A_i is the annual rate of production of HCFC-22 for all uses, whether or not the HCFC-22 is released into the atmosphere or used as feedstock for fluoropolymer manufacture; so that the calculation of future activity will be a projection of both dispersive and feedstock end-uses. The global estimates of the production of HCFC-22 for dispersive use that were made for comparison with atmospheric measurements (McCulloch *et al*., 2003) can be extrapolated in accordance with the provisions of the Montreal Protocol as outlined in Montzka and Fraser (2003). It is important that such estimates include the significant changes in production in the developing world that are evident from UNEP (2003a). The fluoropolymers are products in their own right and have different markets and growth rates from that of HCFC-22, which, in this case, is simply a raw material. These growth parameters will need to be extrapolated separately and explicitly for developed and developing economies in order to calculate a credible total activity.

HFC-23 (trifluoromethane) is formed at the reactor stage of the manufacture of HCFC-22 (chlorodifluoromethane) as a result of over-fluorination. Its formation is dependent upon the conditions used in the manufacturing process and amounts to between 1.5–4.0 % of the quantity of HCFC-22 produced. Its production can be minimized by optimizing process conditions but the most effective means of elimination is destruction by thermal oxidation (Irving and Branscombe, 2002). Thus, the emission factor F_i for HFC-23 lies between zero and 4%. Use of a single value (3%) as the default emission rate (Irving and Branscombe, 2002), although allowed in the methodology for calculating national greenhouse-gas emissions (IPCC, 2000a), is not likely to give a credible forecast. In many cases, actual HFC-23 emission rates are recorded in national greenhouse-gas inventories (UNFCCC, 2003) and these can be used as information on the trends in emission rate (either the absolute rate or the rate relative to HCFC-22 production). It should also be possible to take into consideration national regulations that will affect such emissions in order to generate more robust predictions.

3.7.2 Calculating releases of fluorocarbons during use and disposal from sales data

Models used for extrapolation of emissions need to match historical data, including trends and, at the simplest level this means that the extrapolated data must start from the recorded baseline. Furthermore, the projections need to match the shape of the historical growth (or decline) in the sales from which emissions are calculated.

There is a long record of historic data for audited production for all of the major CFCs, HCFCs and HFCs (AFEAS, 2003). These data are consistent with the aggregated values for CFC and HCFC production and consumption reported under the Montreal Protocol (UNEP, 2002). The annual releases of CFC-11 and CFC-12, HCFC-22 and HFC-134a have been calculated from the audited production and sales (which are reported in categories having similar emission functions), and been shown to be consistent with the atmospheric concentrations observed for these species (McCulloch *et al.,* 2001; 2003). This indicates that the emission functions for these compounds from use in refrigeration, air conditioning, foam blowing, solvent applications and aerosol propulsion are robust. Comparisons between atmospheric concentrations and production or sales can also be used to refine emission functions (Ashford *et al*., 2004).

The primary variables that respond to economic parameters are the activities for the product, which in this case is the use (or sales) of that product in the categories listed above. Emissions are then secondary variables calculated from the deployment in these categories (commonly called the banks) according to models of the time pattern of the extent of emissions. These time patterns may change in response to factors such as legislation (McCulloch *et al.,* 2001).

Consideration of the long-term production databases for a wide range of industrial halocarbons, including CFCs and HCFCs, has shown that the compound growth model can be seriously misleading. It fails to replicate the shape of the demand curve over time for any of the materials examined (McCulloch, 2000). This appears to be because it does not address the changes which occur over the product lifetime. Therefore whereas growth during the early stages of product life may be compound, and hence directly related to an economic parameter such as GDP, it assumes a linear relationship with time when the product becomes more mature and then starts to assume an asymptote at full maturity. As S-curve has been shown to best represent the actual shape of the demand curve over time, the curve used to describe the growth and decline of biological populations (Norton *et al*., 1976; McCulloch, 1994b, 1995b and 1999). There is however no fixed time cycle and some products reach maturity far sooner than others. In the short term (say ten to fifteen years) it may be permissible to forecast future demand on the basis of a relatively simple function based on the historical demand. A product in its early life could be forecast to grow at a rate governed by the growth in GDP (the compound growth model); similarly, one that has reached more mature status may have a linear growth rate, increasing by the same mass rate each year. The completely mature product will have reached a constant demand (and may, in fact, be subject to falling demand if there is replacement technology).

3.7.3 Modelling future sales and emissions from bottom-up methodologies

The first step is to construct a history of the demand for the material in its individual end-uses, both those where it is currently used and those where it has the potential to be used. These demands may then be extrapolated from starting points that reflect the current status. Although it is possible, given sufficient resources and access to much information that may be considered confidential, to construct separate demand models for each new compound (Enviros March, 1999; Haydock *et al*., 2003), the most common methodology involves constructing models of the overall demand in a particular sector, for example hermetic refrigeration. Extrapolation of that demand into the future can be based on a mathematical analysis of the prior changes in functions with time (as outlined above in McCulloch, 1994b, 1995b and 1999) or on the application of an external economic function, such as a compound growth rate (for example the growth in GDP as detailed in McFarland, 1999). Although over the relatively short time-period considered in this report (up to the year 2015), the difference between linear and compound growth for future demand may be small, any robust model should show the sensitivity of the forecasts to assumptions about future growth rates and should justify those rates by reference to the historic growth or models of comparable systems.

Once a forecast for the overall demand for a function has been established, the extent to which the HFC or PFC is deployed in that function can be estimated using a substitution fraction and a view of how that fraction might change in the future. There is now a body of data that describes recent substitution fractions and the changes expected in the coming decades (Enviros March, 1999; Forte, 1999; McFarland, 1999; Harnisch and Hendriks, 2000; Harnisch and Gluckman, 2001; Haydock *et al*., 2003). The most accurate substitution data will be found by examining current technical data for each compound in each application. In almost all cases, the potential for substitution is greater than the actual extent of substitution. Enforced changes in technology have provided the opportunity to switch to completely different materials and techniques (the not-in-kind solutions), to improve recovery and recycling (McFarland, 1999) and to significantly reduce charge in each installation (Baker, 1999). The requirements for continuing economic and environmental improvements will serve to drive these in the direction of further reductions in the substitution fractions.

Emission functions, factors applied to the quantities of material in use at each stage of the equipment life cycle, can also be predicted. In many studies the functions are based on AFEAS methodology, or variants of it. This allows for an initial loss, a loss during use and a final loss on disposal (AFEAS, 2003; McCulloch *et al*., 2001, 2003; Haydock *et al*., 2003; Enviros March, 1999; Harnisch and Hendriks, 2000). Default values for the emission functions for each category of end-use are provided in the IPCC Guidance on Good Practice in Emissions Inventories (IPCC, 2000a). However these emission functions have been shown to change in response to changes in technology and regulations (McCulloch *et al*., 2001) and predictions should take this into account, either explicitly or as a sensitivity case.

Finally the future evolution of emissions for each compound may be calculated by combining the temporally developed emission functions with the forecast demands. This approach of building a quantified description of emissions from databases that can be separately verified, requires a large body of information to be gathered. However, this can be reduced by making assumptions and by estimating quantities and parameters by analogy. During the course of this process it will be relatively easy to identify the parts of the analysis that rely on such assumptions and to calculate the sensitivities of the results to changes in them. This is much more difficult if 'top-down' methods are used because the assumptions are unlikely to be explicit.

3.7.4 *Modelling future sales and emissions using top-down parameterization*

This form of methodology uses forecast changes in major econometric parameters, such as GDP, to predict future emissions. A typical example is the series of scenarios for future emissions of HFCs and PFCs contained in the IPCC Special Report on Emissions Scenarios (IPCC, 2000b). Such long-term forecasts of emissions are desirable for predicting future climate change but the real implications of these forecasts need to be established and the predictions then need to be modified accordingly.

One significant advantage of top-down forecasting is that it depends on a parameter that should be common to all other forecasts of greenhouse-gas emissions – GDP or similar. It is therefore readily scaleableas expectations for the economic parameter change. However, the assumptions must be completely clear and the sensitivity of the result to changes in the assumptions must be an integral part of the analysis.

In the ideal case, the historical connection should be established between economic parameters and the demand for refrigeration, insulation and other categories in which HFCs and PFCs can be used, so that the parameter with the best fit can be chosen. Preferably, the analysis should be done on a regional or even a national basis, but it is unlikely that sufficient data would be available for this. Then the same methodology as used in the bottom-up models should be applied to translate this demand into emissions of individual compounds. In the form of this model it is unlikely that the timing of emissions can be rigorously estimated and so the sensitivity of the result to changes in the assumptions about the timing of emissions is essential. This allows the major failing of top-down models (that deviations from reality are perpetuated throughout the modelled period) to be addressed, with the possibility of making changes in the light of technological developments.

Technology change, diffusion and transfer

In all forms of modelling it is essential to establish the drivers of technological change and to assess their effects on demand. In the case of refrigeration and air conditioning as a whole, continuing improvements to system engineering have resulted in significant reductions in the absolute rates of leakage. In turn, this has allowed similar reductions in charge size, so that the inventory of refrigerants has been reduced together with the quantities required by original equipment manufacturers (OEMs) and for servicing. The scope for such reductions was reported in IPCC/TEAP (1999). Changes of this nature may originate in developed economies but is by no means confined to them. Furthermore, the adoption of new technology in the rest of the world could be expected to accelerate as the manufacturing base shifts from North America, Europe and Japan towards developing economies.

Predictions of future emissions need to take into account the probability of technical change, in terms of both the primary innovation and its diffusion and transfer into the global manufacturing sector. At the very least analyses of the sensitivities to such changes should be incorporated, which address both the magnitude and rate of change, and take into account both geographical and economic factors. Ideally a system should be developed to simply calculate their effects on the predictions.

Uncertainty
As the results are predictions, formal statistical analyses have relatively little meaning. The key to the exercise is how well these predictions will match the future reality and this cannot be tested now. However, the models can be subjected to certain tests and the simplest is replicating the current situation; models that cannot match this from historic data are likely to give meaningless predictions. If the model output does match with reality, then the sensitivity of the result to changes in the historic parameters will provide useful information for predictions of the future. Sensitivity analyses are likely to be the most that will be necessary. Given sufficient resources it may be possible to apply Monte Carlo methods to the predictions in order to derive a more statistically rigorous uncertainty for the result. However, the value of going to such lengths is questionable bearing in mind that the models are based on assumptions and not observations.

3.8 Outlook: Future methodological developments

Some of the assessment methodologies described in this chapter are very comprehensive. For example Life Cycle Assessment was developed for high volume products in mass markets and not for the customized systems found, for example, in commercial refrigeration or fire-protection. for certain areas of application or regions, the amount of resources required for some of these assessment methods will probably be considered inappropriate. There is an evident need for simple and pragmatic assessment methods in many world regions. TEWI and LCCP analyses – using standard assumptions and boundaries – are likely to have a strong role in fulfilling this need.

An important future task in using assessment methods such as TEWI and LCCP lies in achieving consistency and comparability among different studies from different authors and years. One example for this is the choice of weighting factors for the climate impact of emissions of different substances, for example, the choice of sets of GWP values which can come from the second or third IPCC assessment report or from other more recent sources, or the application of other metrics for the radiative impact of substance emissions (see Fuglestvedt *et al.* (2003) for an overview). It would therefore seem advisable for authors to publish enough interim results to allow the recalculation of modified parameters, such as more recent emission factors or values for indirect emissions from a country's electricity production.

In the past little attention was paid to ensuring the comparability and transferability of results from different technology assessments. The treatment of uncertainties was often incomplete and the resulting recommendations were often not robust enough to be transferred across a sector. Researchers and the users of their results should therefore pay more attention to determining the circumstances under which clear and robust conclusions on the relative performance of different technologies can be drawn, and on where uncertainties preclude such rankings. Carefully designed and performed sensitivity tests of the results for variations of key parameters are crucial for obtaining these insights.

In view of the many assumptions and different methodologies, an important role has been identified for comparisons between technologies using a common set of methods and assumptions as well as for the development of simple and pragmatic standard methodologies and the respective quality criteria. A future international standardization of simple as well as more complex or comprehensive evaluation methodologies will be important. An advanced level of international consistency has already been achieved in the field of health and safety. However, international standardization processes consume considerable amounts of time and resources (from scoping, via drafting and review to finalization). More timely and flexible processes will therefore be required as well. Whereas current standards are mainly based on low-toxicity, non-flammable fluids, standardization committees must also prepare proper standards which consider the limits and conditions for the safe use of fluids that are flammable or show higher toxicity. An essential input for this is the global standardization of international levels of requirements in respect to health, safety and environmental performance as well as respective test methods and classifications.

Policymakers need to have such information that is valid for entire sectors and this warrants additional methodology development. Future work will need to bridge the gap between application-specific comparisons and results which are robust enough to be used for policy design in entire subsectors. These analyses will have to be based on extensive databases on equipment populations, which comprise empirical data on fluid emissions and energy consumption. These databases should ideally be consistent and compatible with national greenhouse-gas emission inventories. Information on fluid sales to the different parties involved in the subsector will need to be made available. Significant resources will be required for these fairly comprehensive data requirements to support robust sectoral policies, and a number of resulting confidentiality issues will need to be addressed cautiously. In their efforts to achieve acceptability across subsectors, decision-makers could focus on increasing the involvement of relevant stakeholders and introducing additional measures to increase the transparency for outside users by means of more extensive documentation.

It is important to bear in mind that the methodologies and policies discussed above may be subject to misuse and neglect. For example, although industry uses such assessments, they are rarely determining factors in selecting a particular alternative. In fact, environmental assessment methods that are sensitive to inputs are often employed to justify the suitability of a technology that has already been selected for other reasons.

Policymakers should therefore recognize other parameters industry uses to choose technologies, so that they are aware of the factors affecting the outcomes of an analysis and of the market forces which may counter the spirit of environmental policies.

Cost is clearly one of the most important factors driving decisions for or against certain technologies. Private decision-makers usually take a life-cycle cost perspective based on their enterprises' rules for depreciation times and capital costs for their investment. Policymakers commonly use different rules and parameters to judge the cost-effectiveness of different measures. As this Special Report has shown, there is still little public cost information available which policymakers can use to reach a judgement about the cost-effectiveness of measures. Many firms give considerably less weight to social costs than to private costs in making their decisions. Initial exploratory studies would seem to be a worthwhile means of filling this gap. In the future it might be useful to apply uniform costing methodologies with common standards for transparency and data quality.

In summary the following points can be highlighted as key results:

A systems perspective is usually used to select a technology. This takes into account the system's life-cycle costs, its energy consumption and associated emissions, health and safety impacts, and other environmental impacts. The available assessment methods for each of these attributes have been described in this chapter. These will often need to be adapted to the specific application region concerned. A decision-maker can avoid inconsistencies by initiating concerted technology comparisons of competing technologies under common rules. In any case decision-makers need to make their decisions in the light of the remaining uncertainties and limitations of the available assessment methods, such as Total Equivalent Warming Impact (TEWI), the Life Cycle Climate Performance (LCCP) or a Life Cycle Assessment (LCA).

Ensuring the faithful application of existing assessment methodologies by all players in order to provide information relevant for decisions, is an ongoing challenge. A decision-maker may want to ensure that the full life cycle of the application has been considered, that all relevant stakeholders have been involved in the scoping and execution of the analysis and in the review of its results, that accepted emissions monitoring protocols have been applied for direct and indirect emissions, that all costs are properly accounted based in the best available figures, and that the uncertainties, sensitivities and limitations of the analysis have all been clearly identified.

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4

Refrigeration

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EXECUTIVE SUMMARY

Domestic refrigeration

Domestic refrigerators and freezers are used throughout the world for food storage in dwelling units and in non-commercial areas such as offices. More than 80,000,000 units are produced annually with internal storage capacities ranging from 20 litre to greater than 850 litre. With an estimated average unit lifespan of 20 years, this means there is an installed inventory of approximately 1500 million units. As a result of the Montreal Protocol, manufacturers initiated transition from CFC refrigerant applications during the early 1990s. This transition has been completed in developed countries and significant progress has been made in developing countries. The typical lifespan for domestic refrigerators means that products manufactured using CFC-12 refrigerant still comprise approximately one-half of units in the installed base. This has significantly slowed down the rate of reduction in the demand for CFC-12 refrigerant in the servicing sector.

Isobutane (HC-600a) and HFC-134a are the dominant alternative refrigerants for replacing CFC-12 in new domestic refrigeration appliances. Each of these has demonstrated mass production capability for safe, efficient, reliable and economic use. Both refrigerants give rise to similar product efficiencies. Independent studies have concluded that application design parameters introduce more efficiency variation than that attributable to the refrigerant choice. Comprehensive refrigerant selection criteria include safety, environmental, functional, cost and performance requirements. The choice of refrigerant can be strongly influenced by local regulatory and litigation environments. Each refrigerator typically contains 50–250 grams of refrigerant contained in a factory-sealed hermetic system. A simplified summary of the relative technical considerations for these two refrigerants is:

- HC-600a uses historically familiar mineral oil lubricants. Manufacturing processes and designs must fully take into account the flammable nature of the refrigerant. For example, the need for proper factory ventilation and appropriate electrical equipment, preventing leaking refrigerant from gaining access to electrical components, using sealed or non-sparking electrical components, and the use of proper brazing techniques or preferably the avoidance of brazing operations on charged systems. Service procedures must similarly include appropriate precautions for working with flammable refrigerants;
- HFC-134a uses moisture-sensitive polyolester oils. Manufacturing processes should ensure that low moisture levels are maintained. Long-term reliability requires a more stringent avoidance of contaminants during production or servicing compared to either CFC-12 or HC-600a practices.

The use of the hydrocarbon blend propane (HC-290)/isobutane (HC-600a) allows CFC-12 volumetric capacity to be matched and avoids the capital expense of retooling compressors. These blends introduce manufacturing complexities and require the use of charging techniques suitable for refrigerant blends which have components with different boiling points. The application of these blends in Europe during the 1990s was an interim step towards the transition to HC-600a using retooled compressors. The same safety considerations apply to hydrocarbon blends as to HC-600a.

Alternative refrigeration technologies such as the Stirling cycle, absorption cycle, thermoelectrics, thermionics and thermoacoustics continue to be pursued for special applications or for situations with primary drivers that differ from conventional domestic refrigerators. These technology options are not expected to significantly alter the position of vapour compression technology as the choice for domestic refrigeration.

Vapour compression technology is mature and readily available worldwide. The availability of capital resources is dictating the timing of conversion to HC-600a and HFC-134a. Current technology designs typically use less than half the electrical energy required by the units they replace. This reliable performance is provided without resorting to higher cost or more complex designs. Continued incremental improvements in unit performance and/or energy efficiency are anticipated. Government regulations and voluntary agreements on energy efficiency and labelling programmes have demonstrated their effectiveness in driving improved efficiency product offerings in several countries.

Good design and the implementation of good manufacturing and service practices will minimize refrigerant emissions; however, special attention must be given to the retirement of the large number of units containing CFC-12. With a typical 20-year lifespan, refrigerator end-of-life retirement and disposal happens to about 5% of the installed base each year. This means approximately 75 million refrigerators containing 100 grams per unit, or 7500 total tonnes of refrigerant are disposed of annually. This refrigerant will be predominantly CFC-12 for at least another 10 years. The small refrigerant charge means that refrigerant recovery is not economically justifiable. Regulatory agencies around the world have therefore provided incentives or non-compliance penalties to promote recovery of this ODS.

In 2002, the total amount of refrigerants banked in domestic refrigeration amounted to 160,000 tonnes, with annual refrigerant emissions of 5.3% of banked system charge. The annualized HFC emissions rate from this sector was 1.0% in 2002. HFC emissions mostly occur during useful life. Production transition to HFCs started during 1995; consequently in 2002 the installed product age was 7 years or less compared to a typical lifespan of 20 years. Further, recovery during service and disposal is required in most early conversion countries.

Commercial refrigeration

Commercial refrigeration makes fresh and frozen food available to customers at the appropriate temperature levels: chilled food in the range of 1°C–14 °C and frozen food in the range of –12°C to –20°C.

On a global basis, commercial refrigeration is the refrigeration subsector with the largest refrigerant emissions calculated as CO_2-equivalents. This amounts to 40% of the total annual refrigerant emissions, see Table 11.5. In 2002 worldwide commercial refrigeration emission rates were reported to be 30% yr^{-1} of the installed commercial refrigeration banked inventory of 605,000 tonnes refrigerant. This means that in an environment with an average energy mix, the refrigerant emissions represent about 60% of the total emissions of GHG resulting from system operation, the rest being indirect emissions caused by power production.

Refrigeration equipment types vary considerably in terms of size and application. Stand-alone equipment consists of systems where the components are integrated, such as beverage vending machines, ice cream freezers and stand-alone display cases. Refrigerant charge sizes are small (0.2–1 kg), and the CFCs CFC-12 and R-502 are being replaced by HFCs HFC-134a, R-404A and R-507A. HCFC-22 is also used, but is subject to phase-out requirements. Refrigerant emissions are low in these mainly hermetic systems and are similar to domestic refrigerator emissions. However, end-of-life recovery is almost non-existent on a global basis and this results in an average annual leakage of 7–12% of the refrigerant charge, dependent on the equipment lifetime. Some stand-alone equipment using hydrocarbons as refrigerants have been developed and are available in European countries, with refrigerant charge sizes in accordance with the limitations imposed by European and national safety standards.

Condensing units are small commercial systems with compressors and condensers located external to the sales area, and the evaporators located in display cases in the sales area, or in a cold room for food storage. These units are installed in shops such as bakeries, butchers and convenience stores as well as in larger food retailer stores. Similar refrigerants are used in these applications as in stand-alone equipment; however, with the larger refrigerant charges in these systems (1–5 kg), hydrocarbon refrigerant applications may be limited by national safety standards. Refrigerant emissions depend on the robustness of the system design, installation, monitoring and refrigerant recovery at end of equipment lifetime.

Full supermarket systems can be categorized by whether refrigerant evaporation occurs in the display cabinets and cold stores, or whether a low-temperature, secondary heat transfer fluid that is cooled centrally, is circulated to the display cabinets and cold stores. The first type is termed a direct system and the second type an indirect system.

Supermarket centralized direct systems consist of a series of compressors and condensers located in a remote machinery room, providing a cooling medium to display cabinets and cold storage rooms in other parts of the building. The size of systems can vary from cooling capacities of 20 kW to more than 1 MW, as used in larger supermarkets. Refrigerant charge sizes can range from 100–2000 kg. The most common form of centralized system is direct expansion. Specific units can be dedicated to low-temperature or medium-temperature evaporators. HCFC-22 continues to be extensively used in these systems, with R-502 for low-temperature applications being replaced by R-404A and R-507A. Due to European regulations on HCFCs that have been in force since January 2001, R-404A and R-507A are the most commonly used refrigerants for large capacity low- and medium-temperature systems in Europe.

The 'distributed' system is a variation of the direct system. In this the compressors are located in sound-proof boxes near the display cases, permitting the shortening of refrigerant circuit length and a corresponding 75% reduction of refrigerant charge. Condensing units can be air-cooled or water-cooled. When compressor systems are installed as small packs with roof-mounted, air-cooled condensers, or as small packs adjacent to the sales area in conjunction with remote air-cooled condensers, they are sometimes referred to as close coupled systems. The refrigerants used are mainly HCFC-22 and the low-temperature refrigerants R-404A and R-507A. Other refrigerants such as R-410A are also being considered. With the close-coupled system design, refrigerant emissions are estimated to be 5–7% of charge on an annual basis. Compared to the centralized systems, the absolute reduction in refrigerant emissions is much greater due to the considerable reduction in refrigerant charge size.

The design of indirect systems for supermarkets permits refrigerant charge size reduction of 75–85%. Fluorocarbon-based refrigerants are generally used in these systems. However, if the centralized refrigeration system can be located in a controlled-access room away from the customer area, indirect systems may also use flammable and/or toxic refrigerants, dependent on system safety measures and national safety regulations. Refrigerant emissions are reduced to about 5% of charge yr^{-1} due to the reductions in the reduced piping lengths and the number of connecting joints.

Systems that use ammonia and hydrocarbons as primary refrigerants in indirect systems operate in several European countries. Published results show that ammonia and hydrocarbon indirect systems have a 10–30% higher initial cost than direct expansion systems and an energy consumption 0–20% higher than that of direct expansion systems, due to the additional system requirements (heat exchanger and circulating pumps with their costs and energy penalties). Development work on indirect systems design is continuing with the goals of reducing the cost and energy penalties in these systems.

Carbon dioxide is being evaluated in direct systems for both low- and medium-temperature applications, and in cascade systems with carbon dioxide at the low-temperature stage and ammonia or R-404A at the medium-temperature stage. Thirty cascade systems have been installed in supermarkets and the initial costs and energy consumption are reported to be similar to R-404A direct expansion systems.

Important considerations in the selection of designs for supermarket refrigeration systems and refrigerants are safety, initial cost, operating cost and climate change impact (refrigerant emissions and carbon dioxide from electricity produced to operate the refrigeration systems). In the 1980s the centralized direct systems had annual refrigerant emissions up to 35% of charge. Recent annualized emission rates of 3–22% (average

18%) were reported for 1700 supermarket systems in several European countries and the USA. The reduced emission rates were due to a combination of factors aimed at improving refrigerant containment, such as system design for tightness, maintenance procedures for early detection and repairs of leakage, personnel training, system leakage record keeping, end-of-life recovery of refrigerant and in some countries, increasing the use of indirect cooling systems.

In 2002, worldwide commercial refrigeration emission rates were reported to be 30% yr^{-1} of the installed commercial refrigeration banked inventory of 605,000 tonnes of refrigerant. The higher worldwide emission rates indicate less attention was paid to refrigerant containment and end-of-life recovery than in the limited survey data reported above.

Traditional supermarket centralized direct systems must be designed for lower refrigerant emissions and higher energy efficiency in order to reduce climate change impact. From an overall perspective, significant research and development is underway on several designs of supermarket refrigeration systems to reduce refrigerant emissions, use lower global-warming refrigerants and reduce energy consumption. Life cycle climate performance calculations indicate that direct systems using alternative refrigerants, distributed systems, indirect systems and cascade systems employing carbon dioxide will have significantly lower CO_2-equivalent emissions than centralized direct systems that have the above-stated, historically-high refrigerant emission rates.

Food processing, cold storage and industrial refrigeration

Food processing and cold storage is one of the important applications of refrigeration for preserving and distributing food whilst keeping food nutrients intact. This application of refrigeration is very significant in terms of size and economic importance in both developed and developing countries. The annual consumption of frozen food worldwide is about 30 Mtonnes yr^{-1}. Over the past decade, consumption has increased by 50% and is still growing. The amount of chilled food is about 10–12 times greater than the supply of frozen products. Frozen food in long-term storage is generally kept at –15°C to –30°C, while –30°C to –35°C is typical for freezing. Chilled products are cooled and stored at temperatures from –1°C–10°C.

The majority of refrigeration systems for food processing and cold storage are based on reciprocating and screw compressors. Ammonia, HCFC-22, R-502 and CFC-12 are the refrigerants historically used, with other refrigerant options being HFCs, CO_2 and hydrocarbons. HFC refrigerants are being used instead of CFC-12, R-502 and HCFC-22 in certain regions. The preferred HFCs for food processing and cold storage applications are HFC-134a and HFC blends with an insignificant temperature glide such as R-404A, R-507A and R-410A. Ammonia/CO_2 cascade systems are being introduced in food processing and cold storage.

Some not-in-kind (non-vapour compression) technologies, such as vapour absorption technology and compression-absorption technology, can be used for food processing and cold storage applications. Vapour absorption technology is well established, whereas compression-absorption technology is still under development.

For this category, limited data are available on TEWI/LCCP. A recent study of system performance and LCCP calculations for a 11 kW refrigeration system operating with R-404A, R-410A and HC-290 showed negligible differences in LCCP, based on the assumptions used in the calculations.

Industrial refrigeration includes a wide range of cooling and freezing applications in the chemical, oil and gas industries as well as in industrial ice-making, air liquefaction and other related industry applications. Most systems are vapour compression cycles, with evaporator temperatures ranging from 15°C down to –70°C. Cryogenic applications operate at even lower temperatures. Capacities of units vary from 25 kW to 30 MW, with systems often being custom made and erected on-site. Refrigerant charge size varies from 20–60,000 kg. The refrigerants used are preferably single component or azeotropes, as many of the systems use flooded evaporators to achieve high efficiency. Some designs use indirect systems (with heat transfer fluids) to reduce refrigerant charge size and to the risk of direct contact with the refrigerant.

These refrigeration systems are normally located in industrial areas with limited public access, and ammonia is the main refrigerant. The second refrigerant in terms of volume use is HCFC-22, although the use of HCFC-22 in new systems is forbidden for all types of refrigerating equipment by European regulations since January 2001. Smaller volume CFC refrigerants CFC-12 and R-502 are being replaced by HFC-134a and R-404A, and R-507A and R-410A. CFC-13 and R-503 are being replaced by HFC-23 and R-508A or R-508B. HCFC-22 is being replaced by R-410A, as the energy efficiency of R-410A is slightly higher than that of HCFC-22. The energy efficiency of R-410A can be similar to that of ammonia for evaporation temperatures down to –40°C, dependent on the compressor efficiency. Hydrocarbon refrigerants have historically been used in large refrigeration plants within the oil and gas industry.

Carbon dioxide is another non-HFC refrigerant which is starting to be used in industrial applications, as the energy efficiency of carbon dioxide systems can be similar to that of HCFC-22, ammonia and R-410A in the evaporator temperature range of –40°C to –50°C for condensing temperatures below the 31°C critical temperature of carbon dioxide. Cascade systems with ammonia in the high stage and carbon dioxide in the low stage show favourable cost and energy efficiency. Carbon dioxide is also being used as a heat-transfer fluid in indirect systems.

Attempts are being made to reduce refrigerant emissions in industrial refrigeration, food processing and cold storage by improving the system design, minimizing charge quantities, ensuring proper installation, improving the training of service personnel with respect to the detection of potential refrigerant leakage, and improving procedures for recovery and re-use of refrigerant. The total amount of refrigerants banked in the combined sectors of industrial refrigeration, food processing and cold storage was 298,000 tonnes in 2002, with ammonia at 35% and HCFC-22 at 43% of the total banked inventory. Annual refrigerant emissions were 17% of banked system charge.

Transport refrigeration

Transport refrigeration consists of refrigeration systems for transporting chilled or frozen goods. Transport takes place by road, rail, air and sea; further, containers as refrigerated systems are used with moving carriers. All transport refrigeration systems must be sturdily built to withstand movements, vibrations and accelerations during transportation, and be able to operate in a wide range of ambient temperatures and weather conditions. Despite these efforts, refrigerant leakage continues to be a common issue. It is imperative that refrigerant and spare system parts are available on-board and along the transport routes. Ensuring safe operation with all working fluids is essential, particularly in the case of ships where there are limited options for evacuation.

Ships with cargo-related, on-board refrigeration systems have either refrigerated storage spaces or provide chilled air supply. There are about 1100 such ships, with HCFC-22 being the main refrigerant. In addition, there are approximately 30,000 merchant ships which have refrigerated systems for crew food supply, again mainly using HCFC-22. Alternative refrigerants being implemented are R-404A/R-507A, R-410A, ammonia and ammonia/CO_2.

Refrigerated containers allow storage during transport on rail, road and seaways. There are more than 500,000 such containers that have individual refrigeration units of about 5 kW cooling capacity. Refrigerants in this sector are transitioning from CFC-12 to HFC-134a and R-404A/R-507A.

Refrigerated railway transport is used in North America, Europe, Asia and Australia. The transport is carried out with either refrigerated railcars, or, alternatively, refrigerated containers (combined sea-land transport; see Section 4.6.2) or swap bodies (combined road-land transport; see Section 4.6.4).

Road transport refrigeration systems (with the exception of containers) are truck-mounted systems. The refrigerants historically used were CFC-12, R-502 and HCFC-22. New systems are using HFC-134a, R-407C, R-404A, R-410A and decreasing amounts of HCFC-22. There are about 1 million vehicles in operation, and annual refrigerant use for service is reported to be 20–25% of the refrigerant charge. These high leakage rates call for additional design changes to reduce leakage, which could possibly follow the lead of newer mobile air-conditioning systems. Another option would be for systems to use refrigerants with a lower global-warming potential (GWP).

The non-HFC refrigerant hydrocarbons, ammonia and carbon dioxide are under evaluation, and in some cases these are being used for transport applications in the various sectors, with due consideration for regulatory, safety and cost issues. Fishing trawlers in the North Pacific Ocean already use ammonia for refrigeration, with a smaller number of trawlers using R-404A or R-507A. Carbon dioxide is a candidate refrigerant for low-temperature refrigeration, but the specific application conditions must be carefully considered. Carbon dioxide systems tend towards increased energy consumption during high-temperature ambient conditions, which may be significant when containers are closely stacked on-board ships, leading to high condensation/gas cooler temperatures because of lack of ventilation. In the case of reefer ships and fishing vessels, a promising alternative technology is equipment with ammonia/carbon dioxide systems. These systems have similar energy efficiency to existing refrigeration systems but higher initial costs.

Low GWP refrigerant options will technically be available for transport refrigeration uses where fluorocarbon refrigerants are presently used. In several cases, these low GWP options may increase the costs of the refrigeration system, which is an important consideration for owners of transport equipment. A technology change from an HFC, such as R-404A, to a low-GWP fluid will usually lead to a reduction of TEWI, if the energy consumption is not substantially higher than in existing systems.

The total amount of refrigerants banked in transport refrigeration was 16,000 tonnes in 2002, with annual refrigerant emissions of 38% of banked system charge consisting of CFCs, HCFCs and HFCs.

4.1 Introduction

The availability and application of refrigeration technology is critical to a society's standard of living. Preservation throughout the food chain and medical applications are examples of key contributors to quality of life. Integrated energy consumption information is not available, but this largest demand sector for refrigerants is estimated to use about 9% of world power generation capacity (Bertoldi, 2003; EC, 2003; ECCJ, 2004; EIA, 2004; ERI, 2003; UN-ESCAP, 2002, Table 1.1.9). This consumption of global power-generation capacity means that the relative energy efficiency of alternatives can have a significant impact on indirect greenhouse-gas (GHG) emissions.

Refrigeration applications vary widely in size and temperature level. Sizes range from domestic refrigerators requiring 60–140 W of electrical power and containing 40–180 g of refrigerant, to industrial and cold storage refrigeration systems with power requirements up to several megawatts and containing thousands of kilograms of refrigerant. Refrigeration temperature levels range from –70°C to 15°C. Nearly all current applications use compression-compression refrigeration technology. The potential market size for this equipment may approach US$ 100,000 million annually. This diversity has resulted in unique optimization efforts over the decades, which has resulted in solutions optimized for different applications. For discussion purposes, the refrigeration sector is divided into the five subsectors:

- Domestic Refrigeration: the refrigerators and freezers used for food storage primarily in dwelling units;
- Commercial Refrigeration: the equipment used by retail outlets for holding and displaying frozen and fresh food for customer purchase;
- Food Processing and Cold Storage: the equipment to preserve, process and store food from its source to the wholesale distribution point;
- Industrial Refrigeration: the large equipment, typically 25 kW to 30 MW, used for chemical processing, cold storage, food processing and district heating and cooling;
- Transport Refrigeration: the equipment to preserve and store goods, primarily foodstuffs, during transport by road, rail, air and sea.

Data in Table 4.1 indicate that the annualized refrigerant emission rate from the refrigeration sector was 23% in 2002. This includes end-of-life losses. There is a wide range of annualized emissions from the five subsectors, from 5% for domestic refrigeration to 30% for commercial refrigeration to 38% for transport refrigeration. For commercial refrigeration, the 30% annual refrigerant emissions represent typically 60% of the total emissions of GHGs resulting from system operation, the rest being indirect emissions from power production. This indicates the importance of reducing refrigerant emissions from this sector, in addition to the importance of the energy efficiency of systems stated above.

4.2 Domestic refrigeration

4.2.1 Background

Domestic refrigerators and freezers are used for food storage in dwelling units and in non-commercial areas such as offices throughout the world. More than 80,000,000 units are produced annually with internal storage capacities ranging from 20 litre to greater than 850 litre. With an estimated typical unit life of 20 years (Weston, 1997), the installed inventory is approximately 1500 million units. Life style and food supply infrastructures strongly influence consumer selection criteria, resulting in widely differing product configurations between different global regions. Products are unitary factory assemblies employing hermetically-sealed, compression refrigeration systems. These typically contain 50–250 g of refrigerant.

4.2.2 Refrigerant options

Conversion of the historic application of CFC-12 refrigerant in these units to ozone-safe alternatives was initiated in response to the Montreal Protocol. Comprehensive refrigerant selection criteria include safety, environmental, functional, performance and cost requirements. A draft refrigerant selection-decision map and a detailed discussion of requirements were included in the 1998 report of the Refrigeration, Air Conditioning, and Heat Pumps Technical Options Committee (UNEP, 1998). The integration of these requirements with other potential drivers such as global-warming emissions reduction, capital resource availability and energy conservation results in a comprehensive analysis of refrigerant options for strategic consideration. Two different application areas must be addressed: (1) new equipment manufacture, and (2) service of the installed base. New equipment manufacture can be addressed more effectively, since the ability to redesign avoids constraints and allows optimization.

4.2.2.1 New Equipment Refrigerant options

Most new refrigerators or freezers employ either HC-600a or HFC-134a refrigerant. Each of these refrigerants has demonstrated mass production capability for safe, efficient, reliable and economic use. There are no known systemic problems with properly manufactured refrigerator-freezers applying either of these primary options. The key variables influencing selection between these two refrigerants are refrigerator construction details, energy efficiency, building codes, environmental considerations and the economics of complying with standards. Other selected alternative refrigerants or selected refrigerant blends have had limited regional appeal, driven by either niche application requirements or by availability of suitable compressors or refrigerants. Some brief comments about selected refrigerant use are now given.

Isobutane (HC-600a) refrigerant

HC-600a applications use naphthenic mineral oil, the historic

Table 4.1. Refrigerant bank and direct emissions of CFCs, HCFCs, HFCs and other substances (hydrocarbons, ammonia and carbon dioxide) in 2002, the 2015 business-as-usual scenario and the 2015 mitigation scenario, for the refrigeration sector, the residential and commercial air-conditioning and heating sector ('stationary air conditioning') and the mobile air-conditioning sector.

	Banks (kt)					Emissions (kt yr^{-1})					Emissions ($MtCO_2$-eq yr^{-1}) SAR/TAR[2]	Emissions ($MtCO_2$-eq yr^{-1}) This Report[3]
	CFCs	HCFCs	HFCs	Other	Total	CFCs	HCFCs	HFCs	Other	Total		
2002												
Refrigeration	330	461	180	108	1079	71	132	29	18	250	848	1060
- Domestic refrigeration	*107*	-	*50*	*3*	*160*	*8*	-	*0.5*	*0.04*	*9*	*69*	*91*
- Commercial refrigeration	*187*	*316*	*104*	-	*606*	*55*	*107*	*23*	-	*185*	*669*	*837*
- Industrial refrigeration[1]	*34*	*142*	*16*	*105*	*298*	*7*	*24*	*2*	*18*	*50*	*92*	*110*
- Transport refrigeration	*2*	*4*	*10*	-	*16*	*1*	*1*	*3*	-	*6*	*19*	*22*
Stationary Air Conditioning	84	1028	81	1	1194	13	96	6	0.2	115	222	271
Mobile Air Conditioning	149	20	249	-	418	60	8	66	-	134	583	749
Total 2002	**563**	**1509**	**509**	**109**	**2691**	**144**	**236**	**100**	**18**	**499**	**1653**	**2080**
2015 BAU												
Refrigeration	64	891	720	136	1811	13	321	115	21	471	919	1097
- Domestic refrigeration	*37*	-	*189*	*13*	*239*	*5*	-	*8*	*1*	*13*	*51*	*65*
- Commercial refrigeration	*6*	*762*	*425*	-	*1193*	*5*	*299*	*89*	-	*393*	*758*	*902*
- Industrial refrigeration[1]	*21*	*126*	*85*	*123*	*356*	*4*	*21*	*11*	*21*	*56*	*88*	*104*
- Transport refrigeration	*0.1*	*2.8*	*20.3*	-	*23.2*	*0.1*	*1.3*	*7.4*	-	*9*	*22*	*26*
Stationary Air Conditioning	27	878	951	2	1858	7	124	68	0	199	314	370
Mobile Air Conditioning	13	23	635	4	676	5	11	175	1	191	281	315
Total 2015-BAU	**104**	**1792**	**2306**	**143**	**4345**	**25**	**455**	**359**	**23**	**861**	**1514**	**1782**
2015 Mitigation												
Refrigeration	62	825	568	186	1641	8	202	52	15	278	508	607
- Domestic refrigeration	*35*	-	*105*	*60*	*200*	*3*		*3*	*1*	*6*	*27*	*35*
- Commercial refrigeration	*6*	*703*	*378*	-	*1087*	*3*	*188*	*40*	-	*230*	*414*	*494*
- Industrial refrigeration[1]	*21*	*120*	*65*	*126*	*331*	*3*	*13*	*5*	*14*	*36*	*53*	*63*
- Transport refrigeration	*0.1*	*2.8*	*20.3*	-	*23.2*	*0.0*	*0.9*	*4.3*	-	*5*	*13*	*15*
Stationary Air Conditioning	27	644	1018	2	1691	3	50	38	0	91	145	170
Mobile Air Conditioning	13	23	505	70	611	3	7	65	7	82	119	136
Total 2015 Mitigation	**102**	**1493**	**2090**	**259**	**3943**	**14**	**259**	**155**	**22**	**451**	**772**	**914**

(1) Including food processing/cold storage
(2) Greenhouse gas CO_2-equivalent (GWP-weighted) emissions, using direct GWPs, taken from IPCC (1996 and 2001) (SAR/TAR)
(3) Greenhouse gas CO_2-equivalent (GWP-weighted) emissions, using direct GWPs, taken from Chapter 2 in this report

choice for CFC-12 refrigerant, as the lubricant in the hermetic system. Competent manufacturing processes are required for reliable application but cleanliness control beyond historic CFC-12 practices is not required. HC-600a has a 1.8% lower flammability limit in air, increasing the need for proper factory ventilation and appropriate electrical equipment. This flammable behaviour also introduces incremental product design and servicing considerations. These include preventing leaking refrigerant access to electrical components or using sealed or non-sparking electrical components, using proper brazing methods or preferably avoiding brazing operations on charged systems, and ensuring a more robust protection of refrigerant system components from mechanical damage to help avoid leaks.

HFC-134a refrigerant: HFC-134a applications require synthetic polyolester oil as the lubricant in the hermetic system. This oil is moisture sensitive and requires enhanced manufacturing process control to ensure low system moisture level. HFC-134a is chemically incompatible with some of the electrical insulation grades historically used with CFC-12. Conversion to the electrical insulation materials typically used for HCFC-22 applications may be necessary. HFC-134a is not miscible with silicone oils, phthalate oils, paraffin oils or waxes. Their use should be avoided in fabrication processes for components in contact with the refrigerant. Common items for concern are motor winding lubricants, cutting fluids in machining operations and drawing lubricants. Careful attention to system cleanliness is required to avoid incompatible contaminants. Trace contaminants can promote long-term chemical degradation within the system, which can reduce cooling capacity or cause system breakdown. Necessary process controls are not technically complex but do require competent manufacturing practices and attention to detail (Swatkowski, 1996).

Isobutane (HC-600a)/propane (HC-290) refrigerant blends
The use of these hydrocarbon blends allows matching CFC-12 volumetric capacity and avoids capital expense for retooling compressors. These blends introduce design and manufacturing complexities. For example, they require charging techniques suitable for use with blends having multiple boiling points. The use of HC-600a/HC-290 blends in Europe during the 1990s was an interim step towards a final transition to HC-600a using retooled compressors. Unique application considerations are consistent with those discussed above for HC-600a**.**

Other refrigerants and refrigerant blends
Example applications of additional refrigerants in new equipment include HC-600a/HFC-152a blends in Russia, HCFC-22/HFC-152a blends in China and HCFC-22 replacing R-502 in Japan. These all are low volume applications supplementing high-volume primary conversions to HC-600a or HFC-134a refrigerant. Demand for <u>all</u> refrigerants other than HC-600a and HFC-134a totals less than 2% of all Original Equipment Manufacturer (OEM) refrigerant demand (UNEP, 2003). These special circumstance applications will not be further discussed in this report.

4.2.2.2 Service of existing equipment
Service options range from *service* with original refrigerant, to *drop-in*, where only the refrigerant is changed, to *retrofit*, which changes the refrigerant and other product components to accommodate the specific refrigerant being used. Several binary and ternary blends of various HFC, HCFC, PFC and hydrocarbon refrigerants have been developed to address continuing service demand for CFC-12. These blends are tailored to have physical and thermodynamic properties compatible with the requirements of the original CFC-12 refrigerant charge. Their application has been successful and is growing. Some of these are near-azeotrope blends; others have disparate boiling points or glide. If refrigerants and lubricants other than original design specification are proposed for use, their compatibility with the specific refrigerator-freezer product configuration and its component materials must be specifically reviewed. An extended discussion of domestic refrigerator service options was included in the 1998 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (UNEP, 2003).

4.2.3 Not-in-kind alternatives

Alternative refrigeration technologies such as the Stirling cycle, absorption cycle, thermoelectrics, thermoacoustics and magnetic continue to be pursued for special applications or situations with primary drivers that differ from conventional domestic refrigeration. Two examples of unique drivers are portability or absence of dependence on electrical energy supply. The 1994 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee concluded that no identified technology for domestic refrigerator-freezers was competitive with conventional compression-compression technology in terms of cost or energy efficiency (UNEP, 1994). The 1998 and 2002 reports of this committee reaffirmed this conclusion (UNEP, 1998; UNEP, 2003). No significant near-term developments are expected to significantly alter this conclusion.

4.2.4 Energy efficiency and energy standards

Relative refrigerator energy efficiency is a critical parameter in the assessment of alternatives. In practice, similar refrigeration system efficiency results from the use of either HFC-134a or HC-600a refrigerant. Independent studies have concluded that the relative energy efficiencies of these two primary alternatives are comparable. Efficiency differences from normal manufacturing variation exceed the differences introduced by the refrigerant choice (Sand *et al*., 1997; Fischer *et al.,* 1994; D&T, 1996; Wenning, 1996). Energy efficiency of a product is strongly influenced by configuration, component hardware selection,"thermal insulation, heat exchange surfaces and control algorithms. Effective options are readily available from multiple commercial sources. The improved energy efficiency of domestic refrigeration products is a national initiative in several countries. Energy labelling and energy standards are both being effectively used to facilitate these initiatives. The

Table 4.2. Global refrigerant demand for domestic refrigeration (tonnes) (UNEP, 2003; Euromonitor, 2001).

Refrigerant	Refrigerant demand (tonnes) 1992	1998	2000
New equipment			
CFC-12	10,130	4460	3330
HFC-134a	-	5520	7150
HC-600a	-	430	1380
Other [(1)]	80	200	230
Sub-total New equipment	**10,210**	**10,610**	**12,090**
Field service			
CFC-12	4458	5002	4484
HFC-134a	-	349	391
HC-600a	-	4	146
Other [(2)]	15	40 [(3)]	- [(3)]
Sub-total Field service	**4473**	**5395**	**5021**
Total Global demand	**14,683**	**16,005**	**17,111**

(1) HCFC-22, HFC-152a and HC-190 refrigerants
(2) Three refrigerants above, plus numerous HFC and/or HCFC and/or HC blends
(3) Reliable demand data not available due to disperse nature of demand

Collaborative Labelling and Appliance Standards Program (CLASP) maintains a website with substantive information including links to various national programmes (URL: http://www.clasponline.org).

Energy standards and tests procedures
Energy test procedures provide the basis for energy regulations and labelling initiatives. These test procedures must be reproducible and repeatable and should ideally provide an indication of energy consumption under consumer use conditions. They should also provide an effective amendment protocol to accommodate evolving product technologies. Test procedures have been developed by several global standards organizations. The tests are different, and the results from one should never be directly compared with the results from another. Each can provide a relative energy consumption value for the test conditions specified. The interested reader is referred to instructive discussions and comparisons of energy test procedures, their limitations and their future needs (Bansal and Kruger, 1995; Meier and Hill, 1997; Meier, 1998).

4.2.5 Consumption and consumption trends

Table 4.2 presents consumption of the three most used domestic refrigerator refrigerants during 1992, 1996 and 2000 (UNEP, 2003). Table 4.3 presents consumption details by global region for the year 2000 (UNEP, 2003). New equipment conversions from CFC-12 to ozone-safe alternatives are occurring in advance of the Montreal Protocol requirements. By the year 2000, 76% of new unit production had been converted: 53% to HFC-134a, 21% to HC-600a and 2% to all other (UNEP, 2003). Subsequent developments have maintained this trend with an apparent increase in the percentage converting to hydrocarbon refrigerants. Two large market examples are the production in India converting to either HFC-134a or an HC-600a/HC-290

Table 4.3. Global refrigerant demand in 2000 for domestic refrigeration by global region, in tonnes (UNEP, 2003; Euromonitor, 2001).

Region	Segment[(1)]	Global refrigerant demand in 2000 (tonnes) CFC-12	HFC-134a	HC-600a	Other [(2)]	Total
Western Europe	OEM		900	770		**1670**
	Service	34	14	12	n.a.	**60**
Eastern Europe	OEM	230	420	40	30	**720**
	Service	180	17	4	n.a.	**201**
North America	OEM		2460			**2460**
	Service	60	60		n.a.	**120**
Central and South America	OEM	200	1200			**1400**
	Service	990	20		n.a.	**1010**
Asia and Oceania	OEM	2030	1900	570	200	**4700**
	Service	2420	230	130	n.a.	**2780**
Africa and Mid-east	OEM	870	270			**1140**
	Service	800	50		n.a.	**850**
World	OEM	3330	7150	1380	230	**12,090**
	Service	4484	391	146	n.a.	**5021**
	Total	**7814**	**7541**	**1526**	**230**	**17,111**

(1) OEM: Original Equipment Manufacturer
(2) n.a.: data not available

blend (UNEP, 2000) and some units converting from HFC-134a to HC-600a in Japan.

Conversion of the service demand has been less successful. Field service procedures typically use the originally specified refrigerants. The long useful product life (up to 30+ years for some units with an average around 20 years), large installed base (approximately 1500 million units) and uncertainties with field conversion to alternative refrigerants have resulted in a strong continuing service demand for CFC-12. The estimated percentage of refrigerators requiring post-warranty service of the hermetically sealed system and replacement of the original refrigerant charge at sometime during their service life is 1% in industrialized countries and 7% in developing countries. In industrialized countries this demand is typically satisfied with reclaimed or stockpiled CFC-12 when not contrary to local regulations. (Note: 'Reclaimed' refrigerant refers to recovered refrigerant that has been purified to original specifications. Unpurified recovered refrigerant should never be used in long-life domestic refrigerators. Probable impurities are likely to catalyze systems degradation and cause premature failures.) CFC-12 is normally the lowest cost refrigerant in developing countries. Regardless of location, use of the CFC-free refrigerant service blends mentioned above only becomes significant when CFC-12 availability becomes limited. Since post-warranty service is typically provided by small, independent businesses, reliable service demand data are not available. Further, the limited capital resources in developing countries promotes the labour-intensive refurbishing of units compared to retirement and replacement with new units. This not only prolongs the phase-out of CFC-12, but also results in increased failure rates from the highly variable quality of workmanship.

4.2.6 *Factors affecting emissions*

A text-box example included in Chapter 3 of this report (see Table 3.5) tabulates emission factors which must be considered for comprehensive Life Cycle Climate Performance (LCCP) or Total Equivalent Warming Impact (TEWI) of domestic refrigeration design options. There are two general types of emissions: *direct*, which for discussion of the refrigerant choice are limited to the refrigerant itself; and *indirect*, which depends on the refrigerator design and the infrastructures of supporting services in the use environment (Sand *et al*., 1997). The emission of insulating foam blowing-agents is not addressed in this chapter. Insulating foam is addressed in Chapter 7

Direct emissions

Efficient factory operations and effective process and product designs will minimize emissions at the start of the product life cycle. Significant process variables include refrigerant transfer and storage, charge station operations, maintenance protocols and factory process efficiencies. Key refrigerator design variables include hermetic-system internal volume, number of joints, mechanical fatigue and abuse tolerance and, of course, the choice of refrigerant. Domestic refrigerators contain refrigerant in factory-sealed, hermetic systems. Once sealed, refrigerant emission can only occur if there is a product defect or quality issue. Typical examples are brazing defects or containment component fatigue. In all cases, excluding life-ending failures, the defect will require the product hermetic system to be repaired. Variables influencing emissions during service include refrigerant recovery procedure usage and efficiency, charge technique employed, technician training and technician work standards. Refrigerant recovery during service is practiced in many countries. The small refrigerant charge quantity, typically 50–250 g per unit, make this recovery economically unattractive. Regulations and non-compliance penalties are usually required to provide incentives for recovery. Audits and refrigerant charge logs can provide useful metrics for the quality of refrigerant recovery practices.

Clodic and Palandre (2004) have detailed worldwide refrigerant bank and emissions data for domestic refrigerators (see Table 4.1). CFC emissions for domestic refrigeration in 2002 were estimated to be 8000 tonnes. HFC emissions for domestic refrigeration in 2002 were estimated to be 0.3% of the domestic refrigerant bank, or 500 tonnes. Domestic HFC refrigerant emission estimates will have increased in 2015 to 3000–8000 tonnes, dependent on the extent of refrigerant containment and recovery assumed.

With a typical 20-year lifespan, refrigerator end-of-life retirement and disposal happens to about 5% of the installed base every year. In quantified terms this means approximately 75 million refrigerators containing approximately 100 g per unit or 7500 total tonnes of refrigerant are retired and disposed of annually. For the next few years, or possibly even decades, CFC-12-containing product will continue to be a significant fraction of the waste stream. As is the case for service recovery, the small refrigerant charge makes end-of-life recovery uneconomical. Equipment and procedures commonly used for refrigerant recovery during service can be used but recovery is more typically accomplished in central disposal locations. This allows the use of faster, less labour-intensive procedures to moderate recovery costs. Nevertheless, regulations and non-compliance penalties normally provide incentives for this recovery. Regulating agencies in various global regions administer these requirements and are an appropriate source for further information.

Indirect emissions

Product design affects indirect emissions through refrigerator operating efficiency, and ease of refrigerator disassembly and separation for recycling. Higher efficiency units consume less electricity which, in turn, proportionately reduces the emissions derived from electrical power generation and distribution. Parameters influencing energy efficiency are fundamental design considerations such as heat exchangers, control efficacy, refrigerant systems, heat losses, parasitic power demands such as fans and anti-sweat heaters and product safety. The design approaches taken and options selected are directly related to the desired product features, performance and regulatory environment. A comprehensive discussion of detailed design parameters is beyond the scope of this report. Information is commercially available from multiple sources. Example references listing areas of opportunity are the UNEP Refrigerants Technical Options Committee assessment reports (UNEP, 1994, 1998, 2003), the International Energy Agency energy efficiency policy profiles report (IEA, 2003) and the Arthur D. Little global comparative analysis of HFC and alternative technologies (ADL, 2002). Objective discussions of many options are contained in the Technical Support Documents of the US Department of Energy rulemakings for domestic refrigerators and freezers (US DOE, 1995).

4.2.7 *Comparison of emissions from alternative technologies*

HFC-134a and HC-600a are clearly the significant alternative refrigerants for domestic refrigeration. Consequently, the significant global-warming emissions comparison for this application sector is HFC-134a compared to HC-600a. An accurate comparison of these is very complex. The multiple and widely diverse product configurations available globally are the consequence of consumer needs and choices. Comparative analysis results will be influenced by the example scenario selected and its assumed details. The available degrees of freedom are too high to achieve a comprehensive perspective within a manageable number of scenarios. Any single technical solution will not provide an optimized solution.

Harnisch and Hendriks (2000) and March (March, 1998) estimated the conversion cost from HFC-134a to HC-600a, expressed as unit emissions avoidance cost. Harnisch and Hendriks assumed no product cost or performance impact and a 1 million per manufacturing site conversion cost which yielded an avoidance cost of 3.4 per tonne CO_2-eq. March (1998) assumed higher product and development costs, also with no performance impact, which resulted in an avoidance cost of 400 per tonne of CO_2. These two estimates differ by more than two orders of magnitude in direct emissions abatement costs with assumed equivalent indirect emissions. Table 4.4 summarizes emission abatement opportunities with increased application of HC-600a refrigerant in the three most common domestic refrigerator configurations. Estimates for manufacturing cost premiums, development costs and required implementation investments are also included. Emission abatement opportunities are based on Clodic and Palandre (2004).

The objective is to assess the total emissions from *direct* and *indirect* sources. HC-600a clearly has the advantage of minimizing *direct* GHG emissions. *Indirect* emissions can dominate overall results using some scenarios or assumptions. The energy consumption of basic HFC-134a and HC-600a refrigeration systems is similar. At issue is what product modifications are required or allowed when converting to an alternative refrigerant and what effect these modifications have on product efficiency and performance. This uncertainty is particularly applicable to larger, auto-defrost refrigerators where a trade-off between system efficiency and other product attributes necessary to maintain product safety is not obvious. The consequences of trends in consumer purchase choices and their influence on the rate of emissions reduction are also difficult to predict. LCCP and TEWI are powerful, complementary tools, but results are sensitive to input assumptions. Assumptions should be carefully validated to ensure they are representative of the specific sce-

Table 4.4. Domestic refrigeration, current status and abatement options.

Product Configuration		Cold Wall	Open Evaporator Roll Bond	No-Frost
Cooling capacity	From	60 W	60 W	120 W
	To	140 W	140 W	250 W
Refrigerant charge (HFC)	From	40 g	40 g	120 g
	To	170 g	170 g	180 g
Approximate percentage of sector refrigerant bank (160 kt) in configuration		20 units * 100 g average 18% of 160 kt	15 units * 100 g average 14% of 160 kt	50 units * 150 g average 68% of 160 kt
Approximate percentage of sector refrigerant emissions (8950 tonnes) in subsector		18% of 8950 tonnes	14% of 8950 tonnes	68% of 8950 tonnes
Predominant technology		HC-600a	HFC-134a	HFC-134a
Other commercialized technologies		HFC-134a, CFC-12	HC-600a, CFC-12	HC-600a, CFC-12
Low GWP technologies with fair or better than fair potential for replacement of HCFC/HFC in the markets		R-600a	HC-600a	HC-600a
Status of alternatives		Fully developed and in production	Fully developed and in production	Fully developed and in production
R-600a Mfg. Cost Premium		No Premium	3–5 US$	8–30 US$
Capital Investment		0	45–75 million US$	400–1500 million US$
Emission reduction		1432 tonnes	1253 tonnes	6086 tonnes

narios of interest.

Several investigators have analyzed total emission scenarios comparing HFC-134a and HC-600a for domestic refrigeration:

- An Arthur D. Little, Inc. LCCP study (ADL, 1999) estimated that approximately 14 grams (10% of initial charge) of HFC-134a would be the total net lifetime emissions from a domestic refrigerator in the USA regulatory environment. Using US power generation emission data, this equates to a 0.3% energy consumption increase over a typical 20-year product life;
- Ozone Operations Resource Group of the World Bank Report No. 5: 'The Status of Hydrocarbon and Other Flammable Alternatives Use in Domestic Refrigeration' (World Bank, 1993) cited TEWI assessments presented at the 1993 German National Refrigeration Congress in Nurnberg. Regarding the relative refrigerant selection effects, this TEWI analysis concluded that 'The *direct* contribution of HFC-134a to global warming … should not be given serious consideration within this rough estimate because it does not amount to more than a few percent of the *indirect* contribution caused by the energy consumption of the appliance' (Lotz, 1993).

4.2.8 Emission abatement opportunities

The following emission abatement opportunities are available for domestic refrigerators:

- Conversion to alternatives having reduced GWP: The refrigerant direct emission contribution ranges from less than 2% up to 100% of total emissions. Direct emissions of 100% reflect the condition where the power generation and distribution infrastructure has zero dependence on fossil fuel energy sources. Direct emissions favour HC-600a over HFC-134a. Regional regulatory and product liability considerations can hamper the viability of HC-600a application. Indirect emissions depend upon relative product energy efficiency. Thermodynamic cycle efficiencies of the alternatives are comparable. Product efficiency is dependent upon design attributes required to accommodate the flammability of HC-600a. There is no penalty with the cold-wall evaporator configurations common in Europe. Information concerning configurations commonly used for forced-convection, automatic-defrost products is limited or proprietary;
- Reduction of refrigerant leakage during service life: Annual leakage rates for the factory-sealed, hermetic systems in domestic units are typically less than 1%…This leakage typically drives service demand;
- Recovery of refrigerant during end-of-life disposal or during field repair: Approximately 5% of the installed base are retired each year. The annual service call rate is significantly less than that. Recovery efficiency is a critical variable;
- Reduction of indirect emissions through improved product energy efficiency: The indirect emission contribution for domestic refrigeration ranges from zero to more than 98% of total emissions. Current production refrigerators consume less than half the energy of the typically 20-year-old unit they replace. With a 5% yr^{-1} retirement rate, this translates to a 2.5% yr^{-1} improvement in indirect emissions from the installed base;
- Opportunities for reduced indirect emissions exist via improved product energy efficiency. The IEA energy efficiency policy profiles report (IEA, 2003) estimated the potential improvements to be 16–26%, dependent upon product configuration. Average cost inflation was estimated to be 23 (US$ 31) for manufacturing and 66 (US$ 88) for purchase. The report presents comparative Least Life Cycle Cost analyses for alternatives. Arthur D. Little conducted Life Cycle Climate Performance studies of HFC and other refrigerant alternatives (ADL, 2002). Their report gives heavy domestic refrigeration emphasis on the relative energy efficiency and Total Equivalent Warming Impact assessment of various blowing-agent alternatives.

4.3 Commercial refrigeration

Commercial Refrigeration is the part of the cold chain comprising equipment used by retail outlets for preparing, holding and displaying frozen and fresh food and beverages for customer purchase.

For commercial systems, two levels of temperature (medium temperature for preservation of fresh food and low temperature for frozen products) may imply the use of different refrigerants. Chilled food is maintained in the range 1°C–14°C but the evaporating temperature for the equipment varies between –15 °C and 5 °C dependent upon several factors: the type of product, the type of display case (closed or open) and the type of system (direct or indirect). Frozen products are kept at different temperatures (from –12 °C to –18 °C) depending on the country. Ice cream is kept at –18 to –20 °C. Usual evaporating temperatures are in the range of –30 to –40 °C.

On a global basis, commercial refrigeration is the refrigeration subsector with the largest refrigerant emissions calculated as CO_2 equivalents. These represent 40% of the total annual refrigerant emissions, see Table 11.5. Annual leakage rates higher than 30% of the system refrigerant charge are found when performing a top-down estimate (Clodic and Palandre, 2004; Palandre *et al*., 2004). This means that in an environment with an average energy mix, the refrigerant emissions might represent 60% of the total emissions of GHG resulting from system operation, the rest being indirect emissions caused by power production. This indicates how important emission reductions from this sector are.

There are five main practices in order to reduce direct GHG emissions:

1. A more widespread use of non-HFC refrigerants;
2. Leak-tight systems;
3. Lower refrigerant charge per unit of cooling capacity;
4. Recovery of refrigerant during service and end-of-life;
5. Reduced refrigeration capacity demand.

4.3.1 Sector background

Commercial refrigeration comprises three main types of equipment: stand-alone equipment, condensing units and full supermarket systems.

Stand-alone equipment consists of systems where all the components are integrated: wine coolers, beer coolers, ice cream freezers, beverage vending machines and all kinds of stand-alone display cases. This equipment is installed in small shops, train stations, schools, supermarkets and corporate buildings. Annual growth is significant. All types of stand-alone equipment are used intensively in industrialized countries and are the main form of commercial refrigeration in many developing countries. These systems tend to be less energy efficient per kW cooling power than the full supermarket systems described below. A main drawback to stand-alone units is the heat rejected to ambient air when placed indoors. Therefore, the heat must be removed by the building air conditioning system when there is no heating requirement.

Condensing units are used with small commercial equipment. They comprise one or two compressors, a condenser and a receiver which are normally located external to the sales area. The cooling equipment includes one or more display cases in the sales area and/or a small cold room for food storage. Condensing units are installed in specialized shops such as bakeries, butchers and convenience stores in industrialized countries, whilst in developing countries a typical application is the larger food retailers.

Full supermarket systems can be categorized by whether refrigerant evaporation occurs in the coolers, or whether a low-temperature secondary heat transfer fluid (HTF) that is cooled centrally is circulated in a closed loop to the display cabinets and cold stores. The first type is termed 'direct expansion' or direct system and the second type is termed indirect system. Direct systems have one less thermal resistance and no separate fluid pumping equipment, which gives them an inherent efficiency and cost advantage. The HTF circulated in an indirect system normally gains sensible heat, but may gain latent heat in the case of ice slurry or a volatile fluid like CO_2.

Many different designs of full supermarket systems can be found. *Centralized systems* consist of a central plant in the form of a series of compressors and condenser(s) located in a machinery room or an outside location. This provides refrigerant liquid or an HTF at the correct temperature levels to cabinets and cold stores in other parts of the building. Each rack of multiple compressors is usually associated with a single air-cooled condenser. Specific racks are dedicated to low-temperature or medium-temperature evaporators. The quantity of refrigerant is related to the system design, refrigerating capacity and refrigerant choice varies. The centralized systems can be either direct or indirect systems. Centralized direct systems constitute by far the largest category in use in supermarkets today. The size can vary from refrigerating capacities of about 20 kW to more than 1 MW. The centralized concept is flexible in order to utilize heat recovery when needed (Arias, 2002).

Distributed Systems are characterized by having smaller compressors and condensers close to or within the coolers, so that many sets of compressor/condenser units are distributed around the store. The compressors can be installed within the sales area with remote condensers. When they are installed as small packs with roof-mounted, air-cooled condensers, or as small packs adjacent to the sales area in conjunction with remote air-cooled condensers they are sometimes referred to as C*lose Coupled Systems*. The quantity of such units could range from just a few to upwards of 50 for a large supermarket. They are direct systems, but when installed inside the building that may employ a HTF, usually water, for collecting heat from the different units.

Hybrid systems cover a range of possibilities where there is a combination of types. An example is a variation of the distributed system approach, where low-temperature cabinets and cold stores comprise individual water-cooled condensing units, which are supplied by the medium-temperature HTF. Thus, in the indirect medium temperature section, the refrigerant charge is isolated mainly to the machinery room, whilst an HTF is circulated throughout the sales and storage areas at this temperature level.

In some countries, indirect, close-coupled, distributed and hybrid systems have been employed in increasing number in recent years because they offer the opportunity of a significant reduction in refrigerant charge. Additionally, with indirect systems the refrigerant charge is normally located in a controlled area, enabling the use of low-GWP refrigerants that are flammable and/or have higher toxicity. This approach has been adopted in certain European countries due to regulatory constraints on HCFCs and HFCs (Lundqvist, 2000). A review of possible system solutions is provided by Arias and Lundqvist (1999 and 2001). The close-coupled systems offer the advantages of low charge, multiple compressors and circuits for part load efficiency and redundancy, as well as the efficiency advantage of a direct system (Hundy, 1998).

4.3.2 Population/production

There is a lot of variation in the geographical distribution of commercial refrigeration systems, even in neighbouring countries, due to differing consumption habits, regulation of opening hours, leadership of brand names, state of the economy and governmental regulations.

A number of leading US and European manufacturers are expanding worldwide, especially into Eastern European countries and other countries with fast growing economies, such as: Argentina, Brazil, China, Indonesia, Mexico, Thailand and Tunisia. The growth of all types of commercial refrigerating systems in China is one of the most significant of the past 4 years. For example, the number of small supermarkets (average total sales area of about 380 m^2) has increased by a factor of six in the past 4 years.

Table 4.5 shows the average total sales area of supermarkets, which differs significantly per country. The 'hypermarket' concept of selling food, clothing and all types of household

Table 4.5. Typical sales areas of supermarkets in selected countries (UNEP, 2003).

	Brazil	China	France	Japan	USA
Average surface of supermarkets (m^2)	680	510	1500	1120	4000
Average surface of hypermarkets (m^2)	3500	6800	6000	8250	11,500

goods, is expanding worldwide.

Table 4.6 shows an estimate of supermarket and hypermarket populations and Table 4.7 an evaluation of the population of smaller commercial units.

It is only possible to evaluate the refrigerant quantities based on the number of supermarkets if additional data are used concerning the total sales area of fresh and frozen food and the type of refrigerating system. Nevertheless in terms of the number of supermarkets, China represents more than 30% of the total global population of supermarkets (UNEP, 2003).

For small commercial supermarkets, China represents about 40% of the total global population, with the exception of vending machines. The growth of vending machines is still very significant, especially in Europe (UNEP, 2003).

4.3.3 HFC and HCFC technologies, current usage and emissions

4.3.3.1 Refrigerant choices

Refrigerant choices for new equipment vary according to national regulations and preferences.

Europe: Following CFC phase out for new equipment and servicing in Europe, commercial refrigeration tended towards the use of HCFC-22 and HCFC-22 blends. However, in the Nordic countries, the period with HCFC-22 was very short, and HFCs such as R-404A became the preferred solution from 1996 onwards. Since 2000, European Regulation 2037/2000 (Official Journal, 2000) has prohibited HCFCs in all type of new refrigerating equipment. HFC-404A and HFC-507A are now the most commonly used refrigerants for larger capacity low- and medium-temperature systems, such as condensing units and all types of centralized systems. For stand-alone systems, HFC-134a is used for medium-temperature applications, while both HFC-134a and HFC-404A are used for low-temperature applications.

Table 4.6. Number of supermarkets and hypermarkets (UNEP, 2003).

	Number of Supermarkets	Number of Hypermarkets
EU	58,134	5410
Other Europe	8954	492
USA	40,203	2470
Other America	75,441	7287
China	101,200	100
Japan	14,663	1603
Other Asia	18,826	620
Africa, Oceania	4538	39
Total	**321,959**	**18,021**

Table 4.7. Evaluation of the number of items of commercial equipment (UNEP, 2003).

	Condensing Units	Hermetic groups in stand alone equipment	Vending Machines
EU	6,330,500	6,400,700	1,189,000
Other Europe	862,000	754,700	113,900
USA	247,500	217,400	8,807,900
Other America	3,321,300	2,430,600	411,800
China	13,000,000	12,316,600	385,000
Japan	2,216,000	2,470,600	2,954,500
Other Asia	5,750,400	5,750,600	758,200
Africa, Oceania	843,700	831,400	87,000
Total	**32,571,400**	**31,172,600**	**14,707,300**

Japan: In Japan where HCFCs are still permitted, a voluntary policy is followed by OEMs and more than one-third of new equipment employs HFCs, with the remainder using HCFC-22. Typically, HFC-407C is used for medium temperature and HFC-404A for low temperature in all categories of commercial systems.

USA and Russia: In the USA, HCFC-22 and HCFC-22 blends are commonly used in existing systems, primarily for medium-temperature applications. HCFC-22 continues to dominate new supermarket systems, but HFC-404A and HFC-507A are becoming more widely used. HFC-404A and HFC-134a are used in new stand-alone equipment. These trends are also seen in Russia, where alternatives include HFC-134a, HCFC-22 and HCFC-22 blends as well as HFC-404A in a broad range of commercial equipment.

Developing countries: Stand-alone equipment is the main form of commercial refrigeration in developing countries, with condensing units being used by larger food retailers. CFCs, HCFCs and HFCs are all being used, with trends towards HFCs HFC-134a and HFC-404A in the future.

In China, HCFC-22 and HFC-134a are the major refrigerants for commercial refrigeration, with R-404A showing rapid growth. Only limited amounts of CFC-12 and R-502 are in use, as most of the systems designed for these refrigerants have converted to HFC-134a and R-404A. HCFC blends have very little application, as Chinese regulatory groups prefer to switch directly to HFCs instead of using any transitional HCFC blends.

4.3.3.2 Emissions

Emission rates derived with a bottom-up approach suggest a global annual emissions rate from the commercial refrigeration sector of 30% of the refrigerant charge (leakage and non-recovery) (Palandre *et al.*, 2004). Expressed in CO_2 equivalents, commercial refrigeration represents 40% of total annual refrigerant emissions, see Table 4.1. The emission levels (including fugitive emissions, ruptures, emissions during servicing and at end-of-life) are generally very high, especially for supermarkets and hypermarkets. The larger the charge, the larger the average emission rate. This is due to the due to the very long pipes, the large numbers of fittings and valves, and the huge emissions when ruptures occur.

In the 1980s, the reported average commercial refrigeration emission rates for developed countries were in the range of 20–35% of refrigerant charge per year (Fischer *et al*., 1991; AEAT, 2003; Pedersen, 2003). The high emission rates were due to design, construction, installation and service practices being followed without an awareness of potential environmental impact. In some countries emissions from these systems have been decreasing due to industry efforts and governmental regulations with respect to refrigerant containment, recovery and usage record keeping, increased personnel training and certification, and improved service procedures, as well as increased attention for many system mechanical details including the reduction or elimination of threaded joints and a reduction in the number of joints in refrigerating systems.

Recent annualized emission rates in the range of 3–22% (average of 18%) were reported for 1700 supermarket systems in several European countries and the USA. The country-specific data and references are listed in Table 4.8. It may be concluded that if the emission estimates of Palandre *et al*. (2003 and 2004) are correct, the above-reported values of 3–22% must represent selected company data within countries that have a strong emphasis on emission reductions.

Emission rates vary considerably between equipment categories. Annual emission rates for the several categories are listed in Table 4.9. Individual system leak rates, however, can range from zero to over 100% yr^{-1}. It should also be noted that end-of-life recovery data are mostly not included, and therefore the annual average leakage rates may be 5–10% higher than the values given in the tables.

Table 4.8. Leakage rates of supermarket refrigeration systems.

Country	Year(s)	Annual Refrig. Loss	References
The Netherlands	1999	3.2	Hoogen *et al*., 2002
Germany	2000–2002	5-10%	Birndt *et al*., 2000; Haaf and Heinbokel, 2002
Denmark	2003	10%	Pedersen, 2003
Norway	2002–2003	14%	Bivens and Gage, 2004
Sweden	1993 1998 2001	14% 12.5% 10.4%	Bivens and Gage, 2004
United Kingdom	1998	14.4%	Radford, 1998
USA	2000–2002	13%, 18%, 19%, 22%	Bivens and Gage, 2004

Table 4.9. Indicative leakage rates from commercial refrigeration equipment categories found in the literature.

Category	Annual Refrigerant Loss	References
Stand-alone hermetic	≤1%	March, 1999; ADL, 2002
Small condensing unit	8–10%	March, 1999; AEAT, 2003
Centralized direct (DX)	3–22%	Several; see main text
Distributed	4%	ADL, 2002
Indirect (secondary loop)	2–4%	ADL, 2002

It is important to note that in certain cases, data collection should be considered in context. Some of the base data used in emission and emission projection studies has been collated from telephone interviews, and other similar techniques, from historical reports. This reliance on anecdotal data may suggest underestimated emissions, since both the end-users and refrigeration contractors have an interest in reporting low values because of exposure of poor practices and the threat of restrictive legislation.

As well as measures designed to decrease emissions, there are also drivers – typically at field level – that inhibit emission reduction and must be addressed at a policy level. These include partial success in finding system leaks, end-users employing contractors on an 'as-the-need-arises' basis rather than a preventative basis, additional attendance time for refrigerant recovery and leak testing, and a financial incentive for contractors to sell more refrigerant to the end-user.

There have been important observations on system emission characteristics and how emission reductions have been accomplished. Some are listed below.

In the Netherlands, emissions have been significantly reduced through national mandatory regulations established in 1992 for CFCs, HCFCs and HFCs. These measures have been assisted by an industry supported certification model (STEK, which is the abbreviation for the institution for certification of practices for installation companies in the refrigeration business). Elements of the regulation are detailed by Gerwen and Verwoerd (1998), and include the technical requirements to improve tightness, system commissioning to include pressure and leakage tests, refrigerant record keeping, periodic system-leak tightness inspections, and maintenance and installation work by certified companies and servicing personnel (Gerwen and Verwoerd, 1998). The STEK organization was founded in 1991 to promote competency in the handling of refrigerants and to reduce refrigerant emissions. STEK is responsible for company certification, personnel certification and the setting-up of training courses.

The success of the Dutch regulations and the STEK organization in reducing refrigerant emissions was demonstrated by the results from a detailed study in 1999 of emission data from the refrigeration and air conditioning sectors. For commercial refrigeration, annual refrigerant emissions (emissions during leakage plus disposal) as low as 3.2% of the total bank of refrigerant contained in this sector were reported (Hoogen and Ree, 2002).

In Germany, the report by Birndt *et al*. (2000) found that no leaks were identified in 40.3% of the systems, 14.4% of the leaks contributed to 85% of the refrigerant loss and 83% of the leaks occurred in the assembly joints. The report by Haaf and Heinbokel (2002) was on R-404A systems in medium- and low-temperature supermarket refrigeration. Data was taken on systems installed after 1995 with improved technologies for leak tightness, plus a reduction of refrigerant fill quantities by 15%. Annual leakage rates were determined to be 5% of charge, which represented a 10% reduction on the level reported in previous years.

The data from Sweden showed annual refrigerant losses decreasing from 14% in 1993 to 10.4% in 2002 (Bivens and Gage, 2004), with the lower emissions being attributed, in part, to an increased application of indirect cooling systems with reduced refrigerant charges in supermarkets.

A set of 2000–2001 USA emissions data were available for 223 supermarkets in the California South Coast Air Quality Management District (Los Angeles area). The data were reported in system charge sizes from 23 kg up to 1285 kg. Over the two-year period, 77% of the smaller charge size systems (23−137 kg) required no refrigerant additions, 65% of the medium charge size systems (138−455 kg) required no refrigerant additions and 44% of the larger charge size systems (456−1285 kg) required no refrigerant additions. These are the outcomes expected, based on larger charge size systems having longer piping runs, more assembly joints, more valves and more opportunities for refrigerant leakage. For the 223 supermarkets, total averaged refrigerant emission rates were 13% of charge in 2000, and 19% in 2001 (Bivens and Gage, 2004).

The data from Germany and the USA indicate that, since the average emission rates include systems with no emissions, the leaking systems have higher loss rates than the averages. This amplifies the importance of monitoring refrigerant charge using sight glasses and liquid levels, and of periodic checking with leak detectors. These both represent a significant opportunity for identifying and repairing high leakage rate sources. Procedures for emission reduction have been developed by ANSI/ASHRAE, 2002.

The trend away from the ozone-depleting CFCs and HCFCs, and towards an increased use of HFCs means, that despite lower leakage rates, HFC leakage from refrigeration is set to increase considerably. For example in Europe, a 50% cut in leakage rates due to the initiation of STEK-like programmes in every member state would result in emissions rising from 2.5–4.3 Mtonnes CO_2-eq in 1995 to around 30 Mtonnes CO_2-eq in 2010, instead of 45 Mtonnes CO_2-eq under a business-as-usual scenario (Harnisch and Hendriks, 2000; Enviros, 2003).

The continuing collection of reliable emissions data is an important factor in getting a clear picture of the leakage situation and thereby establishing progress in the reduction of refrigerant emissions. Palandre *et al*. (2003 and 2004) and US EPA (2004) report two global programmes for the collection of such data. Data from the Clodic and Palandre (2004) permits the calculation of the worldwide commercial refrigeration emission rate for the year 2002 and this amounted to 30% of the commercial refrigeration systems inventory. The US EPA model information also permits the calculation of a potential 20−30% reduction business-as-usual HFC emissions from commercial refrigeration in the year 2015, by applying abatement options that require a more aggressive leak detection and repair and the increased use of distributed and indirect systems (Bivens and Gage, 2004).

4.3.4 Non-HFC technologies (vapour compression)

A number of HCs, ammonia and CO_2 systems of different refrigerating capacities have been installed in various European countries during the past 5 years. A few examples of these are now given.

4.3.4.1 Stand-alone equipment and condensing units

Some well-established beverage companies and ice cream manufacturers have recently stated (2000−2001) that by 2004 they will no longer purchase new equipment that uses HFCs in their refrigerant systems, provided that alternative refrigerants or technologies become available at an acceptable cost. HCs, CO_2 and Stirling technology are being evaluated by one of the companies (Coca Cola, 2002). The HFC-free strategy of the companies were confirmed during June 2004 (RefNat, 2004).

4.3.4.1.1 Hydrocarbons

Various companies in several countries have developed vending machines and small commercial equipment using HCs. The equipment uses HC-600a, HC-290 and HC-based blends. Limitations on charge sizes are specified by safety standards (e.g. EN 378, IEC 60335-2-89), where maximum amounts per circuit are 2.5 kg, 1.5 kg and 150 g, dependent on the application. Nevertheless, HC charges tend to be about 50% less than equivalent HFCs and HCFCs due to lower densities which minimize the impact of such limits. Recent developments with charge-reduction techniques (Hoehne and Hrnjak, 2004) suggest that charges for future systems will become even less. Christensen (2004) reports on the experience with stand-alone equipment installed in a restaurant in Denmark. Results from a detailed quantitative risk assessment model that examined the safety of hydrocarbons in commercial refrigeration systems are reported in Colbourne and Suen (2004).

4.3.4.1.2 Carbon dioxide (CO_2)

CO_2 is being evaluated by a European company interested in developing stand-alone equipment with a direct expansion CO_2 system (Christensen, 1999) and is also one of the refrigerants being evaluated by Coca Cola (2002). The company confirmed their HFC-free strategy in June 2004 and announced that CO_2-based refrigeration is their current choice for future equipment (Coca Cola, 2004). R&D activities for CO_2-based solutions have also been announced by another company (McDonalds, 2004).

4.3.4.2 Full supermarket systems

4.3.4.2.1 Direct systems

CO_2 direct systems
CO_2 is non-flammable, non-toxic and has a GWP value of only 1. It is therefore highly suited for use in direct refrigeration systems, as long as acceptable energy efficiency can be achieved at a reasonable cost. There are two basic types of CO_2 direct systems using only CO_2 as a refrigerant and cascade systems.

Direct systems using only CO_2 as a refrigerant have been developed with a transcritical/subcritical cycle, depending on ambient temperature, for both low- and medium-temperature refrigeration are developed. In addition to giving a totally non-HFC solution, reduced pipe diameters due to higher pressures, good heat transfer characteristics of CO_2 and the possibility to obtain energy efficient heat recovery can be mentioned. Five medium-sized supermarkets have been installed with this concept by the beginning of June 2004, in addition to some smaller field test systems (Girotto and Nekså, 2002; Girotto *et al*. 2003; Girotto *et al*. 2004).

Cascade systems are being developed with CO_2 at the low-temperature stage associated with ammonia or other refrigerants (R-404A for example) at the medium-temperature stage. Several of these systems have been installed in the field and are currently being evaluated in different European countries. Haaf and Heinbokel (2003) have described 33 such CO_2 cascade systems from one manufacturer that were in service in 2003. It is emphasized that this technology could receive widespread interest because it has also been developed for the food industry (Rolfsmann, 1999; Christensen, 1999).

In addition to these two options, a third distributed system concept was described by Nekså *et al*. (1998). Self-contained display cabinets, each with CO_2 refrigeration units, are connected to a hydronic heat-recovery circuit that heats service water and buildings. A large temperature glide in the hydronic circuit, typically 50–60 K, and a correspondingly low volume flow rate and small pipe dimensions can be achieved by using the transcritical CO_2 process. Waste heat with a high temperature (70–75^{o}C) is available for tap water and/or space heating. Excess heat is ejected to the ambient air.

The Institute of Refrigeration in London has released a 'Safety Code for Refrigerating Systems Utilizing Carbon Dioxide'. This contains a lot of relevant information despite much of the focus being on larger capacity industrial sized systems.

4.3.4.2.2 Indirect systems

Ammonia and hydrocarbons (HCs)
The quantity of ammonia can be 10% of the usual HFC refrigerant charge, due to indirect system design and the thermodynamic properties such as latent heat vaporization and liquid density (Presotto and Süffert, 2001). For HCs, the refrigerant charge is typically 10% of the direct system HFC reference charge (Baxter, 2003a,b).

In Northern Europe, ammonia or HCs (including HC-1270, HC-290 and HC-290/170 blends) have been used as refrigerants for the same type of indirect systems. For safety purposes, the refrigerant circuits are either separated in a number of independent circuits to limit the charge of each system or a number of independent chiller circuits are used (Powell *et al*., 2000).

Heat transfer fluids (HTF)
The HTFs used in indirect systems require special attention, especially at low temperatures where pumping power may be excessive. The choice of the correct HTF to obtain the desired energy efficiency is critical and a handbook on fluid property data is available from IIR/IIF (Melinder, 1997).

CO_2 as a heat transfer fluid
For indirect systems, CO_2 can be used as either a standard HTF without phase change or as a two-phase HTF that partially evaporates in the display case evaporators and condenses in the primary heat exchanger.

At low temperatures, phase-changing CO_2 HTF shows promising results. Due to the viscosity constraint of other alternatives at low temperatures and the good heat transfer properties of CO_2, the use of CO_2 as a low-temperature HTF has received more consideration than the alternatives. When CO_2 is used with phase change, the diameter of the tubes can be significantly reduced, and the heat transfer in the display case heat-exchanger is far more effective. If the temperature can be maintained below –12°C, traditional technologies in which the tubes and heat exchanger are designed for a maximum operating pressure of 25 bar, are possible. About 50 such systems are in operation in Europe. Expansion vessels, cold finger concepts or simply using the cold stored in the goods, are possible alternatives for keeping the pressures within acceptable limits.

Ice slurry as a heat transfer fluid
An interesting new technology for medium temperature, which offers the possibility of energy storage and high-energy efficiency, is indirect systems that use ice slurry as the HTF. Research has been carried out in some pilot installations. A handbook is currently being developed by the International Institute of Refrigeration and several recent papers on various aspects of the technology are described in Egolf and Kauffeld (2005).

4.3.5 Not in-kind technologies (non-vapour compression)

There are very few examples of the successful implementation of 'not-in-kind' technologies in this sector. One possible example is the Stirling cycle. For low capacity, high-temperature lift applications in particular (>60 K), the Stirling cycle may reach competitive COP values. Although Stirling systems have been developed, cost is still an issue (Lundqvist 1993; Kagawa, 2000). This technology is also being evaluated for display cabinets (Coca Cola, 2002). Another interesting recent technology is thermoacoustic refrigeration (Poese, 2004).

Heat-driven cycles have not found their way into commercial refrigeration. The use of heat-driven cycles such as absorption and adsorption in supermarkets have been discussed in literature (Maidment and Tozer, 2002). Some attempts with solar-driven refrigeration for fresh food handling have also been developed and tested (Pridasawas and Lundqvist, 2003). The use of sorption technologies for dehumidification, thus lowering the cooling load on display cabinets, is an interesting option.

4.3.6 Relevant practices to reduce refrigerant emissions

As stated at the beginning of this section, several abatement strategies can be used to reduce refrigerant greenhouse gas emissions. New design ideas have been mentioned throughout the chapter and these may be summarized as a general trend towards lower refrigerant charge, using direct or indirect systems, and the use of non-HFC refrigerants such as ammonia, CO_2 or HCs. These options should be considered on the basis of a balanced evaluation of refrigerant emission reductions, initial investment costs, safety, operating costs and energy consumption.

The European Commission has proposed a new regulation to reduce the emissions of fluorinated greenhouse gases, including HFCs from refrigeration equipment. In addition to a general obligation to avoid leakage, installations with over 3 kg of charge will require at least annual inspections, and a refrigerant detector will be required for systems over 300 kg. Reports will also be required for the import and export of refrigerants, and end-of-life recovery, recycling or destruction of the refrigerant. Additional information on country initiatives for refrigerant conservation is described in the 2002 UNEP TOC report, Sections 4.7 and 10.1 to 10.9 (UNEP, 2003).

Several programmes, for example in the Netherlands and Sweden, have shown good results with respect to leakage mitigation for existing plants. A common denominator has been a combination of regulation, education and accreditation of service personnel (STEK, 2001). In Denmark and Norway a tax on refrigerants in proportion to their GWP value has proven successful in curbing emissions and promoting systems that use non-HFC refrigerants.

A reduction of the refrigeration capacity demand, for example by using better insulation and closed rather than open cabinets, might indirectly reduce refrigerant emissions, but also the power consumption of a supermarket. Design integration with air-conditioning and heating systems are also important measures in this respect.

An interesting development in new design tools for supermarkets, opens up new possibilities for improving the design of systems using an LCC perspective, which favours more energy efficient systems with lower operating costs (Baxter, 2003a,b).

4.3.7 Comparison of HFC and non-HFC technologies

The current rapid developments in the subsector are moving the targets for energy efficiency, charge reduction and cost. This makes a comparison between technologies difficult. Furthermore, the relatively complex links between energy efficiency, emissions and the costs of systems and their maintenance means that it sis difficult to make fair comparisons.

4.3.7.1 Energy consumption of supermarkets

Depending on the size of the supermarket, the refrigeration equipment energy consumption represents between 35–50% of the total energy consumption of the store (Lundqvist, 2000). This ratio depends on a number of factors such as lighting, air conditioning, and so forth. For typical smaller supermarkets of around 2000 m^2, refrigeration represents between 40–50% of the total energy consumption and for even smaller stores it could be up to 65%.

New, high-efficiency commercial supermarkets have been designed in some European countries and the USA by using a number of efficient technologies. These references can be seen as prototypes and one example from UK presents energy consumption figures which are a factor of two lower compared to usual stores (Baxter, 2003a,b). Most examples however show reductions of between 10–20%.

The high annual growth rate of stand-alone equipment, which tends to be less energy efficient per kW cooling power than centralized systems, should be addressed. Integrating heat rejection from the individual cabinets in a water circuit may be one way of obtaining improved energy efficiency. Excessive heat rejection within the store might also lead to an increased demand for air conditioning, further increasing the energy demand.

4.3.7.2 Energy efficiency of direct systems

The energy efficiency of refrigeration systems first of all depends on the temperature levels for which refrigeration is provided and on the global design of the system. Measurements of system efficiency can be found in the literature, for example in UNEP (2003). However, comparisons of different systems are often difficult because the boundary conditions are rarely comparable.

Potential energy-saving measures may be divided into four different groups: advanced system solutions, utilization of natural cold (free cooling), energy-efficient equipment (display cases, efficient illumination, night curtains, etc.) and indoor climate/building-related measures. Energy-efficient illumination has the double effect of reducing loads on display cases as well as direct electric consumption. Heat recovery from condensers is sometimes preferred in cold climates but internal heat generation from plug-in units and illumination is often enough to heat the premises (Lundqvist, 2000).

The refrigeration system efficiency also depends on a number of parameters: pressure losses related to the circuit length, system control and the seasonal variation of the outside temperature. For a number of global companies energy consumption, and with this the energy efficiency of refrigerating systems, has become an important issue, especially in countries where electricity prices are high. One approach to energy savings is to utilize 'floating condensing temperature' in which the condensing temperature follows ambient temperature. The issue of climate change and the desire to reduce GHG emissions has also heightened the interest in increasing the energy efficiency.

4.3.7.3 Energy efficiency and cost of indirect systems

The evaluation of the additional energy consumption related to indirect systems is an ongoing process. Direct field comparisons between direct and indirect systems are difficult (Lundqvist, 2000; Baxter, 2003a). Moreover, the main driver for centralized systems is initial cost. Due to the design of heat exchangers in display cases (especially medium-temperature, open-type) the performances of some indirect systems can be equal or even slightly better than direct systems (Baxter, 2003a). For low temperatures, the energy penalty can be substantial depending on the design.

On the other hand, the relative energy consumption of indirect systems – compared to conventional direct expansion systems – can show an increased energy consumption of up to 15%. Conclusions can only be drawn if reference lines for the energy consumption of centralized systems are plotted in which the origin of energy inefficiencies are apparent. Due to the extra temperature difference required, inherently indirect systems should give higher energy consumptions compared to direct systems. Recent practical experiences and experimental studies (Mao *et al*., 1998; Mao and Hrnjak, 1999; Lindborg, 2000; Baxter, 2003a,b), however, indicate that well-designed indirect systems may have energy efficiencies approaching those of good direct systems. Further research is clearly needed to clarify the reasons for this. More efficient defrost, better part-load characteristics, better expansion device performance and more reliable systems are believed to contribute to indirect system energy efficiency. The costs might be 10–30% higher, but these can potentially be reduced (Yang, 2001; Christensen and Bertilsen, 2003).

4.3.7.4 Energy efficiency and cost of ammonia systems

There are several indirect systems in operation that are successfully using ammonia as the primary refrigerant (Haaf and Heinbokel, 2002). As ammonia is toxic and may create panic due to the strong smell at low concentrations appropriate safety precautions are required. Excellent energy efficiency can be achieved with properly-designed systems. The drawbacks for ammonia systems are limited service competence (Lindborg, 2002) and higher initial costs, typically 20–30%. A life-cycle cost evaluation is therefore required.

4.3.7.5 Energy efficiency and cost of hydrocarbon systems

Full supermarket systems using hydrocarbons in an indirect design have been installed in several European countries. A dedicated ventilation system (if installed in a machine room), gas detectors, gas-tight electric equipment and so forth have been installed for safety reasons. The use of hydrocarbons has increased the R&D effort to significantly minimize refrigerant charge. A small prototype system of approximately 4 kW cooling capacity using 150 g of HC-290 and micro-channel heat exchanger technology has been demonstrated by Fernando *et. al*. (2003). Cost is still an issue, typically up to 30% higher, but further development is expected to reduce costs. HC-290 and HC-1270 are excellent refrigerants from a thermodynamic point of view and equipment design is relatively straightforward. The availability of some standard components is still limited, but to a certain extent the hydrocarbon systems can use the same type of system components as HFC systems. Cascade systems with HC-290 and CO_2 for full supermarket systems were reported to have an energy efficiency equal to conventional direct system design (Baxter, 2003a,b).

For stand-alone equipment and condensing units, several references report a higher efficiency of HC refrigerants systems compared to equivalent systems with HFCs, for example Elefsen *et al*. (2002). Others claim that higher efficiency can be achieved with HFC systems, if the extra costs used for the safety precautions of HC systems are used to improve system efficiency of the HFC system (Hwang *et al*., 2004).

4.3.7.6 Energy efficiency and cost of CO_2 systems

Centralized CO_2 direct systems for both medium and low temperature, operating in either transcritical or subcritical cycle dependent on the ambient temperature, are reported to require about 10% higher energy consumption than a state-of-the-art R-404A direct system (Girotto *et al*., 2003 and 2004). Several measures for improvements have however been identified. The cost is reported to be about 10–20% higher than for direct expansion R-404A systems and this difference is mainly due to components produced in small series.

Haaf and Heinbokel (2003), report energy consumption and investment costs for R-404A/CO_2 cascade systems that are similar to R-404A direct systems. This is due to the fact that components for CO_2 cascade systems are more similar to R-404A components (maximum pressure 40 bar), allowing more standard components to be used. Girotto *et al*. (2004) report higher costs for cascade systems (see also comment about HC-290/CO_2 above).

4.3.7.7 Energy efficiency and cost of HFC systems with reduced emissions

Ongoing R&D efforts to minimize refrigerant charge without compromizing energy efficiency are applicable to HFC refrigerants as well. The standard approach to charge minimization is to use no receiver or hermetic compressors and to keep piping as short as possible. Tight systems require brazed joints and these are most reliably made when systems are factory assembled. The potential for charge reduction is illustrated by Fernando *et al*. (2003). They present HC systems using as little as 150 g refrigerant for a 5 kW domestic heat pump. The density of HFC refrigerant is approximately twice that of HC and therefore a comparable system using 300 g of HFC refrigerant is within reach, if further heat exchanger development is undertaken. More complex cycles are another way of improving systems. Beeton and Pham (2003), report a 41% capacity increase and a 20% efficiency increase for low-temperature economizer systems using R-404A and R-410A.

4.3.8 Comparison of LCCP and mitigation costs

The number of publications that give TEWI or LCCP data for commercial refrigeration systems is limited but is growing rapidly. Harnisch *et. al*. (2003) calculated the LCCP for several different types of full supermarket refrigeration systems in Germany. They used a straightforward model which took production, emissions and energy usage into account. CO_2 emissions from power production were calculated using an average emission factor of 0.58 kg CO_2 kWh^{-1}. The transparent method to evaluate the various systems allows sensitivity analyses to be performed using other literature references referred to in this report. Table 4.10 presents characteristic figures from Harnisch *et. al*. (2003) and compares these to calculated results based on representative data from other literature references.

The data used for the table are selected as follows: The 30% emission is based on Palandre *et al*., 2004 and the 11.5% and 6.5% emission scenarios are based on Harnisch *et al*. (2003), Bivens and Gage (2004) Baxter (2003a) and ADL (2002). The 11.5% and 6.5% emissions represent 10% and 5% emissions yr^{-1}, with a 15% end-of-life recovery loss apportioned over a 10-year lifetime. Energy consumption figures are extracted from Harnisch *et al*. (2003), Haaf and Heinbokel (2002), Girotto *et al*. (2003) and Baxter (2003b). It is clear that several different alternatives result in reductions in CO_2 equivalent emissions of the same order of magnitude. The same applies for an HFC alternative, if the annual emission rate can be as low as 5%. If a 5% leakage is possible, the dominating contribution from most systems is an indirect effect due to power production.

Supermarket system and mitigation cost estimates are scarce. Harnich *et al*. (2003) give data for German supermarkets with costs ranging from 20–280 US$ per tCO_2–eq mitigated. The lowest values are given for a system using direct expansion CO_2 for low temperature and direct expansion with R-404A for high temperature. Mitigation costs are estimated using a 10% leakage rate and a 1.5 % recovery loss, with a 10-year lifetime and a discount rate of 10% to reflect commercial decision-making. An average cost of 100 US$ m^{-2} of supermarket area is used as a baseline for cost estimates. This figure is confirmed by Sherwood (1999) who reports on cost figures for a 3200 m^2 supermarket in the USA.

Using this data with a broader range of leakage rates and estimated costs, significantly reduces the typical mitigation costs per tonne of CO_2 suggested by Harnisch *et al*. (2003) but also expands the total range to values of 10–300 US$ per tonne CO_2-eq mitigated.

Additional mitigation costs for the various systems suggested in the chapter have not been calculated. Cost estimates for various technologies given in the literature suggest a cost increase between 0 and 30% for alterative technologies compared to a baseline, full supermarket, direct system using R-404A as refrigerant. Some detailed figures are already given under each section and a general summary is given for each technology in Table 4.11.

Table 4.10. LCCP values of full supermarket systems.

Configuration	Refrigerant Emissions % charge yr^{-1}	Energy Consumption	LCCP, in tCO_2-eq yr^{-1} Indirect	Direct	Total
Direct Expansion (DX)	30%	baseline	122	183	305
DX (Harnisch *et al*., 2003, data)	11.5%	baseline	122	70	192
DX distributed 75% charge reduction	6.5%	baseline	122	10	132
Sec. Loop R-404A 80% charge reduction	6.5%	baseline + 15%	140	8	148
Sec. Loop propane 80% charge reduction	6.5%	baseline + 10%	134	0	134
Sec. Loop ammonia 80% charge reduction	6.5%	baseline + 15%	140	0	140
DX R-404A and DX CO_2 50% charge reduction	6.5%	baseline	122	20	142
DX CO_2/CO_2	11.5%	baseline + 10%	134	0	134

Table 4.11. Sector summary for commercial refrigeration – current status and abatement options.

Subsector	Stand-alone Equipment	Condensing Units	Full supermarket system: Direct Centralized	Indirect Centralized	Distributed	Hybrids
Cooling capacity From	0.2 kW	2 kW	20 kW			
Cooling capacity To	3 kW	30 kW	>1000 kW			
Refrigerant charge From	0.5 kg	1 kg	100 kg	20	*	*
Refrigerant charge To	~2 kg	15 kg	2000 kg	500 kg	*	*
Approximate percentage of sector refrigerant bank in subsector	11% of 606 kt	46% of 606 kt	43% of 606 kt			
Approximate percentage of sector refrigerant emissions in subsector	3% of 185 kt	50% of 185 kt	47% of 185 kt			
2002 Refrigerant bank, percentage by weight	CFCs 33%, HCFCs 53%, HFCs 14%					
Typical annual average charge emission rate	30%					
Subsector	**Stand-alone Equipment**	**Condensing Units**	**Full supermarket system: Direct Centralized**	**Indirect Centralized**	**Distributed**	**Hybrids**
Technologies with reduced LCCP EmR – Direct Emission Reduction (compared to installed systems)	**Improved HFC** SDNA	**Improved HFC** SDNA	**Improved HFC** EmR 30% ChEU 0% ChCst 0 ±10%	**Ammonia** EmR 100% ChEU 0–20% ChCst 20–30%	**HFC** EmR 75% ChEU 0–10% ChCst 0–10%	**Cascade-HFC/CO_2** EmR 50–90% ChEU 0%
ChEU – Change in Energy Usage (+/-) (compared to state of the art)	**HC** SDNA	**R-410A** SDNA	**CO_2 (all-CO_2)** EmR 100% ChEU 0 ±10% ChCst 0±10%	**HC** EmR 100% ChEU 0–20 % ChCst 20–30%	**Economized-HFC-404A** SDNA	**Cascade-Ammonia/CO_2** SDNA
ChCst – Change in Cost (+/-) (compared to state of the art)	**CO_2** SDNA	**HC** SDNA		**HFC** EmR 50–90% ChEU 0–20% ChCst 10–25%	**Economized-HFC-410A** SDNA	**Cascade-HC/CO_2** SDNA
SDNA – Sufficient data on emission reduction, energy usage and change in cost not available from literature		**CO_2** SDNA			**CO_2** SDNA	
LCCP reduction potential (world avg. emission factor for power production)	SDNA		35–60%			
Abatement cost estimates (10 yr lifetime, 10% interest rate)	SDNA		20-280 US$ per tonne CO_2 mitigated			

* Alternatives in these categories have been commercialized, but since the current number of systems are limited, they are only referenced as options below

In this report energy efficiency has been treated as relative changes in energy usage for several recent types of systems, the main purpose of which is to mitigate emissions, see also Table 4.11. However, the systems investigated are based on current technological standards for components such as heat exchangers, compressors and so forth. No attempts have been made to predict the future energy-saving potential in commercial refrigeration applications if future possible improvements are achieved. Several possibilities for reducing the energy consumption of refrigeration systems exists, but in principle most of these may be applied irrespective of the refrigerant used in the system. These options may also lead to negative mitigation costs, as for instance reported in Godwin (2004) and March (1998).

The authors firmly believe that the ongoing technical development of components and systems together with various energy-saving measures (such as heat recovery, more efficient compressors and display cases, larger heat exchangers, floating condensation, energy efficient buildings and so forth) may lower supermarket energy consumption considerably.

4.4 Food processing and cold storage

4.4.1 Introduction

Food processing and cold storage is one of the important applications of refrigeration, and is aimed at preserving and distributing food whilst keeping its nutrients intact. This application of refrigeration is very significant in terms of size and economic importance, and this also applies to developing countries. Food processing includes many subsectors such as dairy products, ice cream, meat processing, poultry processing, fish processing, abattoirs, fruit & vegetable processing, coffee, cocoa, chocolate & sugar confectionery, grain, bread & flour confectionery & biscuits, vegetable, animal oils & fats, miscellaneous foods, breweries and soft drinks (March, 1996).

The annual global consumption of frozen foods is about 30 Mtonnes yr^{-1}. Over the past decade, consumption has increased by 50% and it is still growing. The USA accounts for more than half of the consumption, with more than 63 kg per capita. The average figure for the European Union (EU) is 25 kg and for Japan 16 kg. The amount of chilled food is about 10–12 times greater than the supply of frozen products, giving a total volume of refrigerated food of around 350 Mtonnes yr^{-1} (1995) with an estimated annual growth of 5% (IIR, 1996; UNEP, 2003). Like chilling and freezing, food processing is also of growing importance in developing countries. This is partly due to the treatment of high-value food products for export. Even in 1984, about half of the fish landed in developing countries (more than 15 Mtonnes) was refrigerated at certain stages of processing, storage or transport (UNEP, 1998). The estimated annual growth rate in food processing between 1996 and 2002 was 4% in developed countries and 7% in developing countries (UNEP, 2003).

Frozen food in long term-storage is generally kept at −15°C to −30°C, while −30°C to −35 °C is typical for the freezing process. In so-called 'super-freezers', the product is kept at −50°C. Chilled products are cooled and stored at temperatures from −1°C to 10°C.

The majority of refrigerating systems for food processing and cold storage are based on reciprocating and screw compressors. System size may vary from cold stores of 3 kW cooling demand to large processing plants requiring several MW of cooling. Reciprocating compressors are most frequently used in the lower capacity range, whereas screw compressors are common in larger systems (UNEP, 2003).

4.4.2 Technical options

Most of the refrigerating systems used for food processing and cold storage are based on vapour compression systems of the direct type, with the refrigerant distributed to heat exchangers in the space or apparatus to be refrigerated. Such systems are generally custom-made and erected on site. Indirect systems with liquid chiller or ice banks are also commonly used in the food processing industry for fruit and vegetable packing, meat processing and so forth. Ammonia, HCFC-22, R-502 and CFC-12 are the refrigerants historically used. The current technical options are HFCs, and non-fluorocarbons refrigerants such as ammonia, CO_2 and hydrocarbons (UNEP, 2003). Table 4.12 gives the main refrigerant technical options along with percentage annual emissions for food processing, cold storage and industrial refrigeration applications (Clodic and Palandre, 2004).

4.4.3 HFC technologies

HFC refrigerants are being replaced by place of CFC-12, R-502 and HCFC-22 in certain regions. The preferred HFCs for food processing and cold storage applications are HFC-134a, HFC blends with insignificant temperature glide such as R-404A, R-410A and azeotropic blends like R-507A. The HFC blend R-407C is also finding application as a replacement for HCFC-22.

HFC-134a has completely replaced CFC-12 in various applications of refrigeration. However, CFC-12 was not widely used in food processing and cold storage because it requires considerably greater compressor swept volume than HCFC-22 or ammonia to produce the same refrigerating effect. There is limited use of HFC-134a in this subsector.

R-404A, R-407C and R-507A are currently the most used HFCs for cold storage and food processing. These blends are preferred to HFC-134a due to the higher volumetric capacity

Table 4.12. Food processing, cold storage and industrial refrigeration (2002).

	CFCs (CFC-12 and R-502)[(1)]	HCFC-22	NH_3	HFCs (HFC-134a, R-404A, R-507A, R-410A)[(1)]
Cooling Capacity	25 kW–1000 kW	25 kW–30 MW	25 kW–30 MW	25 kW–1000 kW
Emissions, t yr^{-1}	9500	23,500	17,700	1900
Refrigerant in bank, tonnes	48,500	127,500	105,300	16,200
Emissions % yr^{-1}	20%	16%	17%	12%

[(1)] See Annex V for an overview of refrigerant designations for blends of compounds.

and lower system cost (UNEP, 1998). In spite of minor temperature glides, R-404A has proven to be applicable even in flooded systems (Barreau *et al*., 1996). R-404A and R-507A are the primary replacements for R-502. The coefficients of performance are comparable to R-502 but significantly lower compared to those of NH_3 and HCFC-22, especially at high condensing temperatures. Air-cooled condensers should be avoided as far as possible. The liquid should be subcooled to achieve optimal efficiencies and high cost-effectiveness for systems with R-404A and R-507A. In chill applications it may also be necessary to add significant superheat to the suction gas in order to avoid refrigerant condensation in the oil separator (UNEP, 2003).

R-410A is also one of the HFC blends which is expected to gain a market share in food processing and cold storage applications due to the lower compressor swept volume requirements in comparison to other refrigerants (except to CO_2). The compressor efficiencies, pressure drop in suction lines and heat transfer efficiency will benefit from high system pressure (UNEP, 1998). Due to the high volumetric capacity (40% above that of HCFC-22), R-410A compressor efficiency has been reported to be higher than with HCFC-22 (Meurer and König, 1999). R-410A can have system energy efficiency similar to that of ammonia and HCFC-22 and significantly higher than that of R-404A and R-507A for evaporation temperatures down to –40°C.

4.4.4 Non-HFC technologies

Ammonia

Ammonia is one of the leading refrigerants for food processing and cold storage applications. The current market share in several European countries, especially in the north, is estimated to be up to 80% (UNEP, 1998). In the USA ammonia has approximately 90% market share in systems of 100 kW cooling capacity and above in custom-engineered process use (IIR, 1996).

Recently designed ammonia-based systems have improved quality with respect to design, use of low-temperature materials and better welding procedures. Low charge is another positive development. However, more important is that these factory made units or systems represent a new level of quality improvement. These systems are not likely to break or release their charge in another way unless there is a human error or direct physical damage. Charge reduction has been achieved by using plate-type heat exchangers or direct expansion tube and shell evaporators (UNEP, 2003).

HCFC-22

The use of HCFC-22 is declining in food processing and cold storage applications in most developed countries. In Europe some of the end-users prefer ammonia and CO_2 wherever possible, whereas HCFC-22 has become the most common refrigerant to replace CFCs in food processing and cold storage in the USA (UNEP, 2003).

In developing countries, HCFC-22 is still an important replacement refrigerant for CFCs in new systems, as from a technical point of view HCFC-22 could replace CFC-12 and CFC-502 in new systems. Another important consideration in developing countries is that HCFC-22 will be available for service for the full system lifetime.

Hydrocarbons (HCs)

A growing market for low charge hydrocarbon systems has been observed in some European countries. So far market shares are small, which may be due to the flammability of these refrigerants. Nevertheless, several manufacturers have developed a wide range of products.

Commercialized refrigerants used in food processing and cold storage applications include HC-290, HC-1270 and HC-290/600a blends, although pure substances will be preferred in flooded systems. All of these refrigerants possess vapour pressures very similar to those of HCFC-22 and R-502. System performance with regard to system efficiency is comparable to, and in some cases even superior to, that of the halocarbons. Hydrocarbons are soluble with all lubricants, and compatible with materials such as metals and elastomers that are traditionally used in refrigeration equipment. As long as safety aspects are duly considered, standard refrigeration practice for HCFCs and CFCs can be used without major system detriment to system integrity (UNEP, 1998, 2003).

Given the flammability concerns, design considerations as detailed in the relevant safety standards should be adhered to. Additional safety measures should be considered for repairing and servicing. Several national and European standards permit the use of HCs in industrial applications and lay down specific safety requirements (ACRIB, 2001; UNEP, 2003).

Carbon dioxide

Carbon dioxide technology for low temperatures such as food freezing is an attractive alternative, especially in cascade systems with CO_2 in lower stage and ammonia in the upper stage, due to its excellent thermophysical properties along with zero ODP and negligible GWP.

Further, the volumetric refrigerating capacity of CO_2 is five times higher than HFC-410A and eight times higher than for ammonia and other refrigerants. This means that the size of most of the components in the system can be reduced (Roth and König, 2001). However, application of CO_2 places a limitation on evaporating temperatures due to the triple point (the temperature and pressure at which liquid, solid and gaseous CO_2 are in equilibrium) of –56.6°C at 0.52 MPa.

CO_2 technology has been applied to food processing and cold storage, both as a conventional and as secondary refrigerant. It is expected that CO_2 market share will increase in this subsector, especially for freezing and frozen food storage.

Not-in-kind technologies

There are some not-in-kind (non-vapour compression) technologies like air cycle, vapour absorption technology and compression-absorption technology which can be used for food processing and cold storage applications. Vapour absorption technology is well-established whereas compression-absorption technology is still under development.

Vapour absorption technology
Vapour absorption is a tried and tested technology. Absorption technologies are a viable alternative to vapour compression technology wherever low cost residual thermal energy is available. The most commonly used working fluid in food processing and cold storage applications is ammonia with water as the absorbent. The use of absorption technology is often limited to sites that can utilize waste heat, such as co-generation systems.

Compression-absorption technology
Compression-absorption technology has been developed by combining features of the vapour-compression and vapour-absorption cycles. About 20 compression-absorption systems on both a laboratory and full-scale have been developed and tested successfully so far. Various analytical and experimental studies have shown that the COP of compression-absorption systems is comparable to that of vapour compression systems. However, this system suffers from the inherent disadvantage of being capital intensive in nature. The technology is still at developmental stage (Pratihar *et al*., 2001, Ferreira and Zaytsev, 2002).

4.4.5 Factors affecting emission reduction

Design aspects
The refrigeration system design plays a vital role in minimizing the refrigerant emissions. A proper system design including heat exchangers, evaporators and condensers can minimize the charge quantity and hence reduce the potential amount of emissions. Every effort should be made to design tight systems, which will not leak during the system's lifespan. The potential for leakage is first affected by the design of the system; therefore designs must also minimize the service requirements that lead to opening the system. Further, a good design and the proper manufacturing of a refrigerating system determine the containment of the refrigerant over the equipment's intended life. The use of leak tight valves is recommended to permit the removal of replaceable components from the cooling system. The design must also provide for future recovery, for instance by locating valves at the low point of the installation and at each vessel for efficient liquid refrigerant recovery (UNEP, 2003).

Minimizing charge
The goal of minimal refrigerant charge is common for all systems due to system and refrigerant costs. Normally the designer calculates the amount of charge. In large systems such as food processing and cold stores, very little attention was generally given to determining the full quantity of refrigerant charge for the equipment. Its quantity is not often known (except for small factory built units). Charging the refrigerant into the system is done on site to ensure stable running conditions.

Improved servicing practices
Servicing practices in refrigeration systems must be improved in order to reduce emissions. Topping-off cooling systems with refrigerants is a very common practice, especially for the large systems normally used in food processing and cold storage industry, which causes greater emissions of refrigerant. However in general, proper servicing has proven to be more expensive than topping-off refrigeration systems. It is therefore necessary to make end-users understand that their practice of topping-off the systems without fixing leaks must cease because of the increased emissions to the environment. The good service practices are preventive maintenance, tightness control and recovery during service and at disposal.

Installation
After proper designing of the system, installation is the main factor that leads to proper operation and containment during the useful life of the equipment. Tight joints and proper piping materials are required for this purpose. Proper cleaning of joints and evacuation to remove air and non-condensable gases will minimize the service requirements later on and results in reduced emissions. Careful system performance monitoring and leak checks should also be carried out during the first days of operation and on an ongoing basis. The initial checks also give the installer the opportunity to find manufacturing defects before the system becomes fully operational. The proper installation is critical for maximum containment over the life of the equipment (UNEP, 2003). The refrigeration system should be designed and erected according to refrigeration standards (e.g. EN378 (CEN, 2000/2001)) and current codes of good practice.

Recovery and recycling
The recovery and recycling of refrigerants is another important process that results in significant reductions in emissions. The purpose of recovery is to remove as much refrigerant as possible from a system in the shortest possible amount of time. For applications where maintenance operations require opening the circuit, the difference between deep recovery and 'normal recovery' can represent 3–5% of the initial charge (Clodic, 1997). However many countries have adopted final recovery vacuum requirements of 0.3 or 0.6 atm absolute depending on the size of the cooling system and saturation pressure of the refrigerant. This provides a recovery rate of 92–97% of the refrigerant (UNEP, 1998).

The recovered fluorocarbon refrigerants can be recycled and then reused. The process of recycling is expected to remove oil, acid, particulate, moisture and non-condensable contaminants from the used refrigerant. The quality of recycled refrigerant can be measured on contaminated refrigerant samples according to standardized test methods (ARI 700). However, recycling is not common practice in the case of large food processing and cold storage units, where the preference is to recover and re-use the refrigerant.

4.4.6 Trends in consumption

The lifetime emissions of a refrigerant are dependent on the installation losses, leakage rate during operation, irregular events such as tube break and servicing losses including recovery loss and end-of-life loss during reinstallation/reconstruction. In some European countries, HCFC systems with more than 10 kg charge (including all application areas) showed an annual emission rate of 15% of the charge in the early 1990s (Naturvardsverket, 1996). This figure dropped to 9% in 1995 (UNEP 1998). Emissions from HFC systems are reported to be less than this, and this is probably due to more leak-proof designs. On a global scale, current CFC and HCFC annual emission rates are likely to be in the range of 10–12% of the charge (UNEP, 1998). A recent study (Clodic and Palandre, 2004) has provided estimates of emissions of CFCs, HCFCs, HFCs and ammonia from the combined sector of Food Processing, Cold Storage, and Industrial Refrigeration. Table 4.12 gives the percentage annual emissions of these refrigerants.

The consumption and banks of HFCs and other fluorocarbons have been estimated for the industrial refrigeration sector as a whole. Both a top-down (UNEP, 2003) and a bottom-up approach (Clodic and Palandre, 2004) are presented here (Table 4.13). The data for 2002 and the 2015 business-as-usual projections of Clodic and Palandre (2004) are used as a basis for the refrigeration subsectors in this report, so as to ensure consistency with other refrigeration and air conditioning subsectors (see Table 4.1). However, Table 4.13 clearly illustrates the differences between both approaches, which are clearly significant for CFCs.

Food processing and cold storage are assumed to account for 75% of the combined emissions and industrial refrigeration for the remaining 25% (UNEP, 2003).

The business-as-usual projections for 2015 show a significant increase in HFC consumption.

4.4.7 Comparison of HFC and non-HFC technologies

Energy efficiency and performance

As stated above R-404A and R-507A are the proven replacements for R-502 and this also includes the application in flooded evaporators used for food processing and cold storage systems. The cycle efficiencies are comparable to R-502 but significantly lower compared to those of ammonia (non-HFC technology) especially at high condensing temperatures (UNEP, 2003).

R-410A is another important HFC refrigerant in this sector. The energy efficiency of R-410A systems can be similar to ammonia for evaporation temperatures down to −40 °C, depending on compressor efficiency and condensing temperature. The efficiency below −40 °C until its normal boiling point of −51.6 °C is slightly higher for R-410A than that of ammonia and other refrigerants. The compressor efficiencies are also reported to be higher compared to HCFC-22, due to the high volumetric capacity (40% above that of HCFC-22) of R-410A (Meurer and König, 1999).

CO_2 technology is another non-HFC technology which is gaining momentum. CO_2 as a refrigerant is being used in food processing and cold storage units in cascade systems with ammonia in higher cascade. It has been reported that the volumetric refrigerating capacity of CO_2 is five times higher than HFC 410A and eight times higher than that of ammonia and other refrigerants. Therefore the size of most components in the system can be reduced (Roth and König, 2001). The efficiency of CO_2/ammonia cascade system in the temperature range of –40 °C to –55°C is comparable to a two-stage system with R-410A. CO_2 also shows a strong cost benefit in large systems (Axima, 2002).

Life cycle climate performance LCCP

Very limited data are available for TEWI/LCCP for this refrigeration sector. A recent publication (Hwang *et al*., 2004) reports a comprehensive experimental study of system performance and LCCP for an 11 kW refrigeration system operating with R-404A, R-410A and propane (HC-290) at evaporator temperatures of −20°C to 0°C. For a comparison on an equal first cost basis, the increased cost of safety features for HC-290 was used for a larger condenser for the HFC systems. The LCCP of the R-410A system was 4% lower and the LCCP of R-404A was 2% higher than that of the HC-290 system at an annual refrigerant emission rate of 2%. The LCCP values for R-410A and HC-290 were equal at an annual refrigerant emission rate of 5%.

4.5 Industrial refrigeration

4.5.1 Introduction

One characteristic of industrial refrigeration is the temperature range it embraces. While evaporating temperatures may be as high as 15°C, the range extends down to about –70°C.

Table 4.13. Estimated consumption and banks of halocarbons refrigerants for industrial refrigeration, including food processing and cold storage for 2002. (UNEP, 2003 and Clodic and Palandre, 2004).

		Consumption (kt yr^{-1})				Refrigerant Banks (kt)			
		CFCs	HCFCs	HFCs	NH_3	CFCs	HCFCs	HFCs	NH_3
2002	UNEP (2002)	12	28	5	-	109	165	9	-
2002	Clodic and Palandre (2004)	7	27	6	22	34	142	16	105
2015	Clodic and Palandre (2004)	4	24	18	27	21	126	85	123

Table 4.14. Major applications and refrigerants used in industrial refrigeration.

Application	Refrigerant	Other Refrigerants	CFC, HCFC Replacements
freeze drying	NH_3, HCFC-22	R-502	CO_2, R-410A
separation of gases	CFC-12, CFC-13, HCFC-22, R-503	-	PFC14, PFC-116, R-404A, R-507A, CO_2
solidification of substances	HCs, CFC-13, HCFC-22, CFC-12	-	HCs, CO_2, PFC-14, R-404A, R-507A
reaction process	Various		
humidity control of chemicals	CFC-12, CFC-13, HCFC-22, R-503		PFC-14, PFC-116, R-404A, R-507A, CO_2, NH_3, Air
industrial process air conditioning	NH_3, HCFC-22	R-502	NH_3, R-404A, HFC-134a, Water
refrigeration in manufacturing plants	Various		
refrigeration in construction	NH_3, R-502	HCFC-22	NH_3, CO_2, R-410A, R-404A, R-507A
ice rinks	NH_3, HCFC-22		NH_3, CO_2, R-404A, R-507A
wind tunnel	NH_3, R-502, HCFC-22, CFC-12	-	NH_3, R-404A, R-507A, HFC-134a
laboratories	Various		

At temperatures much lower than about –70°C the so-called ‘cryogenics’ technology comes into play. This produces and uses liquefied natural gas, liquid nitrogen, liquid oxygen and other low-temperature substances. Industrial refrigeration in this section covers refrigeration in chemical plants (separation of gases, solidification of substances, removal of reaction heat, humidity control of chemicals), process technology (industrial process air conditioning, refrigeration in manufacturing plants, refrigeration in construction), ice rinks and winter sports facilities, and laboratories where special conditions such as low temperatures, must be maintained. Some definitions of industrial refrigeration include food processing and cold storage; these are described in Section 4.4 of this chapter.

Industrial systems are generally custom-made and erected on site. A detailed description of industrial refrigeration and cold storage systems can be found in the ‘Industrial Refrigeration Handbook’ (Stoecker, 1998). Industrial refrigeration often consists of systems for special and/or large refrigerating purposes. The cooling/heating capacity of such units vary from 25 kW to 30 MW or even higher. These refrigeration systems are based on reciprocating, screw and centrifugal compressors, depending on the capacity and application.

Industrial refrigeration has mainly operated with two refrigerants: ammonia (60–70%) and HCFC-22 (15–20%). To a lesser extent CFC-502 (5–7%) has been used and other minor refrigerants complete the rest of industrial applications. Replacement refrigerants for CFCs and HCFCs, plus other non-fluorocarbon fluids are included in Table 4.14.

The refrigerants used are preferably single compound or azeotropic mixture refrigerants, as most of the systems concerned use flooded evaporators to achieve high thermodynamic efficiencies. Industrial refrigeration systems are normally located in industrial areas with very limited public access. For this reason ammonia is commonly used in many applications where the hazards of toxicity and flammability are clearly evident, well-defined, well understood and easily handled by competent personnel. Hydrocarbons may be used as an alternative to ammonia within sectors handling flammable fluids, such as chemical processing.

There are clear differences in how countries have developed the technology for industrial refrigeration since the starting of the CFC phase-out. In Europe, the use of HCFC-22 and HCFC-22 blends in new systems has been forbidden for all types of refrigerating equipment by European regulation 2037/00 (Official Journal, 2000) since 1 January 2001. The use of CFCs is also forbidden, that is no additional CFC shall be added for servicing. HFCs are occasionally used where ammonia or hydrocarbons are not acceptable, although they are not often preferred in Europe, as European users are expecting regulations limiting the use of GHGs in stationary refrigeration (see proposals in EU, 2004).

4.5.2 Technical options

Most of the industrial refrigerating systems use the vapour compression cycle. The refrigerant is often distributed with pumps to heat exchangers in the space or apparatus to be refrigerated. Indirect systems with heat transfer fluids are used to reduce the risk of direct contact with the refrigerant. Ammonia is the main refrigerant in this sector. HCFC-22, R-502 and CFC-12 are the historically used refrigerants from the group of CFCs and HCFCs. Beside the increasing share of ammonia for new systems, the current technical options to replace CFCs are HFCs, HCFC-22 and non-fluorocarbon technologies such as CO_2 and HCs.

4.5.3 Factors affecting emission reduction

The refrigerant charge in industrial systems varies from about 20 kg up to 10,000 kg or even more. Large ammonia refrigeration systems contain up to 60,000 kg of refrigerant. The high costs of the refrigerants, with the exception of ammonia and

CO_2, and the large refrigerant charge required for the proper operation of the plant have led to low emissions in industrial systems. In these systems annual average leakage rates of 7–10% are reported (UNEP, 2003); smallest leakage rates are observed in ammonia systems because of the pungent smell. Clodic and Palandre (2004) estimate somewhat higher annual leakage rates (17%) for the category of industrial refrigeration (which also includes food processing and cold storage). The abatement costs of refrigerant emissions from industrial refrigeration was determined to be in the range of 27–37 US$ (2002) per tonne CO_2 -eq (March, 1998). Cost data were calculated with a discount rate of 8%.

Design aspects

Industrial refrigeration systems are custom made and designs vary greatly from case to case. Due to the increasing requirements concerning safety and the quantity of refrigerant used in refrigeration systems, a design trend towards indirect systems has been observed over the past 10 years. Yet whenever possible, the majority of systems are still direct. Refrigerant piping fabrication and installation has changed from direct erection on site towards pre-assembled groups and welded connections (see Design aspects in Section 4.4.5 for additional information on design and installation practices to minimize refrigerant emissions).

Minimizing charge

There are limits on design optimization in terms of balancing low charge on the one hand against achieving high COPs or even stable conditions for liquid temperatures to be delivered to heat exchangers on the other. For example, flooded type evaporators represent the best technology available for a low temperature difference between the liquid to be cooled and distributed and the evaporating refrigerant, yet this requires large quantities of refrigerant. The increased use of plate heat exchangers, plate and shell heat exchangers, and printed circuit heat exchangers over the past 15 years has enabled the design of lower charge systems with flooded evaporators. Efforts to minimize the amount of refrigerant charge will continue with improvements in system technology.

Improved servicing practices

Trained service personnel are, according to safety standards (CEN-378, 2000/2001; ISO-5149, 1993), required for the maintenance and operation of industrial systems. Service and maintenance practices on industrial systems are updated periodically according to safety standards and service contracts, which are negotiated with the plant owner in the majority of the cases.

Recovery and recycling

Recovery of refrigerants from industrial plants is common in many countries and is sometimes also a requirement (CEN-378, 2000 and 2001). The recovery of small quantities of ammonia (less than 3 kg) through absorption in water is common practice. Larger quantities are recovered by special large recovery units and pressure vessels.

The recovery rate from industrial systems is high due to the high costs and quantity of the refrigerants, especially CFCs, HCFCs and HFCs. The recovery rate is estimated to be 92–97% of the refrigerant charge (UNEP, 2003). The recovered refrigerants are dried in the recovery systems on site and re-used.

Lifetime refrigerant emissions

As most industrial refrigeration systems are designed for specific manufacturing processes, information on lifetime emissions of refrigerants are not readily available. Even data on cooling capacities are often not official, as the production capacity of the manufactured product could be estimated from this data. However, the estimated annual leakage rates referred to in Section 4.5.3 should be noted.

4.5.4 HFC technologies

HFC refrigerants are options to replace CFC-114, CFC-12, CFC-13, R-502 and HCFC-22. The preferred HFCs are HFC-134a, HFC-23 and HFC-blends with insignificant temperature glide such as R-404A, R-410A and azeotropic blends like R-507A.

HFC-134a has completely replaced CFC-12 because of its comparable thermodynamic properties in various applications of industrial refrigeration. CFC-12 and HFC-134a are used in large systems for higher temperatures with evaporator temperatures from 15°C down to –10°C.

HFC-23 has replaced CFC-13 and to lesser extent CFC-503 for the same reasons as mentioned for CFC-12. The evaporator temperature range varies from –80°C to –55°C in the low-temperature applications of these refrigerants.

HFC-245fa, HFC-365mfc and HFC-236fa are possible replacements for CFC-114 in high-temperature heat pumps. No single fluid is ideal, especially for large industrial heat pumps, because the dew line of the fluids requires large superheat to avoid compression in the vapour region. The temperature range for condensing temperatures varies from 75°C to 100°C.

HFC-410A is not comparable to refrigerants HCFC-22 or CFC-12 in terms of thermodynamic properties because of its considerably higher vapour pressure. HFC-410A compressor efficiencies, the pressure drop in suction lines and the heat transfer efficiency will benefit from high system pressure. This HFC is used mainly in new industrial systems designed for the refrigerant, especially in terms of low condensing temperatures of 35°C to avoid pressures higher than 25 bar. In industrial refrigeration, the evaporator temperature range for HFC-410A varies from –60°C to –35°C. Due to the high volumetric capacity (40% above that of HCFC-22), compressor efficiency has been reported to be higher than with HCFC-22 (Meurer and König, 1999). R-410A has a COP similar to NH_3 and HCFC-22 and slightly higher than that of R-404A, R-507A. Further, at temperatures below –40°C and up to the to HFC-410A normal boiling point at –51.6°C, COPs are slightly higher for R-410A compared to other refrigerants (Roth *et al., 2002*).

R-404A and R-507A are the main refrigerants to replace R-502 in the temperature range from –50°C to –30°C and these have comparable cycle efficiencies (COPs) and slightly lower GWP values than R-502. For systems with R-404A and R-507A, the liquid should be subcooled to achieve optimum efficiencies and high cost-effectiveness . In chiller applications with screw compressors it may also be necessary to add significant superheat to the suction gas in order to avoid refrigerant condensation in the oil separator.

4.5.5 Non-HFC technologies

In large systems CFCs and recently introduced HFCs have a lower average share in industrial refrigeration than NH_3 and HCFC-22. For new industrial systems designers and plant owners will mainly need to decide between NH_3, HFCs and HCFC-22 (except in the EU where HCFC-22 is forbidden in new systems) (Stoecker, 1998). Non-HFC technologies described in the following subsection are sorted by refrigerant.

Ammonia

Ammonia is one of the leading refrigerants for industrial refrigeration, based on performance and safety, and is used in large quantities in locations physically separated from general public access. The current market share in several European countries, especially in Northern Europe, is estimated to be up to 80% (UNEP, 1998). In the USA, ammonia has approximately 90% market share in systems of 100 kW cooling capacity and above that use custom-engineered processes (IIR, 1996).

New ammonia systems have an improved design, use low-temperature materials and standardized welding procedures, and the systems operation and maintenance are under continuous monitoring. A human error or direct physical damage is often the reason for failure (Lindborg, 2003).

Charge reduction has been achieved through dry or direct expansion in plate type heat exchangers and shell and tube evaporators. With soluble oils, it has been possible to reduce charge by 10%. New developments showed charges of 28g ammonia per kW cooling capacity for low overall capacity down to 100 kW (Behnert and König, 2003). With these low charges, new opportunities for applications not previously considered for ammonia have been realized, such as water chillers for air conditioning (Stoecker, 1998). This new ammonia technology with high COP was regarded as being fully practical, but strong market penetration has not been achieved due to price competition with HFC-based units (UNEP, 2003).

HCFC-22

The use of HCFC-22 is declining in industrial refrigeration in Europe, as the use of HCFC-22 in new systems is forbidden by European regulations (Official Journal, 2000).

In developing countries, HCFC-22 is still an important replacement refrigerant for CFCs in new systems, as from a technical point of view HCFC-22 could replace CFC-12 and CFC-502 in new systems. Another important consideration in developing countries is that under the Montreal Protocol the production of HCFC-22 is allowed until 2040, or the full lifetimes of equipment installed in the next 15 years or so.

Hydrocarbons (HCs)

HCs can fit into any temperature range for evaporating temperatures down to –170°C. Historically, their use as working fluids has been restricted to large refrigeration plants within the oil and gas industry. A certain registered increase in hydrocarbon consumption has mainly appeared in these sectors (Stoecker, 1998).

Commercialized products used in industrial refrigeration equipment include HC-290 and HC-1270. System performance with regard to system efficiency is comparable to and, in some cases even superior to, that of the halocarbons. Hydrocarbons are soluble with mineral oils and compatible with materials such as metals and elastomers that are traditionally used in refrigeration equipment. The use of hydrocarbons in screw compressors may be problematic due to the strong dilution of mineral oil. Other less soluble lubricants such as PAG or PAO may be required. As long as safety aspects are taken into consideration, standard refrigeration practices used for HCFCs and CFCs can be used for hydrocarbon fluids without major system detriment.

Given the flammability concerns, design considerations as detailed in the relevant safety standards should be adhered to. Additional safety measures are required for repairing and servicing. Several national and European standards permit the use of HCs in industrial applications and lay down specific safety requirements. Industry guidelines for the safe use of hydrocarbon refrigerants are available (ACRIB, 2001).

Carbon dioxide (CO_2)

As well as being non-ODP and having a GWP of 1, carbon dioxide (CO_2) offers a number of other advantages:

- Excellent thermophysical properties, leading to high heat transfer;
- Efficient compression and compact system design due to high volumetric capacity;
- Non-flammable and low toxicity;
- Low system costs at evaporation temperatures below 45°C (depending on system design);
- Widely available at low cost.

CO_2 systems can be used for industrial refrigeration applications with evaporation temperatures down to –52°C and condensing temperatures up to 5°C. CO_2 is also increasingly being used in the low stage of cascade systems for industrial refrigeration. CO_2 is also commonly used as a secondary refrigerant. The design requires the same pressure of 25 bar for the secondary refrigerant systems and for the CO_2 used as the refrigerant, except for ice rinks and some other limited systems which are designed for 40 bar. Defrosting was an open issue, but the most recent developments show that several different techniques such as electrical heating, hot gas defrosting, high-pressure liquid evaporation and the distribution of hot gas have been realized in plants (Siegel and Metger, 2003).

A comparative study for low temperatures has been carried out using a typical system design with cooling capacities of 600kW at −54°C for R-410A, R-507 and ammonia used as a single fluid in two-stage systems and for NH_3/CO_2 and HFC-134a/R-410A as refrigerants in high/low stage cascade systems. The volumetric refrigerating capacity of CO_2 is five times higher than HFC-410A and eight times higher than for ammonia and other refrigerants. Therefore the size of most components in the system can be reduced. The study found the lowest cost for NH_3/CO_2 (Roth *et al., 2002*). If CO_2 is used as the refrigerant, the cost break-even point for industrial refrigeration compared to NH_3 and R-410A is approximately at an evaporating temperature of –40°C to −45°C. Below this temperature, lower costs for CO_2/NH_3 cascade systems have been achieved. It is expected that costs for screw or reciprocating units, including compressors and oil separation circuit, will be further reduced (Roth *et al., 2002*). The efficiency of CO_2 systems in this low temperature range is similar to other refrigerants such as R-410A or ammonia.

CO_2 shows strong cost benefits if the system size is increased, especially in cases where evaporators or heat exchangers are distributed and long piping systems are required. In industrial refrigeration applications, cost benefits have been achieved with total pipe runs of more than 2500 m (Siegel and Metzger, 2003).

In food processing, a trend can be observed towards CO_2 as a refrigerant at temperatures lower than –45°C and as an HTF for cooling temperatures lower than −5°C (Pirard, 2002).

Some examples are given to illustrate the use of CO_2 as refrigerant in low-temperature applications:

- In the USA, the first large CO_2 system was being erected in 2003 with cooling capacities of 6 MW (Stellar, 2003);
- In Japan a standard low-temperature cascade system has been developed with NH_3/CO_2 as refrigerants. The systems are designed for evaporating temperatures of –40 to –55°C with cooling capacities of 80−4450 kW;
- In Europe more than 30 large systems with CO_2 as the heat transfer fluid and refrigerant have been installed since 1998 and are operating with total cooling capacities of more than 25 MW (Pearson, 2004a,b);
- At least two large systems in Europe have been retrofitted from HCFC-22 (1.5 MW at −45 to −55°C) and from CFC-13B1 (2.4 MW at −35°C) to NH_3/CO_2 cascade systems (Gebhardt, 2001; König, 2002).

4.5.6 Trends in consumption

The trends in the consumption of refrigerants for industrial refrigeration as well as the food processing and cold storage subsector are discussed in Section 4.4.6.

4.5.7 Comparison of HFC and non-HFC technologies

4.5.7.1 Energy efficiency and performance

On a worldwide basis, only two refrigerants have significant market share in industrial refrigeration: ammonia and HCFC-22. Stoecker (1998) provides a comparison of both refrigerants. Compared to ammonia and HCFC-22, the market share of HFCs and non-HFC technologies is small. Nevertheless, one point of comparison is the cost of the refrigerant to be used in the system, and the lowest costs are found for ammonia (Stoecker, 1998).

The energy efficiency comparisons for HFCs 404A, 507A, and 410A with ammonia and HCFC-22 are described in Section 4.5.4. HFC410A has an energy efficiency similar to ammonia and HCFC-22, and slightly higher than R-404A and R-507A (Roth *et al*., 2002).

CO_2 technology is a non-HFC technology which is gaining momentum. The energy efficiency of CO_2 systems in the temperature range of –40ºC to –45ºC is similar to HCFC-22 and HFC refrigerants such as HFC-410A. CO_2 also shows strong cost benefit if the system size is large (Siegel and Metzger, 2003).

4.5.7.2 TEWI/LCCP/LCA

For various reasons, only limited TEWI/LCCP/LCA data are available for industrial refrigeration systems. Such systems are normally custom-designed for special requirements and are erected on site. The design differs not only in terms of cooling capacities and temperatures, but also in terms of temperature control requirements (air blast cooling systems), size of piping, distance to consumers and charge of refrigerant. There are therefore only a few references which compare TEWI and costs for the same application (Pearson , 2004a; Roth *et al*., 2002). Roth *et al*. (2002) give a comparative example for a manufacturing plant with a cooling capacity of 600 kW at −54°C (see Figures 4.1 and 4.2). In this investigation the combination of CO_2 and ammonia was more competitive than other solutions.

In addition to the above references, examples of LCCP calculations for supermarket refrigeration systems provide general guidance for selecting systems and refrigerants with a lower LCCP (see Section 4.3). Lower LCCP results from systems with low energy consumption, and in the case of fluorocarbon refrigerants, low refrigerant charge size and low refrigerant emissions. LCCP calculations should be used to optimize the choice of refrigerant and system design for the lowest environmental impact.

4.6 Transport refrigeration

4.6.1 Introduction

The transport refrigeration subsector consists of refrigeration systems for transporting chilled or frozen goods. Typically the task of a transport refrigeration system is to keep the temperature constant during transport. The technical requirements for transport refrigeration units are more severe than for many other applications of refrigeration. The equipment has to operate in a wide range of ambient temperatures and under extremely variable weather conditions (sun radiation, rain, etc.); it also has to be able to carry any one of a wide range of cargoes with

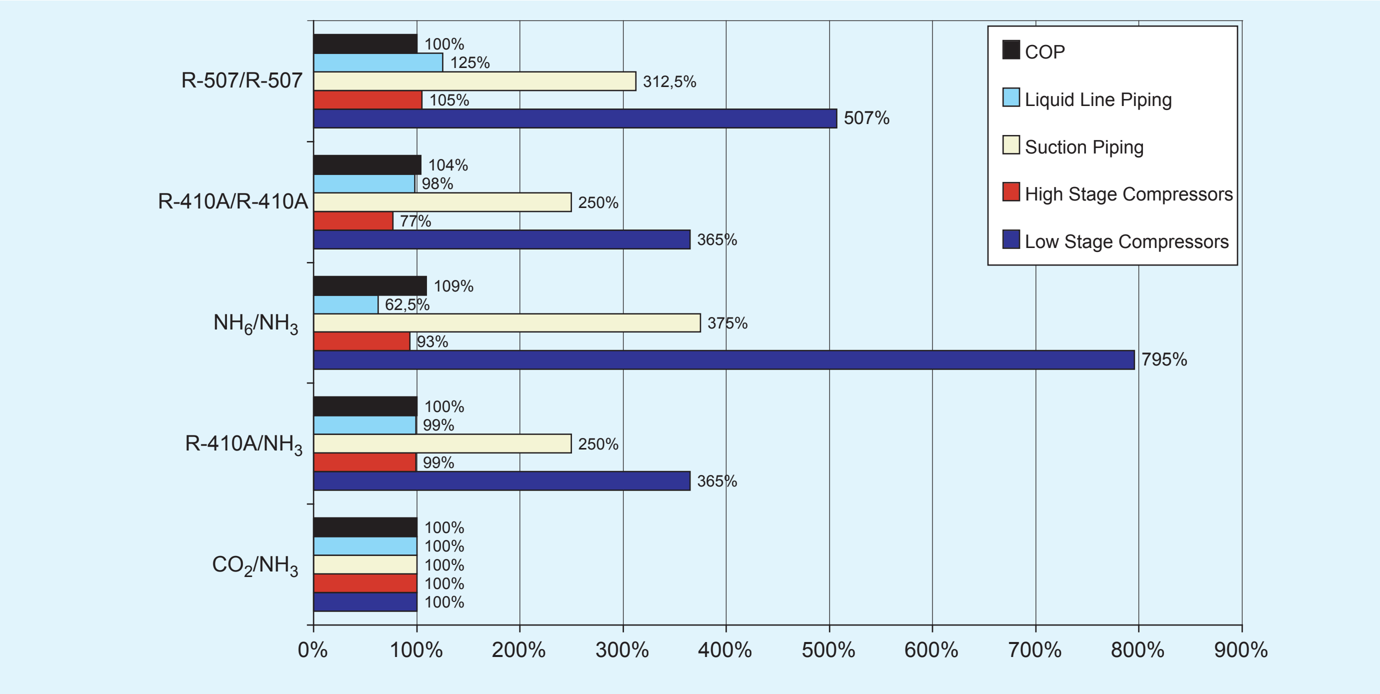

Figure 4.1. COP and size comparison of different components for different refrigerant combinations (Q_0 = 600 kW, t_C = 35°C; t_0 = −54°C; CO_2/NH_3-cascade system is equal to 100 %) (Roth and König, 2002).

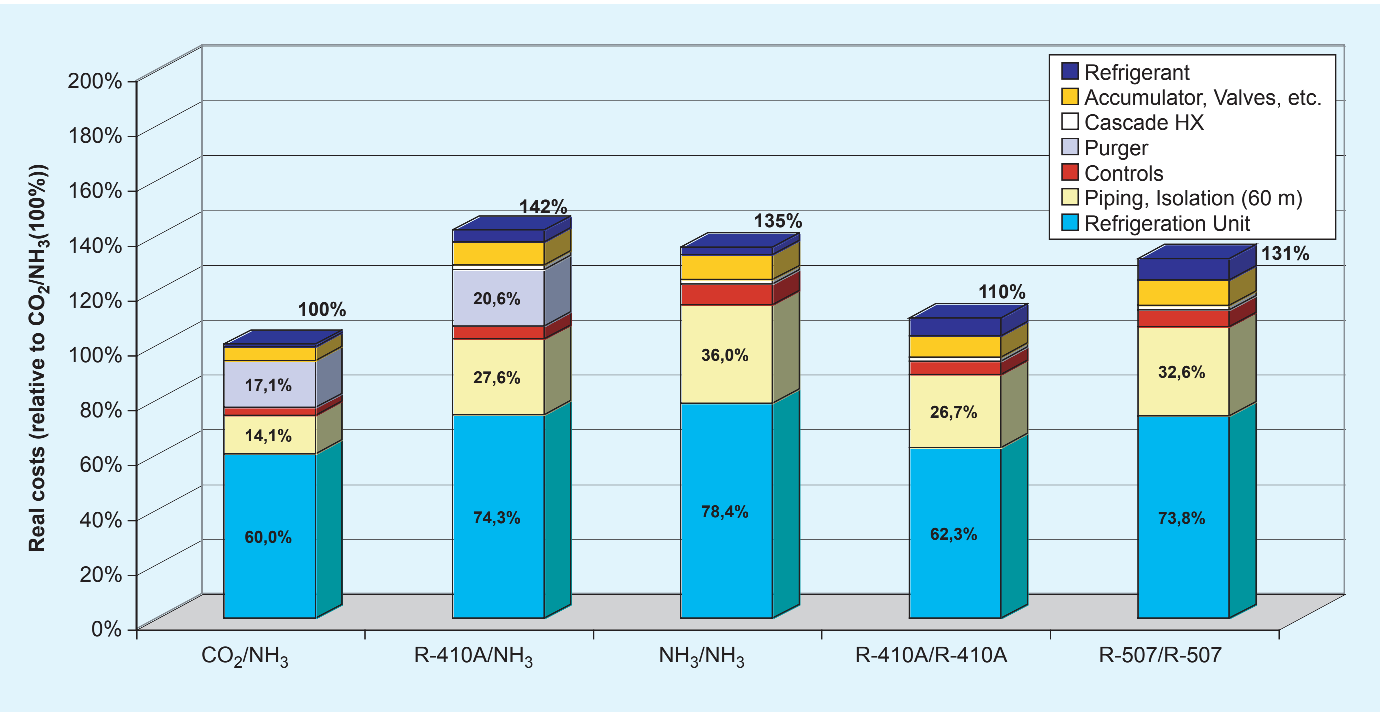

Figure 4.2. Cost comparison for different refrigerant combinations (Q_0 = 600 kW, t_C = 35°C; t_0 = −54°C; CO_2/NH_3-cascade system is equal to 100 % (Roth and König, 2002).

differing temperature requirements, and it must be robust and reliable in the often severe transport environment (IIR, 2003). Typical modes of transport are road, rail, air and sea. In addition, systems which are independent of a moving carrier are also used; such systems are generally called 'intermodal' and can be found as containers (combined sea-land transport) as well as swap bodies (combined road and rail transport). This section covers also the use of refrigeration in fishing vessels where the refrigeration systems are used for both food processing and storage.

The technology used in transport refrigeration is mainly the mechanically- or electrically-driven vapour compression cycle using refrigerants such as CFC, HCFC, HFC, ammonia or carbon dioxide. Due to the complete and worldwide phase-out of CFC consumption by the end of 2009, CFCs are not addressed in this chapter. In addition, a number of refrigeration systems are based on using substances in discontinuous uses. This type of equipment can be found as open uses with solid or liquid CO_2, ice, or liquid nitrogen and in these cases the refrigerant is being completely emitted and lost after removing the heat (Viegas, 2003). Closed systems such as eutectic plates (Cube *et al.*, 1997) or flow-ice, reuse the same substance (Paul, 1999). Such systems used to be very commonplace in transport refrigeration, and are still used on a significant scale. Some propose that their use should be increased in the future.

All transport refrigeration systems need to be compact and lightweight, as well as highly robust and sturdy so that they can withstand movements and accelerations during transportation. Despite these efforts, leaks within the refrigeration system occur due to vibrations, sudden shocks and so forth. The likelihood of leaks or ruptures is also greater than with stationary systems, due to a higher risk of collisions with other objects. Ensuring safe operation with all working fluids is essential, particularly in the case of ships where there are no options to evacuate a larger area (SCANVAC, 2001). The safety is either inherent in the fluids or is ensured through a number of technical measures (Stera, 1999).

4.6.2 Container transport

Refrigerated containers allow uninterrupted storage during transport on different types of mobile platforms, for example railways, road trucks and ships. The two main types of refrigerated containers are porthole containers and integral containers. Porthole containers are the older of the two concepts and are insulated containers with two front apertures and no built-in refrigeration systems. Some predict that by 2006, transport will have been completely converted to integral containers (Hochhaus, 2003; Wild, 2003).

Integral refrigerated containers are systems which have their own small refrigeration unit of about 5 kW refrigeration capacity on board. There were more than 550,000 of these in 2000, representing the transport capacity of 715,000 20-foot containers, and there numbers are set to strongly increase (UNEP, 2003; Sinclair, 1999; Stera, 1999). The electrical power needed to drive the system is supplied from an external power supply via an electrical connection. These systems typically use HFC-134a, R-404A and HCFC-22, and in some cases R-407C (Wild, 2003). Newer systems generally have a more leak-resistant design (Crombie, 1999; Stera, 1999; Yoshida *et al.,* 2003; Wild, 2003). In 1998, when older design systems were prevalent, an average annual leakage rate of 20% of the charge of about 5 kg was assumed for a lifetime of 15 years (Kauffeld and Christensen, 1998).

4.6.3 Sea transport and fishing vessels

Virtually all of the 35,000 plus merchant ships worldwide larger than 500 gross tonnes (Hochhaus, 1998) have some on-board refrigeration system. The majority of systems use HCFC-22. These refrigeration systems and options for emission abatement are referred to in Sections 4.2 and 4.3 of this report. In terms of technology and performance, chillers for air conditioning or, in case of naval vessels for electronics and weapon system cooling, are similar to stationary systems (see section 5.1 on air conditioning). The following remarks and information relate to ship-bound refrigeration systems essential to the main purpose of non-naval vessels, namely the transportation of perishable products, the chilling of fish and the like.

Refrigerated transport vessels, also called reefers, provide transportation for perishable foodstuff at temperatures between –30°C and 16°C (Cube *et al*., 1997). It is estimated that there are around 1300 to 1400 reefer vessels in operation (Hochhaus, 2002; Hochhaus, 1998), a number which has been constant for quite some time and is expected to decrease. In 2001, it was reported that more than 95% of the refrigeration installations on these vessels use HCFC-22 as a refrigerant (SCANVAC, 2001), although various HFCs such as HFC-134a, R-404A, R-507 and R-407C as well as ammonia are being used. About two-thirds of the systems are direct systems with up to 5 tonnes of refrigerant per system and the remaining are indirect systems with a charge below 1 tonne of refrigerant (UNEP, 2003). Estimates of current annual leakage rates based on known refrigerant consumption are 15−20% of the system charge (SCANVAC, 2001).

Worldwide there about 1.3 million decked and about 1.0 million undecked, powered fishing vessels. In 2001, more than 21,500 fishing vessels over 100 gross tonnes were recorded (FAO, 2002), with a slightly decreasing trend. Vessels of that size are assumed to operate internationally and to be equipped with significant refrigeration equipment. Within a wide range, the average larger fishing vessel has a refrigerant charge in the order of 2000 kg with 15−20% annual leakage rate. In 2001 more than 95% of such vessels in Europe used HCFC-22 as the refrigerant (SCANVAC, 2001). It is assumed that 15% of the fleet have full size refrigeration systems, while the remaining fleet is assumed to be equipped with small refrigeration systems that have a filling mass of approximately 100 kg.

Specialized tankers are used to transport liquefied gases, in particular liquefied petrol gas (LPG) and liquefied natural gas (LNG). Medium and large LNG tankers transport LNG at normal pressure. The refrigeration effect needed for this type of transport is provided by evaporating the LNG, which is recondensed using specialized refrigeration units. Since the number of such ships is limited (about 150 ships of above 50,000 tonnes were registered in 1996) (Cube *et al*., 1997) and the refrigeration equipment typically uses the transported, low GWP hydrocarbon gases as the refrigerant, refrigeration use in gas tankers is not further considered in this report.

4.6.4 Road transport

Road transport refrigeration units, with the exception of refrigeration containers, are van, truck or trailer mounted systems. Some trailers are equipped to be mounted or have their main bodies mounted on railroad systems; these are so-called swap-bodies. In a number of uses those systems are of the discontinuous type, using eutectic plates in closed systems (Cube *et al*., 1997) or liquid nitrogen, liquid carbon dioxide or solid carbon dioxide in open systems (UNEP, 2003). These systems are frequently used in local frozen food distribution, for example, delivery directly to the customer (Cube *et al*., 1997). Liquid nitrogen for cooling purposes is used by more than 1000 vehicles in the UK. Liquid carbon dioxide is reported to be used in 50 trucks in Sweden (UNEP, 2003). In general, the necessity for storage and filling logistics, the hazardous handling of very cold liquids and solids and the energetically unfavourable low-temperature storage reduce the widespread application of these historically frequently used technologies.

The predominant technology in road transport, covering virtually all of the remaining refrigerated road transport equipment, is the mechanical vapour compression cycle. Trailers usually have unitary equipment that consists of a diesel engine, compressor, condenser, engine radiator and evaporator with fans as well as refrigerant and controls. These systems are also used for swap bodies. Larger trucks often have similar equipment as trailers. However, as the truck size decreases an increasing proportion of systems have the compressor being driven by the drive engine (ASHRAE, 2002). Alternatively, some truck systems use a generator coupled with the truck engine to generate electricity, which is then used to drive the compressor (Cube *et al*., 1997).

In 1999, it was estimated that in North America alone 300,000 refrigerated trailers were in use (Lang, 1999). For the 15 countries of the European Union in 2000, 120,000 small trucks, vans and eutectic systems with 2 kg refrigerant charge were estimated to be in use, with 70,000 mid-size trucks of 5 kg refrigerant filling and 90,000 trailers with 7.5 kg refrigerant filling (Valentin, 1999). The worldwide numbers in 2002 were estimated to total 1,200,000 units, with 30% trailer units, 40% independent truck units and 30% smaller units. The annual amount of refrigerant needed for service is reported to be 20–25% of the refrigerant charge (UNEP, 2003). The refrigerant typically chosen is HFC-134a for applications where only cooling is needed, and predominantly R-404A and R-410A for freezing applications and general-purpose refrigeration units (UNEP, 2003).

4.6.5 Railway transport

Refrigerated railway transport is used in North America, Europe, Asia and Australia. The transport is carried out by using either refrigerated railcars, or refrigerated containers (combined sea-land transport; see Section 4.6.2) or swap bodies (combined road-land transport; see Section 4.6.4). This section concentrates on transport in refrigerated railcars.

Different technologies have been used in the past: Solid CO_2 as well as ice have been used in discontinuous emissive systems to date (CTI, 2004). Mechanically-driven refrigeration systems have also been used and are now the prime choice because of the typically long duration of trips, which makes refilling of the emitted refrigerant in discontinuous emissive systems a challenge for both logistical and cost reasons.

Mechanically driven systems are almost completely equipped with diesel engines to supply the necessary energy to the refrigeration unit. The existing fleets of railcars in Asia still seem to mostly operate on one-stage (cooling) and two-stage (freezing /combined use) CFC-12 systems (UNEP, 2003). The European railcars have been converted to HFC-134a (Cube *et al*., 1997), and this has been facilitated by European regulations phasing out the use of CFCs (EC No 2037/2000 (Official Journal, 2000)). In North America, existing older systems have been converted to HFC-134a, while newer systems utilize HFC-134a and R-404A (DuPont, 2004).

The lifetime of newer rail refrigeration systems, which are often easily replaceable units originally developed for road transport and only adapted for rail use, is believed to be 8 to 10 years with a running time of 1000 to 1200 hours per annum (refrigeratedtrans.com, 2004). Older units specifically designed for rail use have a lifetime of typically 40 years and a refrigerant filling of approximately 15 kg (UNEP, 2003). The annual leakage rate may be assumed to be at least similar to the leakage rate experienced in road transport, that is 20–25% of the refrigerant charge (UNEP, 2003).

4.6.6 Air transport

In order to provide constant low temperature during the flight, containers to be loaded upon aircraft are provided with refrigeration systems. There are some battery powered mechanical refrigeration systems (Stera, 1999), but the total number of these is believed to be small. Other, more commonly used systems are discontinuous with solid carbon dioxide (Sinclair, 1999; ASHRAE, 2002), or ice (ASHRAE, 2002). As the amount of ODS replacement during use is apparently very small, air transport will not be detailed further in this report.

4.6.7 Abatement options

4.6.7.1 General

Based on the study of Clodic and Palandre (2004), the total amount of refrigerant contained in transport refrigeration systems is estimated to be 16,000 tonnes; 6000 tonnes of this are emitted annually. It should be noted that the widespread use of R-404A as a non-ODS alternative with a relatively high GWP of 3800 kg CO_2 kg^{-1} leads to very high CO_2-equivalent emissions. Using alternatives in systems with a more moderate GWP than R-404A, such as the HFC mixture R-410A, would cut the CO_2-equivalent emissions substantially.

Current system requirements lead to a refrigerant selection which is largely limited to HFC-134a and refrigerant mixtures with a relatively high global-warming impact such as R-404A. Since the emission rates in operation are significant, improvements in energy consumption, alternative substances and not-in-kind technologies are the main options for emission abatement. R-404A is the main refrigerant in current use (IIR, 2002) and is popular because of its flexibility (medium- and low-temperature applications) and safety. Only a limited number of TEWI calculations are available in the literature; the only investigation comparing different technologies such as CFC-12, HFC-134a, R-404A, HC-600a/HC-290, ammonia and CO_2, states that R-404A systems are at least sustainable from the different options investigated for reefer ships (Meffert and Ferreira, 2003).

4.6.7.2 Containment

As there are already considerable incentives to optimize design and to minimize leakage, further containment in most uses would require a new approach not yet seen. One example might be to use fully hermetic systems for road transport (Chopko and Stumpf, 2003a, b), although the effect of this on energy consumption has yet to be determined. The development of hermetic scroll compressors for container systems with acceptable energy efficiency for both cooling and freezing applications (Yoshida *et al.,* 2003; DeVore, 1998) allows their widespread use, and leads to less service requirements and therefore less related refrigerant losses. In addition, these compressors are hermetic, which further decreases leaks (Wild, 2003). This technology has already been introduced and is penetrating the market as existing equipment is gradually replaced.

Recovery and recycling is a statutory requirement in many countries and is probably adhered to since the equipment contains a considerable, but still easy-to-handle, amount of refrigerant and due to its mobility it can easily be transported to a recovery facility (except seagoing). On the other hand due to the large emission rates in operation, the improvements through recovery and recycling, which encompass only the refrigerant losses during service and disposal, are likely to be limited.

An alternative approach to improving systems to reduce leaks might be to improve operating conditions to reduce wear, likeliness of ruptures and refrigerant losses during service. The potential of such measures compared to system-related improvements has yet to be assessed, but might be considerable.

4.6.7.3 Improvement in energy efficiency

Most refrigeration systems operate under partial load conditions for a large proportion of their useful life (Meffert and Ferreira, 1999). Different methods for partial load control have been investigated for both electrically driven compressors and open compressors (e.g. Crombie, 1999). Potential energy savings for electrical systems using frequency converters are said to reach up to 25.8% per voyage (Han and Gan, 2003). Other sources compare a range of control possibilities (Meffert and Ferreira, 1999 and 2003). These sources concluded that energy efficiency gains of more than 70% can be achieved under part-load conditions.

4.6.7.4 Discontinuous processes

The use of ice as well as solid CO_2 are both established alternatives to vapour compression systems. Besides the logistical necessities of such systems, there are also temperature limitations for the use of ice as well as handling and energy issues when using solid CO_2 (as heat absorption is energetically unfavourable at –78.4°C). These issues are even more valid for the use of liquid nitrogen, producing an unnecessarily low temperature of –195.8°C, or liquid air with –194.3°C. Nevertheless, refrigerated systems using ice and solid CO_2 systems remain abatement option for HFC in suitable cases.

The commercialization of a fully self-powered liquid CO_2 system with a moderate evaporation temperature of –51°C for the delivery of frozen product to customers was reported by Viegas (2003), and this addressed handling as well as energy efficiency issues. The system, which needs a service infrastructure, has been commercialized in Sweden (Viegas, 2003) and the UK (UNEP, 2003) and is therefore available as an abatement option, especially for local and short-haul transport.

The use of a pumpable suspension of ice crystals in water (‘binary ice’, ‘flow ice’), has been developed for certain transport uses. The suspension is pumped into the hollow walls, floors, ceilings or trays of a containment to be refrigerated. While equipment for service trolleys for passenger trains is already commercially available, the same principle is being suggested for containers (Paul, 1999). Although the remaining technical issues seem to be standard engineering tasks, the technology is not yet commercially available for cooling of full containers, trucks or vans.

4.6.7.5 Sorption processes

Sorption processes are well known, heat-driven processes using water, methanol or ammonia as a refrigerant, and solids such as activated coal, zeolite or silica gel (adsorption) as well as liquids such as lithium bromide (LiBr) and water (absorption) as sorbents in a closed circuit. The heat to drive such processes can come from a variety of sources; in the case of transport refrigeration, the waste heat from the transporter’s engine could be used. Such a use has been proposed for several years, especially for ship-bound systems (Cube *et al*., 1997).

LiBr-water systems, are frequently used in stationary applications and for the capacity range of 200 kW–600 kW, these have been reported to operate successfully and produce chilled water in certain specialized ships (Han and Zheng, 1999). Below zero refrigeration is not feasible with LiBr-water systems. As such systems have already been successfully employed on ships, their utilization might be increased at a relatively short notice.

The applicability to modes of transportation other than ships might be limited because of downscaling problems as well as design restrictions on those systems.

For truck-mounted refrigeration systems, the use of waste heat from the truck engine has been suggested to drive a water-ammonia sorption cycle (Garrabrant, 2003). For medium and small fishing vessels, adsorption ice-makers with carbon-methanol are being proposed, which utilize the exhaust heat of the ship's engine as an energy source (Wang *et al*., 2003).

4.6.7.6 Hydrocarbons

Hydrocarbon cooling systems for the recondensation of transported hydrocarbons have successfully been installed in gas tankers. International activities are underway to develop hydrocarbon systems for reefer ships (Jakobsen, 1998). In road transport refrigeration, commercially available systems have been developed in Australia, Germany and other European countries using HC-290 (propane). The systems require a leak detector in the trailer and special driver training to fulfil safety-related legal requirements (UNEP, 2003; Frigoblock, 2004).

Technically this solution could be adopted worldwide in certain road and railroad systems, especially in compact systems. Nevertheless, either certain existing regulations or present system use patterns would have to be adapted. The flammability of hydrocarbons will require additional safety measures, thus increasing the costs of the system, and in the beginning at least probably insurance rates as well. Containers might also require changes in the transporting ships.

4.6.7.7 Ammonia

Ammonia as refrigerant is being increasingly used in marine refrigeration equipment. Applications include its use in reefers (Stera, 1999), as a proposed refrigerant for sorption ice machines (Garrabrant, 2003), and the use in fishing vessels both as a single refrigerant (UNEP, 2003; Berends, 2002) and in combination with CO_2 (Nielsen and Lund, 2003). The applicability has been sufficiently proven. Ammonia as a refrigerant requires certain design considerations as well as the presence of additional safety equipment on board (SCANVAC, 2001).

4.6.7.8 Carbon Dioxide

Carbon dioxide as a refrigerant in mechanically-driven vapour compression systems, might be used as a subcritical refrigerant (critical point at 31°C) with a condensing temperature well below the critical point in cascade systems or in applications where low-temperature cooling options means are available. Alternatively, it can be used as a near-critical or, more likely, a super-critical working fluid. If the condensing temperature of CO_2 is below 15°C (border of subcritical region), this refrigerant typically offers, but not always, significant advantages in terms of efficiency and costs in comparison to other refrigerants. This advantage can only be utilized in cascade systems with other refrigerants or where low-temperature heat sinks are available. Near- or super-critical uses require a much higher pressure resistance of the equipment than is currently usual for other refrigerants, and such uses are often energetically less favourable than other refrigerants in the same temperature range.

For low-temperature uses, combinations of ammonia and CO_2 have been developed and built into ships. A comparison shows that the efficiency for a –40°C evaporation and 25°C condensing temperature is 17% higher than for a 2-stage HCFC-22 system (25% improvement at –50°C/25°C) (Nielson and Lund, 2003). The advantage of using CO_2 in such applications is that the necessary components (in particular the compressor) are commercially available or require only minor modifications, while consuming less space than other solutions.

CO_2 has also been proposed for container systems, where it would typically be used in a super-critical manner. A prototype system has yet to be reported as until recently no suitable compressor was available. A prototype CO_2 system for trucks has been developed, laboratory tested and optimized (Sonnekalb, 2000). The calculated TEWI shows a 20% decrease compared to a R-404A system.

4.6.7.9 Air

The air cycle for transport refrigeration purposes has been investigated for a number of years (e.g. Halm, 2000). A prototype system has been developed and tested, but has never been commercialized. Presently air cycle equipment for transport refrigeration does not seem to represent a suitable short- or medium-term abatement option due to the lack of suitable and reliable components.

4.6.8 Comparison of alternatives

Emissions of halocarbons in the transport refrigeration sector are related to four subsectors: Sea transport and fishing, road transport, rail transport and intermodal transport, that is containers and swap bodies. An overview can be found in Table 4.15.

There are a number of possibilities to improve those transport refrigeration systems built today to achieve a lowering of direct or energy-consumption related emissions without changing the working fluid or technology. A number of measures have been proposed and these have in part already been implemented to improve the energy efficiency, for example, the use of efficient compressors, frequency control for part load conditions, water-cooled condensers for containers on board ships, regular preventive maintenance and so forth. Measures to control direct emissions have mainly been proposed for mass-produced systems (e.g. container units) in terms of design improvements.

An alternative to improving the currently predominant halocarbon technologies is the replacement of those refrigerants by fluids or technologies with a lower GWP. Technically there are or will be low GWP replacement options available for all transport refrigeration uses where CFCs, HCFCs or HFCs are currently used. However in several cases these might increase the costs of the refrigeration system.

In case of reefer ships and fishing vessels, the most promising and already implemented non-halocarbon abatement tech-

Table 4.15. Subsectors of transport refrigeration, characteristics and alternatives.

Subsector		Sea Transport & Fishing	Road Transport	Rail Transport	Intermodal Transport
Cooling capacity	From To	5 kW 1400 kW	2 kW 30 kW	10 kW 30 kW	Approx. 5 kW
Refrigerant charge	From To	1 kg Several tonnes	1 kg 20 kg	10 kg 20 kg	Approx. 5 kg
Approximate percentage of sector refrigerant bank in subsector		52% of 15,900 tonnes	27% of 15,900 tonnes	5% of 15,900 tonnes	16% of 15,900 tonnes
Approximate percentage of sector refrigerant emissions in subsector		46% of 6000 tonnes	30% of 6000 tonnes	6% of 6000 tonnes	18% of 6000 tonnes
Predominant technology		HCFC-22	HFC-134a, HFC-404A, HFC-410A	HFC-134a, HFC-404A, HFC-410A	HFC-404A
Other commercialized technologies		Various HFCs, ammonia, ammonia, CO_2 /ammonia for low temperatures; hydrocarbon systems for gas tankers; sorption systems for part of the cooling load	Hydrocarbon, liquid CO_2; with unknown systems for liquefaction/freezing: liquid CO_2, ice slurry; with on-board HCFC/HFC refrigeration systems: Eutectic plates	Solid CO_2 (with unknown systems for freezing)	HFC-134a, HCFC-22
Low GWP technologies with fair or better than fair potential for replacement of HCFC/HFC in the markets		Ammonia, CO_2 /ammonia for low temperatures	Hydrocarbon, CO_2 compression systems; for short haul combination of stationary hydrocarbon or ammonia with liquid CO_2, ice slurry or eutectic plates	Hydrocarbon, CO_2 compression systems; for specific transports (certain fruits, ...) combination of stationary hydrocarbon or ammonia with liquid CO_2, ice slurry or eutectic plates	CO_2 compression system
Status of alternatives		Fully developed. Some cost issues related to additional safety for ammonia plants on ships. Hydrocarbon practical mainly for ships which are built according to explosion-proof standards (gas carriers, ...)	Hydrocarbon mini-series successfully field tested, lack of demand/add. requirements on utilization (driver training, parking, ...). Liquid CO_2 systems commercialized. CO_2 compression tested in prototypes, but open compressor needed for most systems in combination with leaks remains an issue	Solid CO_2 standard use, but not very energy efficient, difficult handling, high infrastructure requirements, therefore presently being phased out. Increasingly use of systems designed for trailer use with optimization for rail requirements (shock resistance, ...)	Under development – prototype testing; might be available in the near future if demanded

nology is equipment with ammonia or ammonia/CO_2 systems. These systems are likely to operate at least as energy efficiently as existing systems. One source (SCANVAC, 2001) estimates the additional costs for a ship-bound ammonia system to be 20–30% higher if retrofitted into an existing vessel and potentially lower if included in the ships planning from the start. Another source (Nielsen and Lund, 2003) assumes that small industrial ammonia/CO_2 systems might be more expensive than conventional systems, but large systems might have a more or less equivalent price for the same capacity.

In the case of container systems, CO_2 in a vapour compression cycle could develop into a promising alternative. The costs for the refrigeration system might be higher than for current conventional systems. The energy consumption will probably be higher if the containers are only air-cooled but if additional water-cooling is installed, as has already implemented on some vessels, the systems could be energetically as good as or even better than existing equipment.

Options using CO_2 and hydrocarbons exist for road transport. The hydrocarbon technology is technically implementable within a short time frame. For larger systems, CO_2 systems or hydrocarbon refrigerants are potential options, depending on the safety issues. The same alternatives could be used for new railway systems. Certain types of refrigerated road transport, such as short-range distribution trucks, might use discontinuous systems with evaporating CO_2 or nitrogen as alternative.

As transport refrigeration systems have very significant emissions and a limited runtime, which is typically far below

100%, direct emissions play a very important role in the calculation of the TEWI. The replacement options currently being considered by manufacturers do not significantly increase transport weight or volume. The data is sufficient to state that in several applications, a substantial reduction in TEWI could be achieved by introducing a low GWP technology.

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CLIMATE CHANGE 1995

The Science of Climate Change

WMO

Contribution of Working Group I
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Intergovernmental Panel on Climate Change

UNEP

Table 4: *Global Warming Potential referenced to the updated decay response for the Bern carbon cycle model and future CO_2 atmospheric concentrations held constant at current levels.*

Species	**Chemical Formula**	**Lifetime (years)**	**Global Warming Potential (Time Horizon)**		
			20 years	**100 years**	**500 years**
CO_2	CO_2	variable§	1	1	1
Methane*	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170
HFC-23	CHF_3	264	9,100	11,700	9,800
HFC-32	CH_2F_2	5.6	2,100	650	200
HFC-41	CH_3F	3.7	490	150	45
HFC-43-10mee	$C_5H_2F_{10}$	17.1	3,000	1,300	400
HFC-125	C_2HF_5	32.6	4,600	2,800	920
HFC-134	$C_2H_2F_4$	10.6	2,900	1,000	310
HFC-134a	CH_2FCF_3	14.6	3,400	1,300	420
HFC-152a	C_2H4F_2	1.5	460	140	42
HFC-143	$C_2H_3F_3$	3.8	1,000	300	94
HFC-143a	$C_2H_3F_3$	48.3	5,000	3,800	1,400
HFC-227ea	C_3HF_7	36.5	4,300	2,900	950
HFC-236fa	$C_3H_2F_6$	209	5,100	6,300	4,700
HFC-245ca	$C_3H_3F_5$	6.6	1,800	560	170
Sulphur hexafluoride	SF_6	3,200	16,300	23,900	34,900
Perfluoromethane	CF_4	50,000	4,400	6,500	10,000
Perfluoroethane	C_2F_6	10,000	6,200	9,200	14,000
Perfluoropropane	C_3F_8	2,600	4,800	7,000	10,100
Perfluorobutane	C_4F_{10}	2,600	4,800	7,000	10,100
Perfluorocyclobutane	$c\text{–}C_4F_8$	3,200	6,000	8,700	12,700
Perfluoropentane	C_5F_{12}	4,100	5,100	7,500	11,000
Perfluorohexane	C_6F_{14}	3,200	5,000	7,400	10,700
Ozone-depleting substances†	e.g., CFCs and HCFCS				

§ Derived from the Bern carbon cycle model.

* The GWP for methane includes indirect effects of tropospheric ozone production and stratospheric water vapour production, as in IPCC (1994). The updated adjustment time for methane is discussed in Section B.2.

† The Global Warming Potentials for ozone-depleting substances (including all CFCs, HCFCs and halons, whose direct GWPs have been given in previous reports) are a sum of a direct (positive) component and an indirect (negative) component which depends strongly upon the effectiveness of each substance for ozone destruction. Generally, the halons are likely to have negative net GWPs, while those of the CFCs are likely to be positive over both 20- and 100-year time horizons (see Chapter 2, Table 2.8).

4

Atmospheric Chemistry and Greenhouse Gases

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Contents

Executive Summary

Two important new findings since the IPCC WGI Second Assessment Report (IPCC, 1996) (hereafter SAR) demonstrate the importance of atmospheric chemistry in controlling greenhouse gases:

Currently, tropospheric ozone (O_3) is the third most important greenhouse gas after carbon dioxide (CO_2) and methane (CH_4). It is a product of photochemistry, and its future abundance is controlled primarily by emissions of CH_4, carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOC). There is now greater confidence in the model assessment of the increase in tropospheric O_3 since the pre-industrial period, which amounts to 30% when globally averaged, as well as the response to future emissions. For scenarios in which the CH_4 abundance doubles and anthropogenic CO and NO_x emissions triple, the tropospheric O_3 abundance is predicted to increase by an additional 50% above today's abundance.

CO is identified as an important indirect greenhouse gas. An addition of CO to the atmosphere perturbs the OH-CH_4-O_3 chemistry. Model calculations indicate that the emission of 100 Mt of CO stimulates an atmospheric chemistry perturbation that is equivalent to direct emission of about 5 Mt of CH_4.

A major conclusion of this report is that atmospheric abundances of almost all greenhouse gases reached the highest values in their measurement records during the 1990s:

The atmospheric abundance of CH_4 continues to increase, from about 1,520 ppb in 1978 to 1,745 ppb in 1998. However, the observed annual increase in CH_4 has declined during the last two decades. This increase is highly variable; it was near zero in 1992 and as large as +13 ppb during 1998. There is no clear, quantitative explanation for this variability. Since the SAR, quantification of certain anthropogenic sources of CH_4, such as that from rice production, has improved.

The atmospheric burden of nitrous oxide (N_2O) continues to increase by about 0.25%/yr. New, higher estimates of emissions from agricultural sources improve our understanding of the global N_2O budget.

The atmospheric abundances of major greenhouse gases that deplete stratospheric ozone are decreasing (CFC-11, CFC-113, CH_3CCl_3, CCl_4), or increasing more slowly (CFC-12), in response to the phase-out in their production agreed to under the Montreal Protocol and its Amendments.

HFC-152a and HFC-134a are increasing in the atmosphere. This growth is consistent with the rise in their industrial use. HFC-23, an unintended by-product of HCFC-22 production, is also increasing.

Perfluorocarbon (PFC) e.g., CF_4 (perfluoromethane) appears to have a natural background; however, current anthropogenic emissions exceed natural ones by a factor of 1,000 or more and are responsible for the observed increase.

There is good agreement between the increase in atmospheric abundances of sulphur hexafluoride (SF_6) and emissions estimates based on revised sales and storage data.

There has been little increase in global tropospheric O_3 since the 1980s at the few remote locations where it is regularly measured. Only two of the fourteen stations, one in Japan and one in Europe, had statistically significant increases in tropospheric O_3 between 1980 and 1995. By contrast, the four Canadian stations, all at high latitudes, had significant decreases in tropospheric O_3 for the same time period. However, limited observations from the late 19th and early 20th centuries combined with models suggest that tropospheric O_3 has increased from a global mean value of 25 DU (where 1 DU = 2.7×10^{16} O_3 molecules/cm^2) in the pre-industrial era to 34 DU today. While the SAR estimated similar values, the new analysis provides more confidence in this increase of 9 DU.

Changes in atmospheric composition and chemistry over the past century have affected, and those projected into the future will affect, the lifetimes of many greenhouse gases and thus alter the climate forcing of anthropogenic emissions:

The atmospheric lifetime relates emissions of a component to its atmospheric burden. In some cases, for instance for methane, a change in emissions perturbs the chemistry and thus the corresponding lifetime. The CH_4 feedback effect amplifies the climate forcing of an addition of CH_4 to the current atmosphere by lengthening the perturbation lifetime relative to the global atmospheric lifetime of CH_4 by a factor of 1.4. This earlier finding is corroborated here by new model studies that also predict only small changes in this CH_4 feedback for the different scenarios projected to year 2100. Another feedback has been identified for the addition of N_2O to the atmosphere; it is associated with stratospheric O_3 chemistry and shortens the perturbation lifetime relative to the global atmospheric lifetime of N_2O by about 5%.

Several chemically reactive gases – CO, NO_x (=NO+NO_2), and VOC – control in part the abundance of O_3 and the oxidising capacity (OH) of the troposphere. These pollutants act as indirect greenhouse gases through their influence on atmospheric chemistry, e.g., formation of tropospheric O_3 or changing the lifetime of CH_4. The emissions of NO_x and CO are dominated by human activities. The abundance of CO in the Northern Hemisphere is about twice that in the Southern Hemisphere and has increased in the second half of the 20th century along with industrialisation and population. The urban and regional abundance of NO_x has generally increased with industrialisation, but the global abundance of this short-lived, highly variable pollutant cannot be derived from measurements. Increased NO_x abundances will in general increase tropospheric O_3 and decrease CH_4. Deposition of NO_x reaction products fertilises the biosphere, stimulates CO_2 uptake, but also provides an input of acidic precipitation.

The IPCC Special Report on Emission Scenarios (SRES) generated six marker/illustrative scenarios (labelled A1B, A1T, A1FI, A2, B1, B2) plus four preliminary marker scenarios (labelled here A1p, A2p, B1p, and B2p). These projected changes in anthropogenic emissions of trace gases from year 2000 to year 2100, making different assumptions on population development, energy use, and technology. Results from both sets of scenarios are discussed here since the preliminary marker scenarios (December 1998) were used in this report:

Model calculations of the abundances of the primary greenhouse gases by year 2100 vary considerably across the SRES scenarios: in general A1B, A1T, and B1 have the smallest increases of emissions and burdens; and A1FI and A2 the largest. CH_4 changes from 1998 to 2100 range from −10 to +115%; and N_2O increases from 13 to 47%. The HFCs – 134a, 143a, and 125 – reach abundances of a few hundred to nearly a thousand ppt from negligible levels today. The PFC CF_4 is projected to increase to between 200 and 400 ppt; and SF_6 to between 35 and 65 ppt.

SRES projected anthropogenic emissions of the indirect greenhouse gases (NO_x, CO and VOC) together with changes in CH_4 are expected to change the global mean abundance of tropospheric OH by −20 to +6% over the next century. Comparable, but opposite sign, changes occur in the atmospheric lifetimes of the greenhouse gases, CH_4 and HFCs. This impact depends in large part on the magnitude of, and the balance between, NO_x and CO emissions.

For the SRES scenarios, changes in tropospheric O_3 between years 2000 and 2100 range from −4 to +21 DU. The largest increase predicted for the 21st century (scenarios A1FI and A2) would be more than twice as large as that experienced since the pre-industrial era. These O_3 increases are attributable to the concurrent, large (almost factor of 3) increases in anthropogenic NO_x and CH_4 emissions.

The large growth in emissions of greenhouse gases and other pollutants as projected in some SRES scenarios for the 21st century will degrade the global environment in ways beyond climate change:

Changes projected in the SRES A2 and A1FI scenarios would degrade air quality over much of the globe by increasing background levels of O_3. In northern mid-latitudes during summer, the zonal average increases near the surface are about 30 ppb or more, raising background levels to nearly 80 ppb, threatening attainment of air quality standards over most metropolitan and even rural regions, and compromising crop and forest productivity. This problem reaches across continental boundaries since emissions of NO_x influence photochemistry on a hemispheric scale.

A more complete and accurate assessment of the human impact on greenhouse gases requires greater understanding of sources, processes, and coupling between different parts of the climate system:

The current assessment is notably incomplete in calculating the total impact of individual industrial / agricultural sectors on greenhouse gases and aerosols. The IPCC Special Report on Aviation demonstrates that the total impact of a sector is not represented by (nor scalable to) the direct emissions of primary greenhouse gases alone, but needs to consider a wide range of atmospheric changes.

The ability to hindcast the detailed changes in atmospheric composition over the past decade, particularly the variability of tropospheric O_3 and CO, is limited by the availability of measurements and their integration with models and emissions data. Nevertheless, since the SAR there have been substantial advances in measurement techniques, field campaigns, laboratory studies, global networks, satellite observations, and coupled models that have improved the level of scientific understanding of this assessment. Better simulation of the past two decades, and in due course the upcoming one, would reduce uncertainty ranges and improve the confidence level of our projections of greenhouse gases.

Feedbacks between atmospheric chemistry, climate, and the biosphere were not developed to the stage that they could be included in the projected numbers here. Failure to include such coupling is likely to lead to systematic errors and may substantially alter the projected increases in the major greenhouse gases.

4.1 Introduction

This chapter investigates greenhouse gases whose atmospheric burdens[1] and climate impacts generally depend on atmospheric chemistry. These greenhouse gases include those listed in the Kyoto Protocol – methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) – and those listed under the Montreal Protocol and its Amendments – the chlorofluorocarbons (CFCs), the hydrochlorofluorocarbons (HCFCs), and the halons. A major focus of this assessment is the change in tropospheric ozone (O_3). Stratospheric water vapour (H_2O) is also treated here, but tropospheric H_2O, which is part of the hydrological cycle and calculated within climate models, is not discussed. This chapter also treats the reactive gases carbon monoxide (CO), volatile organic compounds (VOC), and nitrogen oxides (NO_x = $NO+NO_2$), termed indirect greenhouse gases. These pollutants are not significant direct greenhouse gases, but through atmospheric chemistry they control the abundances[1] of direct greenhouse gases. This chapter reviews the factors controlling the current atmospheric abundances of direct and indirect greenhouse gases; it looks at the changes since the pre-industrial era and their attribution to anthropogenic activities; and it calculates atmospheric abundances to the year 2100 based on projected emissions of greenhouse gases and pollutants. Carbon dioxide (CO_2) is treated in Chapter 3; and aerosols in Chapter 5. The atmospheric abundances of greenhouse gases and aerosols from all chapters are combined in Chapter 6 to calculate current and future radiative forcing. This chapter is an update of the IPCC WGI Second Assessment Report (IPCC, 1996) (hereafter SAR). For a review of the chemical processes controlling the abundance of greenhouse gases see the SAR (Prather *et al.*, 1995) or Ehhalt (1999). More recent assessments of changing atmospheric chemistry and composition include the IPCC Special Report on Aviation and the Global Atmosphere (Penner *et al.*, 1999) and the World Meteorological Organization / United Nations Environmental Programme (WMO/UNEP) Scientific Assessment of Ozone Depletion (WMO, 1999).

4.1.1 Sources of Greenhouse Gases

Substantial, pre-industrial abundances for CH_4 and N_2O are found in the tiny bubbles of ancient air trapped in ice cores. Both gases have large, natural emission rates, which have varied over past climatic changes but have sustained a stable atmospheric abundance for the centuries prior to the Industrial Revolution (see Figures 4.1 and 4.2). Emissions of CH_4 and N_2O due to human activities are also substantial and have caused large relative increases in their respective burdens over the last century. The atmospheric burdens of CH_4 and N_2O over the next century will likely be driven by changes in both anthropogenic and natural sources. A second class of greenhouse gases – the synthetic HFCs, PFCs, SF_6, CFCs, and halons – did not exist in the atmosphere before the 20th century (Butler *et al.*, 1999). CF_4, a PFC, is detected in ice cores and appears to have an extremely small natural source (Harnisch and Eisenhauer, 1998). The current burdens of these latter gases are derived from atmospheric observations and represent accumulations of past anthropogenic releases; their future burdens depend almost solely on industrial production and release to the atmosphere. Stratospheric H_2O could increase, driven by *in situ* sources, such as the oxidation of CH_4 and exhaust from aviation, or by a changing climate.

Tropospheric O_3 is both generated and destroyed by photochemistry within the atmosphere. Its *in situ* sources are expected to have grown with the increasing industrial emissions of its precursors: CH_4, NO_x, CO and VOC. In addition, there is substantial transport of ozone from the stratosphere to the troposphere (see also Section 4.2.4). The effects of stratospheric O_3 depletion over the past three decades and the projections of its recovery, following cessation of emissions of the Montreal Protocol gases, was recently assessed (WMO, 1999).

The current global emissions, mean abundances, and trends of the gases mentioned above are summarised in Table 4.1a. Table 4.1b lists additional synthetic greenhouse gases without established atmospheric abundances. For the Montreal Protocol gases, political regulation has led to a phase-out of emissions that has slowed their atmospheric increases, or turned them into decreases, such as for CFC-11. For other greenhouse gases, the anthropogenic emissions are projected to increase or remain high in the absence of climate-policy regulations. Projections of future emissions for this assessment, i.e., the IPCC Special Report on Emission Scenarios (SRES) (Nakićenović *et al.*, 2000) anticipate future development of industries and agriculture that represent major sources of greenhouse gases in the absence of climate-policy regulations. The first draft of this chapter and many of the climate studies in this report used the greenhouse gas concentrations derived from the SRES preliminary marker scenarios (i.e., the SRES database as of January 1999 and labelled ‘p’ here). The scenario IS92a has been carried along in many tables to provide a reference of the changes since the SAR. The projections of greenhouse gases and aerosols for the six new SRES marker/illustrative scenarios are discussed here and tabulated in Appendix II.

An important policy issue is the complete impact of different industrial or agricultural sectors on climate. This requires aggregation of the SRES scenarios by sector (e.g., transportation) or sub-sector (e.g., aviation; Penner *et al.*, 1999), including not only emissions but also changes in land use or natural ecosystems. Due to chemical coupling, correlated emissions can have synergistic effects; for instance NO_x and CO from transportation produce regional O_3 increases. Thus a given sector may act through several channels on the future trends of greenhouse gases. In this chapter we will evaluate the data available on this subject in the current literature and in the SRES scenarios.

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[1] Atmospheric *abundances* for trace gases are reported here as the mole fraction (molar mixing ratio) of the gas relative to dry air (ppm = 10^{-6}, ppb = 10^{-9}, ppt = 10^{-12}); whereas the *burden* is reported as the total mass of that gas in the atmosphere (e.g., Mt = Tg = 10^{12} g). For most trace gases in this chapter, the burden is based on the total weight of the molecule; for the N-containing gases, it includes only the mass of the N; and for some VOC budgets where noted, it includes only the mass of the C.

Table 4.1(a): *Chemically reactive greenhouse gases and their precursors: abundances, trends, budgets, lifetimes, and GWPs.*

Chemical species	**Formula**	**Abundance [a] ppt** 1998	1750	**Trend ppt/yr [a]** 1990s	**Annual emission** late 90s	**Life-time** (yr)	**100-yr GWP[b]**
Methane	CH_4(ppb)	1745	700	7.0	600 Tg	8.4/12 [c]	23
Nitrous oxide	N_2O (ppb)	314	270	0.8	16.4 TgN	120/114 [c]	296
Perfluoromethane	CF_4	80	40	1.0	~15 Gg	>50000	5700
Perfluoroethane	C_2F_6	3.0	0	0.08	~2 Gg	10000	11900
Sulphur hexafluoride	SF_6	4.2	0	0.24	~6 Gg	3200	22200
HFC-23	CHF_3	14	0	0.55	~7 Gg	260	12000
HFC-134a	CF_3CH_2F	7.5	0	2.0	~25 Gg	13.8	1300
HFC-152a	CH_3CHF_2	0.5	0	0.1	~4 Gg	1.40	120
Important greenhouse halocarbons under Montreal Protocol and its Amendments							
CFC-11	$CFCl_3$	268	0	–1.4		45	4600
CFC-12	CF_2Cl_2	533	0	4.4		100	10600
CFC-13	CF_3Cl	4	0	0.1		640	14000
CFC-113	$CF_2ClCFCl_2$	84	0	0.0		85	6000
CFC-114	CF_2ClCF_2Cl	15	0	<0.5		300	9800
CFC-115	CF_3CF_2Cl	7	0	0.4		1700	7200
Carbon tetrachloride	CCl_4	102	0	–1.0		35	1800
Methyl chloroform	CH_3CCl_3	69	0	–14		4.8	140
HCFC-22	CHF_2Cl	132	0	5		11.9	1700
HCFC-141b	CH_3CFCl_2	10	0	2		9.3	700
HCFC-142b	CH_3CF_2Cl	11	0	1		19	2400
Halon-1211	CF_2ClBr	3.8	0	0.2		11	1300
Halon-1301	CF_3Br	2.5	0	0.1		65	6900
Halon-2402	CF_2BrCF_2Br	0.45	0	~ 0		<20	
Other chemically active gases dirctly or indirectly affecting radiative forcing							
Tropospheric ozone	O_3 (DU)	34	25	?	see text	0.01-0.05	–
Tropospheric NO_x	$NO + NO_2$	5-999	?	?	~52 TgN	<0.01-0.03	–
Carbon monoxide	CO (ppb) [d]	80	?	6	~2800 Tg	0.08 - 0.25	[d]
Stratospheric water	H_2O (ppm)	3-6	3-5	?	see text	1-6	–

[a] All abundances are tropospheric molar mixing ratios in ppt (10^{-12})and trends are in ppt/yr unless superseded by units on line (ppb = 10^{-9}, ppm = 10^{-6}). Where possible, the 1998 values are global, annual averages and the trends are calculated for 1996 to 1998.

[b] GWPs are from Chapter 6 of this report and refer to the 100-year horizon values.

[c] Species with chemical feedbacks that change the duration of the atmospheric response; global mean atmospheric lifetime (LT) is given first followed by perturbation lifetime (PT). Values are taken from the SAR (Prather *et al.*, 1995; Schimel *et al.*, 1996) updated with WMO98 (Kurylo and Rodriguez, 1999; Prinn and Zander, 1999) and new OH-scaling, see text. Uncertainties in lifetimes have not changed substantially since the SAR.

[d] CO trend is very sensitive to the time period chosen. The value listed for 1996 to 1998, +6 ppb/yr, is driven by a large increase during 1998. For the period 1991 to 1999, the CO trend was –0.6 ppb/yr. CO is an indirect greenhouse gas: for comparison with CH_4 see this chapter; for GWP, see Chapter 6.

Table 4.1(b): *Additional synthetic greenhouse gases.*

Chemical species	Formula	Lifetime (yr)	GWP [b]
Perfluoropropane	C_3F_8	2600	8600
Perfluorobutane	C_4F_{10}	2600	8600
Perfluorocyclobutane	C_4F_8	3200	10000
Perfluoropentane	C_5F_{12}	4100	8900
Perfluorohexane	C_6F_{14}	3200	9000
Trifluoromethyl-sulphur pentafluoride	SF_5CF_3	1000	17500
Nitrogen trifluoride	NF_3	>500	10800
Trifluoroiodomethane	CF_3I	<0.005	1
HFC-32	CH_2F_2	5.0	550
HFC-41	CH_3F	2.6	97
HFC-125	CHF_2CF_3	29	3400
HFC-134	CHF_2CHF_2	9.6	1100
HFC-143	CH_2FCHF_2	3.4	330
HFC-143a	CH_3CF_3	52	4300
HFC-152	CH_2FCH_2F	0.5	43
HFC-161	CH_3CH_2F	0.3	12
HFC-227ea	CF_3CHFCF_3	33	3500
HFC-236cb	$CF_3CF_2CH_2F$	13.2	1300
HFC-236ea	$CF_3CHFCHF_2$	10.0	1200
HFC-236fa	$CF_3CH_2CF_3$	220	9400
HFC-245ca	$CH_2FCF_2CHF_2$	5.9	640
HFC-245ea	$CHF_2CHFCHF_2$	4.0	
HFC-245eb	CF_3CHFCH_2F	4.2	
HFC-245fa	$CHF_2CH_2CF_3$	7.2	950
HFC-263fb	$CF_3CH_2CH_3$	1.6	
HFC-338pcc	$CHF_2CF_2CF_2CF_2H$	11.4	
HFC-356mcf	$CF_3CF_2CH_2CH_2F$	1.2	
HFC-356mff	$CF_3CH_2CH_2CF_3$	7.9	
HFC-365mfc	$CF_3CH_2CF_2CH_3$	9.9	890
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15	1500
HFC-458mfcf	$CF_3CH_2CF_2CH_2CF_3$	22	
HFC-55-10mcff	$CF_3CF_2CH_2CH_2CF_2CF_3$	7.7	
HFE-125	CF_3OCHF_2	150	14900
HFE-134	CF_2HOCF_2H	26	2400
HFE-143a	CF_3OCH_3	4.4	750
HFE-152a	CH_3OCHF_2	1.5	
HFE-245fa2	$CHF_2OCH_2CF_3$	4.6	570
HFE-356mff2	$CF_3CH_2OCH_2CF_3$	0.4	

4.1.2 Atmospheric Chemistry and Feedbacks

All greenhouse gases except CO_2 and H_2O are removed from the atmosphere primarily by chemical processes within the atmosphere. Greenhouse gases containing one or more H atoms (e.g., CH_4, HFCs and HCFCs), as well as other pollutants, are removed primarily by the reaction with hydroxyl radicals (OH). This removal takes place in the troposphere, the lowermost part of the atmosphere, ranging from the surface up to 7 to 16 km depending on latitude and season and containing 80% of the mass of the atmosphere. The greenhouse gases N_2O, PFCs, SF_6, CFCs and halons do not react with OH in the troposphere. These gases are destroyed in the stratosphere or above, mainly by solar ultraviolet radiation (UV) at short wavelengths (<240 nm), and are long-lived. Because of the time required to transport these gases to the region of chemical loss, they have a minimum lifetime of about 20 years. CO_2 is practically inert in the atmosphere and does not directly influence the chemistry, but it has a small *in situ* source from the oxidation of CH_4, CO and VOC.

Tropospheric OH abundances depend on abundances of NO_x, CH_4, CO, VOC, O_3 and H_2O plus the amount of solar UV (>300 nm) that reaches the troposphere. As a consequence, OH varies widely with geographical location, time of day, and season. Likewise the local loss rates of all those gases reacting with OH also vary. Because of its dependence on CH_4 and other pollutants, tropospheric OH is expected to have changed since the pre-industrial era and to change again for future emission scenarios. For some of these gases other removal processes, such as photolysis or surface uptake, are also important; and the total sink of the gas is obtained by integrating over all such processes. The chemistry of tropospheric O_3 is closely tied to that of OH, and its abundance also varies with changing precursor emissions. The chemistry of the troposphere is also directly influenced by the stratospheric burden of O_3, climatic changes in temperature (T) and humidity (H_2O), as well as by interactions between tropospheric aerosols and trace gases. Such couplings provide a "feedback" between the climate change induced by increasing greenhouse gases and the concentration of these gases. Another feedback, internal to the chemistry, is the impact of CH_4 on OH and hence its own loss. These feedbacks are expected to be important for tropospheric O_3 and OH. Such chemistry-chemistry or climate-chemistry coupling has been listed under "indirect effects" in the SAR (Prather *et al.*, 1995; Schimel *et al.*, 1996).

This chapter uses 3-D chemistry-transport models (CTMs) to integrate the varying chemical processes over global conditions, to estimate their significance, and to translate the emission scenarios into abundance changes in the greenhouse gases CH_4, HFCs, and O_3. An extensive modelling exercise called OxComp (tropospheric oxidant model comparison) – involving model comparisons, sensitivity studies, and investigation of the IPCC SRES scenarios – was organised to support this report.

Stratospheric circulation and distribution of O_3 control the transport of the long-lived greenhouse gases to regions of photochemical loss as well as the penetration of solar UV into the atmosphere. At the same time, many of these gases (e.g., N_2O and CFCs) supply ozone-depleting radicals (e.g., nitric oxide (NO) and Cl) to the stratosphere, providing a feedback between the gas and its loss rate. Another consequence of the observed stratospheric ozone depletion is that tropospheric photochemical activity is expected to have increased, altering tropospheric OH and O_3. Climate change in the 21st century, including the radiative cooling of the stratosphere by increased levels of CO_2, is expected to alter stratospheric circulation and O_3, and, hence, the global mean loss rates of the long-lived gases. Some of these effects are discussed in WMO (1999) and are briefly considered here.

The biosphere's response to global change will impact the atmospheric composition of the 21st century. The anticipated changes in climate (e.g., temperature, precipitation) and in chemistry will alter ecosystems and thus the "natural", background emissions of trace gases. There is accumulating evidence that increased N deposition (the result of NO_x and ammonia (NH_3) emissions) and elevated surface O_3 abundances have opposite influences on plant CO_2 uptake: O_3 (>40 ppb) inhibits CO_2 uptake; while N deposition enhances it up to a threshold, above which the effects are detrimental. In addition, the increased N availability from atmospheric deposition and direct fertilisation accelerates the emission of N-containing trace gases (NO, N_2O and NH_3) and CH_4, as well as altering species diversity and biospheric functioning. These complex interactions represent a chemistry-biosphere feedback that may alter greenhouse forcing.

4.1.3 Trace Gas Budgets and Trends

The "budget" of a trace gas consists of three quantities: its global source, global sink and atmospheric burden. The burden is defined as the total mass of the gas integrated over the atmosphere and related reservoirs, which usually include just the troposphere and stratosphere. The global burden (in Tg) and its trend (i.e., the difference between sources and sinks, in Tg/yr) can be determined from atmospheric measurements and, for the long-lived gases, are usually the best-known quantities in the budgets. For short-lived, highly variable gases such as tropospheric O_3 and NO_x, the atmospheric burden cannot be measured with great accuracy. The global source strength is the sum of all sources, including emissions and *in situ* chemical production. Likewise, the sink strength (or global loss rate) can have several independent components.

The source strength (Tg/yr) for most greenhouse gases is comprised of surface emissions. For synthetic gases where industrial production and emissions are well documented, the source strengths may be accurately known. For CH_4 and N_2O, however, there are large, not well-quantified, natural emissions. Further, the anthropogenic emissions of these gases are primarily associated with agricultural sources that are difficult to quantify accurately. Considerable research has gone into identifying and quantifying the emissions from individual sources for CH_4 and N_2O, as discussed below. Such uncertainty in source strength also holds for synthetic gases with undocumented emissions. The source strength for tropospheric O_3 includes both a stratospheric influx and *in situ* production and is thus derived primarily from global chemical models.

The sink strength (Tg/yr) of long-lived greenhouse gases can be derived from a combination of atmospheric observations, laboratory experiments, and models. The atmospheric chemistry models are based on physical principles and laboratory data, and include as constraints the observed chemistry of the atmosphere over the past two decades. For example, stratospheric loss rates are derived from models either by combining observed trace gas distributions with theoretically calculated loss frequencies or from the measured correlation of the respective gas with a trace gas of known vertical flux. In such analyses there are a wide range of self-consistency checks. Mean global loss rates based on *a priori* modelling (e.g., the CH_4-lifetime studies from OxComp described later) can be compared with empirically-based loss rates that are scaled from a gas with similar loss processes that has well-known emissions and atmospheric burden (e.g., the AGAGE (Advanced Global Atmospheric Gases Experiment) calibration of mean tropospheric OH using methyl chloroform (CH_3CCl_3); Prinn *et al.*, 1995). Our knowledge of the current budget of a greenhouse gas provides a key constraint in modelling its future abundance. For example, in both the IS92a and SRES projected emissions of CH_4 and N_2O, we apply a constant offset to each set of emissions so that our calculated burden is consistent with the observed budget and trend during the 1990s.

4.1.4 Atmospheric Lifetimes and Time-Scales

The global atmospheric lifetime (yr) characterises the time required to turn over the global atmospheric burden. It is defined as the burden (Tg) divided by the mean global sink (Tg/yr) for a gas in steady state (i.e., with unchanging burden). This quantity was defined as both "lifetime" and "turnover time" in the SAR (see also Bolin and Rodhe, 1973). Lifetimes calculated in this manner are listed in Table 4.1. A corollary of this definition is that, when in steady state (i.e., source strength = sink strength), the atmospheric burden of a gas equals the product of its lifetime and its emissions. A further corollary is that the integrated atmospheric abundance following a single emission is equal to the product of its steady-state lifetime for that emission pattern and the amount emitted (Prather, 1996). This latter, new result since the SAR supports the market-basket approach of aggregating the direct emissions of different greenhouse gases with a GWP (Global Warming Potential) weighting.

The atmospheric lifetime is basically a scale factor relating (i) constant emissions (Tg/yr) to a steady-state burden (Tg), or (ii) an emission pulse (Tg) to the time-integrated burden of that pulse (Tg/yr). The lifetime is often additionally assumed to be a constant, independent of the sources; and it is also taken to represent the decay time (e-fold) of a perturbation. These latter assumptions apply rigorously only for a gas whose local chemical lifetime is constant in space and time, such as for the noble gas radon, whose lifetime is fixed by the rate of its radioactive decay. In such a case the mean atmospheric lifetime equals the local lifetime: the lifetime that relates source strength to global burden is exactly the decay time of a perturbation.

This general applicability of the atmospheric lifetime breaks down for those greenhouse gases and pollutants whose chemical losses vary in space and time. NO_x, for instance, has a local lifetime of <1 day in the lower troposphere, but >5 days in the upper troposphere; and both times are less than the time required for vertical mixing of the troposphere. In this case emission of NO_x into the upper troposphere will produce a larger atmospheric burden than the same emission into the lower troposphere. Consequently, the definition of the atmospheric lifetime of NO_x is not unique and depends on the location (and season) of its emissions. The same is true for any gas whose local lifetime is variable and on average shorter than about 0.5 year, i.e., the decay time of a north-south difference between hemispheres representing one of the longer time-scales for tropospheric mixing. The majority of greenhouse gases considered here have atmospheric lifetimes greater than 2 years, much longer than tropospheric mixing times; and hence their lifetimes are not significantly altered by the location of sources within the troposphere. When lifetimes are reported for gases in Table 4.1, it is assumed that the gases are uniformly mixed throughout the troposphere. This assumption is unlikely for gases with lifetimes <1 year, and reported values must be viewed only as approximations.

Some gases have chemical feedbacks that change their lifetimes. For example, the increasing CH_4 abundance leads to a longer lifetime for CH_4 (Prather *et al.*, 1995; Schimel *et al.*, 1996). A chemical feedback with opposite effect has been identified for N_2O where a greater N_2O burden leads to increases in stratospheric NO_x which in turn depletes mid-stratospheric ozone. This ozone loss enhances the UV, and as a consequence N_2O is photolysed more rapidly (Prather, 1998). Such feedbacks cause the time-scale of a perturbation, henceforth called perturbation lifetime (*PT*), to differ from the global atmospheric lifetime (*LT*). In the limit of small perturbations, the relation between the perturbation lifetime of a gas and its global atmospheric lifetime can be derived from a simple budget relationship as $PT = LT / (1 - s)$, where the sensitivity coefficient $s = \partial ln(LT) / \partial ln(B)$ and B = burden. Without a feedback on lifetime, $s = 0$, and *PT* is identical to *LT*. The product, *PT* times a sustained change in emission, gives the resulting change in the burden. The ratio of *PT/LT* adopted here for CH_4, 1.4, is based on recent model studies (see Section 4.4) and is consistent with the SAR results.

To evaluate the total greenhouse effect of a given gas molecule, one needs to know, first, how long it remains in the atmosphere and, second, how it interacts chemically with other molecules. This effect is calculated by injecting a pulse of that gas (e.g., 1 Tg) into the atmosphere and watching the added abundance decay as simulated in a CTM. This decay is represented by a sum of exponential functions, each with its own decay time. These exponential functions are the chemical modes of the linearised chemistry-transport equations of the CTM (Prather, 1996). In the case of a CH_4 addition, the longest-lived mode has an e-fold time of 12 years, close to the perturbation lifetime (*PT*) of CH_4, and carries most of the added burden. (This e-fold time was called the adjustment time in the SAR.) In the case of a CO addition, this same mode is also excited, but at a reduced amplitude (Prather, 1996; Daniel and Solomon, 1998). The pulse of added CO, by causing the concentration of OH to decrease and thus the lifetime of CH_4 to increase temporarily, causes a build-up of CH_4 while the added burden of CO persists. After the initial period of a few months defined by the CO photochemical lifetime, this built-up CH_4 then decays in the same manner as would a direct pulse of CH_4. Similarly, an addition of NO_x (e.g., from aviation; see Isaksen and Jackman, 1999) will excite this mode, but with a negative amplitude. Thus, changes in the emissions of short-lived gases can generate long-lived perturbations as shown in 3-D CTMs (Wild and Prather, 2000; Derwent *et al.*, 2001). Changes in tropospheric O_3 accompany the CH_4 decay on a 12 year time-scale as an inherent component of this mode, a key example of chemical coupling in the troposphere. Thus, any chemically reactive gas, whether a greenhouse gas or not, will produce some level of indirect greenhouse effect through its impact on atmospheric chemistry.

4.2 Trace Gases: Current Observations, Trends, and Budgets

4.2.1 Non-CO_2 Kyoto Gases

4.2.1.1 Methane (CH_4)

Methane's globally averaged atmospheric surface abundance in 1998 was 1,745 ppb (see Figure 4.1), corresponding to a total burden of about 4,850 Tg(CH_4). The uncertainty in the burden is small (±5%) because the spatial and temporal distributions of tropospheric and stratospheric CH_4 have been determined by extensive high-precision measurements and the tropospheric variability is relatively small. For example, the Northern Hemisphere CH_4 abundances average about 5% higher than those in the Southern Hemisphere. Seasonal variations, with a minimum in late summer, are observed with peak-to-peak amplitudes of about 2% at mid-latitudes. The average vertical gradient in the troposphere is negligible, but CH_4 abundances in the stratosphere decrease rapidly with altitude, e.g., to 1,400 ppb at 30 km altitude in the tropics and to 500 ppb at 30 km in high latitude northern winter.

The most important known sources of atmospheric methane are listed in Table 4.2. Although the major source terms of atmospheric CH_4 have probably been identified, many of the source strengths are still uncertain due to the difficulty in assessing the global emission rates of the biospheric sources, whose strengths are highly variable in space and time: e.g., local emissions from most types of natural wetland can vary by a few orders of magnitude over a few metres. Nevertheless, new approaches have led to improved estimates of the global emissions rates from some source types. For instance, intensive studies on emissions from rice agriculture have substantially improved these emissions estimates (Ding and Wang, 1996; Wang and Shangguan, 1996). Further, integration of emissions over a whole growth period (rather than looking at the emissions on individual days with different ambient temperatures) has lowered the estimates of CH_4 emissions from rice agriculture from about 80 Tg/yr to about 40 Tg/yr (Neue and Sass, 1998; Sass *et al.*, 1999). There have also been attempts to deduce emission rates from observed spatial and temporal distributions of atmospheric CH_4 through inverse modelling (e.g., Hein *et al.*, 1997; Houweling *et al.*, 1999). The emissions so derived depend on the precise knowledge of the mean global loss rate and represent a relative attribution into aggregated sources of similar properties. The results of some of these studies have been included in Table 4.2. The global CH_4 budget can also be constrained by measurements of stable isotopes ($\delta^{13}C$ and δD) and radiocarbon ($^{14}CH_4$) in atmospheric CH_4 and in CH_4 from the major sources (e.g., Stevens and Engelkemeir, 1988; Wahlen *et al.*, 1989; Quay *et al.*, 1991, 1999; Lassey *et al.*, 1993; Lowe *et al.*, 1994). So far the measurements of isotopic composition of CH_4 have served mainly to constrain the contribution from fossil fuel related sources. The emissions from the various sources sum up to a global total of about 600 Tg/yr, of which about 60% are related to human activities such as agriculture, fossil fuel use and waste disposal. This is consistent with the SRES estimate of 347 Tg/yr for anthropogenic CH_4 emissions in the year 2000.

The current emissions from CH_4 hydrate deposits appear small, about 10 Tg/yr. However, these deposits are enormous, about 10^7 TgC (Suess *et al.*, 1999), and there is an indication of a catastrophic release of a gaseous carbon compound about 55 million years ago, which has been attributed to a large-scale perturbation of CH_4 hydrate deposits (Dickens, 1999; Norris and Röhl, 1999). Recent research points to regional releases of CH_4 from clathrates in ocean sediments during the last 60,000 years (Kennett *et al.*, 2000), but much of this CH_4 is likely to be oxidised by bacteria before reaching the atmosphere (Dickens, 2001). This evidence adds to the concern that the expected global warming may lead to an increase in these emissions and thus to another positive feedback in the climate system. So far, the size of that feedback has not been quantified. On the other hand, the historic record of atmospheric CH_4 derived from ice cores (Petit *et al.*, 1999), which spans several large temperature swings plus glaciations, constrains the possible past releases from methane hydrates to the atmosphere. Indeed, Brook *et al.* (2000) find little evidence for rapid, massive CH_4 excursions that might be associated with large-scale decomposition of methane hydrates in sediments during the past 50,000 years.

The mean global loss rate of atmospheric CH_4 is dominated by its reaction with OH in the troposphere.

$$OH + CH_4 \quad \rightarrow \quad CH_3 + H_2O$$

This loss term can be quantified with relatively good accuracy based on the mean global OH concentration derived from the methyl chloroform (CH_3CCL_3) budget described in Section 4.2.6 on OH. In that way we obtain a mean global loss rate of 507 Tg(CH_4)/yr for the current tropospheric removal of CH_4 by OH. In addition there are other minor removal processes for atmospheric CH_4. Reaction with Cl atoms in the marine boundary layer probably constitutes less than 2% of the total sink (Singh *et al.*, 1996). A recent process model study (Ridgwell *et al.*, 1999) suggested a soil sink of 38 Tg/yr, and this can be compared to SAR estimates of 30 Tg/yr. Minor amounts of CH_4 are also destroyed in the stratosphere by reactions with OH, Cl, and $O(^1D)$, resulting in a combined loss rate of 40 Tg/yr. Summing these, our best estimate of the current global loss rate of atmospheric CH_4 totals 576 Tg/yr (see Table 4.2), which agrees reasonably with the total sources derived from process models. The atmospheric lifetime of CH_4 derived from this loss rate and the global burden is 8.4 years. Attributing individual lifetimes to the different components of CH_4 loss results in 9.6 years for loss due to tropospheric OH, 120 years for stratospheric loss, and 160 years for the soil sink (i.e., 1/8.4 yr = 1/9.6 yr + 1/120 yr + 1/160 yr).

The atmospheric abundance of CH_4 has increased by about a factor of 2.5 since the pre-industrial era (see Figure 4.1a) as evidenced by measurements of CH_4 in air extracted from ice cores and firn (Etheridge *et al.*, 1998). This increase still continues, albeit at a declining rate (see Figure 4.1b). The global tropospheric CH_4 growth rate averaged over the period 1992 through 1998 is about 4.9 ppb/yr, corresponding to an average annual increase in atmospheric burden of 14 Tg. Superimposed on this long-term decline in growth rate are interannual variations in the trend (Figure 4.1c). There are no clear quantitative explanations for this variability, but understanding these variations in

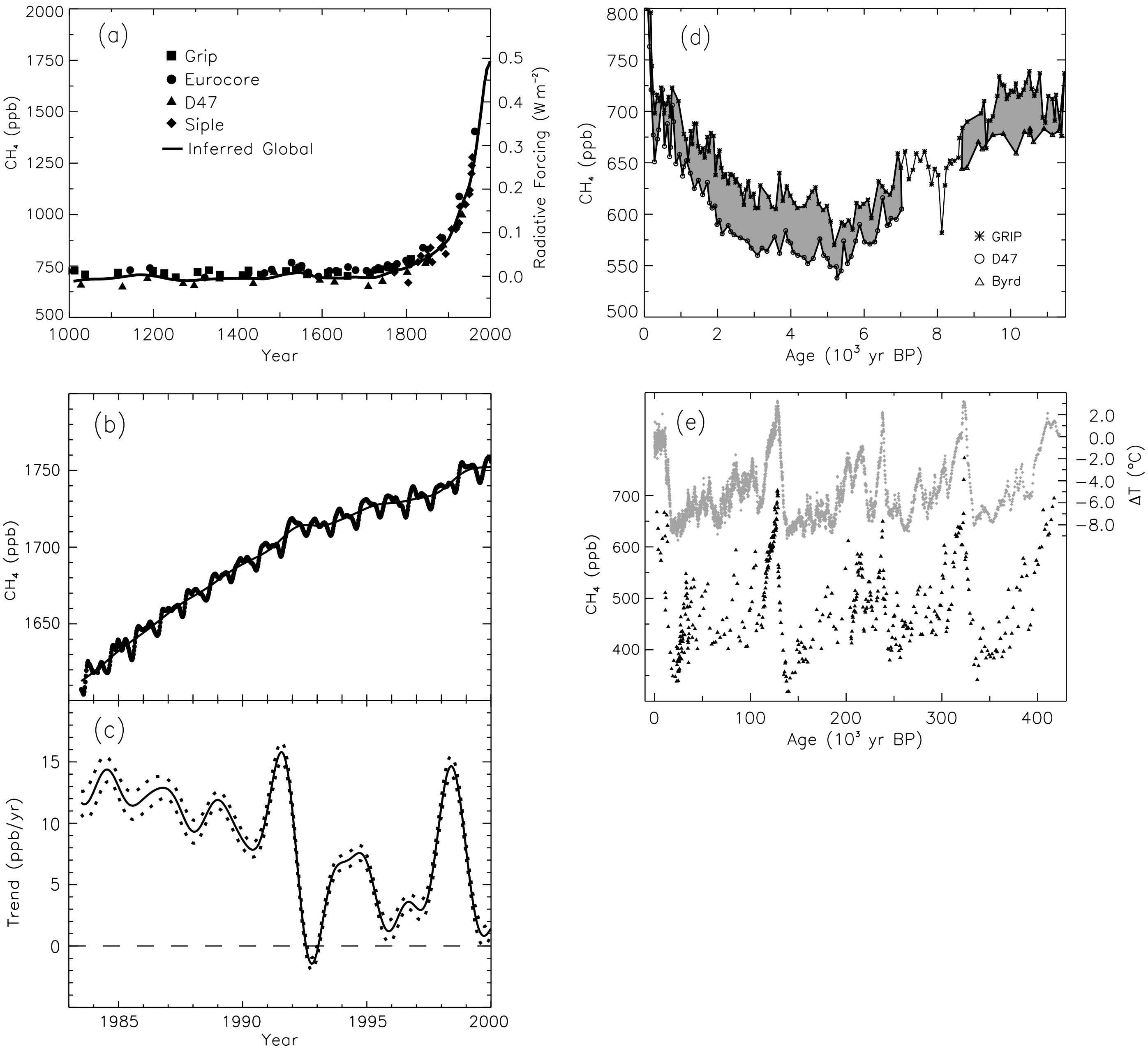


Figure 4.1: (a) Change in CH_4 abundance (mole fraction, in ppb = 10^{-9}) determined from ice cores, firn, and whole air samples plotted for the last 1,000 years. Data sets are as follows: Grip, Blunier *et al.* (1995) and Chappellaz *et al.* (1997); Eurocore, Blunier *et al.* (1993); D47, Chappellaz *et al.* (1997); Siple, Stauffer *et al.* (1985); Global (inferred from Antarctic and Greenland ice cores, firn air, and modern measurements), Etheridge *et al.* (1998) and Dlugokencky *et al.* (1998). Radiative forcing, approximated by a linear scale since the pre-industrial era, is plotted on the right axis. (b) Globally averaged CH_4 (monthly varying) and deseasonalised CH_4 (smooth line) abundance plotted for 1983 to 1999 (Dlugokencky *et al.*, 1998). (c) Instantaneous annual growth rate (ppb/yr) in global atmospheric CH_4 abundance from 1983 through 1999 calculated as the derivative of the deseasonalised trend curve above (Dlugokencky *et al.*, 1998). Uncertainties (dotted lines) are ±1 standard deviation. (d) Comparison of Greenland (GRIP) and Antarctic (D47 and Byrd) CH_4 abundances for the past 11.5 kyr (Chappellaz *et al.*, 1997). The shaded area is the pole-to-pole difference where Antarctic data exist. (e) Atmospheric CH_4 abundances (black triangles) and temperature anomalies with respect to mean recent temperature (grey diamonds) determined for the past 420 kyr from an ice core drilled at Vostok Station in East Antarctica (Petit *et al.*, 1999).

trend will ultimately help constrain specific budget terms. After the eruption of Mt. Pinatubo, a large positive anomaly in growth rate was observed at tropical latitudes. It has been attributed to short-term decreases in solar UV in the tropics immediately following the eruption that decreased OH formation rates in the troposphere (Dlugokencky *et al.*, 1996). A large decrease in growth was observed, particularly in high northern latitudes, in 1992. This feature has been attributed in part to decreased northern wetland emission rates resulting from anomalously low surface temperatures (Hogan and Harriss, 1994) and in part to

Table 4.2: *Estimates of the global methane budget (in Tg(CH_4/yr) from different sources compared with the values adopted for this report (TAR).*

Reference:	Fung *et al.* (1991)	Hein *et al.* (1997)	Lelieveld *et al.* (1998)	Houweling *et al.* (1999)	Mosier *et al.* (1998a)	Olivier *et al.* (1999)	Cao *et al.* (1998)	SAR	TAR[a]
Base year:	1980s	–	1992	–	1994	1990	–	1980s	1998
Natural sources									
Wetlands	115	237	225[c]	145			92		
Termites	20	–	20	20					
Ocean	10	–	15	15					
Hydrates	5	–	10	–					
Anthropogenic sources									
Energy	75	97	110	89		109			
Landfills	40	35	40	73		36			
Ruminants	80	90[b]	115	93	80	93[b]			
Waste treatment	–	[b]	25	–	14	[b]			
Rice agriculture	100	88	[c]	–	25-54	60	53		
Biomass burning	55	40	40	40	34	23			
Other	–	–	–	20	15				
Total source	**500**	**587**	**600**					**597**	**598**
Imbalance (trend)								+37	+22
Sinks									
Soils	10	–	30	30	44			30	30
Tropospheric OH	450	489	510					490	506
Stratospheric loss	–	46	40					40	40
Total sink	**460**	**535**	**580**					**560**	**576**

[a] TAR budget based on 1,745 ppb, 2.78 Tg/ppb, lifetime of 8.4 yr, and an imbalance of +8 ppb/yr.
[b] Waste treatment included under ruminants.
[c] Rice included under wetlands.

stratospheric ozone depletion that increased tropospheric OH (Bekki *et al.*, 1994; Fuglestvedt *et al.*, 1994). Records of changes in the $^{13}C/^{12}C$ ratios in atmospheric CH_4 during this period suggest the existence of an anomaly in the sources or sinks involving more than one causal factor (Lowe *et al.*, 1997; Mak *et al.*, 2000).

There is no consensus on the causes of the long-term decline in the annual growth rate. Assuming a constant mean atmospheric lifetime of CH_4 of 8.9 years as derived by Prinn *et al.* (1995), Dlugokencky *et al.* (1998) suggest that during the period 1984 to 1997 global emissions were essentially constant and that the decline in annual growth rate was caused by an approach to steady state between global emissions and atmospheric loss rate. Their estimated average source strength was about 550 Tg/yr. (Inclusion of a soil sink term of 30 Tg/yr would decrease the lifetime to 8.6 years and suggest an average source strength of about 570 Tg/yr.) Francey *et al.* (1999), using measurements of $^{13}CH_4$ from Antarctic firn air samples and archived air from Cape Grim, Tasmania, also concluded that the decreased CH_4 growth rate was consistent with constant OH and constant or very slowly increasing CH_4 sources after 1982. However, other analyses of the global methyl chloroform (CH_3CCl_3) budget (Krol *et al.*, 1998) and the changing chemistry of the atmosphere (Karlsdottir and Isaksen, 2000) argue for an increase in globally averaged OH of +0.5%/yr over the last two decades (see Section 4.2.6 below) and hence a parallel increase in global CH_4 emissions by +0.5%/yr.

The historic record of atmospheric CH_4 obtained from ice cores has been extended to 420,000 years before present (BP) (Petit *et al.*, 1999). As Figure 4.1e demonstrates, at no time during this record have atmospheric CH_4 mixing ratios approached today's values. CH_4 varies with climate as does CO_2. High values are observed during interglacial periods, but these maxima barely exceed the immediate pre-industrial CH_4 mixing ratio of 700 ppb. At the same time, ice core measurements from Greenland and Antarctica indicate that during the Holocene CH_4 had a pole-to-pole difference of about 44 ± 7 ppb with higher values in the Arctic as today, but long before humans influenced atmospheric methane concentrations (Chappelaz *et al.*, 1997; Figure 4.1d). Finally, study of CH_4 ice-core records at high time resolution reveals no evidence for rapid, massive CH_4 excursions that might be associated with large-scale decomposition of methane hydrates in sediments (Brook *et al.*, 2000).

The feedback of CH_4 on tropospheric OH and its own lifetime is re-evaluated with contemporary CTMs as part of OxComp, and results are summarised in Table 4.3. The calculated OH feedback, $\partial\ln(OH) / \partial\ln(CH_4)$, is consistent between the models, indicating that tropospheric OH abundances decline by 0.32% for every 1% increase in CH_4. The TAR value for the sensitivity coefficient $s = \partial\ln(LT) / \partial\ln(CH_4)$ is then 0.28 and the ratio PT/LT is 1.4. This 40% increase in the integrated effect of a CH_4 perturbation does not appear as a 40% larger amplitude in the perturbation but rather as a lengthening of the duration of the perturbation to 12 years. This feedback is difficult

Table 4.3: *Methane lifetime and feedback on tropospheric OH*[a] *for the 1990s.*

CTM	lifetime vs. OH(yr)[b]	$\delta\ln(OH)/\delta\ln(CH_4)$	$s= \delta\ln(LT)/\delta\ln(CH_4)$	PT/LT
IASB	8.1	–0.31	+0.27	1.37
KNMI	9.8	–0.35	+0.31	1.45
MPIC	8.5	–0.29	+0.25	1.33
UCI	9.0	–0.34 (–0.38)[c]	+0.30	1.43
UIO1	6.5	–0.33	+0.29	1.41
UKMO	8.3	–0.31 (–0.34)[c]	+0.27	1.37
ULAQ	13.8	–0.29	+0.25	1.33
TAR value[d]	9.6	–0.32		1.4

[a] Global mean tropospheric OH is weighted by the CH_4 loss rate.

[b] Lifetime against tropospheric OH loss at 1,745 ppb.

[c] Evaluated at 4,300 ppb CH_4 plus emissions for Y2100/draft-A2 scenario.

[d] TAR recommended OH lifetime for CH_4, 9.6 yr, is scaled from a CH_3CCl_3 OH lifetime of 5.7 yr (WMO, 1999; based on Prinn *et al.*, 1995) using a temperature of 272K (Spivakovsky *et al*., 2000). Stratospheric (120 yr) and soil-loss (160 yr) lifetimes are added (inversely) to give mean atmospheric lifetime of 8.4 yr. Only the OH lifetime is diagnosed and is subject to chemical feedback factor, and thus the total atmospheric lifetime for a CH_4 perturbation is 12 yr. In the SAR, the feedback factor referred only to the increase in the lifetime against tropospheric OH, and hence was larger. For Chemistry Transport Model (CTM) code see Table 4.10.

to observe, since it would require knowledge of the *increase* in CH_4 sources plus other factors affecting OH over the past two decades. Unlike for the global mean tropospheric OH abundance, there is also no synthetic compound that can calibrate this feedback; but it is possible that an analysis of the budgets of $^{13}CH_4$ and $^{12}CH_4$ separately may lead to an observational constraint (Manning, 1999).

4.2.1.2 Nitrous oxide (N_2O)

The globally averaged surface abundance of N_2O was 314 ppb in 1998, corresponding to a global burden of 1510 TgN. N_2O abundances are about 0.8 ppb greater in the Northern Hemisphere than in the Southern Hemisphere, consistent with about 60% of emissions occurring in the Northern Hemisphere. Almost no vertical gradient is observed in the troposphere, but N_2O abundances decrease in the stratosphere, for example, falling to about 120 ppb by 30 km at mid-latitudes.

The known sources of N_2O are listed in Table 4.4 with estimates of their emission rates and ranges. As with methane, it remains difficult to assess global emission rates from individual sources that vary greatly over small spatial and temporal scales. Total N_2O emissions of 16.4 TgN/yr can be inferred from the N_2O global sink strength (burden/lifetime) plus the rate of increase in the burden. In the SAR the sum of N_2O emissions from specific sources was notably less than that inferred from the loss rate. The recent estimates of global N_2O emissions from Mosier *et al.* (1998b) and Kroeze *et al.* (1999) match the global loss rate and underline the progress that has been made on quantification of natural and agricultural sources. The former study calculated new values for N_2O agricultural emissions that include the full impact of agriculture on the global nitrogen cycle and show that N_2O emissions from soils are the largest term in the budget (Table 4.4). The latter study combined these with emissions from other anthropogenic and natural sources to calculate a total emission of 17.7 TgN/yr for 1994.

The enhanced N_2O emissions from agricultural and natural ecosystems are believed to be caused by increasing soil N availability driven by increased fertilizer use, agricultural nitrogen (N_2) fixation, and N deposition; and this model can explain the increase in atmospheric N_2O abundances over the last 150 years (Nevison and Holland, 1997). Recent discovery of a faster-than-linear feedback in the emission of N_2O and NO from soils in response to external N inputs is important, given the projected increases of N fertilisation and deposition increases in tropical countries (Matson *et al.*, 1999). Tropical ecosystems, currently an important source of N_2O (and NO) are often phosphorus-limited rather than being N-limited like the Northern Hemispheric terrestrial ecosystems. Nitrogen fertiliser inputs into these phosphorus-limited ecosystems generate NO and N_2O fluxes that are 10 to 100 times greater than the same fertiliser addition to nearby N-limited ecosystems (Hall and Matson, 1999). In addition to N availability, soil N_2O emissions are regulated by temperature and soil moisture and so are likely to respond to climate changes (Frolking *et al.*, 1998; Parton *et al.*, 1998). The magnitude of this response will be affected by feedbacks operating through the biospheric carbon cycle (Li *et al.*, 1992, 1996).

The industrial sources of N_2O include nylon production, nitric acid production, fossil fuel fired power plants, and vehicular emissions. It was once thought that emission from

Table 4.4: *Estimates of the global nitrous oxide budget (in TgN/yr) from different sources compared with the values adopted for this report (TAR).*

Reference:	Mosier *et al.* (1998b) Kroeze *et al.* (1999)		Olivier *et al.* (1998)		SAR	TAR
Base year:	1994	range	1990	range	1980s	1990s
Sources						
Ocean	3.0	1 – 5	3.6	2.8 – 5.7	3	
Atmosphere (NH_3 oxidation)	0.6	0.3 – 1.2	0.6	0.3 – 1.2		
Tropical soils						
Wet forest	3.0	2.2 – 3.7			3	
Dry savannas	1.0	0.5 – 2.0			1	
Temperate soils						
Forests	1.0	0.1 – 2.0			1	
Grasslands	1.0	0.5 – 2.0			1	
All soils			6.6	3.3 – 9.9		
Natural sub-total	9.6	4.6 – 15.9	10.8	6.4 – 16.8	9	
Agricultural soils	4.2	0.6 – 14.8	1.9	0.7 – 4.3	3.5	
Biomass burning	0.5	0.2 – 1.0	0.5	0.2 – 0.8	0.5	
Industrial sources	1.3	0.7 – 1.8	0.7	0.2 – 1.1	1.3	
Cattle and feedlots	2.1	0.6 – 3.1	1.0	0.2 – 2.0	0.4	
Anthropogenic Sub-total	8.1	2.1 – 20.7	4.1	1.3 – 7.7	5.7	6.9[a]
Total sources	**17.7**	**6.7 – 36.6**	**14.9**	**7.7 – 24.5**	**14.7**[b]	
Imbalance (trend)	3.9	3.1 – 4.7			3.9	3.8
Total sinks (stratospheric)	**12.3**	**9 – 16**			**12.3**	**12.6**
Implied total source	16.2				16.2	16.4

[a] SRES 2000 anthropogenic N_2O emissions.
[b] N.B. total sources do not equal sink + imbalance.

automobile catalytic converters were a potential source of N_2O, but extrapolating measurements of N_2O emissions from automobiles in roadway tunnels in Stockholm and Hamburg during 1992 to the global fleet gives a source of only 0.24 ± 0.14 TgN/yr (Berges *et al.*, 1993). More recent measurements suggest even smaller global emissions from automobiles, 0.11 ± 0.04 TgN/yr (Becker *et al.*, 1999; Jiménez *et al.*, 2000).

The identified sinks for N_2O are photodissociation (90%) and reaction with electronically excited oxygen atoms ($O(^1D)$); they occur in the stratosphere and lead to an atmospheric lifetime of 120 years (SAR; Volk *et al.*, 1997; Prinn and Zander, 1999). The small uptake of N_2O by soils is not included in this lifetime, but is rather incorporated into the net emission of N_2O from soils because it is coupled to the overall N-partitioning.

Isotopic ($\delta^{15}N$ and $\delta^{18}O$) N_2O measurements are also used to constrain the N_2O budget. The isotopic composition of tropospheric N_2O derives from the flux-weighted isotopic composition of sources corrected for fractionation during destruction in the stratosphere. Typical observed values are $\delta^{15}N = 7$ ‰ and $\delta^{18}O =$ 20.7 ‰ relative to atmospheric N_2 and oxygen (O_2) (Kim and Craig, 1990). Most surface sources are depleted in ^{15}N and ^{18}O relative to tropospheric N_2O (e.g., Kim and Craig, 1993), and so other processes (sources or sinks) must lead to isotopic enrichment. Rahn and Wahlen (1997) use stratospheric air samples to show that the tropospheric isotope signature of N_2O can be explained by a return flux of isotopically enriched N_2O from the stratosphere, and no exotic sources of N_2O are needed. Yung and Miller (1997) point out that large isotopic fractionation can occur in the stratosphere during photolysis due to small differences in the zero point energies of the different isotopic species, and Rahn *et al.* (1998) have verified this latter effect with laboratory measurements. Wingen and Finlayson-Pitts (1998) failed to find evidence that reaction of CO_3 with N_2 (McElroy and Jones, 1996) is an atmospheric source of N_2O. The use of isotopes has not yet conclusively identified new sources nor constrained the N_2O budget better than other approaches, but the emerging data set of isotopic measurements, including measurements of the intramolecular position of ^{15}N in N_2O isotopomers (Yoshida and Toyoda, 2000) will provide better constraints in the future.

Tropospheric N_2O abundances have increased from pre-industrial values of about 270 ppb (Machida *et al.*, 1995; Battle *et al.*, 1996; Flückiger *et al.*, 1999) to a globally averaged value of 314 ppb in 1998 (Prinn *et al.*, 1990, 1998; Elkins *et al.*, 1998) as shown in Figure 4.2. The pre-industrial source is estimated to

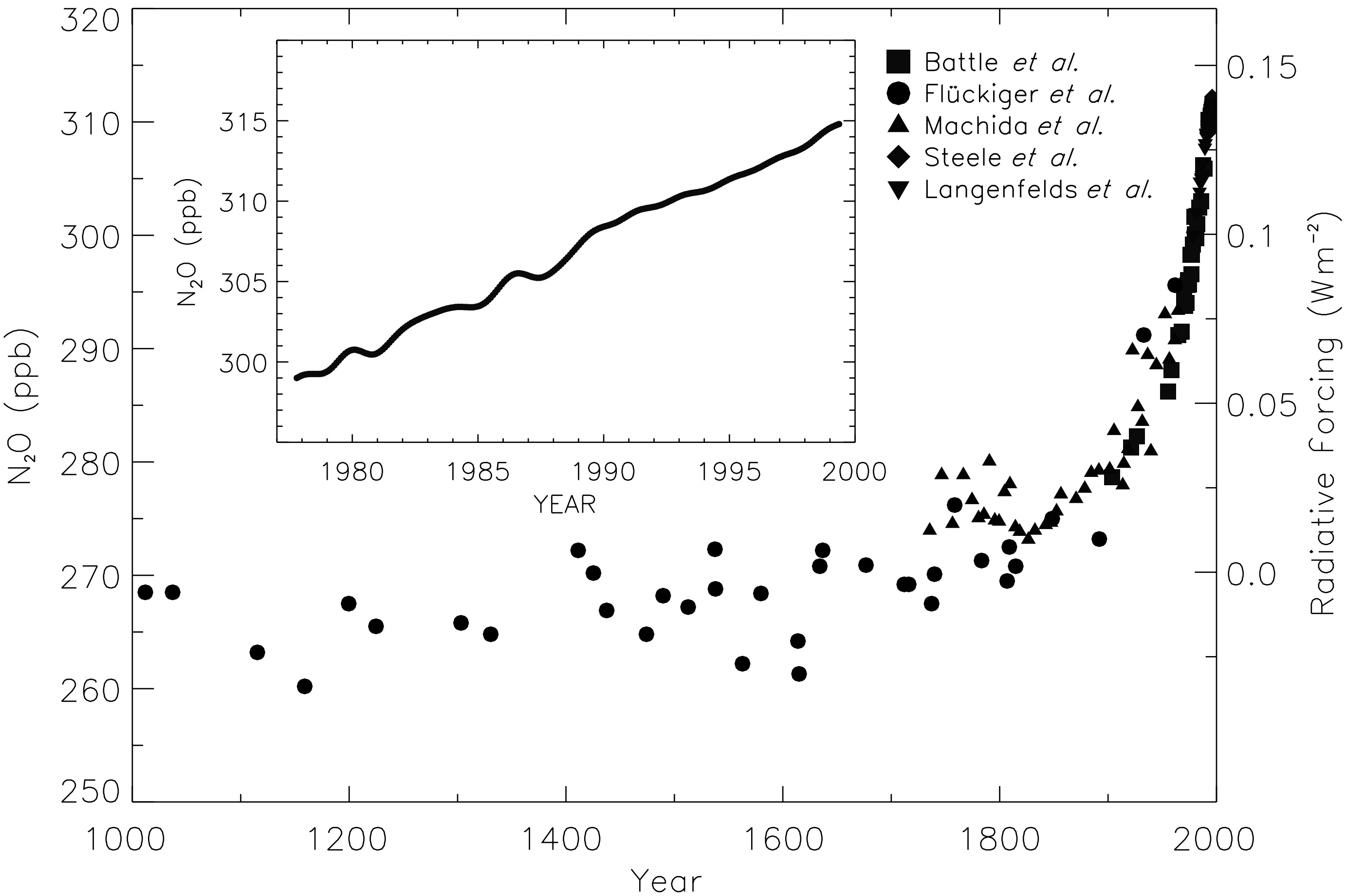


Figure 4.2: Change in N_2O abundance for the last 1,000 years as determined from ice cores, firn, and whole air samples. Data sets are from: Machida *et al.* (1995); Battle *et al.* (1996); Langenfelds *et al.* (1996); Steele *et al.* (1996); Flückiger *et al.* (1999). Radiative forcing, approximated by a linear scale, is plotted on the right axis. Deseasonalised global averages are plotted in the inset (Butler *et al.*, 1998b).

be 10.7 TgN/yr, which implies that current anthropogenic emissions are about 5.7 TgN/yr assuming no change in the natural emissions over this period. The average rate of increase during the period 1980 to 1998 determined from surface measurements was +0.8 ± 0.2 ppb/yr (+0.25 ± 0.05 %/yr) and is in reasonable agreement with measurements of the N_2O vertical column density above Jungfraujoch Station, +0.36 ± 0.06%/yr between 1984 and 1992 (Zander *et al.*, 1994). Large interannual variations in this trend are also observed. Thompson *et al.* (1994) report that the N_2O growth rate decreased from 1 ppb/yr in 1991 to 0.5 ppb/yr in 1993 and suggest that decreased use of nitrogen-containing fertiliser and lower temperatures in the Northern Hemisphere may have been in part responsible for lower biogenic soil emissions. Schauffler and Daniel (1994) suggest that the N_2O trend was affected by stratospheric circulation changes induced by massive increase in stratospheric aerosols following the eruption of Mt. Pinatubo. Since 1993, the N_2O increase has returned to rates closer to those observed during the 1980s.

The feedback of N_2O on its own lifetime (Prather, 1998) has been examined for this assessment with additional studies from established 2-D stratospheric chemical models. All models give similar results, see Table 4.5. The global mean atmospheric lifetime of N_2O decreases about 0.5% for every 10% increase in N_2O (s = –0.05). This shift is small but systematic, and it is included in Table 4.1a as a shorter perturbation lifetime for N_2O, 114 years instead of 120 years. For N_2O (unlike for CH_4) the time to mix the gas into the middle stratosphere where it is destroyed, about 3 years, causes a separation between PT (about 114 years) and the e-fold of the long-lived mode (about 110 years).

4.2.1.3 Hydrofluorocarbons (HFCs)

The HFCs with the largest measured atmospheric abundances are (in order), HFC-23 (CHF_3), HFC-134a (CF_3CH_2F), and HFC-152a (CH_3CHF_2). The recent rises in these HFCs are shown in Figure 4.3 along with some major HCFCs, the latter being controlled under the Montreal Protocol and its Amendments. HFC-23 is a by-product of HCFC-22 production. It has a long atmospheric lifetime of 260 years, so that most emissions, which have occurred over the past two decades, will have accumulated in the atmosphere. Between 1978 and 1995, HFC-23 increased from about 3 to 10 ppt; and it continues to rise even more rapidly (Oram *et al.*, 1996). HFC-134a is used primarily as a refrigerant, especially in car air conditioners. It has an atmospheric lifetime of 13.8 years, and its annual emissions have grown from near

Table 4.5: *Nitrous oxide lifetime feedback and residence time.*

Models	**Contributor**	**Lifetime LT** (yr)	**Sensitivity,** $s=\partial \ln(LT)/\partial \ln(B)$	**Decay Time of mode** (yr)
AER 2D	Ko and Weisenstein	111	–0.062	102
GSFC 2D	Jackman	137	–0.052	127
UCI 1D	Prather	119	–0.046	110
Oslo 2D	Rognerud	97	–0.061	

Lifetime (LT_B) is calculated at steady-state for an N_2O burden (B) corresponding to a tropospheric abundance of 330 ppb. The sensitivity coefficient (s) is calculated by increasing the N_2O burden approximately 10% to B+ΔB, calculating the new steady state atmospheric lifetime ($LT_{B+\Delta B}$), and then using a finite difference approximation for s, $\ln(LT_{B+\Delta B}/LT_B)/\ln(1+\Delta B/B)$. The perturbation lifetime (PT), i.e., the effective duration of an N_2O addition, can be derived as $PT = LT/(1-s)$ or equivalently from the simple budget-balance equation: $(B+\Delta B)/LT_{B+\Delta B} = B/LT_B + \Delta B/PT$.

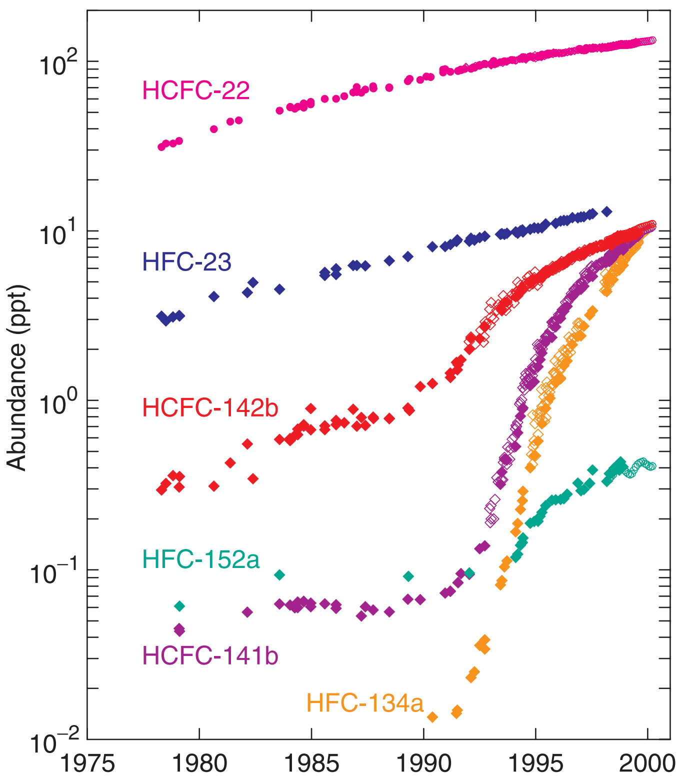


Figure 4.3: HFC-23 (blue, UEA scale), -152a (green, UEA scale), -134a (orange, NOAA scale), and HCFC-22 (magenta, SIO scale), -142b (red, NOAA scale), and -141b (purple, NOAA scale) abundances (ppt) at Cape Grim, Tasmania for the period 1978 to 1999. Different symbols are data from different measurement networks: SIO (filled circles), NOAA-CMDL (open diamonds, Montzka *et al.*, 1994, 1996a,b, 1999), UEA (filled diamonds, Oram *et al.*, 1995, 1996, 1998, 1999) and AGAGE (open circles, only for 1998 to 2000, all gases but HFC-23, Miller *et al.*, 1998; Sturrock *et al.*, 1999; Prinn *et al.*, 2000). Southern Hemisphere values (Cape Grim) are slightly lower than global averages.

zero in 1990 to an estimated 0.032 Tg/yr in 1996. The abundance continues to rise almost exponentially as the use of this HFC increases (Montzka *et al.*, 1996b; Oram *et al.*, 1996; Simmonds *et al.*, 1998). HFC-152a is a short-lived gas with a mean atmospheric lifetime of 1.4 years. Its rise has been steady, but its low emissions and a short lifetime have kept its abundance below 1 ppt.

4.2.1.4 Perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)

PFCs, in particular CF_4 and C_2F_6, as well as SF_6 have sources predominantly in the Northern Hemisphere, atmospheric lifetimes longer than 1,000 years, and large absorption cross-sections for terrestrial infra-red radiation. These compounds are far from a steady state between sources and sinks, and even small emissions will contribute to radiative forcing over the next several millennia. Current emissions of C_2F_6 and SF_6 are clearly anthropogenic and well quantified by the accumulating atmospheric burden. Harnisch and Eisenhauer (1998) have shown that CF_4 and SF_6 are naturally present in fluorites, and out-gassing from these materials leads to natural background abundances of 40 ppt for CF_4 and 0.01 ppt for SF_6. However, at present the anthropogenic emissions of CF_4 exceed the natural ones by a factor of 1,000 or more and are responsible for the rapid rise in atmospheric abundance. Atmospheric burdens of CF_4 and SF_6 are increasing as shown in Figures 4.4 and 4.5, respectively. Surface measurements show that SF_6 has increased by about 7%/yr during the 1980s and 1990s (Geller *et al.*, 1997; Maiss and Brenninkmeijer, 1998). Recent relative rates of increase are 1.3%/yr for CF_4 and 3.2%/yr for C_2F_6 (Harnisch *et al.*, 1996). The only important sinks for PFCs and SF_6 are photolysis or ion reactions in the mesosphere. These gases provide useful tracers of atmospheric transport in both troposphere and stratosphere.

A new, long-lived, anthropogenic greenhouse gas has recently been found in the atmosphere (Sturges *et al.*, 2000). Trifluoromethyl sulphur pentafluoride (SF_5CF_3) – a hybrid of PFCs and SF_6 not specifically addressed in Annex A of the Kyoto Protocol – has the largest radiative forcing, on a per molecule basis, of any gas found in the atmosphere to date. Its abundance has grown from near zero in the late 1960s to about 0.12 ppt in 1999.

4.2.2 Montreal Protocol Gases and Stratospheric Ozone (O_3)

The Montreal Protocol is an internationally accepted agreement whereby nations agree to control the production of ozone-depleting substances. Many of the chemicals that release chlorine atoms into the stratosphere, and deplete stratospheric O_3, are also greenhouse gases, so they are discussed briefly here. Detailed assessment of the current observations, trends, lifetimes, and emissions for substances covered by the protocol are in WMO (Kurylo and Rodriguez, 1999; Prinn and Zander, 1999). The ozone-depleting gases with the largest potential to influence climate are CFC-11 ($CFCl_3$), CFC-12 (CF_2Cl_2), and CFC-113 ($CF_2ClCFCl_2$). It is now clear from measurements in polar firn air that there are no natural sources of these compounds (Butler *et al.*, 1999). Surface measurements of these compounds show that their growth rates continue to decline. Growth rates are slightly negative for CFC-11 and CFC-113 (Montzka *et al.*, 1996a, 1999; Prinn *et al.*, 2000); see Figure 4.6. CFC-12 increased by 4 ppt/yr during 1995 to 1996, down from about 12 ppt/yr in the late 1980s, see Figure 4.7). Methyl chloroform (CH_3CCl_3) has decreased dramatically since the Montreal Protocol was invoked, due to its relatively short lifetime (about 5 years) and the rapidity with which emissions were phased out. Its decline was 13 ppt/yr during the period 1995 to 1996 (Prinn *et al.*, 1998, 2000). The halon abundances are small relative to the CFCs, and will never become large if the Montreal Protocol is adhered to. Atmospheric measurements show that growth rates of halon-1301 and halon-2402 decreased in response to the Montreal Protocol, but halon-1211 continues to increase at rates larger than expected based on industrial emissions data (Butler *et al.*, 1998a; Fraser *et al.*, 1999; Montzka *et al.*, 1999).

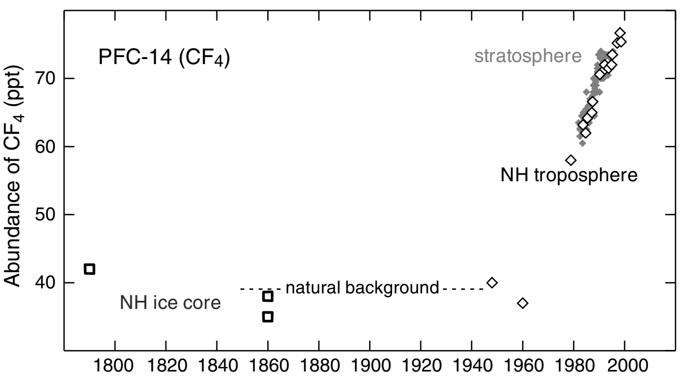


Figure 4.4: Abundance of CF_4 (ppt) over the last 200 years as measured in tropospheric air (open diamonds), stratospheric air (small filled diamonds), and ice cores (open squares) (Harnisch *et al.*, 1996; 1999).

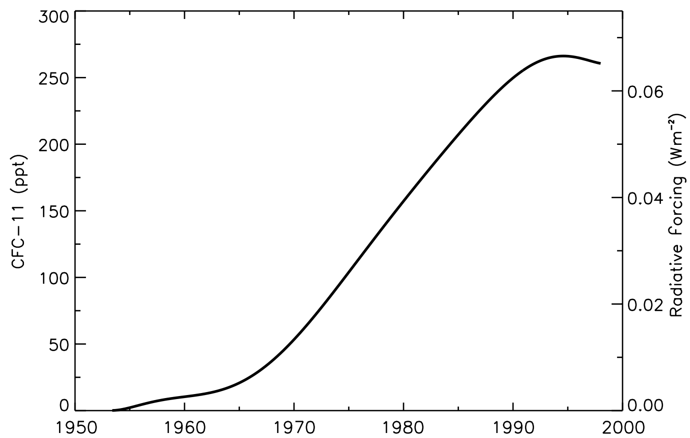


Figure 4.6: Global mean CFC-11 ($CFCl_3$) tropospheric abundance (ppt) from 1950 to 1998 based on smoothed measurements and emission models (Prinn *et al.*, 2000). CFC-11's radiative forcing is shown on the right axis.

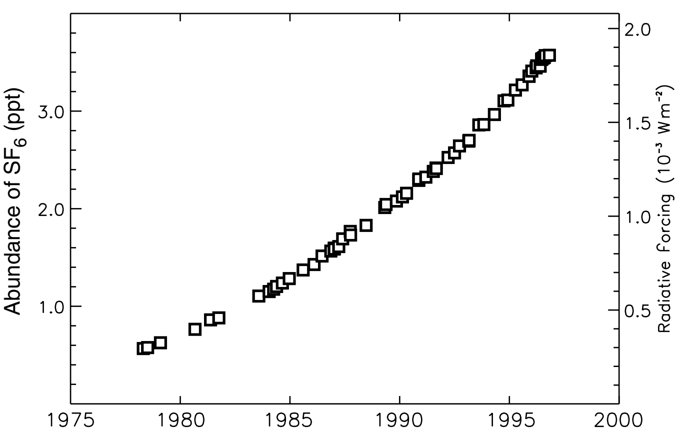


Figure 4.5: Abundance of SF_6 (ppt) measured at Cape Grim, Tasmania since 1978 (Maiss *et al.*, 1996; Maiss and Brenninkmeijer, 1998). Cape Grim values are about 3% lower than global averages.

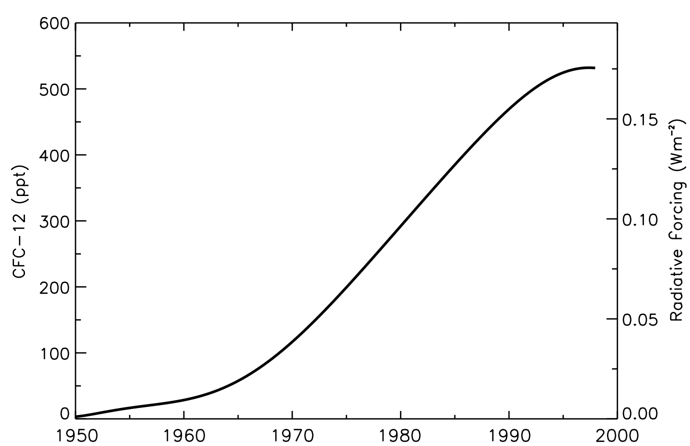


Figure 4.7: Global mean CFC-12 (CF_2Cl_2) tropospheric abundance (ppt) from 1950 to 1998 based on smoothed measurements and emission models (Prinn *et al.*, 2000). CFC-12's radiative forcing is shown on the right axis.

The depletion of stratospheric ozone over the past three decades has been substantial. Between 60°S and 60°N it averaged about 2%/decade. A thorough review of the direct and possible indirect effects of stratospheric ozone depletion are given in WMO (Granier and Shine, 1999). The depletion of O_3 (and its radiative forcing) is expected to follow the weighted halogen abundance in the stratosphere. Therefore, both will reach a maximum in about 2000 before starting to recover; however, detection of stratospheric O_3 recovery is not expected much before 2010 (Jackman *et al.*, 1996; Hofmann and Pyle, 1999). Methyl chloroform has been the main driver of the rapid turnaround in stratospheric chlorine during the late 1990s (Montzka *et al.*, 1999; Prinn *et al.*, 2000), and further recovery will rely on the more slowly declining abundances of CFC-11 and -12, and halons (Fraser *et al.*, 1999; Montzka *et al.*, 1999). It is expected that stratospheric ozone depletion due to halogens will recover during the next 50 to 100 years (Hofmann and Pyle, 1999). In the short run, climatic changes, such as cooling in the northern winter stratosphere, may enhance ozone depletion, but over the next century, the major uncertainties in stratospheric ozone lie with (i) the magnitude of future consumption of ozone-depleting substances by developing countries (Fraser and Prather, 1999; Montzka *et al.*, 1999), (ii) the projected abundances of CH_4 and N_2O, and (iii) the projected climate change impacts on stratospheric temperatures and circulation.

4.2.3 Reactive Gases

4.2.3.1 Carbon monoxide (CO) and hydrogen (H_2)

Carbon monoxide (CO) does not absorb terrestrial infrared radiation strongly enough to be counted as a direct greenhouse gas, but its role in determining tropospheric OH indirectly affects the atmospheric burden of CH_4 (Isaksen and Hov, 1987) and can lead to the formation of O_3. More than half of atmospheric CO emissions today are caused by human activities, and as a result the Northern Hemisphere contains about twice as much CO as the Southern Hemisphere. Because of its relatively short lifetime and distinct emission patterns, CO has large gradients in the atmosphere, and its global burden of about 360 Tg is more uncertain than those of CH_4 or N_2O. In the high northern latitudes, CO abundances vary from about 60 ppb during summer to 200 ppb during winter. At the South Pole, CO varies between about 30 ppb in summer and 65 ppb in winter. Observed abundances, supported by column density measurements, suggest that globally, CO was slowly increasing until the late 1980s, but has started to decrease since then (Zander *et al.* 1989; Khalil and Rasmussen, 1994), possibly due to decreased automobile emissions as a result of catalytic converters (Bakwin *et al.*, 1994). Measurements from a globally distributed network of sampling sites indicate that CO decreased globally by about 2 %/yr from 1991 to 1997 (Novelli *et al.*, 1998) but then increased in 1998. In the Southern Hemisphere, no long-term trend has been detected in CO measurements from Cape Point, South Africa for the period 1978 to 1998 (Labuschagne *et al.*, 1999).

Some recent evaluations of the global CO budget are presented in Table 4.6. The emissions presented by Hauglustaine *et al.* (1998) were used in a forward, i.e., top-down, modelling study of the CO budget; whereas Bergamasschi *et al.* (2000) used a model inversion to derive CO sources. These varied approaches do not yet lead to a consistent picture of the CO budget. Anthropogenic sources (deforestation, savanna and waste burning, fossil and domestic fuel use) dominate the direct emissions of CO, emitting 1,350 out of 1,550 Tg(CO)/yr. A source of 1,230 Tg(CO)/yr is estimated from *in situ* oxidation of CH_4 and other hydrocarbons, and about half of this source can be attributed to anthropogenic emissions. Fossil sources of CO have already been accounted for as release of fossil C in the CO_2 budget, and thus we do not double-count this CO as a source of CO_2.

It has been proposed that CO emissions should have a GWP because of their effects on the lifetimes of other greenhouse gases (Shine *et al.*, 1990; Fuglesvedt *et al.*, 1996; Prather, 1996). Daniel and Solomon (1998) estimate that the cumulative indirect radiative forcing due to anthropogenic CO emissions may be larger than that of N_2O. Combining these early box models with 3-D global CTM studies using models from OxComp (Wild and Prather, 2000; Derwent *et al.*, 2001) suggests that emitting 100 Tg(CO) is equivalent to emitting 5 Tg(CH_4): the resulting CH_4 perturbation appears after a few months and lasts 12 years as would a CH_4 perturbation; and further, the resulting tropospheric O_3 increase is global, the same as for a direct CH_4 perturbation. Effectively the CO emission excites the global 12-year chemical mode that is associated with CH_4 perturbations. This equivalency is not unique as the impact of CO appears to vary by as much as 20% with latitude of emission. Further, this equivalency systematically underestimates the impact of CO on greenhouse gases because it does not include the short-term tropospheric O_3 increase during the early period of very high CO abundances (< 6 months). Such O_3 increases are regional, however, and their magnitude depends on local conditions.

Molecular hydrogen (H_2) is not a direct greenhouse gas. But it can reduce OH and thus indirectly increase CH_4 and HFCs. Its atmospheric abundance is about 500 ppb. Simmonds *et al.* (2000) report a trend of +1.2 ± 0.8 ppb/yr for background air at Mace Head, Ireland between 1994 and 1998; but, in contrast, Novelli *et al.* (1999) report a trend of –2.3 ± 0.1 ppb/yr based on a global network of sampling sites. H_2 is produced in many of the same processes that produce CO (e.g., combustion of fossil fuel and atmospheric oxidation of CH_4), and its atmospheric measurements can be used to constrain CO and CH_4 budgets. Ehhalt (1999) estimates global annual emissions of about 70 Tg(H_2)/yr, of which half are anthropogenic. About one third of atmospheric H_2 is removed by reaction with tropospheric OH, and the remainder, by microbial uptake in soils. Due to the larger land area in the Northern Hemisphere than in the Southern Hemisphere, most H_2 is lost in the Northern Hemisphere. As a result, H_2 abundances are on average greater in the Southern Hemisphere despite 70% of emissions being in the Northern Hemisphere (Novelli *et al.*, 1999; Simmonds *et al.*, 2000). Currently the impact of H_2 on tropospheric OH is small, comparable to some of the VOC. No scenarios for changing H_2 emissions are considered here; however, in a possible fuel-cell economy, future emissions may need to be considered as a potential climate perturbation.

***Table 4.6:** Estimates of the global tropospheric carbon monoxide budget (in Tg(CO)/yr) from different sources compared with the values adopted for this report (TAR).*

Reference:	Hauglustaine *et al.* (1998)	Bergamasschi *et al.* (2000)	WMO (1999)	SAR (1996)	TAR [a]
Sources					
Oxidation of CH_4		795		400 – 1000	800
Oxidation of Isoprene		268		200 – 600 [b]	270
Oxidation of Terpene		136			~0
Oxidation of industrial NMHC		203			110
Oxidation of biomass NMHC		–			30
Oxidation of Acetone		–			20
Sub-total *in situ* oxidation	**881**	**1402**			**1230**
Vegetation		–	100	60 – 160	150
Oceans		49	50	20 – 200	50
Biomass burning [c]		768	500	300 – 700	700
Fossil & domestic fuel		641	500	300 – 550	650
Sub-total direct emissions	**1219**	**1458**	**1150**		**1550**
Total sources	**2100**	**2860**		**1800 – 2700**	**2780**
Sinks					
Surface deposition	190			250 – 640	
OH reaction	1920			1500 – 2700	

Anthropogenic emissions by continent/region	Y2000	Y2100(A2p)
Africa	80	480
South America	36	233
Southeast Asia	44	203
India	64	282
North America	137	218
Europe	109	217
East Asia	158	424
Australia	8	20
Other	400	407
Sum	1036	2484

[a] Recommended for OxComp model calculations for year 2000.
[b] Includes all VOC oxidation.
[c] From deforestation, savannah and waste burning.

4.2.3.2 Volatile organic compounds (VOC)

Volatile organic compounds (VOC), which include non-methane hydrocarbons (NMHC) and oxygenated NMHC (e.g., alcohols, aldehydes and organic acids), have short atmospheric lifetimes (fractions of a day to months) and small direct impact on radiative forcing. VOC influence climate through their production of organic aerosols and their involvement in photochemistry, i.e., production of O_3 in the presence of NO_x and light. The largest source, by far, is natural emission from vegetation. Isoprene, with the largest emission rate, is not stored in plants and is only emitted during photosynthesis (Lerdau and Keller, 1997). Isoprene emission is an important component in tropospheric photochemistry (Guenther *et al.*, 1995, 1999) and is included in the OxComp simulations. Monoterpenes are stored in plant reservoirs, so they are emitted throughout the day and night. The monoterpenes play an important role in aerosol formation and are discussed in Chapter 5. Vegetation also releases other VOC at relatively small rates, and small amounts of NMHC are emitted naturally by the oceans. Anthropogenic sources of VOC include fuel production, distribution, and combustion, with the largest source being emissions (i) from motor vehicles due to either evaporation or incomplete combustion of fuel, and (ii) from biomass burning. Thousands of different compounds with varying lifetimes and chemical behaviour have been observed in the atmosphere, so most models of tropospheric chemistry include some chemical speciation of the VOC. Generally, fossil

Table 4.7(a): *Estimates of global VOC emissions (in TgC/yr) from different sources compared with the values adopted for this report (TAR).*

Ehhalt (1999)	**Isoprene (C_5H_8)**	**Terpene ($C_{10}H_{16}$)**	**C_2H_6**	**C_3H_8**	**C_4H_{10}**	**C_2H_4**	**C_3H_6**	**C_2H_2**	**Benzene (C_6H_6)**	**Toluene (C_7H_8)**
Fossil fuel[a]	–	–	4.8	4.9	8.3	8.6	8.6	2.3	4.6	13.7
Biomass burning	–	–	5.6	3.3	1.7	8.6	4.3	1.8	2.8	1.8
Vegetation	503	124	4.0	4.1	2.5	8.6	8.6	–	–	–
Oceans	–	–	0.8	1.1	–	1.6	1.4	–	–	–

TAR[b]	**Total**	**Isoprene**	**Terpene**	**Acetone**
Fossil fuel[a]	161			
Biomass burning	33			
Vegetation	377	220	127	30

[a] Fossil includes domestic fuel.
[b] TAR refers to recommended values for OxComp model calculations for the year 2000.

Table 4.7(b): *Detailed breakdown of VOC emissions by species adopted for this report (TAR).*

Species	**Industrial** wt%	#C atoms	**Biomass burning** wt%	#C atoms
Alcohols	3.2	2.5	8.1	1.5
Ethane	4.7	2.0	7.0	2.0
Propane	5.5	3.0	2.0	3.0
Butanes	10.9	4.0	0.6	4.0
Pentanes	9.4	5.0	1.4	5.0
Higher alkanes	18.2	7.5	1.3	8.0
Ethene	5.2	2.0	14.6	2.0
Propene	2.4	3.0	7.0	3.0
Ethyne	2.2	2.0	6.0	2.0
Other alkenes, alkynes, dienes	3.8	4.8	7.6	4.6
Benzene	3.0	6.0	9.5	6.0
Toluene	4.9	7.0	4.1	7.0
Xylene	3.6	8.0	1.2	8.0
Trimethylbenzene	0.7	9.0	–	–
Other aromatics	3.1	9.6	1.0	8.0
Esters	1.4	5.2	–	–
Ethers	1.7	4.7	5.5	5.0
Chlorinated HC's	0.5	2.6	–	–
Formaldehyde	0.5	1.0	1.2	1.0
Other aldehydes	1.6	3.7	6.1	3.7
Ketones	1.9	4.6	0.8	3.6
Acids	3.6	1.9	15.1	1.9
Others	8.1	4.9	–	–

wt% values are given for the individual VOC with the sums being: industrial, 210 Tg(VOC)/yr, corresponding to 161 TgC/yr; and biomass burning, 42 Tg(VOC)/yr, corresonding to 33 TgC/yr.

VOC sources have already been accounted for as release of fossil C in the CO_2 budgets and thus we do not count VOC as a source of CO_2.

Given their short lifetimes and geographically varying sources, it is not possible to derive a global atmospheric burden or mean abundance for most VOC from current measurements. VOC abundances are generally concentrated very near their sources. Natural emissions occur predominantly in the tropics (23°S to 23°N) with smaller amounts emitted in the northern mid-latitudes and boreal regions mainly in the warmer seasons. Anthropogenic emissions occur in heavily populated, industrialised regions (95% in the Northern Hemisphere peaking at 40°N to 50°N), where natural emissions are relatively low, so they have significant impacts on regional chemistry despite small global emissions. A few VOC, such as ethane and acetone, are longer-lived and impact tropospheric chemistry on hemispheric scales. Two independent estimates of global emissions (Ehhalt, 1999; and TAR/OxComp budget based on the Emission Database for Global Atmospheric Research (EDGAR)) are summarised in Table 4.7a. The OxComp specification of the hydrocarbon mixture for both industrial and biomass-burning emissions is given in Table 4.7b.

One of the NMHC with systematic global measurements is ethane (C_2H_6). Rudolph (1995) have used measurements from five surface stations and many ship and aircraft campaigns during 1980 to 1990 to derive the average seasonal cycle for ethane as a function of latitude. Ehhalt *et al.* (1991) report a trend of +0.8%/yr in the column density above Jungfraujoch, Switzerland for the period 1951 to 1988, but in the following years, the trend turned negative. Mahieu *et al.* (1997) report a trend in C_2H_6 of -2.7 ± 0.3%/yr at Jungfraujoch, Switzerland for 1985 to 1993; Rinsland *et al.* (1998) report a trend of -1.2 ± 0.4%/yr at Kitt Peak, Arizona for 1977 to 1997 and -0.6 ± 0.8%/yr at Lauder, New Zealand for 1993 to 1997. It is expected that anthropogenic emissions of most VOC have risen since pre-industrial times due to increased use of gasoline and other hydrocarbon products. Due to the importance of VOC abundance in determining tropospheric O_3 and OH, systematic measurements and analyses of their budgets will remain important in understanding the chemistry-climate coupling.

There is a serious discrepancy between the isoprene emissions derived by Guenther *et al.* (1995) based on a global scaling of emission from different biomes, about 500 TgC/yr, and those used in OxComp for global chemistry-transport modelling, about 200 TgC/yr. When the larger isoprene fluxes are used in the CTMs, many observational constraints on CO and even isoprene itself are poorly matched. This highlights a key uncertainty in global modelling of highly reactive trace gases: namely, what fraction of primary emissions escapes immediate reaction/removal in the vegetation canopy or immediate boundary layer and participates in the chemistry on the scales represented by global models? For the isoprene budget, there are no measurements of the deposition of reaction products within the canopy. More detail on the scaling of isoprene and monoterpene emissions is provided in Chapter 5. Although isoprene emissions are likely to change in response to evolving chemical and climate environment over the next century, this assessment was unable to include a projection of such changes.

4.2.3.3 Nitrogen oxides (NO_x)

Nitrogen oxides ($NO_x = NO + NO_2$) do not directly affect Earth's radiative balance, but they catalyse tropospheric O_3 formation through a sequence of reactions, e.g.,

$$
\begin{array}{llll}
 & OH + CO + O_2 & \rightarrow & CO_2 + HO_2 \\
 & HO_2 + NO & \rightarrow & NO_2 + OH \\
 & NO_2 + h\nu & \rightarrow & NO + O(^3P) \\
 & O(^3P) + O_2 + M & \rightarrow & O_3 + M \\
 & & & \\
\text{net:} & CO + 2O_2 + h\nu & \rightarrow & CO_2 + O_3
\end{array}
$$

By rapidly converting HO_2 to OH, NO enhances tropospheric OH abundances and thus indirectly reduces the atmospheric burdens of CO, CH_4, and HFCs. Much of recent understanding of the role of NO_x in producing tropospheric O_3 and changing OH abundances is derived from *in situ* measurement campaigns that sample over a wide range of chemical conditions in the upper troposphere or at the surface (see Section 4.2.6 on tropospheric OH). These atmospheric measurements generally support the current photochemical models. There is substantial spatial and temporal variability in the measured abundance of NO_x, which ranges from a few ppt near the surface over the remote tropical Pacific Ocean to >100 ppb in urban regions. The local chemical lifetime of NO_x is always short, but varies widely throughout the troposphere, being 1 day or less in the polluted boundary layer, day or night, and 5 to 10 days in the upper troposphere. As with VOC, it is not possible to derive a global burden or average abundance for NO_x from measurements of atmospheric abundances.

Most tropospheric NO_x are emitted as NO, which photochemically equilibrates with nitrogen dioxide (NO_2) within a few minutes. Significant sources, summarised in Table 4.8, include both surface and *in situ* emissions, and only a small amount is transported down from the stratosphere. NO_x emitted within polluted regions are more rapidly removed than those in remote regions. Emissions directly into the free troposphere have a disproportionately large impact on global greenhouse gases. The major source of NO_x is fossil fuel combustion, with 40% coming from the transportation sector. Benkovitz *et al.* (1996) estimated global emissions at 21 TgN/yr for 1985. The NO_x emissions from fossil fuel use used in model studies here for year 2000 are considerably higher, namely 33 TgN/yr. The large American and European emissions are relatively stable, but emissions from East Asia are increasing by about +4%/yr (Kato and Akimoto, 1992). Other important, but more uncertain surface sources are biomass burning and soil emissions. The soil source recently derived from a bottom-up compilation of over 100 measurements from various ecosystems is 21 TgN/yr (Davidson and Kingerlee, 1997), much higher than earlier estimates. Part of the discrepancy can be explained by the trapping of soil-emitted NO in the vegetation canopy. Inclusion of canopy scavenging reduces the NO_x flux to the free troposphere to 13 TgN/yr, which is still twice the flux estimated by another recent study (Yienger and Levy, 1995). Emissions of NO_x in the free troposphere include NO_x from aircraft (8 to 12 km), ammonia oxidation, and lightning (Lee *et al.*, 1997). Estimates of the lightning NO_x source are quite variable; some recent global estimates are 12 TgN/yr (Price *et al.*, 1997a,b), while other studies recommend 3 to 5 TgN/yr (e.g., Huntrieser *et al.*, 1998; Wang *et al.*, 1998a). Recent studies indicate that the global lightning frequency may be lower than previously estimated (Christian *et al.*, 1999) but that intra-cloud lightning may be much more effective at producing NO (DeCaria *et al.*, 2000). In total, anthropogenic NO_x emissions dominate natural sources, with fossil fuel combustion concentrated in northern industrial regions. However, natural sources may control a larger fraction of the globe. Overall, anthropogenic NO_x emissions are expected to undergo a fundamental shift from the current dominance of the

Table 4.8: *Estimates of the global tropospheric NO_x budget (in TgN/yr) from different sources compared with the values adopted for this report.*

Reference:	TAR	Ehhalt (1999)	Holland *et al.* (1999)	Penner *et al.* (1999)	Lee *et al.* (1997)
Base year	2000	~1985	~1985	1992	
Fossil fuel	33.0	21.0	20 – 24	21.0	22.0
Aircraft	0.7	0.45	0.23 – 0.6	0.5	0.85
Biomass burning	7.1	7.5	3 – 13	5 – 12	7.9
Soils	5.6	5.5	4 – 21	4 – 6	7.0
NH_3 oxidation	–	3.0	0.5 – 3	–	0.9
Lightning	5.0	7.0	3 – 13	3 – 5	5.0
Stratosphere	<0.5	0.15	0.1 –0.6	–	0.6
Total	**51.9**	**44.6**			**44.3**

Anthropogenic emissions by continent/region	Y2000	Y2100(A2p)
Africa	2.5	21.8
South America	1.4	10.8
Southeast Asia	1.2	6.8
India	1.7	10.0
North America	10.1	18.5
Europe	7.3	14.3
East Asia	5.6	24.1
Australia	0.5	1.1
Other	2.3	2.6
Sum	**32.6**	**110.0**

The TAR column was used in OxComp model calculations for year 2000; fossil fuel includes bio-fuels, but surface sources only; stratospheric source in TAR is upper limit and includes HNO_3; the range of values used in modelling for IPCC aviation assessment (Penner *et al.* 1999) is given.

Northern Hemisphere to a more tropical distribution of emissions. Asian emissions from fossil fuel are expected to drive an overall increase in NO_x emissions in the 21st century (Logan, 1994; Van Aardenne *et al.*, 1999).

The dominant sink of NO_x is atmospheric oxidation of NO_2 by OH to form nitric acid (HNO_3), which then collects on aerosols or dissolves in precipitation and is subsequently scavenged by rainfall. Other pathways for direct NO_x removal occur through canopy scavenging of NO_x and direct, dry deposition of NO_x, HNO_3, and particulate nitrates to the land surface and the ocean. Dry deposition can influence the surface exchanges and can thus alter the release of NO_x and N_2O to the atmosphere. Peroxyacetyl nitrate (PAN), formed by the reaction of $CH_3C(O)O_2$ with NO_2, can transport HO_x and NO_x to remote regions of the atmosphere due to its stability at the cold temperatures of the upper troposphere. In addition tropospheric aerosols provide surfaces on which reactive nitrogen, in the form of NO_3 (nitrate radical) or N_2O_5, is converted to HNO_3 (Dentener and Crutzen, 1993; Jacob, 2000).

Some CTM studies argue against either the large soil source or the large lightning source of NO_x. A climatology of NO_x measurements from aircraft was prepared by Emmons *et al.* (1997) and compared with six chemical transport models. They found that the processes controlling NO_x in the remote troposphere are not well modelled and that, of course, there is a paucity of global NO_x measurements. For short-lived gases like NO_x, resolution of budget discrepancies is even more challenging than for the long-lived species, because the limited atmospheric measurements offer few real constraints on the global budget. However, an additional constraint on the NO_x budget is emerging as the extensive measurements of wet deposition of nitrate over Northern Hemisphere continents are compiled and increasing numbers of surface measurements of dry deposition of HNO_3, NO_2, and particulate nitrate become available, and thus allow a much better estimate of the NO_x sink.

4.2.4 Tropospheric O_3

Tropospheric O_3 is a direct greenhouse gas. The past increase in tropospheric O_3 is estimated to provide the third largest increase in direct radiative forcing since the pre-industrial era. In addition, through its chemical impact on OH, it modifies the lifetimes of other greenhouse gases, such as CH_4. Its budget, however, is much more difficult to derive than that of a long-lived gas for

***Table 4.9:** Estimates of the change in tropospheric ozone since the pre-industrial era from various sources compared with the values recommended in this report.*

Current climatology of tropospheric ozone (Park *et al.*, 1999)**:**

Global mean tropospheric O_3: 34 DU = 370 Tg(O)$_3$ content in the Northern Hemisphere = 36 DU, in the Southern Hemisphere = 32 DU.

SAR recommendation:

"50% of current Northern Hemisphere is anthropogenic" gives pre-industrial global mean content = 25 DU.

Increase = +9 DU

19th & early 20th century observations:[a]

Assume Northern Hemisphere tropospheric ozone has increased uniformly by >30 ppb.

Increase = +10 to +13 DU

Survey of CTM simulated change from pre-industrial:[b]

DU increase	*Model*	*Reference*
9.6	UIO	Berntsen *et al.* (1999)
7.9	GFDL	Haywood *et al.* (1998)
8.9	MOZART-1	Hauglustaine *et al.* (1998)
8.4	NCAR/2D	Kiehl *et al.* (1999)
9.5	GFDL-scaled	Levy *et al.* (1997)
12.0	Harvard/GISS	Mickley *et al.* (1999)
7.2	ECHAM4	Roelofs *et al.* (1997)
8.7	UKMO	Stevenson *et al.* (2000)
8.0	MOGUNTIA	VanDorland *et al.* (1997)

Increase = +7 to +12 DU (model range)

TAR recommendation:

Pre-industrial era global mean tropospheric O_3 has increased from 25 DU to 34 DU.

This increase, +9 DU, has a 67% likely range of 6 to 13 DU.

Increase = +9 DU (+6 to +13 DU)

The troposphere is defined as air with O_3 <150 ppb, see Logan (1999). The Dobson Unit is 1 DU = 2.687 × 10^{16} molecules of O_3 per square centimetre; globally 1 DU = 10.9 Tg(O_3) and 1 ppb of tropospheric O_3 = 0.65 DU. The change in CH_4 alone since pre-industrial conditions would give about +4 DU global increase in tropospheric O_3 alone (see Table 4.11).

[a] Early observations are difficult to interpret and do not provide coverage needed to derive the tropospheric burden of O_3 (see Harris *et al.*, 1997). The change in burden is derived here by shifting tropospheric O_3 uniformly in altitude to give 10 ppb at the surface in Northern Hemisphere mid-latitudes and 20 ppb at surface in Northern Hemisphere tropics (implies 10 DU), or by additionally reducing Southern Hemisphere tropics to 20 ppb and Southern Hemisphere mid-latitudes to 25 ppb at the surface (13 DU).

[b] From a survey of models by Hauglustaine and Solomon and Chapter 4. Except for Kiehl *et al.*, these were all CTMs; they used widely varying assumptions about pre-industrial conditions for CH_4, CO, NO_x, and biomass burning and they did not all report consistent diagnostics.

several reasons. Ozone abundances in the troposphere typically vary from less than 10 ppb over remote tropical oceans up to about 100 ppb in the upper troposphere, and often exceed 100 ppb downwind of polluted metropolitan regions. This variability, reflecting its rapid chemical turnover, makes it impossible to determine the tropospheric burden from the available surface sites, and we must rely on infrequent and sparsely sited profiles from ozone sondes (e.g., Logan, 1999). The total column of ozone is measured from satellites, and these observations have been used to infer the tropospheric ozone column after removing the much larger stratospheric column (e.g., Fishman and Brackett, 1997; Hudson and Thompson, 1998; Ziemke *et al.*, 1998). The current burden of tropospheric O_3 is about 370 Tg(O_3), which is equivalent to a globally averaged column density of 34 DU (Dobson Units, 1 DU = 2.687 × 10^{16} molecules/cm^{-2}) or a mean abundance of about 50 ppb, see Table 4.9.

The sources and sinks of tropospheric ozone are even more difficult to quantify than the burden. Influx of stratospheric air is a source of about 475 Tg(O_3)/yr based on observed correlations with other gases (Murphy and Fahey, 1994; McLinden *et al.*, 2000). The *in situ* photochemical sources are predicted to be many times larger, but are nearly balanced by equally large *in situ* chemical sinks (see discussion on CTM modelling of tropospheric O_3 in Sections 4.4 and 4.5, Table 4.12). Photochemical production of ozone is tied to the abundance of pollutants and thus varies widely over a range of spatial scales, the most important of which (e.g., biomass burning plumes, urban plumes, aircraft corridors, and convective outflows) are not well represented in most global CTMs and cannot be quantified globally with regional models. The dominant photochemical sinks for tropospheric O_3 are the catalytic destruction cycle involving the HO_2 + O_3 reaction and photolytic destruction by pathways involving the reaction of $O(^1D)$, a product of O_3 photodissociation. The other large sink, comparable in magnitude to the stratospheric source, is surface loss mainly to vegetation. Another loss of O_3 is observed under certain conditions in the polar marine boundary layer, notably at the end of Arctic winter. It indicates reactions involving halogen radicals and aerosols (Oum *et al.,* 1998; Dickerson *et al.*, 1999; Impey *et al.*, 1999; Platt and Moortgat, 1999; Prados *et al.*, 1999; Vogt *et al.*, 1999). The contribution of these processes to the global budget is not yet quantified, but is probably small.

Atmospheric measurement campaigns, both at surface sites and with aircraft, have focused on simultaneous observations of the many chemical species involved in tropospheric O_3 production. Primary areas of O_3 production are the mid-latitude industrialised and tropical biomass burning regions. For example, the North Atlantic Regional Experiment (NARE) and the Atmosphere Ocean Chemistry Experiment (AEROCE) showed that the prevailing westerly winds typically carry large quantities of ozone and precursors from the eastern USA over the North Atlantic, reaching Bermuda and beyond (e.g., Dickerson *et al.*, 1995; Penkett *et al.*, 1998; Prados *et al.*, 1999). The Pacific Exploratory Missions (PEM: Hoell *et al.*, 1997, 1999) measured extensive plumes of pollution including ozone and its precursors downwind of eastern Asia. Convective transport of emissions from biomass burning affect the abundance of O_3 in the mid- and upper troposphere (Pickering *et al.,* 1996). Emissions by tropical fires in South America and southern Africa have been identified as the cause of enhanced O_3 over the South Atlantic (Thompson *et al.*, 1996), and the effects of biomass burning were seen in the remote South Pacific in PEM Tropics A (Schultz *et al.*, 1999; Talbot *et al* ., 1999). Due to the widely varying chemical environments, these extensive studies provide a statistical sampling of conditions along with a critical test of the photochemistry in CTM simulations, but they do not provide an integrated budget for tropospheric O_3. An example of such model-and-measurements study is given in the Section 4.2.6 discussion of tropospheric OH.

Recent trends in global tropospheric O_3 are extremely difficult to infer from the available measurements, while trends in the stratosphere are readily identified (Randel *et al.*, 1999; WMO, 1999). With photochemistry producing local lifetimes as short as a few days in the boundary layer, the local measurement of tropospheric O_3 does not reflect the abundance over the surrounding continent, and a surface measurement is not representative of the bulk of the troposphere above. Thus it is not contradictory for decadal trends in different atmospheric regions to be different, e.g., driven by the regional changes in pollutants, particularly NO_x. Ozone sondes offer the best record of O_3 throughout the troposphere, although measurements at many stations are made only weekly (infrequently for a variable gas like O_3). Weekly continuous data since 1970 are available from only nine stations in the latitude range 36°N to 59°N (Logan *et al.*, 1999; WMO, 1999). Different trends are seen at different locations for different periods. Most stations show an increase from 1970 to 1980, but no clear trend from 1980 to 1996. A composite record of the mid-tropospheric O_3 abundance from 1970 to 1996 from the nine stations is taken from the analysis of Logan *et al.* (1999) and presented in Figure 4.8. There is no obvious linear increase in O_3 abundance over this period, although the second half of this record (about 57 ppb) is clearly greater than the first half (about 53 ppb). Of the fourteen stations with records since 1980, only two, one in Japan and one in Europe, had statistically significant increases in mid-tropospheric O_3 between 1980 and 1995. By contrast, the four Canadian stations, all at high latitudes, had significant decreases for the same time period. Surface O_3 measurements from seventeen background stations also show no clear trend, even in the northern mid-latitudes (Oltmans *et al.*, 1998; WMO, 1999). The largest negative trend in surface O_3 was -0.7 ± 0.2%/yr at the South Pole (1975 to 1997), while the largest positive trend was $+1.5 \pm 0.5$%/yr at Zugspitze, Germany (1978 to 1995). This ambiguous record of change over the past two decades may possibly be reconciled with the model predictions (see Section 4.4) of increasing tropospheric O_3 driven regionally by increasing emissions of pollutants: the growth in NO_x emissions is expected to have shifted from North America and Europe to Asia.

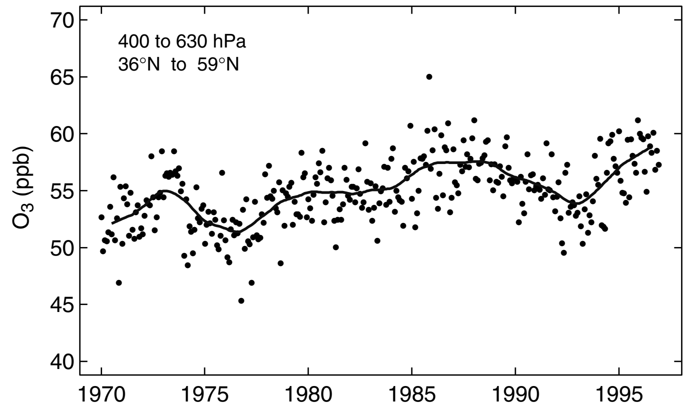


Figure 4.8: Mid-tropospheric O_3 abundance (ppb) in northern mid-latitudes (36°N-59°N) for the years 1970 to 1996. Observations between 630 and 400 hPa are averaged from nine ozone sonde stations (four in North America, three in Europe, two in Japan), following the data analysis of Logan *et al.* (1999). Values are derived from the residuals of the trend fit with the trend added back to allow for discontinuities in the instruments. Monthly data (points) are shown with a smoothed 12-month-running mean (line).

The change in tropospheric O_3 since the pre-industrial era is even more difficult to evaluate on the basis of measurements alone. Since O_3 is reactive, atmospheric abundances cannot be retrieved from ice cores. Recent evaluations of surface measurements in the 19th and early 20th century in Europe (Volz and Kley, 1988; Staehelin *et al.*, 1994, 1998; Harris *et al.*, 1997) indicate much lower O_3 abundances than today, yet the scaling of these data to a tropospheric O_3 burden, even for northern mid-latitudes, is not obvious. In the SAR, these data were used to make a rough estimate that O_3 abundances in the Northern Hemispheric troposphere have doubled since the pre-industrial era. A similar difference, of 10 to 13 DU when globally averaged, is obtained using the climatology given by Park *et al.* (1999) for tropospheric O_3 today and a parallel one with abundances adjusted to match the 19th century measurements in the Northern Hemisphere. CTM calculations predict that current anthropogenic emissions of NO_x, CO, and VOC, as well as the increase in CH_4 should have increased tropospheric O_3 by a similar amount, primarily in the Northern Hemisphere. A recent survey of CTM studies gives global average increases ranging from 8 to 12 DU, although this small range does not adequately represent the uncertainty. These results are summarised in Table 4.9. Based on measurements, analyses, and models, the most likely increase in tropospheric O_3 was 9 DU globally averaged, with a 67% confidence range of 6 to 13 DU. For some of the emissions scenarios considered here, tropospheric O_3 is expected to increase even more in the 21st century as emissions of its precursors – NO_x, CO and VOC – continue to grow (see Section 4.4).

4.2.5 Stratospheric H_2O

Water vapour in the lower stratosphere is a very effective greenhouse gas. Baseline levels of stratospheric H_2O are controlled by the temperature of the tropical tropopause, a parameter that changes with climate (Moyer *et al.*, 1996; Rosenlof *et al.*, 1997; Dessler, 1998; Mote *et al.*, 1998). The oxidation of CH_4 is a source of mid-stratospheric H_2O and currently causes its abundance to increase from about 3 ppm at the tropopause to about 6 ppm in the upper stratosphere. In addition, future direct injections of H_2O from high-flying aircraft may add H_2O to the lower stratosphere (Penner *et al.*, 1999). Oltmans and Hofmann (1995) report statistically significant increases in lower stratospheric H_2O above Boulder, Colorado between 1981 and 1994. The vertical profile and amplitude of these changes do not correspond quantitatively with that expected from the recognised anthropogenic sources (CH_4 oxidation). Analyses of satellite and ground-based measurements (Nedoluha *et al*., 1998; Michelsen *et al*., 2000) find increases in upper stratospheric H_2O from 1985 to 1997, but at rates (>1%/yr) that exceed those from identified anthropogenic sources (i.e., aviation and methane increases) and that obviously could not have been maintained over many decades. In principle such a temporary trend could be caused by a warming tropopause, but a recent analysis indicates instead a cooling tropopause (Simmons *et al*., 1999). It is important to resolve these apparent discrepancies; since, without a physical basis for this recent trend, no recommendation can be made here for projecting changes in lower stratospheric H_2O over the 21st century.

4.2.6 Tropospheric OH and Photochemical Modelling

The hydroxyl radical (OH) is the primary cleansing agent of the lower atmosphere, in particular, it provides the dominant sink for CH_4 and HFCs as well as the pollutants NO_x, CO and VOC. Once formed, tropospheric OH reacts with CH_4 or CO within a second. The local abundance of OH is controlled by the local abundances of NO_x, CO, VOC, CH_4, O_3, and H_2O as well as the intensity of solar UV; and thus it varies greatly with time of day, season, and geographic location.

The primary source of tropospheric OH is a pair of reactions that start with the photodissociation of O_3 by solar UV.

$$O_3 + h\nu \rightarrow O(^1D) + O_2$$
$$O(^1D) + H_2O \rightarrow OH + OH$$

Although in polluted regions and in the upper troposphere, photodissociation of other trace gases such as peroxides, acetone and formaldehyde (Singh *et al.*, 1995; Arnold *et al.*, 1997) may provide the dominant source (e.g., Folkins *et al.*, 1997; Prather and Jacob, 1997; Wennberg *et al.*, 1998; Müller and Brasseur, 1999). OH reacts with many atmospheric trace gases, in most cases as the first and rate-determining step of a reaction chain that leads to more or less complete oxidation of the compound. These chains often lead to formation of an HO_2 radical, which then reacts with O_3 or NO to recycle back to OH. Tropospheric OH is lost through reactions with other radicals, e.g., the reaction with HO_2 to form H_2O or with NO_2 to form HNO_3. In addition to providing the primary loss for CH_4 and other pollutants, HO_x radicals (OH and HO_2) together with NO_x are key catalysts in the production of tropospheric O_3 (see Section 4.2.3.3). The sources and sinks of OH involve most of the fast photochemistry of the troposphere.

Pre-industrial OH is likely to have been different than today, but because of the counteracting effects of lower CO and CH_4 (increasing OH) and reduced NO_x and O_3 (decreasing OH), there is no consensus on the magnitude of this change (e.g., Wang and Jacob, 1998). Trends in the current OH burden appear to be <1%/yr. Separate analyses of the CH_3CCl_3 observations for the period 1978 to 1994 report two different but overlapping trends in global OH: no trend within the uncertainty range (Prinn *et al.*, 1995), and 0.5 ± 0.6%/yr (Krol *et al.*, 1998). Based on the OxComp workshop, the SRES projected emissions would lead to future changes in tropospheric OH that ranging from +5% to −20% (see Section 4.4).

4.2.6.1 Laboratory data and the OH lifetime of greenhouse gases

Laboratory data on the rates of chemical reactions and photodissociation provide a cornerstone for the chemical models used here. Subsequent to the SAR there have been a number of updates to the recommended chemical rate databases of the International Union of Pure and Applied Chemistry (IUPAC 1997a,b, 1999) and the Jet Propulsion Laboratory (JPL) (DeMore *et al.*, 1997; Sander *et al.*, 2000). The CTMs in the OxComp workshop generally used the JPL-1997 database (JPL, 1997) with some updated rates similar to JPL-2000 (JPL, 2000). The most significant changes or additions to the databases include: (i) revision of the low temperature reaction rate coefficients for OH + NO_2 leading to enhancement of HO_x

and NO_x abundances in the lower stratosphere and upper troposphere; (ii) extension of the production of $O(^1D)$ from O_3 photodissociation to longer wavelengths resulting in enhanced OH production in the upper troposphere; and (iii) identification of a new heterogeneous reaction involving hydrolysis of $BrONO_2$ which serves to enhance HO_x and suppress NO_x in the lower stratosphere. These database improvements, along with many other smaller refinements, do not change the overall understanding of atmospheric chemical processes but do impact the modelled tropospheric OH abundances and the magnitude of calculated O_3 changes by as much as 20% under certain conditions.

Reaction rate coefficients used in this chapter to calculate atmospheric lifetimes for gases destroyed by tropospheric OH are from the 1997 and 2000 NASA/JPL evaluations (DeMore *et al.*, 1997; Sander *et al.*, 2000) and from Orkin *et al.* (1999) for HFE-356mff2. These rate coefficients are sensitive to atmospheric temperature and can be ten times faster near the surface than in the upper troposphere. The global mean abundance of OH cannot be directly measured, but a weighted average of the OH sink for certain synthetic trace gases (whose budgets are well established and whose total atmospheric sinks are essentially controlled by OH) can be derived. The ratio of the atmospheric lifetimes against tropospheric OH loss for a gas is scaled to that of CH_3CCl_3 by the inverse ratio of their OH-reaction rate coefficients at an appropriate scaling temperature. A new analysis of the modelled global OH distribution predicts relatively greater abundances at mid-levels in the troposphere (where it is colder) and results in a new scaling temperature for the rate coefficients of 272K (Spivakovsky *et al.*, 2000), instead of 277K (Prather and Spivakovsky, 1990; SAR). The atmospheric lifetimes reported in Table 4.1 use this approach, adopting an "OH lifetime" of 5.7 years for CH_3CCl_3 (Prinn *et al.*, 1995; WMO, 1999). Stratospheric losses for all gases are taken from published values (Ko *et al.*, 1999; WMO, 1999) or calculated as 8% of the tropospheric loss (with a minimum lifetime of 30 years). The only gases in Table 4.1 with surface losses are CH_4 (a soil-sink lifetime of 160 years) and CH_3CCl_3 (an ocean-sink lifetime of 85 years). The lifetime for nitrogen trifluoride (NF_3) is taken from Molina *et al.* (1995). These lifetimes agree with the recent compendium of Naik *et al.* (2000).

Analysis of the CH_3CCl_3 burden and trend (Prinn *et al.*, 1995; Krol *et al.*, 1998; Montzka *et al.*, 2000) has provided a cornerstone of our empirical derivations of the OH lifetimes of most gases. Quantification of the "OH-lifetime" of CH_3CCl_3 has evolved over the past decade. The SAR adopted a value of 5.9 ± 0.7 years in calculating the lifetimes of the greenhouse gases. This range covered the updated analysis of Prinn *et al.* (1995), 5.7 years, which was used in WMO (1999) and adopted for this report. Montzka *et al.* (2000) extend the atmospheric record of CH_3CCl_3 to include the rapid decay over the last five years following cessation of emissions and derive an OH lifetime of 6.3 years. The new information on the CH_3CCl_3 lifetime by Montzka *et al.* (2000) has not been incorporated into this report, but it falls within the ±15% uncertainty for these lifetimes. If the new value of 6.3 years were adopted, then the lifetime of CH_4 would increase to 9.2 yr, and all lifetimes, perturbation lifetimes, and GWPs for gases controlled by tropospheric OH would be about 10% greater.

4.2.6.2 Atmospheric measurements and modelling of photochemistry

Atmospheric measurements provide another cornerstone for the numerical modelling of photochemistry. Over the last five years direct atmospheric measurements of HO_x radicals, made simultaneously with the other key species that control HO_x, have been conducted over a wide range of conditions: the upper troposphere and lower stratosphere (e.g., SPADE, ASHOE/MAESA, STRAT; SUCCESS, SONEX, PEM-TROPICS A & B), the remote Pacific (MLOPEX), and the polluted boundary layer and its outflow (POPCORN, NARE, SOS). These intensive measurement campaigns provide the first thorough tests of tropospheric OH chemistry and production of O_3 for a range of global conditions. As an example here, we present an analysis of the 1997 SONEX (Subsonic assessment program Ozone and Nitrogen oxide EXperiment) aircraft campaign over the North Atlantic that tests one of the chemical models from the OxComp workshop (HGIS).

The 1997 SONEX aircraft campaign over the North Atlantic provided the first airborne measurements of HO_x abundances concurrent with the controlling chemical background: H_2O_2, CH_3OOH, CH_2O, O_3, NO_x, H_2O, acetone and hydrocarbons. These observations allowed a detailed evaluation of our understanding of HO_x chemistry and O_3 production in the upper troposphere. Figure 4.9 (panels 1-3) shows a comparison between SONEX measurements and model calculations (Jaeglé *et al.*, 1999) for OH and HO_2 abundances and the ratio HO_2/OH. At each point the model used the local, simultaneously observed chemical abundances. The cycling between OH and HO_2 takes place on a time-scale of a few seconds and is mainly controlled by reaction of OH with CO producing HO_2, followed by reaction of HO_2 with NO producing OH. This cycle also leads to the production of ozone. As seen in Figure 4.9, the HO_2/OH ratio is reproduced by model calculations to within the combined uncertainties of observations (±20%) and those from propagation of rate coefficient errors in the model (±100%), implying that the photochemical processes driving the cycling between OH and HO_2 appear to be understood (Wennberg *et al.*, 1998; Brune *et al.*, 1999). The absolute abundances of OH and HO_2 are matched by model calculations to within 40% (the reported accuracy of the HO_x observations) and the median model-to-observed ratio for HO_2 is 1.12. The model captures 80% of the observed variance in HO_x, which is driven by the local variations in NO_x and the HO_x sources (Faloona *et al.*, 2000, Jaeglé *et al.*, 2000;). The predominant sources of HO_x during SONEX were reaction of $O(^1D)$ with H_2O and photodissociation of acetone; the role of H_2O_2 and CH_3OOH as HO_x sources was small. This was not necessarily the case in some of the other airborne campaigns, where large differences between measured and modelled OH, up to a factor of 5, were observed in the upper troposphere. In these campaigns the larger measured OH concentrations were tentatively ascribed to enhanced levels of OH precursors, such as H_2O_2, CH_3OOH, or CH_2O, whose concentrations had not been measured.

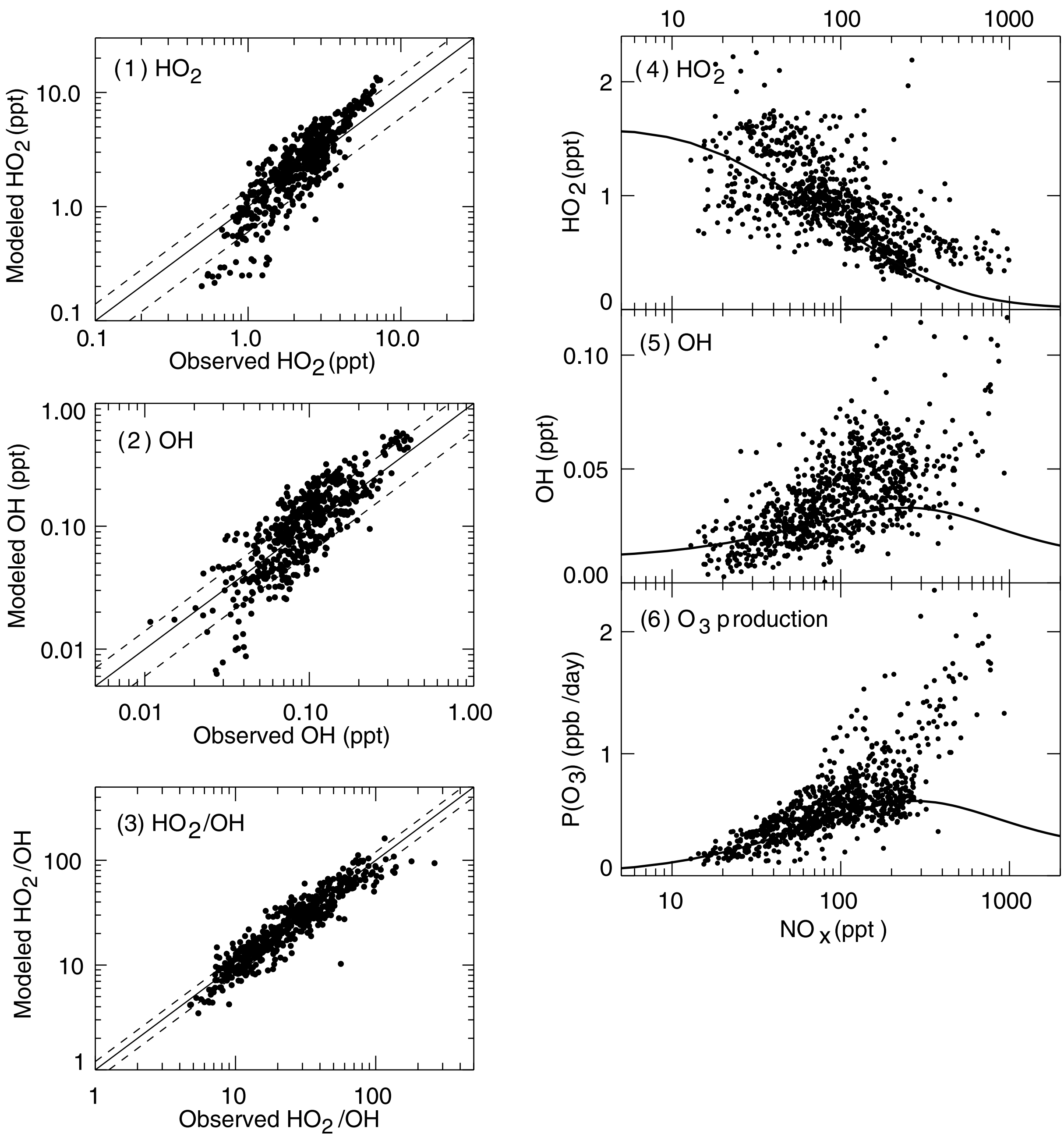


Figure 4.9: (left panel) Observed versus modelled (1) HO_2 abundance (ppt), (2) OH abundance (ppt), and (3) HO_2/OH ratio in the upper troposphere (8 to 12 km altitude) during SONEX. Observations are for cloud-free, daytime conditions. Model calculations are constrained with local observations of the photochemical background (H_2O_2, CH_3OOH, NO, O_3, H_2O, CO, CH_4, ethane, propane, acetone, temperature, pressure, aerosol surface area and actinic flux). The 1:1 line (solid) and instrumental accuracy range (dashed) are shown. Adapted from Brune *et al.* (1999). (right panel) Observed (4) HO_2 abundance (ppt), (5) OH abundance (ppt), and (6) derived O_3 production rate (ppb/day) as a function of the NO_x (NO+NO_2) abundance (ppt). Data taken from SONEX (8 to 12 km altitude, 40° to 60°N latitude) and adapted from Jaeglé *et al.* (1999). All values are 24-hour averages. The lines correspond to model-calculated values as a function of NO_x using the median photochemical background during SONEX rather than the instantaneous values (points).

Tropospheric O_3 production is tightly linked to the abundance of NO_x, and Figure 4.9 (panel 6) shows this production rate (calculated as the rate of the reaction of HO_2 with NO) for each set of observations as function of NO_x during the SONEX mission. Also shown in Figure 4.9 (panels 4-5) are the measured abundances of OH and HO_2 as a function of NO_x. The smooth curve on each panel 4-6 is a model simulation of the expected relationship if the chemical background except for NO_x remained unchanged at the observed median abundances. This curve shows the "expected" behaviour of tropospheric chemistry when only NO_x is increased: OH increases with NO_x abundances up to 300 ppt because HO_2 is shifted into OH; it decreases with increasing NO_x at higher NO_x abundances because the OH reaction with NO_2 forming HNO_3 becomes the dominant sink for HO_x radicals.

Production of O_3 is expected to follow a similar pattern with rates suppressed at NO_x abundances greater than 300 ppt under these atmospheric conditions (e.g., Ehhalt, 1998). These SONEX observations indicate, however, that both OH abundance and O_3 production may continue to increase with NO_x concentrations up to 1,000 ppt because the high NO_x abundances were often associated with convection and lightning events and occurred simultaneously with high HO_x sources. By segregating observations according to HO_x source strengths, Jaeglé *et al.* (1999) identified the approach to NO_x-saturated conditions predicted by the chemical models when HO_x sources remain constant. A NO_x-saturated environment was clearly found for the POPCORN (Photo-Oxidant formation by Plant emitted Compounds and OH Radicals in north-eastern Germany) boundary layer measurements in Germany (Rohrer *et al.*, 1998; Ehhalt and Rohrer, 2000). The impact of NO_x-saturated conditions on the production of O_3 is large in the boundary layer, where much of the NO_x is removed within a day, but may be less important in the upper troposphere, where the local lifetime of NO_x is several days and the elevated abundances of NO_x are likely to be transported and diluted to below saturation levels. This effective reduction of the NO_x-saturation effect due to 3-D atmospheric mixing is seen in the CTM modelling of aviation NO_x emissions where a linear increase in tropospheric O_3 is found, even with large NO_x emissions in the upper troposphere (Isaksen and Jackman, 1999).

4.3 Projections of Future Emissions

The IPCC SRES (Nakićenović *et al.*, 2000) developed 40 future scenarios that are characterised by distinctly different levels of population, economic, and technological development. Six of these scenarios were identified as illustrative scenarios and these were used for the analyses presented in this chapter. The SRES scenarios define only the changes in anthropogenic emissions and not the concurrent changes in natural emissions due either to direct human activities such as land-use change or to the indirect impacts of climate change. The annual anthropogenic emissions for all greenhouse gases, NO_x, CO, VOC and SO_2 (sulphur dioxide) are given in the SRES for the preliminary marker scenarios (Nakićenović *et al.*, 2000, Appendix VI) and the final marker/illustrative scenarios (Nakićenović *et al.*, 2000, Appendix VII). Much of these data is also tabulated in Appendix II to this report. There are insufficient data in the published SRES (Nakićenović *et al.*, 2000) to break down the individual contributions to HFCs, PFCs, and SF_6, but these emissions were supplied by Lead Authors of the SRES (available at sres.ciesin.org) and are also reproduced in this Appendix. The geographic distribution of emissions of the short-lived compounds – NO_x, CO, VOC, and SO_2 – is an important factor in their greenhouse forcing, and the preliminary gridded emissions were likewise supplied by the SRES Lead Authors (Tom Kram and Steven Smith, December 1998) and used in the OxComp model studies. A synopsis of the regional shift in CO and NO_x emissions projected by 2100 is given in Tables 4.6 and 4.8.

This chapter evaluates the SRES emissions from year 2000 to year 2100 in terms of their impact on the abundances of non-CO_2 greenhouse gases. A new feature of this report, i.e., use of NO_x, CO and VOC emissions to project changes in tropospheric O_3 and OH, represents a significant advance over the level-of-science in the SAR. The original four preliminary marker scenarios (December 1998) are included here because they have been used in preliminary model studies for the TAR and are designated A1p, A2p, B1p, B2p. In January 1999, these emissions were converted into greenhouse gas abundances using the level-of-science and methodology in the SAR, and the radiative forcings from these greenhouse gas abundances were used in this report for some climate model simulations.

The recently approved six marker/illustrative scenarios (March 2000) are also evaluated and are designated A1B-AIM, A1T-MESSAGE, A1FI-MiniCAM, A2-ASF, B1-IMAGE, B2-MESSAGE (hereafter abbreviated as A1B, A1T, A1FI, A2, B1, B2). For comparison with the previous assessment, we also evaluate the IPCC emissions scenario IS92a used in the SAR; for the full range of IS92 scenarios, see the SAR. An agreed-upon property of all SRES scenarios is that there is no intervention to reduce greenhouse gases; but, in contrast, regional controls on SO_2 emissions across the illustrative SRES scenarios lead to emissions in the last two decades of the century that are well below those of 1990 levels. There appear to be few controls on NO_x, CO and VOC emissions across all scenarios; however, the large increases in surface O_3 abundances implied by these results may be inconsistent with the SRES storylines that underpin the emissions scenarios. As understanding of the relationship between emissions and tropospheric O_3 abundances improves, particularly on regional scales, more consistent emissions scenarios can be developed. The SRES scenarios project substantial emissions of HFC-134a as in IS92a, but only half as much HFC-125, and no emissions of HFC-152a. The SRES emissions scenarios do include a much larger suite of HFCs plus SF_6 and PFCs, which are not included in IS92a. The emissions of greenhouse gases under the Montreal Protocol and its Amendments (CFCs, HCFCs, halons) have been evaluated in WMO (Madronich and Velders, 1999). This report adopts the single WMO baseline Montreal Protocol Scenario A1 (no relation to SRES A1) for emissions and concentrations of these gases, while the SRES adopted a similar WMO Scenario A3 (maximum production); however, the differences between scenarios in terms of climate forcing is inconsequential. The resulting abundances of greenhouse gases are given in Appendix II and discussed in Section 4.4.5.

4.3.1 The Adjusted/Augmented IPCC/SRES Emission Scenarios

Among the four SRES preliminary marker scenarios, A2p has overall the highest emissions. For model simulations of future atmospheric chemistry in the OxComp workshop, we needed to focus on a single test case and chose scenario A2p in the year 2100 since it represents the largest increase in emissions of CH_4, CO, NO_x, and VOC. Once the response of O_3 and OH to these extreme emissions is understood, other scenarios and intermediate years can be interpolated with some confidence.

Y2000

For the OxComp workshop, we adopt Y2000 emissions that include both natural and anthropogenic sources. The OxComp Y2000 anthropogenic emissions are roughly consistent with, but different in detail from, the anthropogenic emissions provided by SRES. These adjustments were necessary to be consistent with current budgets, to include natural sources as discussed previously, and to provide more detailed information on source categories, including temporal and spatial distribution of emissions that are not specified by SRES. Emissions of NO_x, CO and VOC for the year 2000 are based on GEIA(Global Emissions Inventory Activity)/EDGAR emissions for 1990 (Graedel *et al.*, 1993; Olivier *et al.*, 1999) projected to year 2000. Tropospheric abundances of long-lived gases such as CH_4 were fixed from recent observations. The difference between SRES and OxComp Y2000 emissions are nominally within the range of uncertainty for these quantities. The OxComp Y2000 simulations provide a "current" atmosphere to compare with observations.

Y2100(A2p)
Since the OxComp Y2000 emissions differ somewhat from the A2p emissions for the year 2000, we define Y2100(A2p) emissions by the sum of our adjusted Y2000 emissions plus the difference between the SRES-A2p emissions for the years 2100 and 2000. Thus our absolute increase in emissions matches that of SRES-A2p. In these Y2100(A2p) simulations, natural emissions were not changed.

4.3.2 Shifting Regional Emissions of NO_x CO, and VOC in 2100

A shift of the growth of anthropogenic emissions of NO_x, CO and VOC, such as that from North America and Europe to Southern and Eastern Asia over the past decades, is changing the geographic pattern of emissions, which in turn will change the distribution of the O_3 increases in the troposphere predicted for the year 2100. In contrast, for long-lived greenhouse gases, shifting the location of emissions has little impact. We use the SRES emission maps, to take into account such changes in emissions patterns. For Y2000 and Y2100(A2p) the emissions of CO and NO_x, broken down by continents, are given in Tables 4.6 and 4.8, respectively. In terms of assessing future changes in tropospheric OH and O_3, it is essential to have a coherent model for emissions scenarios that consistently projects the spatial patterns of the emissions along with the accompanying changes in urbanisation and land use.

4.3.3 Projections of Natural Emissions in 2100

SRES scenarios do not consider the changes in natural emissions and sinks of reactive gases that are induced by alterations in land use and agriculture or land-cover characteristics. (Land-use change statistics, however, are reported, and these could, in principle, be used to estimate such changes.) In some sense these altered emissions must be considered as anthropogenic changes. Examples of such changes may be increased NO_x, N_2O and NH_3 emissions from natural waters and ecosystems near agricultural areas with intensified use of N-fertiliser. A change of land cover, such as deforestation, may lead to reduced isoprene emissions but to increases in soil emissions of NO_x. At present we can only point out the lack of projecting these parallel changes in once natural emissions as an uncertainty in this assessment.

4.4 Projections of Atmospheric Composition for the 21st Century

4.4.1 Introduction

Calculating the abundances of chemically reactive greenhouse gases in response to projected emissions requires models that can predict how the lifetimes of these gases are changed by an evolving atmospheric chemistry. This assessment focuses on predicting changes in the oxidative state of the troposphere, specifically O_3 (a greenhouse gas) and OH (the sink for many greenhouse gases). Many research groups have studied and predicted changes in global tropospheric chemistry, and we seek to establish a consensus in these predictions, using a standardised set of scenarios in a workshop organised for this report. The projection of stratospheric O_3 recovery in the 21st century – also a factor in radiative forcing and the oxidative state of the atmosphere – is reviewed extensively in WMO (Hofmann and Pyle, 1999), and no new evaluation is made here. The only stratospheric change included implicitly is the N_2O feedback on its lifetime. Overall, these projections of atmospheric composition for the 21st century include the most extensive set of trace gas emissions for IPCC assessments to date: greenhouse gases (N_2O, CH_4, HFCs, PFCs, SF_6) plus pollutants (NO_x, CO, VOC).

4.4.2 The OxComp Workshop

In the SAR, the chapter on atmospheric chemistry included two modelling studies: PhotoComp (comparison of ozone photochemistry in box models) and Delta-CH_4 (methane feedbacks in 2-D and 3-D tropospheric chemistry models). These model studies established standard model tests for participation in IPCC. They resulted in a consensus regarding the CH_4 feedback and identified the importance (and lack of uniform treatment) of NMHC chemistry on tropospheric O_3 production. This synthesis allowed for the SAR to use the CH_4-lifetime feedback and a simple estimate of tropospheric O_3 increase due solely to CH_4. The SAR noted that individual CTMs had calculated an impact of changing NO_x and CO emissions on global OH and CH_4 abundances, but that a consensus on predicting future changes in O_3 and OH did not exist.

Since 1995, considerable research has gone into the development and validation of tropospheric CTMs. The IPCC Special Report on Aviation and the Global Atmosphere (Derwent and Friedl, 1999) used a wide range of global CTMs to predict the enhancement of tropospheric O_3 due to aircraft NO_x emissions. The results were surprisingly robust, not only for the hemispheric mean O_3 increase, but also for the increase in global mean OH reported as a decrease in the CH_4 lifetime. The current state-of-modelling in global tropospheric chemistry has advanced since PhotoComp and Delta-CH_4 in the SAR and now includes as standard a three-dimensional synoptic meteorology and treatment of non-methane hydrocarbon chemistry. A survey of

Table 4.10: *Chemistry-Transport Models (CTM) contributing to the OxComp evaluation of predicting tropospheric O_3 and OH.*

CTM	**Institute**	**Contributing authors**	**References**
GISS	GISS	Shindell /Grenfell	Hansen *et al.* (1997b)
HGEO	Harvard U.	Bey / Jacob	Bey *et al.* (1999)
HGIS	Harvard U.	Mickley / Jacob	Mickley *et al.* (1999)
IASB	IAS/Belg.	Mülller	Müller and Brasseur (1995, 1999)
KNMI	KNMI/Utrecht	van Weele	Jeuken *et al.* (1999), Houweling *et al.* (2000)
MOZ1	NCAR/CNRS	Hauglustaine / Brasseur	Brasseur *et al.* (1998b), Hauglustaine *et al.* (1998)
MOZ2	NCAR	Horowitz/ Brasseur	Brasseur *et al.* (1998b), Hauglustaine *et al.* (1998)
MPIC	MPI/Chem	Kuhlmann / Lawrence	Crutzen *et al.* (1999), Lawrence *et al.* (1999)
UCI	UC Irvine	Wild	Hannegan *et al.* (1998), Wild and Prather (2000)
UIO	U. Oslo	Berntsen	Berntsen and Isaksen (1997), Fuglestvedt *et al.* (1999)
UIO2	U. Oslo	Sundet	Sundet (1997)
UKMO	UK Met Office	Stevenson	Collins *et al.* (1997), Johnson *et al.* (1999)
ULAQ	U. L. Aquila	Pitari	Pitari *et al.* (1997)
UCAM	U. Cambridge	Plantevin /Johnson	Law *et al.* (1998, 2000)(TOMCAT)

recent CTM-based publications on the tropospheric O_3 budget, collected for this report, is discussed in Section 4.5.

This assessment, building on these developments, organised a workshop to compare CTM results for a few, well-constrained atmospheric simulations. An open invitation, sent out in March 1999 to research groups involved in 3-D global tropospheric chemistry modelling, invited participation in this report's assessment of change in tropospheric oxidative state through a model intercomparison and workshop (OxComp). This workshop is an IPCC-focused follow-on to the Global Integration and Modelling (GIM) study (Kanakidou *et al.*, 1999). The infrastructure for OxComp (ftp site, database, graphics, and scientific support) was provided by the University of Oslo group, and the workshop meeting in July 1999 was hosted by the Max Planck Institute for Meteorology (MPI) Hamburg. Participating models are described by publications in peer-reviewed literature as summarised in Table 4.10; all include 3-D global tropospheric chemistry including NMHC; and assessment results are based on models returning a sufficient number of OxComp cases. The two goals of OxComp are (i) to build a consensus on current modelling capability to predict changes in tropospheric OH and O_3 and (ii) to develop a useful parametrization to calculate the greenhouse gases (including tropospheric O_3 but not CO_2) using the IPCC emissions scenarios.

4.4.3 Testing CTM Simulation of the Current (Y2000) Atmosphere

The OxComp workshop defined a series of atmospheres and emission scenarios. These included Y2000, a new reference atmosphere meant to represent year 2000 that provides a baseline from which all changes in greenhouse gases were calculated. For Y2000, abundances of long-lived gases were prescribed by 1998 measurements (Table 4.1a), and emissions of short-lived pollutants, NO_x, CO and VOC, were based primarily on projections to the year 2000 of GEIA/EDGAR emissions for 1990 (Olivier *et al.*, 1998, 1999), see Section 4.3.1. Stratospheric O_3 was calculated in some models and prescribed by current observation in others. The predicted atmospheric quantities in all these simulations are therefore short-lived tropospheric gases: O_3, CO, NO_x, VOC, OH and other radicals. Following the GIM model study (Kanakidou *et al.*, 1999), we use atmospheric measurement of O_3 and CO to test the model simulations of the current atmosphere. The Y2000 atmosphere was chosen because of the need for an IPCC baseline, and it does not try to match conditions over the l980s and 1990s from which the measurements come. Although the observed trends in tropospheric O_3 and CO are not particularly large over this period and thus justify the present approach, a more thorough comparison of model results and measurements would need to use the regional distribution of the pollutant emissions for the observation period.

The seasonal cycle of O_3 in the free troposphere (700, 500, and 300 hPa) has been observed over the past decade from more than thirty ozone sonde stations (Logan, 1999). These measurements are compared with the OxComp Y2000 simulations for Resolute (75°N), Hohenpeissenberg (48°N), Boulder (40°N), Tateno (36°N), and Hilo (20°N) in Figure 4.10. Surface measurements from Cape Grim (40°S), representative of the marine boundary layer in southern mid-latitudes, are also compared with the models in Figure 4.10. With the exception of a few outliers, the model simulations are within ±30% of observed tropospheric O_3 abundance, and they generally show a maximum in spring to early summer as observed, although they often miss the month of maximum O_3. At 300 hPa the large springtime variation at many stations is due to the influence of stratospheric air that is approximately simulated at Resolute, but, usually overestimated at the other stations. The CTM simulations in the tropics (Hilo) at 700 to 500 hPa show much greater spread and hence generally worse agreement with observations. The mean concentration of surface O_3 observed at Cape Grim is well matched by most models, but the seasonality is underestimated.

Observed CO abundances are compared with the Y2000 model simulations in Figure 4.11 for surface sites at various altitudes and latitudes: Cape Grim (CGA, 94 m), Tae Ahn (KOR,

Table 4.11: *Changes in tropospheric O_3 (DU) and OH (%) relative to year 2000 for various perturbations to the atmosphere. Individual values calculated with chemistry transport-models (CTMs) plus the average values adopted for this report (TAR).*

	Y2000	A2x: Y2100 – Y2000		
	+10% CH_4	All A2x	$–NO_x$	$–NO_x$–VOC–CH_4
CTM	Case A	Case B	Case C	Case D
Effective[a] tropospheric O_3 change (DU):				
HGIS		26.5		
GISS		25.2		
IASB	0.66	18.9	9.2	0.4
KNMI	0.63	18.0	9.0	
MOZ1		16.6		
MOZ2		22.4		
MPIC	0.40			
UCI	0.69	23.3	10.2	2.8
UIO	0.51	26.0	6.0	2.1
UKMO		18.9	4.6	3.1
ULAQ	0.85	22.2	14.5	5.9
TAR[b]	**0.64**	**22.0**	**8.9**	**2.0**
Tropospheric OH change (%)				
IASB	–2.9%	–7%		
KNMI	–3.3%	–25%	–41%	
MOZ1		–21%		
MOZ2		–18%		
MPIC	–2.7%			
UCI	–3.2%	–15%	–39%	–16.0%
UIO	–3.1%	–6%	–37%	–12.3%
UKMO	–2.9%	–12%	–37%	–10.8%
ULAQ	–2.7%	–17%	–43%	–22.0%
TAR[b]	**–3.0%**	**–16%**	**–40%**	**–14%**

Model results from OxComp workshop; all changes (DU for O_3 and % for OH) are relative to the year Y2000. Tropospheric mean OH is weighted by CH_4 loss rate. Mean O_3 changes (all positive) are derived from the standard reporting grid on which the CTMs interpolated their results. See Table 4.10 for the model key. The different cases include (A) a 10% increase in CH_4 to 1,920 ppb and (B) a full 2100 simulation following SRES draft marker scenario A2 (based on February 1999 calculations for preliminary work of this report). Case C drops the NO_x emissions back to Y2000 values; and case D drops NO_x, VOC, and CH_4 likewise.

Adopted CH_4 abundances and pollutant emissions from Y2000 to Y2100 are:

Y2000: CH_4=1,745 ppb, e–NO_x=32.5 TgN/yr, e–CO=1,050 Tg/yr, e–VOC=150 Tg/yr.

Y2100: CH_4=4,300 ppb, e–NO_x=110.0 TgN/yr, e–CO=2,500 Tg/yr, e–VOC=350 Tg/yr.

[a] N.B. Unfortunately, after the government review it was discovered that the method of integrating O_3 changes on the reporting grid was not well defined and resulted in some unintentional errors in the values reported above. Thus, the values here include in effect the O_3 increases predicted/expected in the lower stratosphere in addition to the troposphere. In terms of climate change, use of these values may not be unreasonable since O_3 changes in the lower stratosphere do contribute to radiative forcing. Nevertheless, the troposphere-only changes are about 25 to 33% less than the values above.

$$\delta(\text{tropospheric } O_3) = +5.0\times\delta\ln(CH_4) + 0.125\times\delta(e-NO_x) + 0.0011\times\delta(e-CO) + 0.0033\times\delta(e-VOC) \text{ in DU.}$$

[b] TAR adopts the weighted average for cases A to D as shown, where the weighting includes factors about model formulation and comparison with observations. A linear interpolation is derived from these results and used in the scenarios:

$$\delta\ln(\text{tropospheric OH}) = -0.32\times\delta\ln(CH_4) + 0.0042\times\delta(e-NO_x) - 1.05e-4\times\delta(e-CO) - 3.15e-4\times\delta(e-VOC),$$

$$\delta(\text{effective } O_3) = +6.7\times\delta\ln(CH_4) + 0.17\times\delta(e-NO_x) + 0.0014\times\delta(e-CO) + 0.0042\times\delta(e-VOC) \text{ in DU.}$$

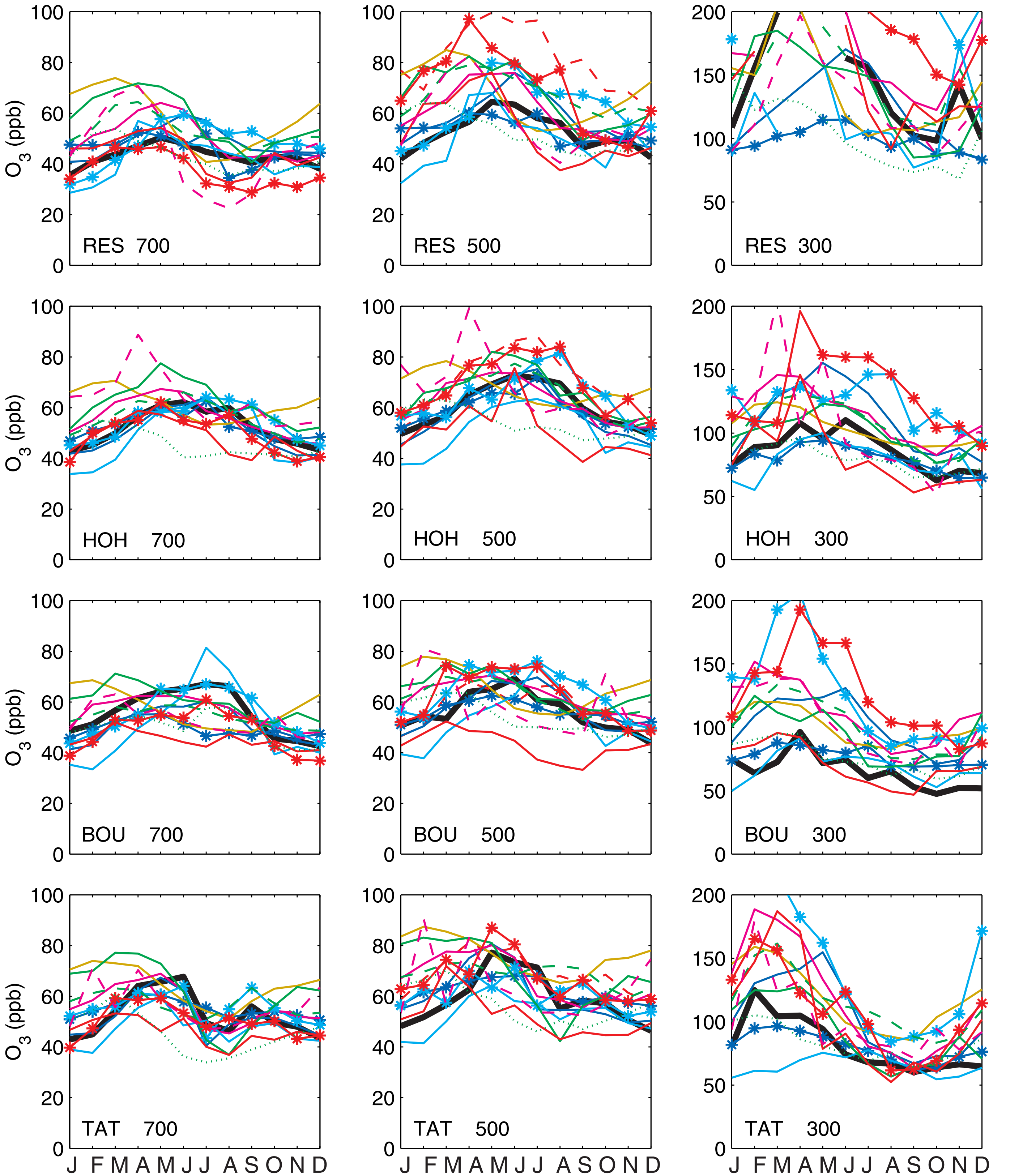
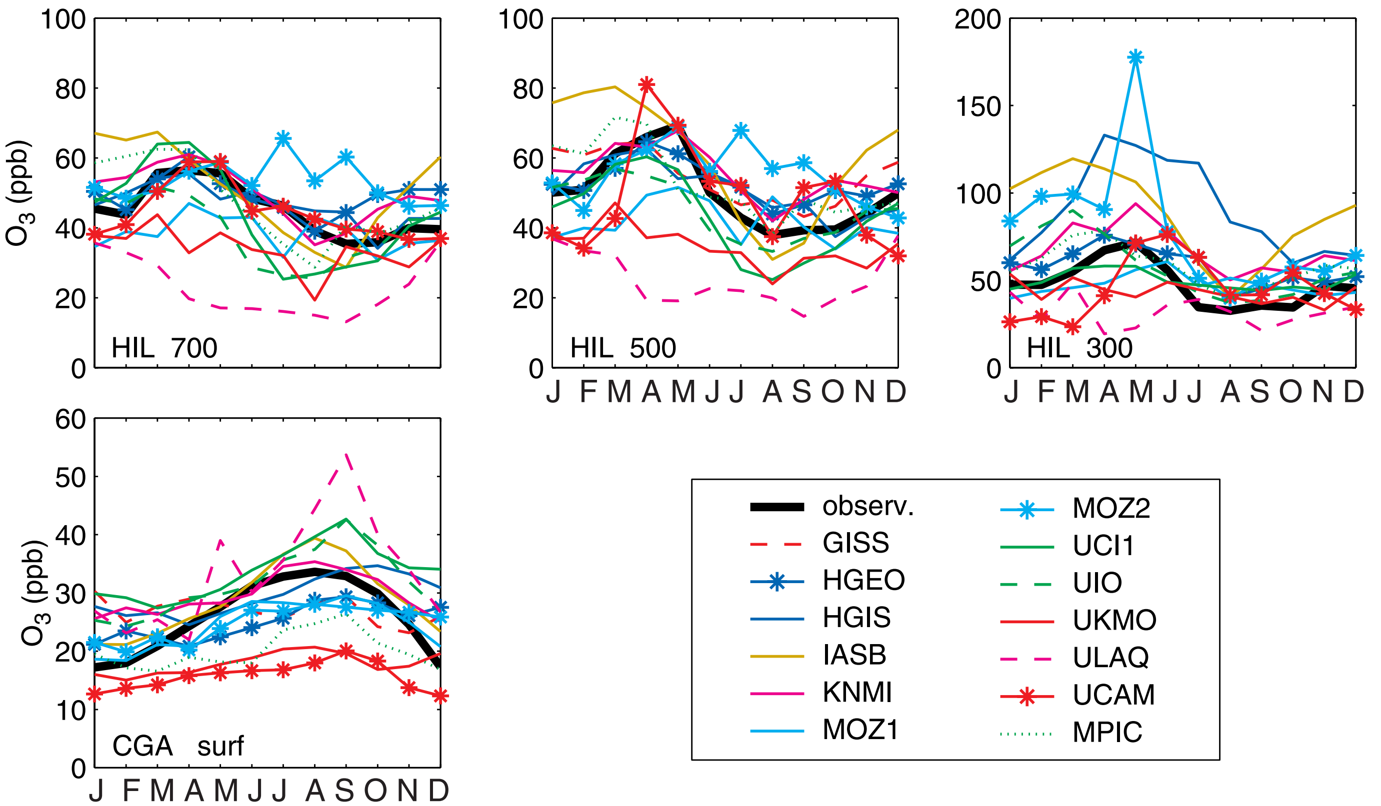


Figure 4.10: Observed monthly mean O_3 abundance (ppb) from sondes at 700 hPa (left column), 500 hPa (centre) and 300 hPa (right) from a sample of stations (thick black line) compared with Y2000 model simulations from OxComp (thin coloured lines, see model key in legend and Table 4.10). The sonde stations include RESolute (75°N, 95°W), HOHenpeissenberg (48ºN, 11°E), BOUlder (40°N, 105°W), TATeno (36°N, 140°E), and HILo (20°N, 155°W). Surface monthly O_3 observations (thick black line) at Cape Grim Observatory (CGA, 40°S, 144°E, 94 m above mean sea level) are also compared with the models. (Continues opposite.)



20 m), Mauna Loa (MLH, 3397 m), Alert (ALT, 210 m), and Niwot Ridge (NWR, 3475 m). The Alert abundances are well matched by most but not all models. Niwot Ridge and Mauna Loa are reasonably well modelled except for the February to March maximum. At Tae Ahn, the models miss the deep minimum in late summer, but do predict the much larger abundances downwind of Asian sources. At Cape Grim the seasonal cycle is matched, but the CO abundance is uniformly overestimated (30 to 50%) by all the models, probably indicating an error in Southern Hemisphere emissions of CO.

Overall, this comparison with CO and O_3 observations shows good simulations by the OxComp models of the global scale chemical features of the current troposphere as evidenced by CO and O_3; however, the critical NO_x chemistry emphasises variability on much smaller scales, such as biomass burning plumes and lightning storms, that are not well represented by the global models. With this large variability and small scales, the database of NO_x measurements needed to provide a test for the global models, equivalent to CO and O_3, would need to be much larger.

The current NO_x database (e.g., Emmons *et al.*, 1997; Thakur *et al.*, 1999) does not provide critical tests of CTM treatment of these sub-grid scales.

4.4.4 Model Simulations of Perturbed and Y2100 Atmospheres

The OxComp workshop also defined a series of perturbations to the Y2000 atmosphere for which the models reported the monthly averaged 3-D distribution of O_3 abundances and the budget for CH_4, specifically the loss due to reaction with tropospheric OH. From these diagnostics, the research group at Oslo calculated the change in global mean tropospheric O_3 (DU) and in OH (%) relative to Y2000, as shown in Table 4.11. For each model at every month, the "troposphere" was defined as where O_3 abundances were less than 150 ppb in the Y2000 simulation, a reasonably conservative diagnostic of the tropopause (see Logan, 1999). Because O_3 is more effective as a greenhouse gas when it lies above the surface boundary layer (SAR; Hansen *et al.*, 1997a; Prather and Sausen, 1999; Chapter 6 of this report), the model study diagnosed the O_3 change occurring in the 0 to 2 km layers of the model. This amount is typically 20 to 25% of the total change and is consistent across models and types of perturbations here.

Case A, a +10% increase in CH_4 abundance for Y2000, had consistent results across reporting models that differed little from the SAR's Delta-CH_4 model study. The adopted values for this report are −3% change in OH and +0.64 DU increase in O_3, as listed under the "TAR" row in Table 4.11.

The Y2100 atmosphere in OxComp mimics the increases in pollutant emissions in SRES A2p scenario from year 2000 to year 2100 with the year 2100 abundance of CH_4, 4,300 ppb, calculated with the SAR technology and named here A2x. (See discussion in section 4.4.5; for the SAR, only the CH_4-OH feedback is included.) The long-lived gases CO_2 and N_2O have no impact on these tropospheric chemistry calculations as specified.

Cases B-C-D are a sequence of three Y2100 atmospheres based on A2x: Case B is the full Y2100-A2x scenario; Case C is the same Y2100-A2x scenario but with unchanged (Y2000) NO_x

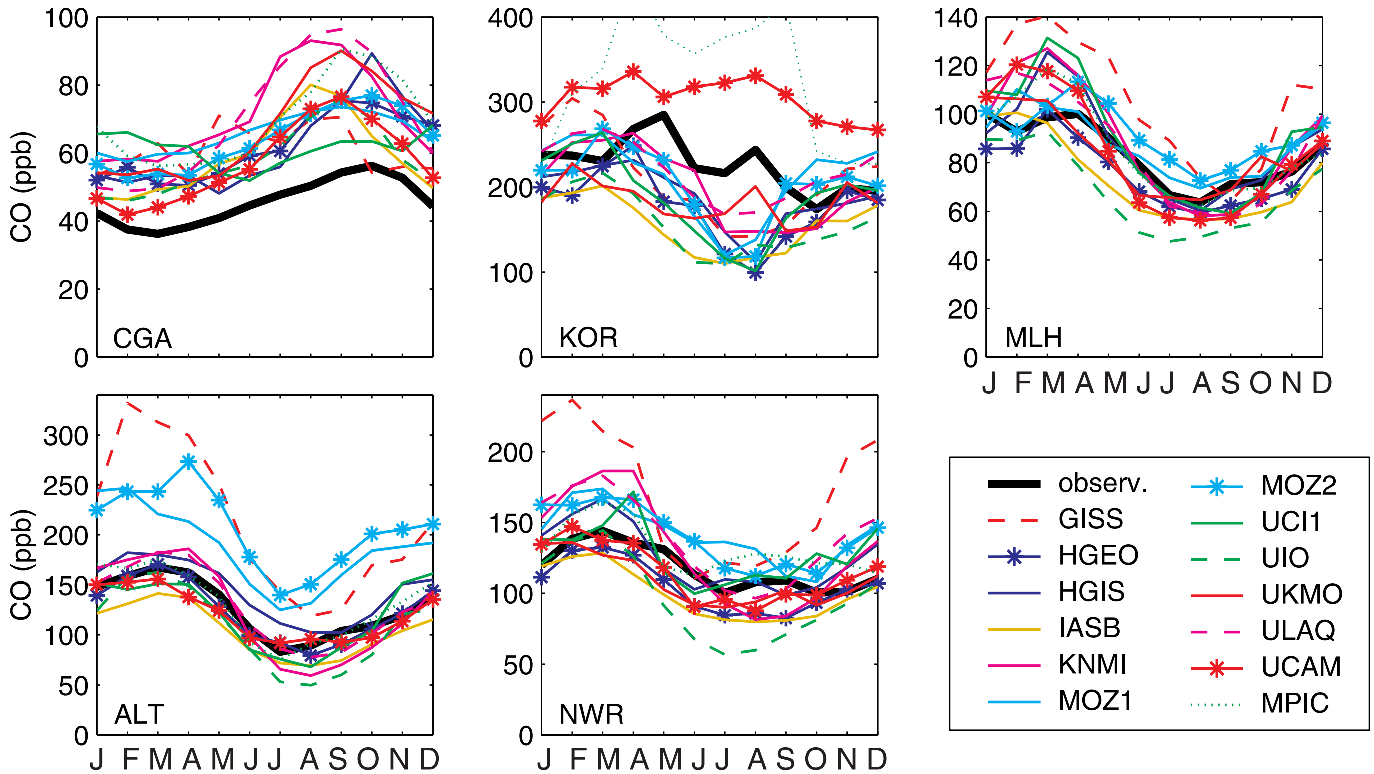


Figure 4.11: Observed seasonal surface CO abundance (ppb, thick black lines) at Cape Grim (CGA: 40°S, 144°E, 94 m above mean sea level), Tae Ahn (KOR: 36°N, 126°E, 20 m), Mauna Loa (MLH: 19°N, 155°W, 3397 m), Alert (ALT: 82°N, 62°W, 210 m), and Niwot Ridge (NWR: 40°N, 105°W, 3475 m) are compared with the OxComp model simulations from Y2000, see Figure 4.10.

emissions; and Case D is the same but with NO_x, VOC and CH_4 unchanged since Y2000 (i.e., only CO emissions change). Case B (Y2100-A2x) results are available from most OxComp participants. All models predict a decrease in OH, but with a wide range from –6 to –25%, and here we adopt a decrease of –16%. Given the different distributions of the O_3 increase from the OxComp models (Figures 4.12-13), the increases in globally integrated O_3 were remarkably consistent, ranging from +16.6 to +26.5 DU, and we adopt +22 DU. Without the increase in NO_x emissions (Case C) the O_3 increase drops substantially, ranging from +4.6 to +14.5 DU; and the OH decrease is large, –37 to –43%. With only CO emissions (Case D) the O_3 increase is smallest in all models, +0.4 to +5.9 DU.

This report adopts a weighted, rounded average of the changes in OH and O_3 for cases A-D as shown in the bold rows in Table 4.11. The weighting includes factors about model formulation and comparison with observations. This sequence of calculations (Y2000 plus Cases A-B-C-D) allows us to define a simple linear relationship for the absolute change in tropospheric O_3 and the relative change in OH as a function of the CH_4 abundance and the emission rates for NO_x, for CO, and for VOC. These two relationships are given in Table 4.11. Since the change in CH_4 abundance and other pollutant emissions for Y2100-A2x are among the largest in the SRES scenarios, we believe that interpolation of the O_3 and OH changes for different emission scenarios and years introduces little additional uncertainty.

The possibility that future emissions of CH_4 and CO overwhelm the oxidative capacity of the troposphere is tested (Case E, see Table 4.3 footnote &) with a +10% increase in CH_4 on top of Y2100-A2x (Case B). Even at 4,300 ppb CH_4, the decrease in OH calculated by two CTMs is only slightly larger than in Case A, and thus, at least for SRES A2p, the CH_4-feedback factor does not become as large as in the runaway case (Prather, 1996). This report assumes that the CH_4 feedback remains constant over the next century; however, equivalent studies for the low-NO_x future scenarios are not assessed.

The apparent agreement on predicting the single global, annual mean tropospheric O_3 increase, e.g., Case B in Table 4.11, belies the large differences as to where this increase occurs and what is its peak magnitude. The spatial distributions of the tropospheric O_3 increases in July for Case B are shown in Figure 4.12 (latitude by altitude zonal average abundance, ppb) and Figure 4.13 (latitude by longitude column density, DU) for nine CTMs. The largest increase in abundance occurs near the tropopause at 40°N latitude; yet some models concentrate this increase in the tropics and others push it to high latitudes. In terms of column density, models generally predict large increases along the southern edge of Asia from Arabia to eastern China; although the increases in tropical, biomass-burning regions varies widely from model to model.

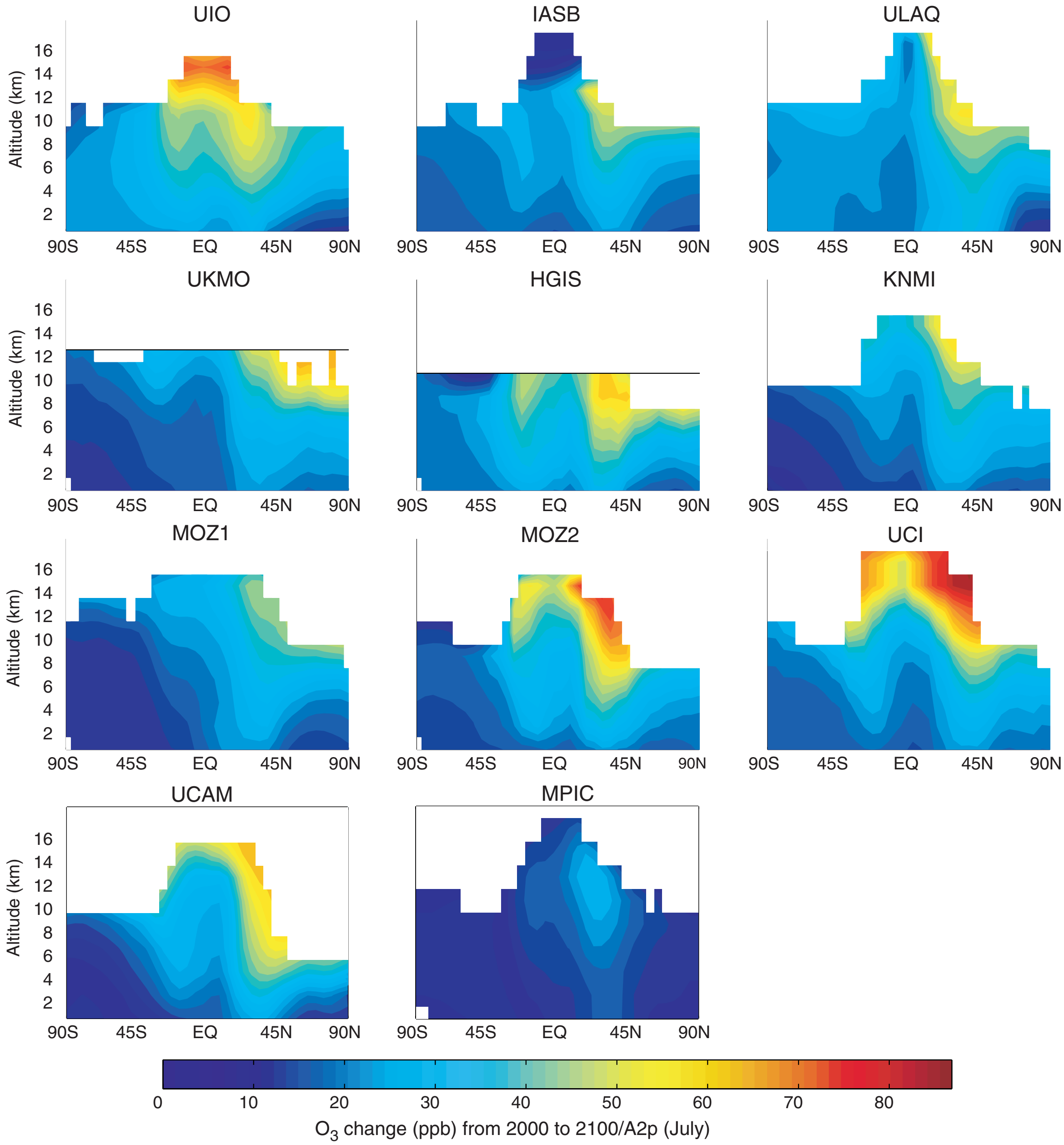


Figure 4.12: July zonal mean increase in tropospheric O_3 (ppb) as a function of latitude and altitude from Y2000 to Y2100 adopting SRES A2p projections for CH_4, CO, VOC, and NO_x. Results are shown for a sample of the chemistry-transport models (CTM) participating in IPCC OxComp workshop. Increases range from 0 to more than 80 ppb. Changes in the stratosphere (defined as $O_3 > 150$ ppb in that model's Y2000 simulation) are masked off, as are also regions in the upper troposphere for some CTMs (UKMO, HGIS) where O_3 is not explicitly calculated. See Table 4.10 for participating models.

This similarity in the total, but difference in the location, of the predicted O_3 increases is noted in Isaksen and Jackman (1999) and is probably due to the different transport formulations of the models as documented in previous CTM intercomparisons (Jacob *et al.*, 1997). Possibly, the agreement on the average O_3 increase may reflect a more uniform production of O_3 molecules as a function of NO_x emissions and CH_4 abundance across all models. Nevertheless, the large model range in the predicted patterns of O_3 perturbations leads to a larger uncertainty in climate impact than is indicated by Table 4.11.

The projected increases in tropospheric O_3 under SRES A2 and A1FI will have serious consequences on the air quality of most of the Northern Hemisphere by year 2100. Taking only the global numbers from Figure 4.14, the mean abundance of tropospheric O_3 will increase from about 52 ppb (typical mid-tropospheric abundances) to about 84 ppb in year 2100. Similar increases of about +30 ppb are seen near the surface at 40°N on a zonal average in Figure 4.12. Such increases will raise the "background" levels of O_3 in the northern mid-latitudes to close to the current clean-air standard.

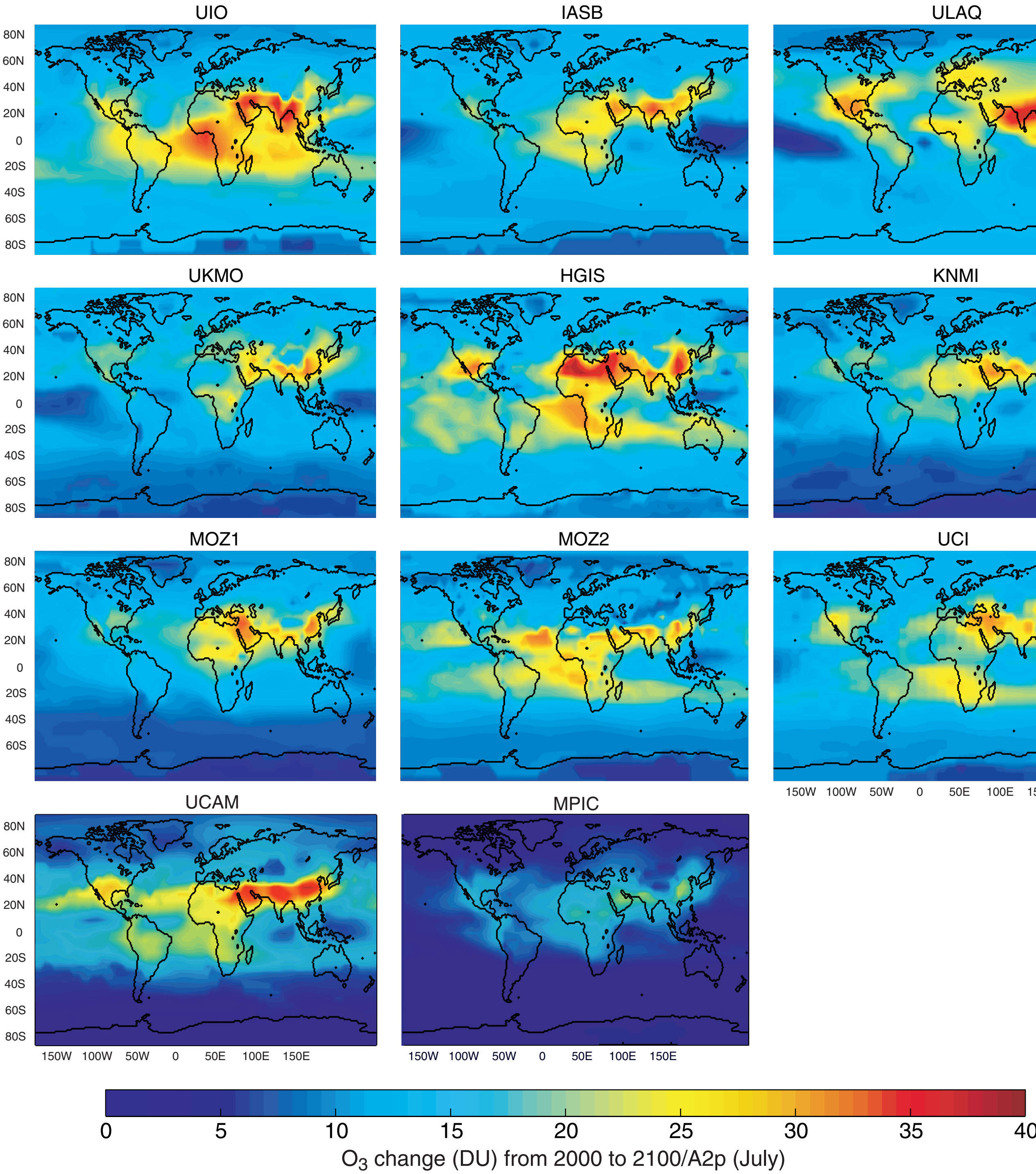


Figure 4.13: July column increase in tropospheric O_3 (DU) as a function of latitude and longitude from Y2000 to Y2100 adopting SRES A2p projections for CH_4, CO, VOC, and NO_x is shown for some OxComp simulations. See Figure 4.12.

4.4.5 Atmospheric Composition for the IPCC Scenarios to 2100

Mean tropospheric abundances of greenhouse gases and other chemical changes in the atmosphere are calculated by this chapter for years 2000 to 2100 from the SRES scenarios for anthropogenic emissions of CH_4, N_2O, HFCs, PFCs, SF_6, NO_x, CO, and VOC (corresponding emissions of CO_2 and aerosol precursors are not used). The emissions from the six SRES marker/illustrative scenarios (A1B, A1T, A1FI, A2, B1, B2) are tabulated in Appendix II, as are the resulting greenhouse gas abundances, including CO_2 and aerosol burdens. Chlorine- and bromine-containing greenhouse gases are not calculated here, and we adopt the single baseline scenario from the WMO assessment (Montreal Protocol Scenario A1 of Madronich and Velders, 1999), which is reproduced in Appendix II. Also given in Appendix II are the parallel data for the SRES preliminary marker scenarios (A1p, A2p, B1p, B2p) and, in many cases, the SAR scenario IS92a as a comparison with the previous assessment.

Greenhouse gas abundances are calculated using a methodology similar to the SAR: (1) The troposphere is treated as a single box with a fill-factor for each gas that relates the burden to the tropospheric mean abundance (e.g., Tg/ppb). (2) The atmospheric lifetime for each gas is recalculated each year based on conditions at the beginning of the year and the formulae in Table 4.11. (Changes in tropospheric OH are used to scale the lifetimes of CH_4 and HFCs, and the abundance of N_2O is used to calculate its new lifetime.) (3) The abundance of a gas is integrated exactly over the year assuming that emissions remain constant for 12 months. (4) Abundances are annual means, reported at the beginning of each year (e.g., year 2100 = 1 January 2100).

In the SAR, the only OH feedback considered was that of CH_4 on its own lifetime. For this report, we calculate the change in tropospheric OH due to CH_4 abundance as well as the immediate emissions of NO_x, CO and VOC. Likewise, the increase in tropospheric O_3 projected in the SAR considered only increases in CH_4; whereas now it includes the emissions of NO_x, CO and VOC. Thus the difference between IS92a in the SAR and in this report is similar to that noted by Kheshgi *et al.* (1999). Also, the feedback of N_2O on its lifetime is included here for the first time and shows up as reduction of 14 ppb by year 2100 in this report's IS92a scenario as compared to the SAR.

The 21st century abundances of CH_4, N_2O, tropospheric O_3, HFC-134a, CF_4, and SF_6 for the SRES scenarios are shown in Figure 4.14. Historical data are plotted before year 2000; and the SRES projections, thereafter to year 2100. CH_4 continues to rise in B2, A1FI, and A2 (like IS92a), with abundances reaching 2,970 to 3,730 ppb, in order. For A1B and A1T, CH_4 peaks in mid-century at about 2,500 ppb and then falls. For B1, CH_4 levels off and eventually falls to 1980-levels by year 2100. N_2O continues to rise in all scenarios, reflecting in part its long lifetime, and abundances by the end of the century range from 350 to 460 ppb. Most scenarios lead to increases in tropospheric O_3, with scenarios A1FI and A2 projecting the maximum tropospheric O_3 burdens of 55 DU by year 2100. This increase of about 60% from today is more than twice the change from pre-industrial to present. Scenario B1 is alone in projecting an overall decline in tropospheric O_3 over most of the century: the drop to 30 DU is about halfway back to pre-industrial values. HFC-134a, the HFC with the largest projected abundance, is expected to reach about 900 ppt by year 2100 for all scenarios except B1. Likewise by 2100, the abundance of CF_4 rises to 340 to 400 ppt in all scenarios except B1. The projected increase in SF_6 is much smaller in absolute abundance, reaching about 60 ppt in scenarios A1 and A2. For the major non-CO_2 greenhouse gases, the SRES A2 and A1FI increases are similar to, but slightly larger than, those of IS92a. The SRES mix of lesser greenhouse gases (HFCs, PFCs, SF_6) and their abundances are increased substantially relative to IS92a. The summed radiative forcings from these gases plus CO_2 and aerosols are given in Chapter 6.

The chemistry of the troposphere is changing notably in these scenarios, and this is illustrated in Figure 4.14 with the lifetime (LT) of CH_4 and the change in mean tropospheric OH relative to year 2000. In all scenarios except B1, OH decreases 10% or more by the end of the century, pushing the lifetime of CH_4 up from 8.4 years, to 9.2 to 10.0 years. While increasing emissions of NO_x in most of these scenarios increases O_3 and would tend to increase OH (see notes to Table 4.11), the increase in CH_4 abundance and the greater CO emissions appear to dominate, driving OH down. In such an atmosphere, emissions of CH_4 and HFCs persist longer with greater greenhouse impact. In contrast the B1 atmosphere is more readily able to oxidise these compounds and reduce their impact.

4.4.6 Gaps in These Projections – the Need for Coupled Models

There are some obvious gaps in these projections where processes influencing the greenhouse gas abundances have been omitted. One involves coupling of tropospheric chemistry with the stratosphere. For one, we did not include the recovery of stratospheric ozone expected over the next century. The slow recovery of stratospheric ozone depletion from the halogens will lead to an increase in the flux of ozone into the troposphere and also to reduced solar UV in the troposphere, effectively reversing over the next century what has occurred over the past two decades. A more important impact on the Y2100 stratosphere, however, is the response to increases in CH_4 and N_2O projected by most scenarios (see Hofmann and Pyle, 1999), which in terms of coupled stratosphere-troposphere chemistry models could be evaluated in only one of the OxComp models (ULAQ, Université degli studi dell' Aguila) and is not included here.

Another major gap in these projections is the lack of global models coupling the atmospheric changes with biogeochemical models. There have been studies that tackled individual parts of the problem, e.g., deposition of reactive N (Holland *et al.*, 1997), crop damage from O_3 (Chameides *et al.*, 1994). Integrated assessment studies have coupled N_2O and CH_4 emission models with lower dimension or parametrized climate and chemistry models (e.g., Alcamo, 1994; Holmes and Ellis, 1999; Prinn *et al.*, 1999). However, the inherent local nature of this coupling, along with the possible feedbacks through, for example NO and VOC emissions, point to the need for coupled 3-D global chemistry and ecosystem models in these assessments.

Finally, there is an obvious need to couple the physical changes in the climate system (water vapour, temperature, winds, convection) with the global chemical models. This has been partially accomplished for some cases that are highlighted here (Section 4.5.2), but like other gaps presents a major challenge for the next assessment.

4.4.7 Sensitivity Analysis for Individual Sectors

In order to assess the overall impact of changing industry or agriculture, it would be necessary to combine all emissions from a specific sector or sub-sector as has been done with the IPCC assessment of aviation (Penner *et al.*, 1999). Further, the impact on natural emissions and land-use change (e.g., albedo, aerosols) would also need to be included. Such a sector analysis would cut across Chapters 3, 4, 5 and 6 of this report (e.g., as in Prather and

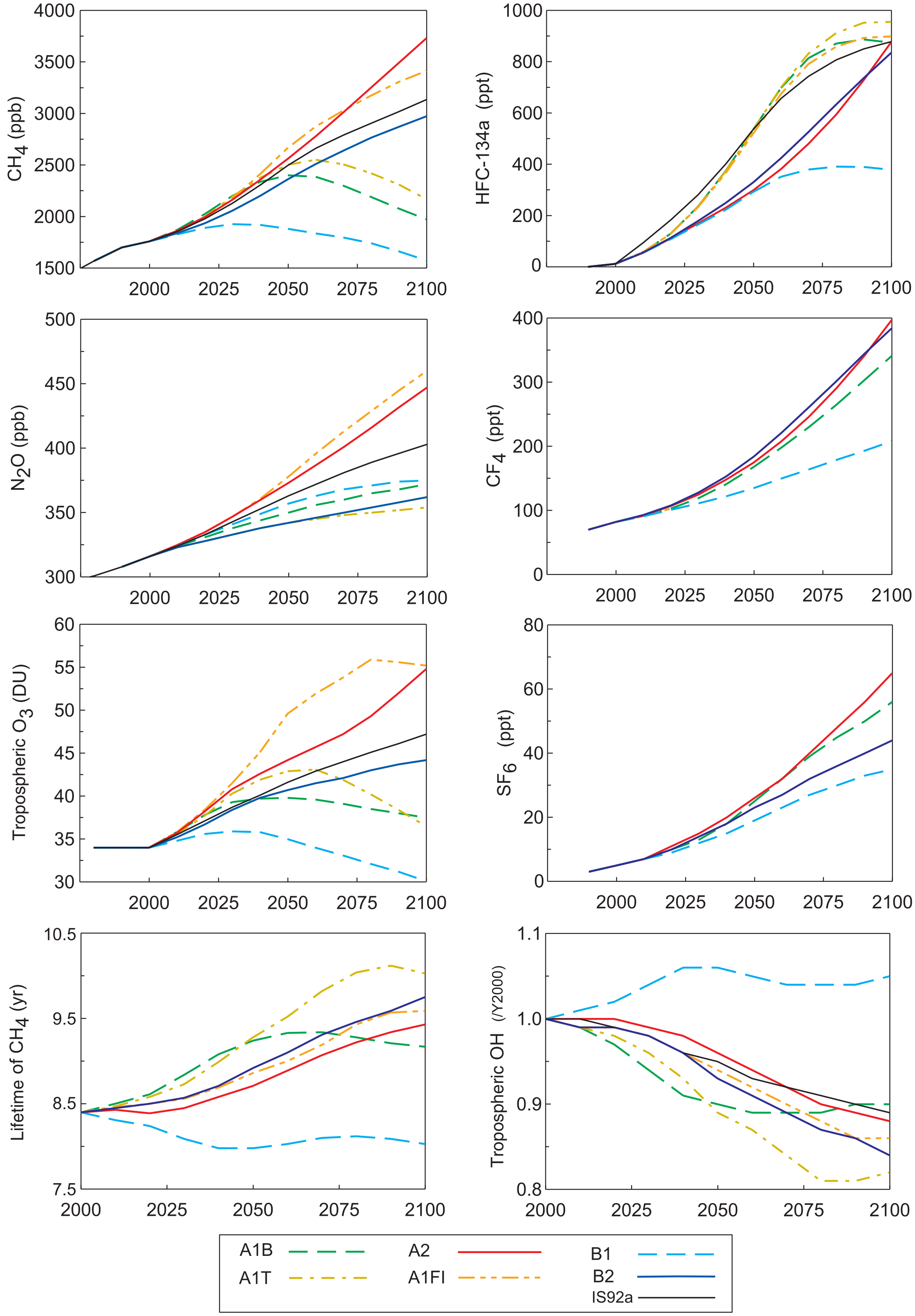


Figure 4.14: Atmospheric composition and properties predicted using the six SRES Marker-Illustrative scenarios for anthropogenic emissions: A1B (green dashed line), A1T (yellow dash-dotted), A1FI (orange dash-dot-dotted), A2 (red solid), B1 (cyan dashed), B2 (solid dark blue). Abundances prior to year 2000 are taken from observations, and the IS92a scenario computed with current methodology is shown for reference (thin black line). Results are shown for CH_4 (ppb), N_2O (ppb), tropospheric O_3 (DU), HFC-134a (ppt), CF_4 (ppt), SF_6 (ppt), the lifetime of CH_4 (yr), and the global annual mean abundance of tropospheric OH (scaled to year 2000 value). All SRES A1-type scenarios have the same emissions for HFCs, PFCs, and SF_6 (appearing a A1B), but the HFC-134a abundances vary because the tropospheric OH values differ affecting its lifetime. The IS92a scenario did not include emissions of PFCs and SF_6. For details, see chapter text and tables in Appendix II.

Sausen, 1999). Such an analysis cannot be done for the SRES emissions scenarios, which lack a breakdown by sector and also lack numbers for the changes in the land area of agriculture or urbanisation.

4.5 Open Questions

Many processes involving atmospheric chemistry, and the coupling of atmospheric chemistry with other elements of global change, have been proposed in the scientific literature. These are generally based on sound physical and chemical principles, but unfortunately, there is no consensus on their quantitative role in atmospheric chemistry on a global scale (e.g., the effects of clouds on tropospheric ozone: Lelieveld and Crutzen (1990) vs. Liang and Jacob (1997)), on the magnitude of possible compensating effects (e.g., net settling of HNO_3 on cloud particles: Lawrence and Crutzen (1999) vs. full cloud-scale dynamics), or even on how to implement them or whether these are already effectively included in many of the model calculations. While many of these processes may be important, there is inadequate information or consensus to make a quantitative evaluation in this assessment. This assessment is not a review, and so this section presents only a few examples of recent publications studying feedbacks or chemical processes, which are not included, but which are potentially important in this assessment.

4.5.1 Chemical Processes Important on the Global Scale

4.5.1.1 Missing chemistry, representation of small scales, and changing emission patterns

Analyses and observations (see Section 4.2.6) continue to test and improve the chemistry and transport used in the global CTMs. In terms of the chemistry, recent studies have looked, for example, at the representation of NMHC chemistry (Houweling *et al.* 1998; Wang *et al.* 1998b), the role of halogens in the O_3 budget of the remote marine troposphere, and the acetone source of upper tropospheric OH (see Sections 4.2.4 and 4.2.6). Most of these improvements in understanding will eventually become adopted as standard in the global CTMs, but at this stage, for example, the role of tropospheric halogen chemistry on the Y2100 predictions has not been evaluated in the CTMs.

Convection, as well as urban pollution and biomass burning plumes, occur on horizontal scales not resolved in global CTMs. These sub-grid features appear to be important in calculating OH abundances and O_3 production for biomass burning emissions (Pickering *et al.*, 1996; Folkins *et al.*, 1997), for the remote upper troposphere (Jaeglé *et al.*, 1997; Prather and Jacob, 1997; Wennberg *et al.*, 1998), and in urban plumes (e.g., Sillman *et al.*, 1990). Convection is represented in all CTMs here (e.g., Collins *et al.*, 1999; Müller and Brasseur, 1999) but in quite different ways, and it still involves parametrization of processes occurring on a sub-grid scale. A substantial element of the differences in CTM simulations appears to lie with the different representations of convection and boundary layer transport, particularly for the short-lived gases such as NO_x.

A change in the geographic emission pattern of the pollutants (NO_x, CO and VOC) can by itself alter tropospheric O_3 and OH abundances and in turn the abundances of CH_4 and HFCs. In one study of regional NO_x emissions and control strategy, Fuglestvedt *et al.* (1999) find that upper tropospheric O_3 is most sensitive to NO_x reductions in Southeast Asia and Australia and least to those in Scandinavia. Understanding trends in CO requires knowledge not only of the *in situ* chemistry of CO (e.g., Granier *et al.*, 1996; Kanakidou and Crutzen, 1999), but also of how local pollution control has altered the global pattern of emissions (e.g., Hallock-Waters *et al.*, 1999). These shifts have been included to some extent in the SRES emissions for year 2100 used here; however, the projected change in emission patterns have not been formally evaluated within the atmospheric chemistry community in terms of uncertainty in the Y2100 global atmosphere.

4.5.1.2 Aerosol interactions with tropospheric O_3 and OH

Over the past decade of assessments, stratospheric O_3 chemistry has been closely linked with aerosols, and global models in the recent WMO assessments have included some treatment of the stratospheric sulphate layer and polar stratospheric clouds. In the troposphere, studies have identified mechanisms that couple gas-phase and aerosol chemistry (Jacob, 2000). Many aerosols are photochemically formed from trace gases, and at rates that depend on the oxidative state of the atmosphere. Such processes are often included in global aerosol models (see Chapter 5). The feedback of the aerosols on the trace gas chemistry includes a wide range of processes: conversion of NO_x to nitrates, removal of HO_x, altering the UV flux and hence photodissociation rates (e.g., Dickerson *et al.*, 1997; Jacobson, 1998), and catalysing more exotic reactions leading to release of NO_x or halogen radicals. These processes are highly sensitive to the properties of the aerosol and the local chemical environment, and their importance on a global scale is not yet established. Only the first example above of aerosol chemistry is generally included in many of the CTMs represented here; however, the surface area of wet aerosols (that converts NO_x to HNO_3 via the intermediate species NO_3 and N_2O_5) is usually specified and not interactively calculated. More laboratory and field research is needed to define the processes so that implementation in global scale models can evaluate their quantitative impact on these calculations of greenhouse gases.

4.5.1.3 Stratosphere-troposphere coupling

The observed depletion of stratospheric ozone over the past three decades, which can be attributed in large part but not in total to the rise in stratospheric chlorine levels, has been reviewed extensively in WMO (1999). This depletion has lead to increases in tropospheric UV and hence forces tropospheric OH abundances upward (Bekki *et al.*, 1994). The total effect of such a change is not simple and involves the coupled stratosphere-troposphere chemical system; for example, ozone depletion may also have reduced the influx of O_3 from the stratosphere, which would reduce tropospheric O_3 (Karlsdottir *et al.*, 2000) and tend to reverse the OH trend. Such chemical feedbacks are reviewed as “climate-chemistry” feedbacks in WMO 1999 (Granier and Shine, 1999). There is insufficient understanding or quantitative consensus on these effects to be included in this assessment. While chlorine-driven O_3 depletion becomes much less of an issue in the latter half of the 21st century, the projected increases in CO_2, CH_4, and N_2O may cause even larger changes in stratospheric O_3. The lack of coupled CTMs that include stratospheric changes adds uncertainty to these projections.

4.5.1.4 Uncertainties in the tropospheric O_3 budget

An updated survey of global tropospheric CTM studies since the SAR focuses on the tropospheric O_3 budget and is reported in Table 4.12. In this case authors were asked for diagnostics that did not always appear in publication. The modelled tropospheric O_3 abundances generally agree with observations; in most cases the net budgets are in balance; and yet the individual components vary greatly. For example, the stratospheric source ranges from 400 to 1,400 Tg/yr, while the surface sink is only slightly more constrained, 500 to 1,200 Tg/yr. If absolute production is diagnosed as the reactions of HO_2 and other peroxy radicals with NO, then the globally integrated production is calculated to be very large, 2,300 to 4,300 Tg/yr and is matched by an equally large sink (see Sections 4.2.3.3 and 4.2.6). The differences between the flux from the stratosphere and the destruction at the surface is balanced by the net *in situ* photochemical production. In this survey, the net production varies widely, from −800 to +500 Tg/yr, indicating that in some CTMs the troposphere is a large chemical source and in others a large sink. Nevertheless, the large differences in the stratospheric source are apparently the driving force behind whether a model calculates a chemical source or sink of tropospheric O_3. Individual CTM studies of the relative roles of stratospheric influx versus tropospheric chemistry in determining the tropospheric O_3 abundance (e.g., Roelofs and Lelieveld, 1997; Wang *et al.*, 1998a; Yienger *et al.*, 1999) will not represent a consensus until all CTMs develop a more accurate representation of the stratospheric source consistent with observations (Murphy and Fahey, 1994).

4.5.2 Impacts of Physical Climate Change on Atmospheric Chemistry

As global warming increases in the next century, the first-order atmospheric changes that impact tropospheric chemistry are the anticipated rise in temperature and water vapour. For example, an early 2-D model study (Fuglestvedt *et al.*, 1995) reports that tropospheric O_3 decreases by about 10% in response to a warmer, more humid climate projected for year 2050 as compared to an atmosphere with current temperature and H_2O. A recent study based on NCAR (National Center for Atmospheric Research) CCM (Community Climate Model) projected year 2050 changes in tropospheric temperature and H_2O (Brasseur *et al.*, 1998a) finds a global mean 7% increase in the OH abundance and a 5% decrease in tropospheric O_3, again relative to the same calculation with the current physical climate.

A 3-D tropospheric chemistry model has been coupled to the Hadley Centre Atmosphere-Ocean General Circulation Model (AOGCM) and experiments performed using the SRES preliminary marker A2p emissions (i) as annual snapshots (Stevenson *et al.*, 2000) and (ii) as a 110-year, fully coupled experiment (Johnson *et al.*, 1999) for the period 1990 to 2100. By 2100, the experiments with coupled climate change have increases in CH_4 which are only about three-quarters those of the simulation without climate change and increases in Northern Hemisphere mid-latitude O_3 which are reduced by half. The two major climate-chemistry feedback mechanisms identified in these and previous studies were (1) the change of chemical reaction rates with the average 3°C increase in tropospheric temperatures and (2) the enhanced photochemical destruction of tropospheric O_3 with the approximately 20% increase in water vapour. The role of changes in the circulation and convection appeared to play a lesser role but have not been fully evaluated. These studies clearly point out the importance of including the climate-chemistry feedbacks, but are just the beginning of the research that is needed for adequate assessment.

Thunderstorms, and their associated lightning, are a component of the physical climate system that provides a direct source of a key chemical species, NO_x. The magnitude and distribution of this lightning NO_x source controls the magnitude of the anthropogenic perturbations, e.g., that of aviation NO_x emissions on upper tropospheric O_3 (Berntsen and Isaksen, 1999). In spite of thorough investigations of the vertical distribution of lightning NO_x (Huntrieser *et al.*, 1998; Pickering *et al.* 1998), uncertainty in the source strength of lightning NO_x cannot be easily derived from observations (Thakur *et al.*, 1999; Thompson *et al.*, 1999). The link of lightning with deep convection (Price and Rind, 1992) opens up the possibility that this source of NO_x would vary with climate change, however, no quantitative evaluation can yet be made.

4.5.3 Feedbacks through Natural Emissions

Natural emissions of N_2O and CH_4 are currently the dominant contributors to their respective atmospheric burdens, with terrestrial emissions greatest in the tropics. Emissions of both of these gases are clearly driven by changes in physical climate as seen in the ice-core record (Figure 4.1e). Soil N_2O emissions are sensitive to temperature and soil moisture and changes in rates of carbon and nitrogen cycling (Prinn *et al.*, 1999). Similarly, methane emissions from wetlands are sensitive to the extent of inundation, temperature rise, and changes in rates of carbon and nitrogen cycling. Natural emissions of the pollutants NO_x, CO, and VOC play an important role in production of tropospheric O_3 and the abundance of OH; and these emissions are subject to similar forcings by both the physical and chemical climates. Terrestrial and aquatic ecosystems in turn respond to near-surface pollution (O_3, NO_2, acidic gases and aerosols) and to inadvertent fertilisation through deposition of reactive nitrogen (often emitted from the biosphere as NO or NH_3). This response can take the form of die back, reduced growth, or changed species composition competition that may alter trace gas surface exchange and ecosystem health and function. The coupling of this feedback system – between build-up of greenhouse gases, human-induced climate change, ecosystem responses, trace gas exchange at the surface, and back to atmospheric composition – has not been evaluated in this assessment. The variety and complexity of these feedbacks relating to ecosystems, beyond simple increases with rising temperatures and changing precipitation, argues strongly for the full interactive coupling of biogeochemical models of trace gas emissions with chemistry and climate models.

Table 4.12: *Tropospheric ozone budgets for circa 1990 conditions from a sample of global 3-D CTMs since the SAR.*

CTM	STE	Prod	Loss (Tg/yr)	P–L	SURF	Burden (Tg)	Reference
MATCH	1440	2490	3300	–810	620		Crutzen *et al.* (1999)
MATCH-MPIC	1103	2334	2812	–478	621		Lawrence *et al.* (1999)
ECHAM/TM3	768	3979	4065	–86	681	311	Houweling *et al.* (1998)
ECHAM/TM3[a]	740	2894	3149	–255	533	266	Houweling *et al.* (1998)
HARVARD	400	4100	3680	+420	820	310	Wang *et al.* (1998a)
GCTM	696			+128	825	298	Levy *et al.* (1997)
UIO	846			+295	1178	370	Berntsen *et al.* (1996)
ECHAM4	459	3425	3350	+75	534	271	Roelofs and Lelieveld (1997)
MOZART[b]	391	3018	2511	+507	898	193	Hauglustaine *et al.* (1998)
STOCHEM	432	4320	3890	+430	862	316	Stevenson *et al.* (2000)
KNMI	1429	2864	3719	–855	574		Wauben *et al.* (1998)
UCI	473	4229	3884	+345	812	288	Wild and Prather (2000)

STE = stratosphere-troposphere exchange (net flux from stratosphere) (Tg/yr).
Prod & Loss = *in situ* tropospheric chemical terms, P–L = net. (Tg/yr).
SURF = surface deposition (Tg/yr). Burden = total content (Tg, 34DU = 372Tg).
Budgets should balance exactly (STE+P–L=SURF), but may not due to roundoff.
[a] Results using CH_4-only chemistry without NMHC.
[b] Budget/burden calculated from surface to 250 hPa (missing part of upper troposphere).

4.6 Overall Impact of Global Atmospheric Chemistry Change

The projected growth in emissions of greenhouse gases and other pollutants in the IPCC SRES scenarios for the 21st century is expected to increase the atmospheric burden of non-CO_2 greenhouse gases substantially and contribute a sizable fraction to the overall increase in radiative forcing of the climate. These changes in atmospheric composition may, however, degrade the global environment in ways beyond climate change.

The impact of metropolitan pollution, specifically O_3 and CO, on the background air of the Atlantic and Pacific Oceans has been highlighted by many studies over the past decade. These have ranged from observations of anthropogenic pollution reaching across the Northern Hemisphere (e.g., Parrish *et al.*, 1993; Jaffe *et al.*, 1999) to analyses of rapidly increasing emissions of pollutants (NO_x, CO, VOC) in, for example, East Asia (Kato and Akimoto 1992; Elliott *et al.*, 1997). CTM studies have tried to quantify some of these projections for the near term: Berntsen *et al.* (1999) predict notable increases in CO and O_3 coming into the north-west USA from a doubling of current Asian emissions; Jacob *et al.* (1999) calculate that monthly mean O_3 abundances over the USA will increase by 1 to 6 ppb from a tripling of these emissions between 1985 and 2010; and Collins *et al.* (2000) project a 3 ppb increase from 1990 to 2015 in monthly mean O_3 over north-west Europe due to rising North American emissions. The impact of metropolitan pollution will expand over the coming decades as urban areas grow and use of resources intensifies.

What is new in this IPCC assessment is the extension of these projections to the year 2100, whereupon the cumulative impact of all Northern Hemisphere emissions, not just those immediately upwind, may for some scenarios double O_3 abundances over the northern mid-latitudes. Surface O_3 abundances during July over the industrialised continents of the Northern Hemisphere are about 40 ppb with 2000 emissions; and under SRES scenarios A2 and A1FI they would reach 45 to 50 ppb with 2030 emissions, 60 ppb with 2060 emissions, and >70 ppb with 2100 emissions. Since regional ozone episodes start with these background levels and build upon them with local smog production, it may be impossible under these circumstances to achieve a clean-air standard of <80 ppb over most populated regions. This problem reaches across continental boundaries and couples emissions of NO_x on a hemispheric scale. In the 21st century a global perspective will be needed to meet regional air quality objectives. The impact of this threatened degradation of air quality upon societal behaviour and policy decisions will possibly change the balance of future emissions impacting climate change (e.g., more fuel burn (CO_2) to achieve lower NO_x as in aviation; Penner *et al.*, 1999).

Under some emission scenarios, the large increases in tropospheric O_3 combined with the decreases in OH may alter the oxidation rate and the degradation paths for hydrocarbons and other hazardous substances. The damage caused by higher O_3 levels to both crops and natural systems needs to be assessed, and societal responses to this threat would likely change the emissions scenarios evaluated here (e.g., the current SRES scenarios anticipate the societal demand to control urban aerosols and acid rain by substantially cutting sulphur emissions) .

Coupling between atmospheric chemistry, the biosphere, and the climate are not at the stage that these feedbacks can be included in this assessment. There are indications, however, that the evolution of natural emissions and physical climate projected over the next century will change the baseline atmospheric chemistry and lead to altered biosphere-atmosphere exchanges and continued atmospheric change independent of anthropogenic emissions.

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CHAPTER 5

INCINERATION AND OPEN BURNING OF WASTE

5 INCINERATION AND OPEN BURNING OF WASTE

5.1 INTRODUCTION

Waste incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities. Modern refuse combustors have tall stacks and specially designed combustion chambers, which provide high combustion temperatures, long residence times, and efficient waste agitation while introducing air for more complete combustion. Types of waste incinerated include municipal solid waste (MSW), industrial waste, hazardous waste, clinical waste and sewage sludge[1]. The practice of MSW incineration is currently more common in developed countries, while it is common for both developed and developing countries to incinerate clinical waste.

Emissions from waste incineration without energy recovery are reported in the Waste Sector, while emissions from incineration with energy recovery are reported in the Energy Sector, both with a distinction between fossil and biogenic carbon dioxide (CO_2) emissions. The methodology described in this chapter is applicable in general both to incineration with and without energy recovery. Co-firing of specific waste fractions with other fuels is not addressed in this chapter, as co-firing is covered in Volume 2, Energy. Emissions from agricultural residue burning are considered in the AFOLU Sector, Chapter 5 of Volume 4.

Open burning of waste can be defined as the combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in nature (open-air) or in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack. Open burning can also include incineration devices that do not control the combustion air to maintain an adequate temperature and do not provide sufficient residence time for complete combustion. This waste management practice is used in many developing countries while in developed countries open burning of waste may either be strictly regulated, or otherwise occur more frequently in rural areas than in urban areas.

Incineration and open burning of waste are sources of greenhouse gas emissions, like other types of combustion. Relevant gases emitted include CO_2, methane (CH_4) and nitrous oxide (N_2O). Normally, emissions of CO_2 from waste incineration are more significant than CH_4 and N_2O emissions.

Consistent with the *1996 Guidelines* (IPCC, 1997), only CO_2 emissions resulting from oxidation, during incineration and open burning of carbon in waste of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) are considered net emissions and should be included in the national CO_2 emissions estimate. The CO_2 emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in the waste are biogenic emissions and should not be included in national total emission estimates. However, if incineration of waste is used for energy purposes, both fossil and biogenic CO_2 emissions should be estimated. Only fossil CO_2 should be included in national emissions under Energy Sector while biogenic CO_2 should be reported as an information item also in the Energy Sector. Moreover, if combustion, or any other factor, is causing long term decline in the total carbon embodied in living biomass (e.g., forests), this net release of carbon should be evident in the calculation of CO_2 emissions described in the Agriculture, Forestry and Other Land Use (AFOLU) Volume of the *2006 Guidelines*.

This chapter provides guidance on methodological choices for estimating and reporting CO_2, CH_4 and N_2O emissions from incineration and open burning of all types of combustible waste. Where possible, default values for activity data, emission factors and other parameters are provided.

Traditional air pollutants from combustion - non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x) - are covered by existing emission inventory systems. Therefore, the IPCC does not provide new methodologies for these gases here, but recommends that national experts or inventory compilers use existing published methods under international agreements. Some key examples of the current literature providing methods include EMEP/CORINAIR Guidebook (EMEP 2004), US EPA's Compilation of Air Pollutant Emissions Factors, AP-42, Fifth Edition (USEPA, 1995), EPA Emission Inventory Improvement Program Technical Report Series, Vol. III Chapter 16: Open Burning (USEPA, 2001).

The estimation of indirect N_2O emissions, resulting from the conversion of nitrogen deposition to soils due to NO_x emissions from waste incineration and open burning, is addressed in Section 5.4.3 of this chapter. General background

[1] Waste generation, composition and management practices, including waste incineration and open burning, are addressed in detail in Chapter 2 of this volume.

A report of Working Group I of the Intergovernmental Panel on Climate Change

Summary for Policymakers

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Introduction

The Working Group I contribution to the IPCC Fourth Assessment Report describes progress in understanding of the human and natural drivers of climate change,[1] observed climate change, climate processes and attribution, and estimates of projected future climate change. It builds upon past IPCC assessments and incorporates new findings from the past six years of research. Scientific progress since the Third Assessment Report (TAR) is based upon large amounts of new and more comprehensive data, more sophisticated analyses of data, improvements in understanding of processes and their simulation in models and more extensive exploration of uncertainty ranges.

The basis for substantive paragraphs in this Summary for Policymakers can be found in the chapter sections specified in curly brackets.

Human and Natural Drivers of Climate Change

Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing,[2] which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Since the TAR, new observations and related modelling of greenhouse gases, solar activity, land surface properties and some aspects of aerosols have led to improvements in the quantitative estimates of radiative forcing.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (see Figure SPM.1). The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. {2.3, 6.4, 7.3}

- Carbon dioxide is the most important anthropogenic greenhouse gas (see Figure SPM.2). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm[3] in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth rate was larger during the last 10 years (1995–2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates. {2.3, 7.3}

- The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land-use change providing another significant but smaller contribution. Annual fossil carbon dioxide emissions[4] increased from an average of 6.4 [6.0 to 6.8][5] GtC (23.5 [22.0 to 25.0] $GtCO_2$) per year in the 1990s to 7.2 [6.9 to 7.5] GtC (26.4 [25.3 to 27.5] $GtCO_2$) per year in 2000–2005 (2004 and 2005 data are interim estimates). Carbon dioxide emissions associated with land-use change

[1] *Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

[2] *Radiative forcing* is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it. In this report, radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750 and are expressed in watts per square metre (W m^{-2}). See Glossary and Section 2.2 for further details.

[3] ppm (parts per million) or ppb (parts per billion, 1 billion = 1,000 million) is the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a greenhouse gas per million molecules of dry air.

[4] Fossil carbon dioxide emissions include those from the production, distribution and consumption of fossil fuels and as a by-product from cement production. An emission of 1 GtC corresponds to 3.67 $GtCO_2$.

[5] In general, uncertainty ranges for results given in this Summary for Policymakers are 90% uncertainty intervals unless stated otherwise, that is, there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Best estimates are given where available. Assessed uncertainty intervals are not always symmetric about the corresponding best estimate. Note that a number of uncertainty ranges in the Working Group I TAR corresponded to 2 standard deviations (95%), often using expert judgement.

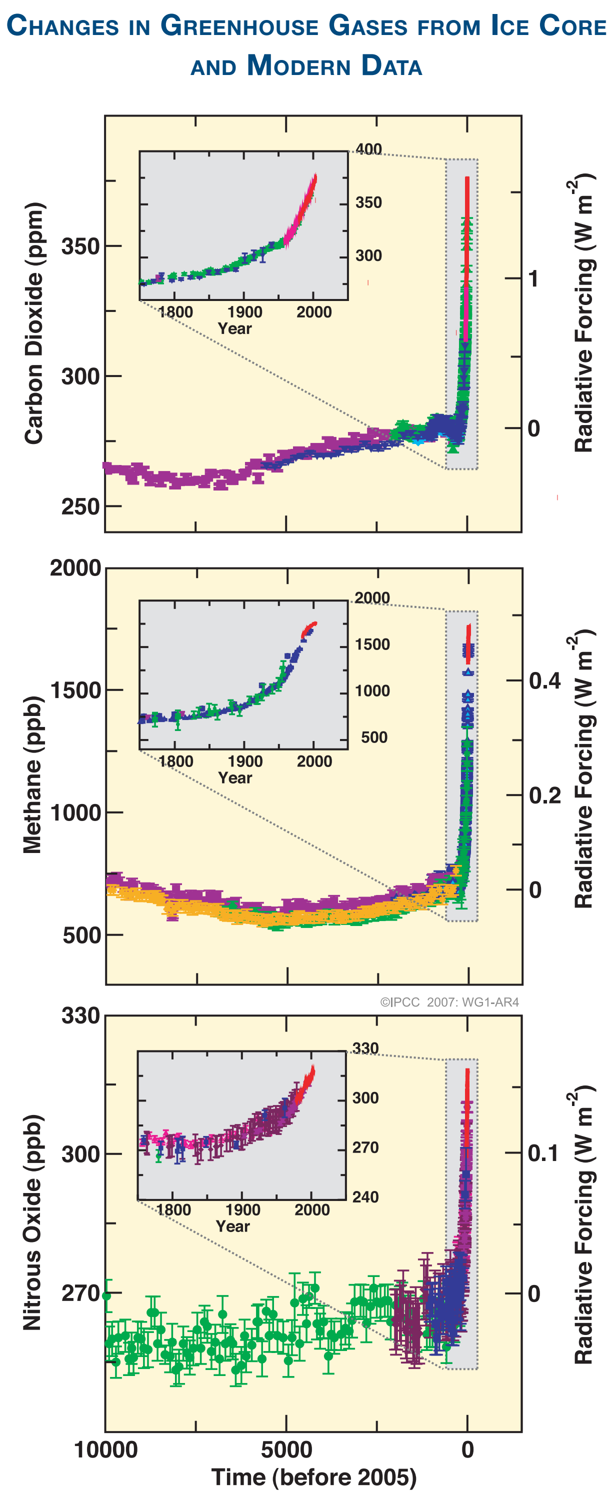

Figure SPM.1. *Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. {Figure 6.4}*

are estimated to be 1.6 [0.5 to 2.7] GtC (5.9 [1.8 to 9.9] $GtCO_2$) per year over the 1990s, although these estimates have a large uncertainty. {7.3}

- The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and was 1774 ppb in 2005. The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320 to 790 ppb) as determined from ice cores. Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. It is *very likely*[6] that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use, but relative contributions from different source types are not well determined. {2.3, 7.4}

- The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005. The growth rate has been approximately constant since 1980. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture. {2.3, 7.4}

The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR, leading to *very high confidence*[7] that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2} (see Figure SPM.2). {2.3., 6.5, 2.9}

- The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is +2.30 [+2.07 to +2.53] W m^{-2}, and its rate of increase during the industrial era is *very likely* to have been unprecedented in more than 10,000 years (see Figures

[6] In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5% (see Box TS.1 for more details).

[7] In this Summary for Policymakers the following levels of confidence have been used to express expert judgements on the correctness of the underlying science: *very high confidence* represents at least a 9 out of 10 chance of being correct; *high confidence* represents about an 8 out of 10 chance of being correct (see Box TS.1)

A report accepted by Working Group I of the Intergovernmental Panel on Climate Change but not approved in detail

"Acceptance" of IPCC Reports at a Session of the Working Group or Panel signifies that the material has not been subject to line-by-line discussion and agreement, but nevertheless presents a comprehensive, objective and balanced view of the subject matter.

Technical Summary

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Table of Contents

TS.1 Introduction

In the six years since the IPCC's Third Assessment Report (TAR), significant progress has been made in understanding past and recent climate change and in projecting future changes. These advances have arisen from large amounts of new data, more sophisticated analyses of data, improvements in the understanding and simulation of physical processes in climate models and more extensive exploration of uncertainty ranges in model results. The increased confidence in climate science provided by these developments is evident in this Working Group I contribution to the IPCC's Fourth Assessment Report.

While this report provides new and important policy-relevant information on the scientific understanding of climate change, the complexity of the climate system and the multiple interactions that determine its behaviour impose limitations on our ability to understand fully the future course of Earth's global climate. There is still an incomplete physical understanding of many components of the climate system and their role in climate change. Key uncertainties include aspects of the roles played by clouds, the cryosphere, the oceans, land use and couplings between climate and biogeochemical cycles. The areas of science covered in this report continue to undergo rapid progress and it should be recognised that the present assessment reflects scientific understanding based on the peer-reviewed literature available in mid-2006.

The key findings of the IPCC Working Group I assessment are presented in the Summary for Policymakers. This Technical Summary provides a more detailed overview of the scientific basis for those findings and provides a road map to the chapters of the underlying report. It focuses on key findings, highlighting what is new since the TAR. The structure of the Technical Summary is as follows:

- Section 2: an overview of current scientific understanding of the natural and anthropogenic drivers of changes in climate;
- Section 3: an overview of observed changes in the climate system (including the atmosphere, oceans and cryosphere) and their relationships to physical processes;
- Section 4: an overview of explanations of observed climate changes based on climate models and physical understanding, the extent to which climate change can be attributed to specific causes and a new evaluation of climate sensitivity to greenhouse gas increases;
- Section 5: an overview of projections for both near- and far-term climate changes including the time scales of responses to changes in forcing, and probabilistic information about future climate change; and
- Section 6: a summary of the most robust findings and the key uncertainties in current understanding of physical climate change science.

Each paragraph in the Technical Summary reporting substantive results is followed by a reference in curly brackets to the corresponding chapter section(s) of the underlying report where the detailed assessment of the scientific literature and additional information can be found.

TS.2 Changes in Human and Natural Drivers of Climate

The Earth's global mean climate is determined by incoming energy from the Sun and by the properties of the Earth and its atmosphere, namely the reflection, absorption and emission of energy within the atmosphere and at the surface. Although changes in received solar energy (e.g., caused by variations in the Earth's orbit around the Sun) inevitably affect the Earth's energy budget, the properties of the atmosphere and surface are also important and these may be affected by climate feedbacks. The importance of climate feedbacks is evident in the nature of past climate changes as recorded in ice cores up to 650,000 years old.

Changes have occurred in several aspects of the atmosphere and surface that alter the global energy budget of the Earth and can therefore cause the climate to change. Among these are increases in greenhouse gas concentrations that act primarily to increase the atmospheric absorption of outgoing radiation, and increases in aerosols (microscopic airborne particles or droplets) that act to reflect and absorb incoming solar radiation and change cloud radiative properties. Such changes cause a radiative forcing of the climate system.[1] Forcing agents can differ considerably from one another in terms of the magnitudes of forcing, as well as spatial and temporal features. Positive and negative radiative forcings contribute to increases and decreases, respectively, in

[1] 'Radiative forcing' is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it. In this report, radiative forcing values are for changes relative to a pre-industrial background at 1750, are expressed in Watts per square metre (W m^{-2}) and, unless otherwise noted, refer to a global and annual average value. See Glossary for further details.

Box TS.1: Treatment of Uncertainties in the Working Group I Assessment

The importance of consistent and transparent treatment of uncertainties is clearly recognised by the IPCC in preparing its assessments of climate change. The increasing attention given to formal treatments of uncertainty in previous assessments is addressed in Section 1.6. To promote consistency in the general treatment of uncertainty across all three Working Groups, authors of the Fourth Assessment Report have been asked to follow a brief set of guidance notes on determining and describing uncertainties in the context of an assessment.[2] This box summarises the way that Working Group I has applied those guidelines and covers some aspects of the treatment of uncertainty specific to material assessed here.

Uncertainties can be classified in several different ways according to their origin. Two primary types are 'value uncertainties' and 'structural uncertainties'. Value uncertainties arise from the incomplete determination of particular values or results, for example, when data are inaccurate or not fully representative of the phenomenon of interest. Structural uncertainties arise from an incomplete understanding of the processes that control particular values or results, for example, when the conceptual framework or model used for analysis does not include all the relevant processes or relationships. Value uncertainties are generally estimated using statistical techniques and expressed probabilistically. Structural uncertainties are generally described by giving the authors' collective judgment of their confidence in the correctness of a result. In both cases, estimating uncertainties is intrinsically about describing the limits to knowledge and for this reason involves expert judgment about the state of that knowledge. A different type of uncertainty arises in systems that are either chaotic or not fully deterministic in nature and this also limits our ability to project all aspects of climate change.

The scientific literature assessed here uses a variety of other generic ways of categorising uncertainties. Uncertainties associated with 'random errors' have the characteristic of decreasing as additional measurements are accumulated, whereas those associated with 'systematic errors' do not. In dealing with climate records, considerable attention has been given to the identification of systematic errors or unintended biases arising from data sampling issues and methods of analysing and combining data. Specialised statistical methods based on quantitative analysis have been developed for the detection and attribution of climate change and for producing probabilistic projections of future climate parameters. These are summarised in the relevant chapters.

The uncertainty guidance provided for the Fourth Assessment Report draws, for the first time, a careful distinction between levels of confidence in scientific understanding and the likelihoods of specific results. This allows authors to express high confidence that an event is extremely unlikely (e.g., rolling a dice twice and getting a six both times), as well as high confidence that an event is about as likely as not (e.g., a tossed coin coming up heads). Confidence and likelihood as used here are distinct concepts but are often linked in practice.

The standard terms used to define levels of confidence in this report are as given in the IPCC Uncertainty Guidance Note, namely:

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Note that 'low confidence' and 'very low confidence' are only used for areas of major concern and where a risk-based perspective is justified.

Chapter 2 of this report uses a related term 'level of scientific understanding' when describing uncertainties in different contributions to radiative forcing. This terminology is used for consistency with the Third Assessment Report, and the basis on which the authors have determined particular levels of scientific understanding uses a combination of approaches consistent with the uncertainty guidance note as explained in detail in Section 2.9.2 and Table 2.11.

(continued)

[2] The IPCC Uncertainty Guidance Note is included in Supplementary Material for this report.

The standard terms used in this report to define the likelihood of an outcome or result where this can be estimated probabilistically are:

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

The terms 'extremely likely', 'extremely unlikely' and 'more likely than not' as defined above have been added to those given in the IPCC Uncertainty Guidance Note in order to provide a more specific assessment of aspects including attribution and radiative forcing.

Unless noted otherwise, values given in this report are assessed best estimates and their uncertainty ranges are 90% confidence intervals (i.e., there is an estimated 5% likelihood of the value being below the lower end of the range or above the upper end of the range). Note that in some cases the nature of the constraints on a value, or other information available, may indicate an asymmetric distribution of the uncertainty range around a best estimate. In such cases, the uncertainty range is given in square brackets following the best estimate.

global average surface temperature. This section updates the understanding of estimated anthropogenic and natural radiative forcings.

The overall response of global climate to radiative forcing is complex due to a number of positive and negative feedbacks that can have a strong influence on the climate system (see e.g., Sections 4.5 and 5.4). Although water vapour is a strong greenhouse gas, its concentration in the atmosphere changes in response to changes in surface climate and this must be treated as a feedback effect and not as a radiative forcing. This section also summarises changes in the surface energy budget and its links to the hydrological cycle. Insights into the effects of agents such as aerosols on precipitation are also noted.

TS.2.1 Greenhouse Gases

The dominant factor in the radiative forcing of climate in the industrial era is the increasing concentration of various greenhouse gases in the atmosphere. Several of the major greenhouse gases occur naturally but increases in their atmospheric concentrations over the last 250 years are due largely to human activities. Other greenhouse gases are entirely the result of human activities. The contribution of each greenhouse gas to radiative forcing over a particular period of time is determined by the change in its concentration in the atmosphere over that period and the effectiveness of the gas in perturbing the radiative balance. Current atmospheric concentrations of the different greenhouse gases considered in this report vary by more than eight orders of magnitude (factor of 10^8), and their radiative efficiencies vary by more than four orders of magnitude (factor of 10^4), reflecting the enormous diversity in their properties and origins.

The current concentration of a greenhouse gas in the atmosphere is the net result of the history of its past emissions and removals from the atmosphere. The gases and aerosols considered here are emitted to the atmosphere by human activities or are formed from precursor species emitted to the atmosphere. These emissions are offset by chemical and physical removal processes. With the important exception of carbon dioxide (CO_2), it is generally the case that these processes remove a specific fraction of the amount of a gas in the atmosphere each year and the inverse of this removal rate gives the mean lifetime for that gas. In some cases, the removal rate may vary with gas concentration or other atmospheric properties (e.g., temperature or background chemical conditions).

Long-lived greenhouse gases (LLGHGs), for example, CO_2, methane (CH_4) and nitrous oxide (N_2O), are chemically stable and persist in the atmosphere over time scales of a decade to centuries or longer, so that their emission has a long-term influence on climate. Because these gases are long lived, they become well mixed throughout the atmosphere much faster than they are removed and their global concentrations can be accurately estimated from data at a few locations. Carbon dioxide does not have a specific lifetime because it is continuously cycled between the atmosphere, oceans and land biosphere and its net removal from the atmosphere involves a range of processes with different time scales.

Short-lived gases (e.g., sulphur dioxide and carbon monoxide) are chemically reactive and generally removed by natural oxidation processes in the atmosphere, by removal at the surface or by washout in precipitation; their concentrations are hence highly variable. Ozone is a significant greenhouse gas that is formed and destroyed by chemical reactions involving other species in the atmosphere. In the troposphere, the human influence on ozone occurs primarily through changes in precursor gases that lead to its formation, whereas in the stratosphere, the human influence has been primarily through changes in ozone removal rates caused by chlorofluorocarbons (CFCs) and other ozone-depleting substances.

TS.2.1.1 Changes in Atmospheric Carbon Dioxide, Methane and Nitrous Oxide

Current concentrations of atmospheric CO_2 and CH_4 far exceed pre-industrial values found in polar ice core records of atmospheric composition dating back 650,000 years. Multiple lines of evidence confirm that the post-industrial rise in these gases does not stem from natural mechanisms (see Figure TS.1 and Figure TS.2). {2.3, 6.3–6.5, FAQ 7.1}

The total radiative forcing of the Earth's climate due to increases in the concentrations of the LLGHGs CO_2, CH_4 and N_2O, and *very likely* the rate of increase in the total forcing due to these gases over the period since 1750, are unprecedented in more than 10,000 years (Figure TS.2). It is *very likely* that the sustained rate of increase in the combined radiative forcing from these greenhouse gases of about +1 W m^{-2} over the past four decades is at least six times faster than at any time during the two millennia before the Industrial Era, the period for which ice core data have the required temporal resolution. The radiative forcing due to these LLGHGs has the highest level of confidence of any forcing agent. {2.3, 6.4}

GLACIAL-INTERGLACIAL ICE CORE DATA

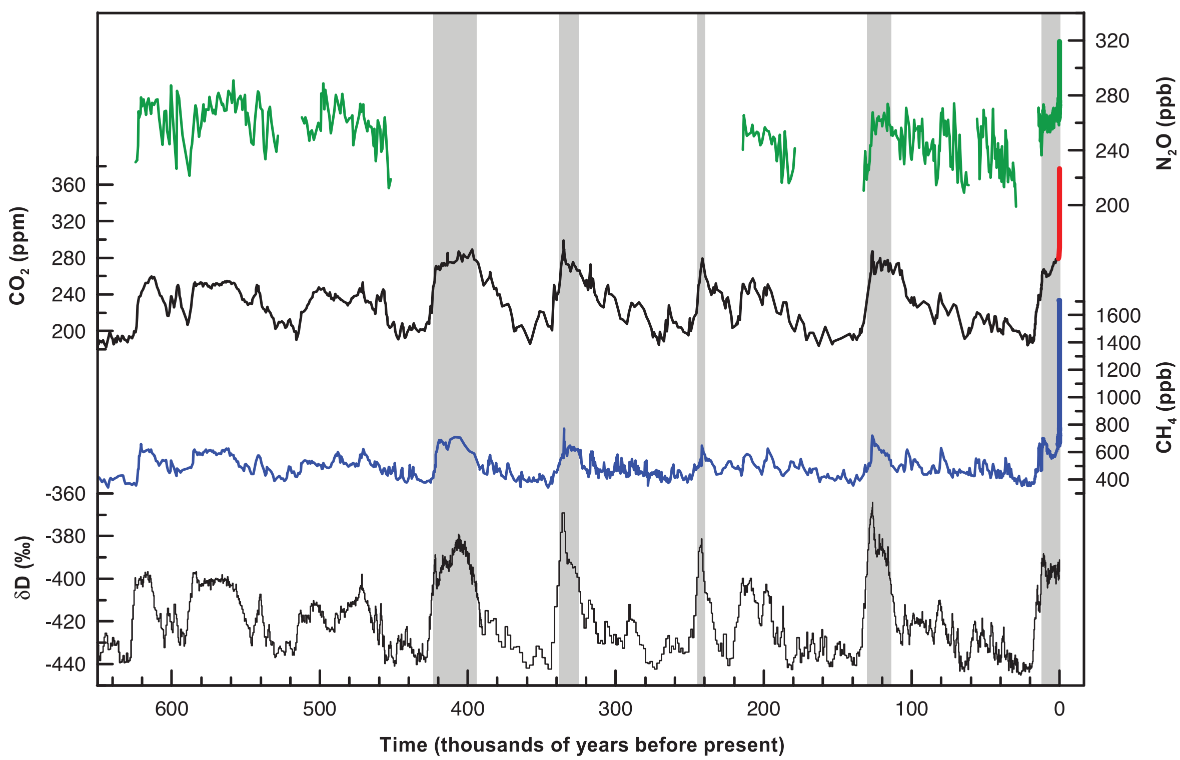


Figure TS.1. *Variations of deuterium (δD) in antarctic ice, which is a proxy for local temperature, and the atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in air trapped within the ice cores and from recent atmospheric measurements. Data cover 650,000 years and the shaded bands indicate current and previous interglacial warm periods. {Adapted from Figure 6.3}*

Changes in Greenhouse Gases from Ice Core and Modern Data

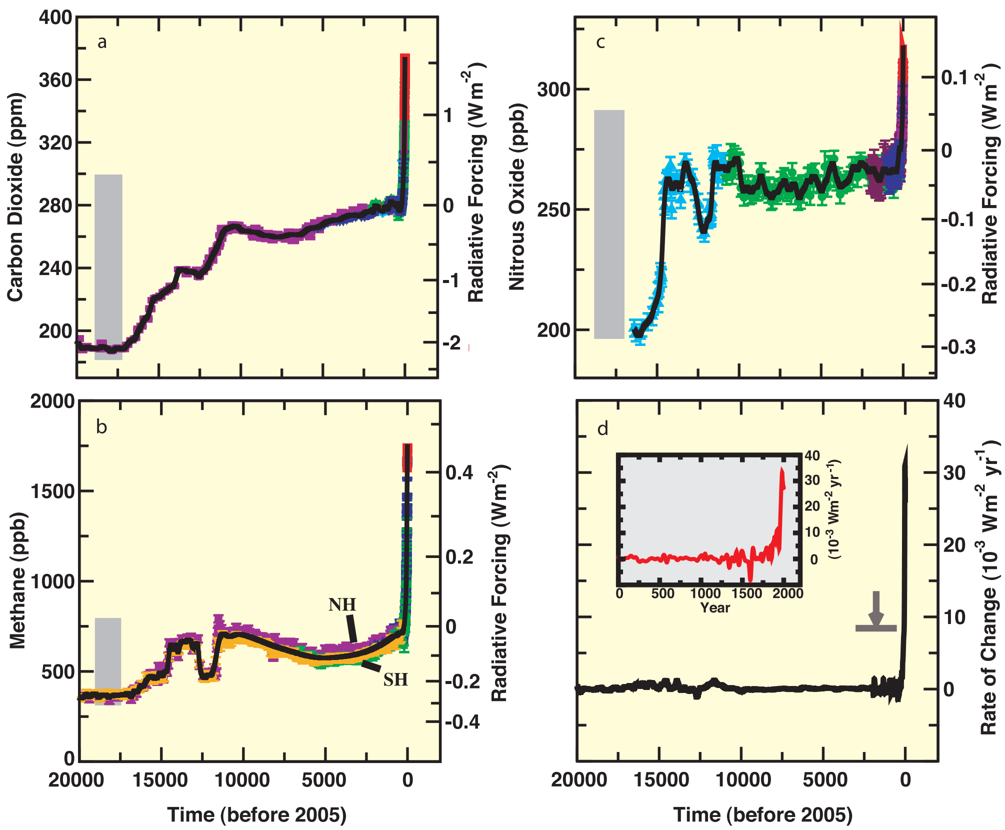


Figure TS.2. *The concentrations and radiative forcing by (a) carbon dioxide (CO_2), (b) methane (CH_4), (c) nitrous oxide (N_2O) and (d) the rate of change in their combined radiative forcing over the last 20,000 years reconstructed from antarctic and Greenland ice and firn data (symbols) and direct atmospheric measurements (panels a,b,c, red lines). The grey bars show the reconstructed ranges of natural variability for the past 650,000 years. The rate of change in radiative forcing (panel d, black line) has been computed from spline fits to the concentration data. The width of the age spread in the ice data varies from about 20 years for sites with a high accumulation of snow such as Law Dome, Antarctica, to about 200 years for low-accumulation sites such as Dome C, Antarctica. The arrow shows the peak in the rate of change in radiative forcing that would result if the anthropogenic signals of CO_2, CH_4, and N_2O had been smoothed corresponding to conditions at the low-accumulation Dome C site. The negative rate of change in forcing around 1600 shown in the higher-resolution inset in panel d results from a CO_2 decrease of about 10 ppm in the Law Dome record. {Figure 6.4}*

The concentration of atmospheric CO_2 has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. Atmospheric CO_2 concentration increased by only 20 ppm over the 8000 years prior to industrialisation; multi-decadal to centennial-scale variations were less than 10 ppm and *likely* due mostly to natural processes. However, since 1750, the CO_2 concentration has risen by nearly 100 ppm. The annual CO_2 growth rate was larger during the last 10 years (1995–2005 average: 1.9 ppm yr^{-1}) than it has been since continuous direct atmospheric measurements began (1960–2005 average: 1.4 ppm yr^{-1}). {2.3, 6.4, 6.5}

Increases in atmospheric CO_2 since pre-industrial times are responsible for a radiative forcing of +1.66 ± 0.17 W m^{-2}; a contribution which dominates all other radiative forcing agents considered in this report. For the decade from 1995 to 2005, the growth rate of CO_2 in the atmosphere led to a 20% increase in its radiative forcing. {2.3, 6.4, 6.5}

Emissions of CO_2 from fossil fuel use and from the effects of land use change on plant and soil carbon are the primary sources of increased atmospheric CO_2. Since 1750, it is estimated that about 2/3rds of anthropogenic CO_2 emissions have come from fossil fuel burning and about 1/3rd from land use change. About 45% of this CO_2 has remained in the atmosphere, while about 30% has been taken up by the oceans and the remainder has been taken up by the terrestrial biosphere. About half of a CO_2 pulse to the atmosphere is removed over a time scale of 30 years; a further 30% is removed within a few centuries; and the remaining 20% will typically stay in the atmosphere for many thousands of years. {7.3}

In recent decades, emissions of CO_2 have continued to increase (see Figure TS.3). Global annual fossil

CO_2 emissions[3] increased from an average of 6.4 ± 0.4 GtC yr^{-1} in the 1990s to 7.2 ± 0.3 GtC yr^{-1} in the period 2000 to 2005. Estimated CO_2 emissions associated with land use change, averaged over the 1990s, were[4] 0.5 to 2.7 GtC yr^{-1}, with a central estimate of 1.6 Gt yr^{-1}. Table TS.1 shows the estimated budgets of CO_2 in recent decades. {2.3, 6.4, 7.3, FAQ 7.1}

Since the 1980s, natural processes of CO_2 uptake by the terrestrial biosphere (i.e., the residual land sink in Table TS.1) and by the oceans have removed about 50% of anthropogenic emissions (i.e., fossil CO_2 emissions and land use change flux in Table TS.1). These removal processes are influenced by the atmospheric CO_2 concentration and by changes in climate. Uptake by the oceans and the terrestrial biosphere have been similar in magnitude but the terrestrial biosphere uptake is more variable and was higher in the 1990s than in the 1980s by about 1 GtC yr^{-1}. Observations demonstrate that dissolved CO_2 concentrations in the surface ocean (pCO_2) have been increasing nearly everywhere, roughly following the atmospheric CO_2 increase but with large regional and temporal variability. {5.4, 7.3}

Carbon uptake and storage in the terrestrial biosphere arise from the net difference between uptake due to vegetation growth, changes in reforestation and sequestration, and emissions due to heterotrophic respiration, harvest, deforestation, fire, damage by pollution and other disturbance factors affecting biomass and soils. Increases and decreases in fire frequency in different regions have affected net carbon uptake, and in boreal regions, emissions due to fires appear to have increased over recent decades. Estimates of net CO_2 surface fluxes from inverse studies using networks of atmospheric data demonstrate significant land uptake in the mid-latitudes of the Northern Hemisphere (NH) and near-zero land-atmosphere fluxes in the tropics, implying that tropical deforestation is approximately balanced by regrowth. {7.3}

Short-term (interannual) variations observed in the atmospheric CO_2 growth rate are primarily controlled by changes in the flux of CO_2 between the atmosphere and the terrestrial biosphere, with a smaller but significant fraction due to variability in ocean fluxes (see Figure TS.3). Variability in the terrestrial biosphere flux is driven by climatic fluctuations, which affect the uptake of CO_2 by plant growth and the return of CO_2 to the atmosphere by the decay of organic material through heterotrophic respiration and fires. El Niño-Southern Oscillation (ENSO) events are a major source of interannual variability in atmospheric CO_2 growth rate, due to their effects on fluxes through land and sea surface temperatures, precipitation and the incidence of fires. {7.3}

The direct effects of increasing atmospheric CO_2 on large-scale terrestrial carbon uptake cannot be quantified reliably at present. Plant growth can be stimulated by increased atmospheric CO_2 concentrations and by nutrient deposition (fertilization effects). However, most experiments and studies show that such responses appear to be relatively short lived and strongly coupled

Table TS.1. *Global carbon budget. By convention, positive values are CO_2 fluxes (GtC yr^{-1}) into the atmosphere and negative values represent uptake from the atmosphere (i.e., 'CO_2 sinks'). Fossil CO_2 emissions for 2004 and 2005 are based on interim estimates. Due to the limited number of available studies, for the net land-to-atmosphere flux and its components, uncertainty ranges are given as 65% confidence intervals and do not include interannual variability (see Section 7.3). NA indicates that data are not available.*

	1980s	1990s	2000–2005
Atmospheric increase	3.3 ± 0.1	3.2 ± 0.1	4.1 ± 0.1
Fossil carbon dioxide emissions	5.4 ± 0.3	6.4 ± 0.4	7.2 ± 0.3
Net ocean-to-atmosphere flux	–1.8 ± 0.8	–2.2 ± 0.4	–2.2 ± 0.5
Net land-to-atmosphere flux	–0.3 ± 0.9	–1.0 ± 0.6	–0.9 ± 0.6
Partitioned as follows			
Land use change flux	1.4 (0.4 to 2.3)	1.6 (0.5 to 2.7)	NA
Residual land sink	–1.7 (–3.4 to 0.2)	–2.6 (–4.3 to –0.9)	NA

[3] Fossil CO_2 emissions include those from the production, distribution and consumption of fossil fuels and from cement production. Emission of 1 GtC corresponds to 3.67 $GtCO_2$.

[4] As explained in Section 7.3, uncertainty ranges for land use change emissions, and hence for the full carbon cycle budget, can only be given as 65% confidence intervals.

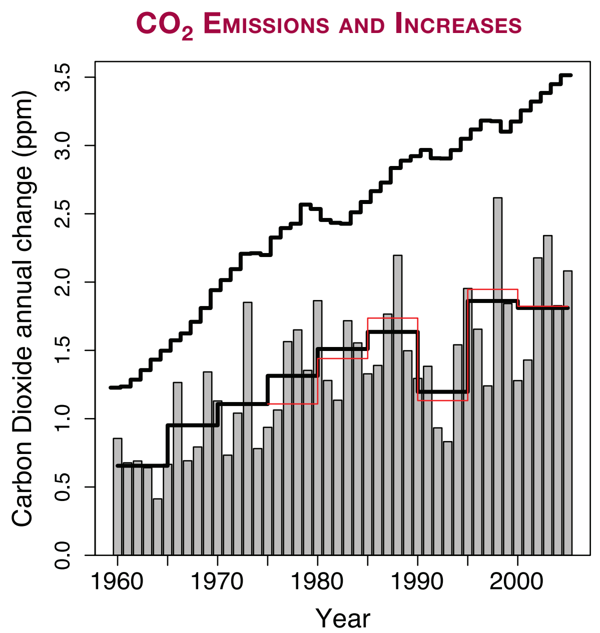


Figure TS.3. *Annual changes in global mean CO_2 concentration (grey bars) and their five-year means from two different measurement networks (red and lower black stepped lines). The five-year means smooth out short-term perturbations associated with strong ENSO events in 1972, 1982, 1987 and 1997. Uncertainties in the five-year means are indicated by the difference between the red and lower black lines and are of order 0.15 ppm. The upper stepped line shows the annual increases that would occur if all fossil fuel emissions stayed in the atmosphere and there were no other emissions. {Figure 7.4}*

to other effects such as availability of water and nutrients. Likewise, experiments and studies of the effects of climate (temperature and moisture) on heterotrophic respiration of litter and soils are equivocal. Note that the effect of climate change on carbon uptake is addressed separately in section TS.5.4. {7.3}

The CH_4 abundance in 2005 of about 1774 ppb is more than double its pre-industrial value. Atmospheric CH_4 concentrations varied slowly between 580 and 730 ppb over the last 10,000 years, but increased by about 1000 ppb in the last two centuries, representing the fastest changes in this gas over at least the last 80,000 years. In the late 1970s and early 1980s, CH_4 growth rates displayed maxima above 1% yr^{-1}, but since the early 1990s have decreased significantly and were close to zero for the six-year period from 1999 to 2005. Increases in CH_4 abundance occur when emissions exceed removals. The recent decline in growth rates implies that emissions now approximately match removals, which are due primarily to oxidation by the hydroxyl radical (OH). Since the TAR, new studies using two independent tracers (methyl chloroform and ^{14}CO) suggest no significant long-term change in the global abundance of OH. Thus, the slowdown in the atmospheric CH_4 growth rate since about 1993 is *likely* due to the atmosphere approaching an equilibrium during a period of near-constant total emissions. {2.3, 7.4, FAQ 7.1}

Increases in atmospheric CH_4 concentrations since pre-industrial times have contributed a radiative forcing of +0.48 ± 0.05 W m^{-2}. Among greenhouse gases, this forcing remains second only to that of CO_2 in magnitude. {2.3}

Current atmospheric CH_4 levels are due to continuing anthropogenic emissions of CH_4, which are greater than natural emissions. Total CH_4 emissions can be well determined from observed concentrations and independent estimates of removal rates. Emissions from individual sources of CH_4 are not as well quantified as the total emissions but are mostly biogenic and include emissions from wetlands, ruminant animals, rice agriculture and biomass burning, with smaller contributions from industrial sources including fossil fuel-related emissions. This knowledge of CH_4 sources, combined with the small natural range of CH_4 concentrations over the past 650,000 years (Figure TS.1) and their dramatic increase since 1750 (Figure TS.2), make it *very likely* that the observed long-term changes in CH_4 are due to anthropogenic activity. {2.3, 6.4, 7.4}

In addition to its slowdown over the last 15 years, the growth rate of atmospheric CH_4 has shown high interannual variability, which is not yet fully explained. The largest contributions to interannual variability during the 1996 to 2001 period appear to be variations in emissions from wetlands and biomass burning. Several studies indicate that wetland CH_4 emissions are highly sensitive to temperature and are also affected by hydrological changes. Available model estimates all indicate increases in wetland emissions due to future climate change but vary widely in the magnitude of such a positive feedback effect. {7.4}

The N_2O concentration in 2005 was 319 ppb, about 18% higher than its pre-industrial value. Nitrous oxide increased approximately linearly by about 0.8 ppb yr^{-1} over the past few decades. Ice core data show that the atmospheric concentration of N_2O varied by less than about 10 ppb for 11,500 years before the onset of the industrial period. {2.3, 6.4, 6.5}

The increase in N_2O since the pre-industrial era now contributes a radiative forcing of +0.16 ± 0.02 W m^{-2} and is due primarily to human activities, particularly agriculture and associated land use change. Current estimates are that about 40% of total N_2O emissions are anthropogenic but individual source estimates remain subject to significant uncertainties. {2.3, 7.4}

TS.2.1.3 Changes in Atmospheric Halocarbons, Stratospheric Ozone, Tropospheric Ozone and Other Gases

CFCs and hydrochlorofluorocarbons (HCFCs) are greenhouse gases that are purely anthropogenic in origin and used in a wide variety of applications. Emissions of these gases have decreased due to their phase-out under the Montreal Protocol, and the atmospheric concentrations of CFC-11 and CFC-113 are now decreasing due to natural removal processes. Observations in polar firn cores since the TAR have now extended the available time series information for some of these greenhouse gases. Ice core and *in situ* data confirm that industrial sources are the cause of observed atmospheric increases in CFCs and HCFCs. {2.3}

The Montreal Protocol gases contributed +0.32 ± 0.03 W m^{-2} to direct radiative forcing in 2005, with CFC-12 continuing to be the third most important long-lived radiative forcing agent. These gases as a group contribute about 12% of the total forcing due to LLGHGs. {2.3}

The concentrations of industrial fluorinated gases covered by the Kyoto Protocol (hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6)) are relatively small but are increasing rapidly. Their total radiative forcing in 2005 was +0.017 W m^{-2}. {2.3}

Tropospheric ozone is a short-lived greenhouse gas produced by chemical reactions of precursor species in the atmosphere and with large spatial and temporal variability. Improved measurements and modelling have advanced the understanding of chemical precursors that lead to the formation of tropospheric ozone, mainly carbon monoxide, nitrogen oxides (including sources and possible long-term trends in lightning) and formaldehyde. Overall, current models are successful in describing the principal features of the present global tropospheric ozone distribution on the basis of underlying processes. New satellite and *in situ* measurements provide important global constraints for these models; however, there is less confidence in their ability to reproduce the changes in ozone associated with large changes in emissions or climate, and in the simulation of observed long-term trends in ozone concentrations over the 20th century. {7.4}

Tropospheric ozone radiative forcing is estimated to be +0.35 [+0.25 to +0.65] W m^{-2} with a *medium* level of scientific understanding. The best estimate of this radiative forcing has not changed since the TAR. Observations show that trends in tropospheric ozone during the last few decades vary in sign and magnitude at many locations, but there are indications of significant upward trends at low latitudes. Model studies of the radiative forcing due to the increase in tropospheric ozone since pre-industrial times have increased in complexity and comprehensiveness compared with models used in the TAR. {2.3, 7.4}

Changes in tropospheric ozone are linked to air quality and climate change. A number of studies have shown that summer daytime ozone concentrations correlate strongly with temperature. This correlation appears to reflect contributions from temperature-dependent biogenic volatile organic carbon emissions, thermal decomposition of peroxyacetylnitrate, which acts as a reservoir for nitrogen oxides (NO_x), and association of high temperatures with regional stagnation. Anomalously hot and stagnant conditions during the summer of 1988 were responsible for the highest surface-level ozone year on record in the north-eastern USA. The summer heat wave in Europe in 2003 was also associated with exceptionally high local ozone at the surface. {Box 7.4}

The radiative forcing due to the destruction of stratospheric ozone is caused by the Montreal Protocol gases and is re-evaluated to be –0.05 ± 0.10 W m^{-2}, weaker than in the TAR, with a medium level of scientific understanding. The trend of greater and greater depletion of global stratospheric ozone observed during the 1980s and 1990s is no longer occurring; however, global stratospheric ozone is still about 4% below pre-1980 values and it is not yet clear whether ozone recovery has begun. In addition to the chemical destruction of ozone, dynamical changes may have contributed to NH mid-latitude ozone reduction. {2.3}

Direct emission of water vapour by human activities makes a negligible contribution to radiative forcing. However, as global mean temperatures increase, tropospheric water vapour concentrations increase and this represents a key feedback but not a forcing of climate change. Direct emission of water to the atmosphere by anthropogenic activities, mainly irrigation, is a possible forcing factor but corresponds to less than 1% of the natural sources of atmospheric water vapour. The direct injection of water vapour into the atmosphere from fossil fuel combustion is significantly lower than that from agricultural activity. {2.5}

Based on chemical transport model studies, the radiative forcing from increases in stratospheric water vapour due to oxidation of CH_4 is estimated to be +0.07 ± 0.05 W m^{-2}. The level of scientific understanding is low because the contribution of CH_4 to the corresponding vertical structure of the water vapour change near the tropopause is uncertain. Other potential human causes of stratospheric water vapour increases that could contribute to radiative forcing are poorly understood. {2.3}

TS.2.2 Aerosols

Direct aerosol radiative forcing is now considerably better quantified than previously and represents a major advance in understanding since the time of the TAR, when several components had a very low level of scientific understanding. A total direct aerosol radiative forcing combined across all aerosol types can now be given for the first time as –0.5 ± 0.4 W m^{-2}, with a medium-low level of scientific understanding. Atmospheric models have improved and many now represent all aerosol components of significance. Aerosols vary considerably in their properties that affect the extent to which they absorb and scatter radiation, and thus different types may have a net cooling or warming effect. Industrial aerosol consisting mainly of a mixture of sulphates, organic and black carbon, nitrates and industrial dust is clearly discernible over many continental regions of the NH. Improved *in situ*, satellite and surface-based measurements (see Figure TS.4) have enabled verification of global aerosol model simulations. These improvements allow quantification of the total direct aerosol radiative forcing for the first time, representing an important advance since the TAR. The direct radiative forcing for individual species remains less certain and is estimated from models to be –0.4 ± 0.2 W m^{-2} for sulphate, –0.05 ± 0.05 W m^{-2} for fossil fuel organic carbon, +0.2 ± 0.15 W m^{-2} for fossil fuel black carbon, +0.03 ± 0.12 W m^{-2} for biomass burning, –0.1 ± 0.1 W m^{-2} for nitrate and –0.1 ± 0.2 W m^{-2} for mineral dust. Two recent emission inventory studies support data from ice cores and suggest that global anthropogenic sulphate emissions decreased over the 1980 to 2000 period and that the geographic distribution of sulphate forcing has also changed. {2.4, 6.6}

Significant changes in the estimates of the direct radiative forcing due to biomass-burning, nitrate and mineral dust aerosols have occurred since the TAR. For biomass-burning aerosol, the estimated direct radiative forcing is now revised from being negative to near zero due to the estimate being strongly influenced by the occurrence of these aerosols over clouds. For the first time, the radiative forcing due to nitrate aerosol is given. For mineral dust, the range in the direct radiative forcing is reduced due to a reduction in the estimate of its anthropogenic fraction. {2.4}

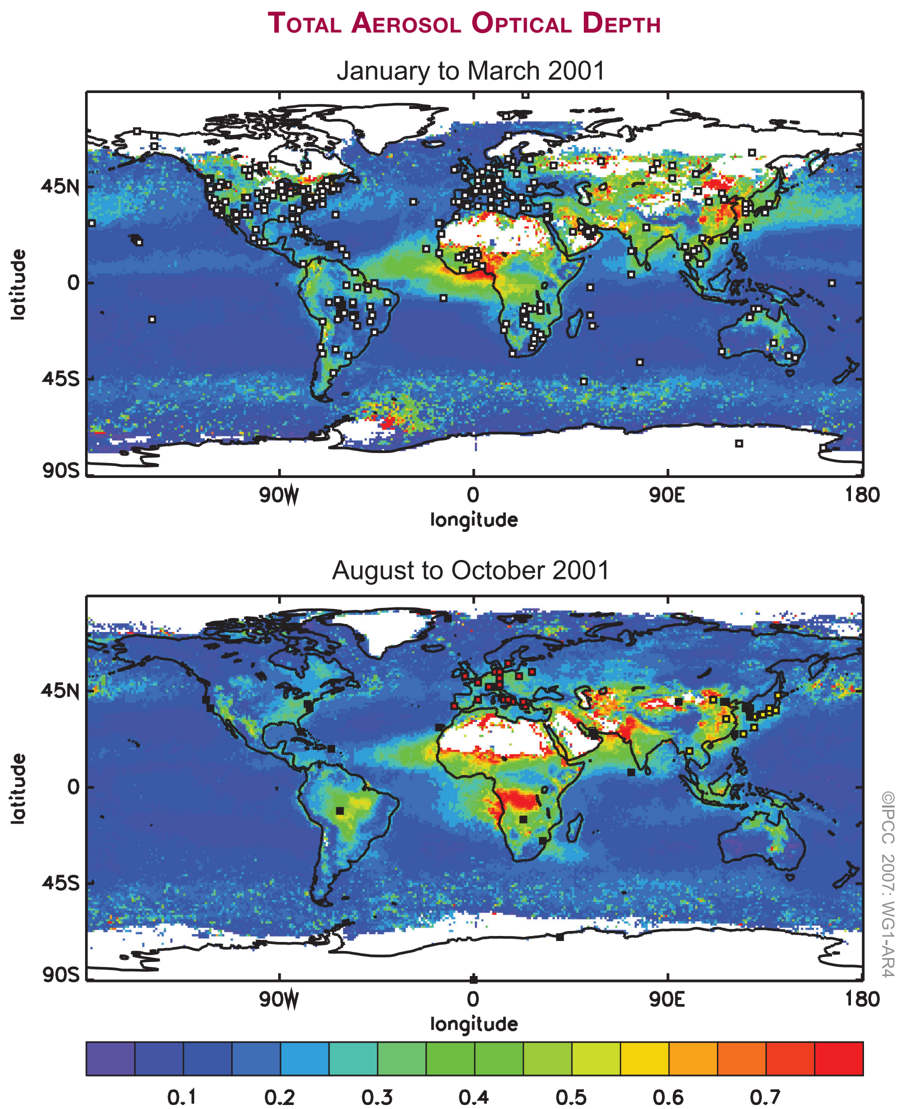


Figure TS.4. *(Top) The total aerosol optical depth (due to natural plus anthropogenic aerosols) at a mid-visible wavelength determined by satellite measurements for January to March 2001 and (bottom) August to October 2001, illustrating seasonal changes in industrial and biomass-burning aerosols. Data are from satellite measurements, complemented by two different kinds of ground-based measurements at locations shown in the two panels (see Section 2.4.2 for details). {Figure 2.11}*

Anthropogenic aerosols effects on water clouds cause an indirect cloud albedo effect (referred to as the first indirect effect in the TAR), which has a best estimate for the first time of –0.7 [–0.3 to –1.8] W m^{-2}. The number of global model estimates of the albedo effect for liquid water clouds has increased substantially since the TAR, and the estimates have been evaluated in a more rigorous way. The estimate for this radiative forcing comes from multiple model studies incorporating more aerosol species and describing aerosol-cloud interaction processes in greater detail. Model studies including more aerosol species or constrained by satellite observations tend to yield a relatively weaker cloud albedo effect. Despite the advances and progress since the TAR and the reduction in the spread of the estimate of the forcing, there remain large uncertainties in both measurements and modelling of processes, leading to a low level of scientific understanding, which is an elevation from the very low rank in the TAR. {2.4, 7.5, 9.2}

Other effects of aerosol include a cloud lifetime effect, a semi-direct effect and aerosol-ice cloud interactions. These are considered to be part of the climate response rather than radiative forcings. {2.4, 7.5}

TS.2.3 Aviation Contrails and Cirrus, Land Use and Other Effects

Persistent linear contrails from global aviation contribute a small radiative forcing of +0.01 [+0.003 to +0.03] W m^{-2}, with a low level of scientific understanding. This best estimate is smaller than the estimate in the TAR. This difference results from new observations of contrail cover and reduced estimates of contrail optical depth. No best estimates are available for the net forcing from spreading contrails. Their effects on cirrus cloudiness and the global effect of aviation aerosol on background cloudiness remain unknown. {2.6}

Human-induced changes in land cover have increased the global surface albedo, leading to a radiative forcing of –0.2 ± 0.2 W m^{-2}, the same as in the TAR, with a medium-low level of scientific understanding. Black carbon aerosols deposited on snow reduce the surface albedo and are estimated to yield an associated radiative forcing of +0.1 ± 0.1 W m^{-2}, with a low level of scientific understanding. Since the TAR, a number of estimates of the forcing from land use changes have been made, using better techniques, exclusion of feedbacks in the evaluation and improved incorporation of large-scale observations. Uncertainties in the estimate include mapping and characterisation of present-day vegetation and historical state, parametrization of surface radiation processes and biases in models' climate variables. The presence of soot particles in snow leads to a decrease in the albedo of snow and a positive forcing, and could affect snowmelt. Uncertainties are large regarding the manner in which soot is incorporated in snow and the resulting optical properties. {2.5}

The impacts of land use change on climate are expected to be locally significant in some regions, but are small at the global scale in comparison with greenhouse gas warming. Changes in the land surface (vegetation, soils, water) resulting from human activities can significantly affect local climate through shifts in radiation, cloudiness, surface roughness and surface temperatures. Changes in vegetation cover can also have a substantial effect on surface energy and water balance at the regional scale. These effects involve non-radiative processes (implying that they cannot be quantified by a radiative forcing) and have a very low level of scientific understanding. {2.5, 7.2, 9.3, Box 11.4}

The release of heat from anthropogenic energy production can be significant over urban areas but is not significant globally. {2.5}

TS.2.4 Radiative Forcing Due to Solar Activity and Volcanic Eruptions

Continuous monitoring of total solar irradiance now covers the last 28 years. The data show a well-established 11-year cycle in irradiance that varies by 0.08% from solar cycle minima to maxima, with no significant long-term trend. New data have more accurately quantified changes in solar spectral fluxes over a broad range of wavelengths in association with changing solar activity. Improved calibrations using high-quality overlapping measurements have also contributed to a better understanding. Current understanding of solar physics and the known sources of irradiance variability suggest comparable irradiance levels during the past two solar cycles, including at solar minima. The primary known cause of contemporary irradiance variability is the presence on the Sun's disk of sunspots (compact, dark features where radiation is locally depleted) and faculae (extended bright features where radiation is locally enhanced). {2.7}

The estimated direct radiative forcing due to changes in the solar output since 1750 is +0.12 [+0.06 to +0.3] W m^{-2}, which is less than half of the estimate given in the TAR, with a low level of scientific understanding. The reduced radiative forcing estimate comes from a re-evaluation of the long-term change in solar irradiance since 1610 (the Maunder Minimum) based upon: a new reconstruction using a model of solar magnetic flux variations that does not invoke geomagnetic, cosmogenic or stellar proxies; improved understanding of recent solar variations and their relationship to physical processes; and re-evaluation of the variations of Sun-like stars. While this leads to an elevation in the level of scientific understanding from very low in the TAR to low in this assessment, uncertainties remain large because of the lack of direct observations and incomplete understanding of solar variability mechanisms over long time scales. {2.7, 6.6}

Empirical associations have been reported between solar-modulated cosmic ray ionization of the atmosphere and global average low-level cloud cover but evidence for a systematic indirect solar effect remains ambiguous. It has been suggested that galactic cosmic rays with sufficient energy to reach the troposphere could alter the population of cloud condensation nuclei and hence microphysical cloud properties (droplet number and concentration), inducing changes in cloud processes analogous to the indirect cloud albedo effect of tropospheric aerosols and thus causing an indirect solar forcing of climate. Studies have probed various correlations with clouds in particular regions or using limited cloud types or limited time periods; however, the cosmic ray time series does not appear to correspond to global total cloud cover after 1991 or to global low-level cloud cover after 1994. Together with the lack of a proven physical mechanism and the plausibility of other causal factors affecting changes in cloud cover, this makes the association between galactic cosmic ray-induced changes in aerosol and cloud formation controversial. {2.7}

Explosive volcanic eruptions greatly increase the concentration of stratospheric sulphate aerosols. A single eruption can thereby cool global mean climate for a few years. Volcanic aerosols perturb both the stratosphere and surface/troposphere radiative energy budgets and climate in an episodic manner, and many past events are evident in ice core observations of sulphate as well as temperature records. There have been no explosive volcanic events since the 1991 Mt. Pinatubo eruption capable of injecting significant material to the stratosphere. However, the potential exists for volcanic eruptions much larger than the 1991 Mt. Pinatubo eruption, which could produce larger radiative forcing and longer-term cooling of the climate system. {2.7, 6.4, 6.6, 9.2}

TS.2.5 Net Global Radiative Forcing, Global Warming Potentials and Patterns of Forcing

The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR, leading to *very high confidence* that the effect of human activities since 1750 has been a net positive forcing of +1.6 [+0.6 to +2.4] W m^{-2}. Improved understanding and better quantification of the forcing mechanisms since the TAR make it possible to derive a combined net anthropogenic radiative forcing for the first time. Combining the component values for each forcing agent and their uncertainties yields the probability distribution of the combined anthropogenic radiative forcing estimate shown in Figure TS.5; the most likely value is about an order of magnitude larger than the estimated radiative forcing from changes in solar irradiance. Since the range in the estimate is +0.6 to +2.4 W m^{-2}, there is very high confidence in the net positive radiative forcing of the climate system due to human activity. The LLGHGs together contribute +2.63 ± 0.26 W m^{-2}, which is the dominant radiative forcing term and has the highest level of scientific understanding. In contrast, the total direct aerosol, cloud albedo and surface albedo effects that contribute negative forcings are less well understood and have larger uncertainties. The range in the net estimate is increased by the negative forcing terms, which have larger uncertainties than the positive terms. The nature of the uncertainty in the estimated cloud albedo effect introduces a noticeable asymmetry in the distribution. Uncertainties in the distribution include structural aspects (e.g., representation of extremes in the component values, absence of any weighting of the radiative forcing mechanisms, possibility of unaccounted for but as yet unquantified radiative forcings) and statistical aspects (e.g., assumptions about the types of distributions describing component uncertainties). {2.7, 2.9}

The Global Warming Potential (GWP) is a useful metric for comparing the potential climate impact of the emissions of different LLGHGs (see Table TS.2). Global Warming Potentials compare the integrated radiative forcing over a specified period (e.g., 100 years) from a unit mass pulse emission and are a way of comparing the potential climate change associated with emissions of different greenhouse gases. There are well-documented shortcomings of the GWP concept, particularly in using it to assess the impact of short-lived species. {2.10}

For the magnitude and range of realistic forcings considered, evidence suggests an approximately linear relationship between global mean radiative forcing and global mean surface temperature response. The spatial patterns of radiative forcing vary between different forcing agents. However, the spatial signature of the climate response is not generally expected to match that of the forcing. Spatial patterns of climate response

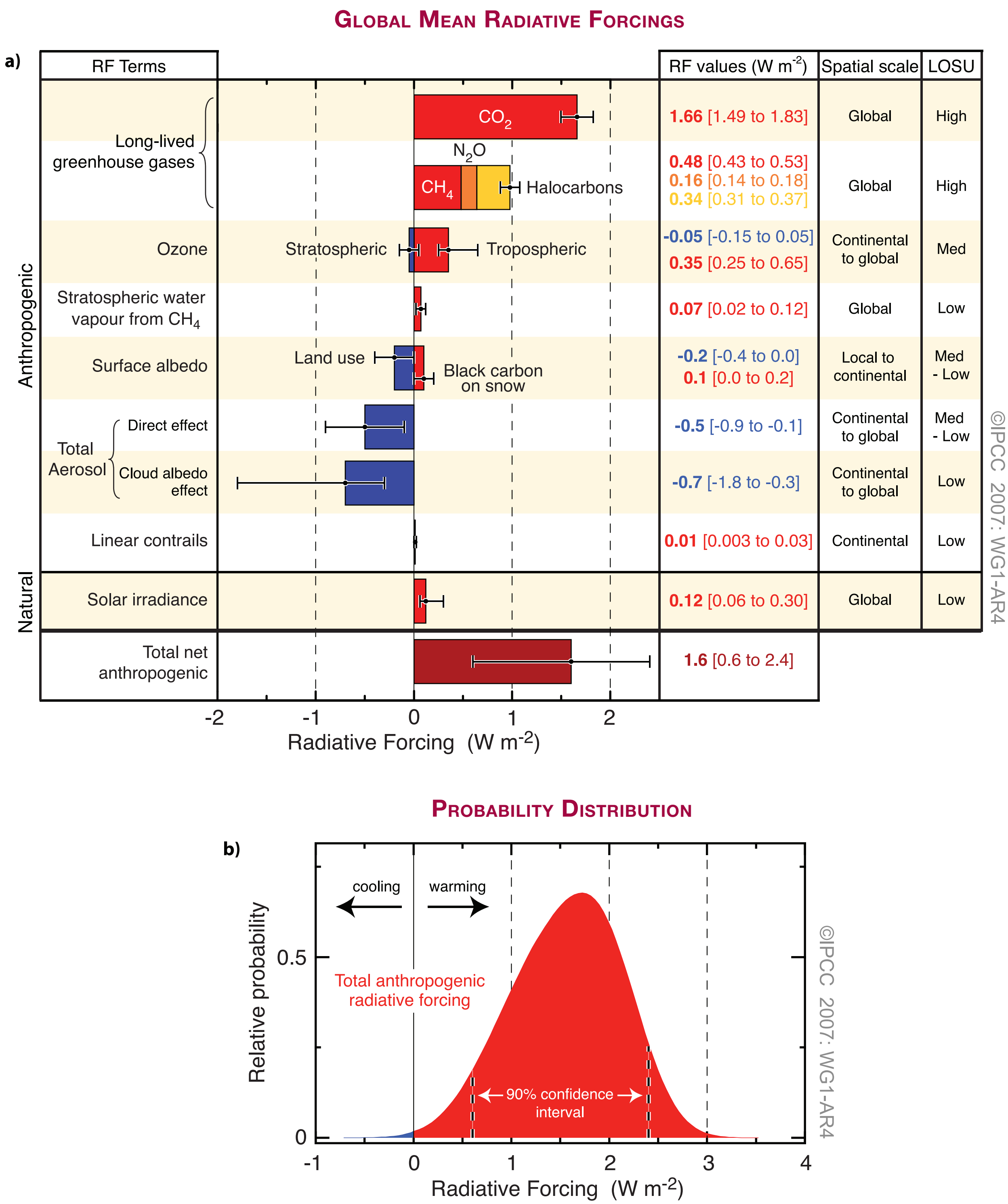


Figure TS.5. *(a) Global mean radiative forcings (RF) and their 90% confidence intervals in 2005 for various agents and mechanisms. Columns on the right-hand side specify best estimates and confidence intervals (RF values); typical geographical extent of the forcing (Spatial scale); and level of scientific understanding (LOSU) indicating the scientific confidence level as explained in Section 2.9. Errors for CH_4, N_2O and halocarbons have been combined. The net anthropogenic radiative forcing and its range are also shown. Best estimates and uncertainty ranges can not be obtained by direct addition of individual terms due to the asymmetric uncertainty ranges for some factors; the values given here were obtained from a Monte Carlo technique as discussed in Section 2.9. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional form of natural forcing but are not included due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. (b) Probability distribution of the global mean combined radiative forcing from all anthropogenic agents shown in (a). The distribution is calculated by combining the best estimates and uncertainties of each component. The spread in the distribution is increased significantly by the negative forcing terms, which have larger uncertainties than the positive terms. {2.9.1, 2.9.2; Figure 2.20}*

Table TS.2. *Lifetimes, radiative efficiencies and direct (except for CH_4) global warming potentials (GWP) relative to CO_2. {Table 2.14}*

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency ($W\ m^{-2}\ ppb^{-1}$)	Global Warming Potential for Given Time Horizon SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4×10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7×10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03×10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_2	100	0.32	8,100	11,000	10,900	5,200
CFC-13	$CClF_3$	640	0.25		10,800	14,400	16,400
CFC-113	CCl_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	1,700	0.18		5,310	7,370	9,990
Halon-1301	$CBrF_3$	65	0.32	5,400	8,480	7,140	2,760
Halon-1211	$CBrClF_2$	16	0.3		4,750	1,890	575
Halon-2402	$CBrF_2CBrF_2$	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl_4	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		506	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	5.8	0.32		2,030	595	181
Hydrofluorocarbons							
HFC-23	CHF_3	270	0.19	11,700	12,000	14,800	12,200
HFC-32	CH_2F_2	4.9	0.11	650	2,330	675	205
HFC-125	CHF_2CF_3	29	0.23	2,800	6,350	3,500	1,100
HFC-134a	CH_2FCF_3	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH_3CF_3	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH_3CHF_2	1.4	0.09	140	437	124	38
HFC-227ea	CF_3CHFCF_3	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	$CF_3CH_2CF_3$	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	$CHF_2CH_2CF_3$	7.6	0.28		3,380	1030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.6	0.21		2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15.9	0.4	1,300	4,140	1,640	500
Perfluorinated compounds							
Sulphur hexafluoride	SF_6	3,200	0.52	23,900	16,300	22,800	32,600
Nitrogen trifluoride	NF_3	740	0.21		12,300	17,200	20,700
PFC-14	CF_4	50,000	0.10	6,500	5,210	7,390	11,200
PFC-116	C_2F_6	10,000	0.26	9,200	8,630	12,200	18,200

Table TS.2 (continued)

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency ($W\ m^{-2}\ ppb^{-1}$)	Global Warming Potential for Given Time Horizon SAR‡ (100-yr)	20-yr	100-yr	500-yr
***Perfluorinated compounds** (continued)*							
PFC-218	C_3F_8	2,600	0.26	7,000	6,310	8,830	12,500
PFC-318	$c\text{-}C_4F_8$	3,200	0.32	8,700	7,310	10,300	14,700
PFC-3-1-10	C_4F_{10}	2,600	0.33	7,000	6,330	8,860	12,500
PFC-4-1-12	C_5F_{12}	4,100	0.41		6,510	9,160	13,300
PFC-5-1-14	C_6F_{14}	3,200	0.49	7,400	6,600	9,300	13,300
PFC-9-1-18	$C_{10}F_{18}$	>1,000[d]	0.56		>5,500	>7,500	>9,500
trifluoromethyl sulphur pentafluoride	SF_5CF_3	800	0.57		13,200	17,700	21,200
Fluorinated ethers							
HFE-125	CHF_2OCF_3	136	0.44		13,800	14,900	8,490
HFE-134	CHF_2OCHF_2	26	0.45		12,200	6,320	1,960
HFE-143a	CH_3OCF_3	4.3	0.27		2,630	756	230
HCFE-235da2	$CHF_2OCHClCF_3$	2.6	0.38		1,230	350	106
HFE-245cb2	$CH_3OCF_2CHF_2$	5.1	0.32		2,440	708	215
HFE-245fa2	$CHF_2OCH_2CF_3$	4.9	0.31		2,280	659	200
HFE-254cb2	$CH_3OCF_2CHF_2$	2.6	0.28		1,260	359	109
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	5.2	0.34		1,980	575	175
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	7.1	0.25		1,900	580	175
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	0.33	0.93		386	110	33
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	3.8	0.31		1,040	297	90
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	0.77	0.3		207	59	18
HFE-43-10pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$	6.3	1.37		6,320	1,870	569
HFE-236ca12 (HG-10)	$CHF_2OCF_2OCHF_2$	12.1	0.66		8,000	2,800	860
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	6.2	0.87		5,100	1,500	460
Perfluoropolyethers							
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	800	0.65		7,620	10,300	12,400
Hydrocarbons and other compounds – Direct Effects							
Dimethylether	CH_3OCH_3	0.015	0.02		1	1	<<1
Methylene chloride	CH_2Cl_2	0.38	0.03		31	8.7	2.7
Methyl chloride	CH_3Cl	1.0	0.01		45	13	4

Notes:

‡ SAR refers to the IPCC Second Assessment Report (1995) used for reporting under the UNFCCC.

a The CO_2 response function used in this report is based on the revised version of the Bern Carbon cycle model used in Chapter 10 of this report (Bern2.5CC; Joos et al. 2001) using a background CO_2 concentration value of 378 ppm. The decay of a pulse of CO_2 with time t is given by

$$a_0 + \sum_{i=1}^{3} a_i \cdot e^{-t/\tau_i}$$ where $a_0 = 0.217$, $a_1 = 0.259$, $a_2 = 0.338$, $a_3 = 0.186$, $\tau_1 = 172.9$ years, $\tau_2 = 18.51$ years, and $\tau_3 = 1.186$ years, for $t < 1{,}000$ years.

b The radiative efficiency of CO_2 is calculated using the IPCC (1990) simplified expression as revised in the TAR, with an updated background concentration value of 378 ppm and a perturbation of +1 ppm (see Section 2.10.2).

c The perturbation lifetime for CH_4 is 12 years as in the TAR (see also Section 7.4). The GWP for CH_4 includes indirect effects from enhancements of ozone and stratospheric water vapour (see Section 2.10) .

d The assumed lifetime of 1000 years is a lower limit.

are largely controlled by climate processes and feedbacks. For example, sea ice-albedo feedbacks tend to enhance the high-latitude response. Spatial patterns of response are also affected by differences in thermal inertia between land and sea areas. {2.8, 9.2}

The pattern of response to a radiative forcing can be altered substantially if its structure is favourable for affecting a particular aspect of the atmospheric structure or circulation. Modelling studies and data comparisons suggest that mid- to high-latitude circulation patterns are *likely* to be affected by some forcings such as volcanic eruptions, which have been linked to changes in the Northern Annular Mode (NAM) and North Atlantic Oscillation (NAO) (see Section 3.1 and Box TS.2). Simulations also suggest that absorbing aerosols, particularly black carbon, can reduce the solar radiation reaching the surface and can warm the atmosphere at regional scales, affecting the vertical temperature profile and the large-scale atmospheric circulation. {2.8, 7.5, 9.2}

The spatial patterns of radiative forcings for ozone, aerosol direct effects, aerosol-cloud interactions and land use have considerable uncertainties. This is in contrast to the relatively high confidence in the spatial pattern of radiative forcing for the LLGHGs. The net positive radiative forcing in the Southern Hemisphere (SH) *very likely* exceeds that in the NH because of smaller aerosol concentrations in the SH. {2.9}

TS 2.6 Surface Forcing and the Hydrologic Cycle

Observations and models indicate that changes in the radiative flux at the Earth's surface affect the surface heat and moisture budgets, thereby involving the hydrologic cycle. Recent studies indicate that some forcing agents can influence the hydrologic cycle differently than others through their interactions with clouds. In particular, changes in aerosols may have affected precipitation and other aspects of the hydrologic cycle more strongly than other anthropogenic forcing agents. Energy deposited at the surface directly affects evaporation and sensible heat transfer. The instantaneous radiative flux change at the surface (hereafter called 'surface forcing') is a useful diagnostic tool for understanding changes in the heat and moisture surface budgets and the accompanying climate change. However, unlike radiative forcing, it cannot be used to quantitatively compare the effects of different agents on the equilibrium global mean surface temperature change. Net radiative forcing and surface forcing have different equator-to-pole gradients in the NH, and are different between the NH and SH. {2.9, 7.2, 7.5, 9.5}

TS.3 Observations of Changes in Climate

This assessment evaluates changes in the Earth's climate system, considering not only the atmosphere, but also the ocean and the cryosphere, as well as phenomena such as atmospheric circulation changes, in order to increase understanding of trends, variability and processes of climate change at global and regional scales. Observational records employing direct methods are of variable length as described below, with global temperature estimates now beginning as early as 1850. Observations of extremes of weather and climate are discussed, and observed changes in extremes are described. The consistency of observed changes among different climate variables that allows an increasingly comprehensive picture to be drawn is also described. Finally, palaeoclimatic information that generally employs indirect proxies to infer information about climate change over longer time scales (up to millions of years) is also assessed.

TS.3.1 Atmospheric Changes: Instrumental Record

This assessment includes analysis of global and hemispheric means, changes over land and ocean and distributions of trends in latitude, longitude and altitude. Since the TAR, improvements in observations and their calibration, more detailed analysis of methods and extended time series allow more in-depth analyses of changes including atmospheric temperature, precipitation, humidity, wind and circulation. Extremes of climate are a key expression of climate variability, and this assessment includes new data that permit improved insights into the changes in many types of extreme events including heat waves, droughts, heavy precipitation and tropical cyclones (including hurricanes and typhoons). {3.2–3.4, 3.8}

Furthermore, advances have occurred since the TAR in understanding how a number of seasonal and long-term anomalies can be described by patterns of climate variability. These patterns arise from internal interactions and from the differential effects on the atmosphere of land and ocean, mountains and large changes in heating. Their response is often felt in regions far removed from their physical source through atmospheric teleconnections associated with large-scale waves in the atmosphere. Understanding temperature and precipitation anomalies associated with the dominant patterns of climate variability is essential to understanding many regional climate anomalies and why these may differ from those at the global scale. Changes in storm tracks, the jet streams, regions of preferred blocking anticyclones and changes in monsoons can also occur in conjunction with these preferred patterns of variability. {3.5–3.7}

TS.3.1.1 Global Average Temperatures

2005 and 1998 were the warmest two years in the instrumental global surface air temperature record since 1850. Surface temperatures in 1998 were enhanced by the major 1997–1998 El Niño but no such strong anomaly was present in 2005. Eleven of the last 12 years (1995 to 2006) – the exception being 1996 – rank among the 12 warmest years on record since 1850. {3.2}

The global average surface temperature has increased, especially since about 1950. The updated 100-year trend (1906–2005) of 0.74°C ± 0.18°C is larger than the 100-year warming trend at the time of the TAR (1901–2000) of 0.6°C ± 0.2°C due to additional warm years. The total temperature increase from 1850-1899 to 2001-2005 is 0.76°C ± 0.19°C. The rate of warming averaged over the last 50 years (0.13°C ± 0.03°C per decade) is nearly twice that for the last 100 years. Three different global estimates all show consistent warming trends. There is also consistency between the data sets in their separate land and ocean domains, and between sea surface temperature (SST) and nighttime marine air temperature (see Figure TS.6). {3.2}

Recent studies confirm that effects of urbanisation and land use change on the global temperature record are negligible (less than 0.006°C per decade over land and zero over the ocean) as far as hemispheric- and continental-scale averages are concerned. All observations are subject to data quality and consistency checks to correct for potential biases. The real but local effects of urban areas are accounted for in the land temperature data sets used. Urbanisation and land use effects are not relevant to the widespread oceanic warming that has been observed. Increasing evidence suggests that urban heat island effects also affect precipitation, cloud and diurnal temperature range (DTR). {3.2}

The global average DTR has stopped decreasing. A decrease in DTR of approximately 0.1°C per decade was reported in the TAR for the period 1950 to 1993. Updated observations reveal that DTR has not changed from 1979 to 2004 as both day- and night time temperature have risen at about the same rate. The trends are highly variable from one region to another. {3.2}

New analyses of radiosonde and satellite measurements of lower- and mid-tropospheric temperature show warming rates that are generally consistent with each other and with those in the surface temperature record within their respective uncertainties for the periods 1958 to 2005 and 1979 to 2005. This largely resolves a discrepancy noted in the TAR (see Figure TS.7). The radiosonde record is markedly less spatially complete than the surface record and increasing evidence suggests that a number of radiosonde data sets are unreliable, especially in the tropics. Disparities remain among different tropospheric temperature trends estimated from satellite Microwave Sounding Unit (MSU) and advanced MSU measurements since 1979, and all likely still contain residual errors. However, trend estimates have been substantially improved and data set differences reduced since the TAR, through adjustments for changing satellites, orbit decay and drift in local crossing time (diurnal cycle effects). It appears that the satellite tropospheric temperature record is broadly consistent with surface temperature trends provided that the stratospheric influence on MSU channel 2 is accounted for. The range across different data sets of global surface warming since 1979 is 0.16°C to 0.18°C per decade, compared to 0.12°C to 0.19°C per decade for MSU-derived estimates of tropospheric temperatures. It is likely that there is increased warming with altitude from the surface through much of the troposphere in the tropics, pronounced cooling in the stratosphere, and a trend towards a higher tropopause. {3.4}

Stratospheric temperature estimates from adjusted radiosondes, satellites and reanalyses are all in qualitative agreement, with a cooling of between 0.3°C and 0.6°C per decade since 1979 (see Figure TS.7). Longer radiosonde records (back to 1958) also indicate stratospheric cooling but are subject to substantial instrumental uncertainties. The rate of cooling increased after 1979 but has slowed in the last decade. It is *likely* that radiosonde records overestimate stratospheric cooling, owing to changes in sondes not yet taken into account. The trends are not monotonic, because of stratospheric warming episodes that follow major volcanic eruptions. {3.4}

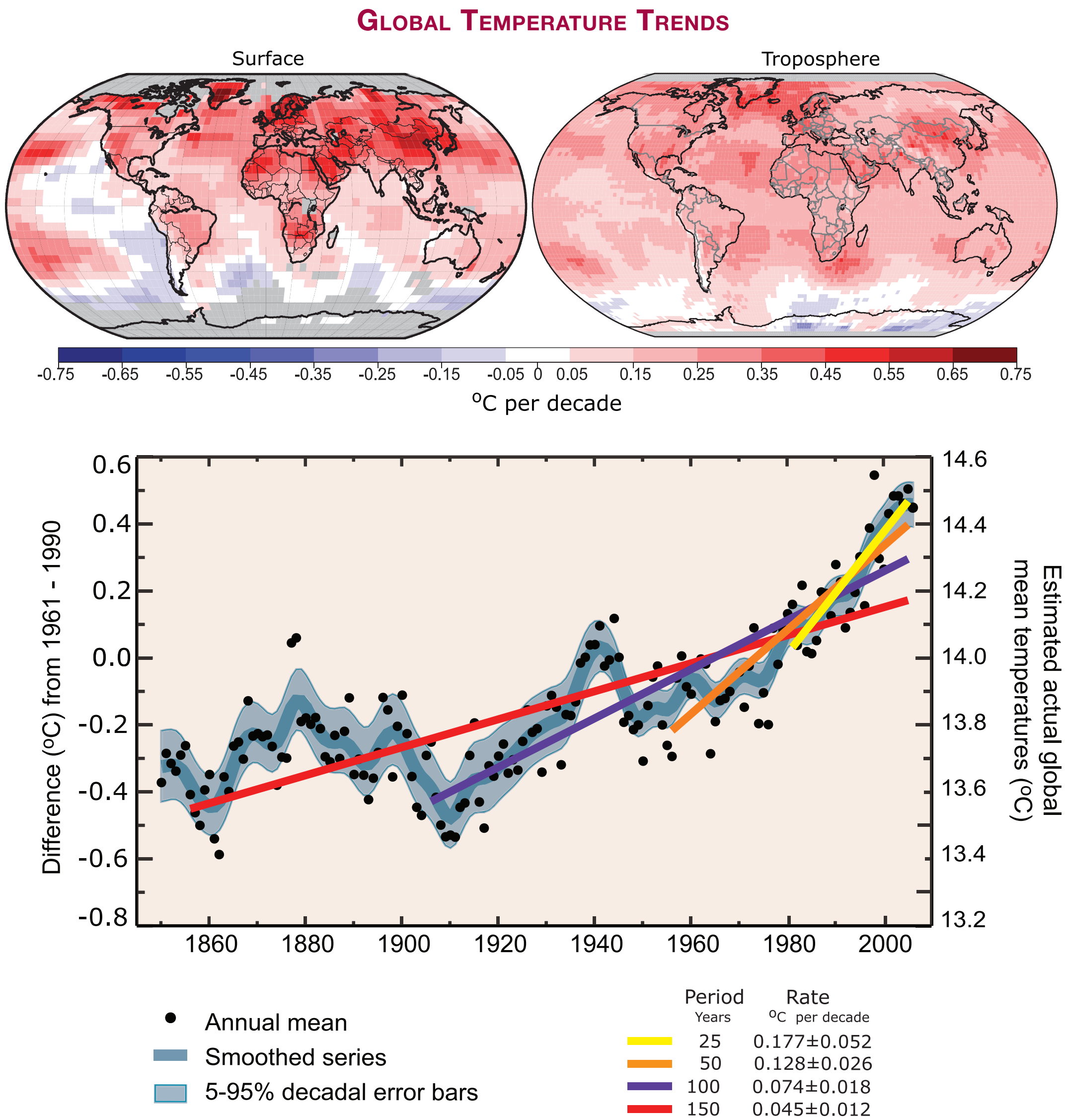


Figure TS.6. *(Top) Patterns of linear global temperature trends over the period 1979 to 2005 estimated at the surface (left), and for the troposphere from satellite records (right). Grey indicates areas with incomplete data. (Bottom) Annual global mean temperatures (black dots) with linear fits to the data. The left hand axis shows temperature anomalies relative to the 1961 to 1990 average and the right hand axis shows estimated actual temperatures, both in °C. Linear trends are shown for the last 25 (yellow), 50 (orange), 100 (purple) and 150 years (red). The smooth blue curve shows decadal variations (see Appendix 3.A), with the decadal 90% error range shown as a pale blue band about that line. The total temperature increase from the period 1850 to 1899 to the period 2001 to 2005 is 0.76°C ± 0.19°C. {FAQ 3.1, Figure 1.}*

TS.3.1.2 Spatial Distribution of Changes in Temperature, Circulation and Related Variables

Surface temperatures over land regions have warmed at a faster rate than over the oceans in both hemispheres. Longer records now available show significantly faster rates of warming over land than ocean in the past two decades (about 0.27°C vs. 0.13°C per decade). {3.2}

The warming in the last 30 years is widespread over the globe, and is greatest at higher northern latitudes. The greatest warming has occurred in the NH winter (DJF) and spring (MAM). Average arctic temperatures have been increasing at almost twice the rate of the rest of the world in the past 100 years. However, arctic temperatures are highly variable. A slightly longer arctic warm period, almost as warm as the present, was observed from 1925 to 1945, but its geographical distribution appears to have been different from the recent warming since its extent was not global. {3.2}

There is evidence for long-term changes in the large-scale atmospheric circulation, such as a poleward shift and strengthening of the westerly winds. Regional climate trends can be very different from the global average, reflecting changes in the circulations and interactions of the atmosphere and ocean and the other components of the climate system. Stronger mid-latitude westerly wind maxima have occurred in both hemispheres in most seasons from at least 1979 to the late 1990s, and poleward displacements of corresponding Atlantic and southern polar front jet streams have been documented. The westerlies in the NH increased from the 1960s to the 1990s but have since returned to values close to the long-term average. The increased strength of the westerlies in the NH changes the flow from oceans to continents, and is a major factor in the observed winter changes in storm tracks and related patterns of precipitation and temperature trends at mid- and high-latitudes. Analyses of wind and significant wave height support reanalysis-based evidence for changes in NH extratropical storms from the start of the reanalysis record in the late 1970s until the late 1990s. These changes are accompanied by a tendency towards stronger winter polar vortices throughout the troposphere and lower stratosphere. {3.2, 3.5}

Observed Air Temperatures

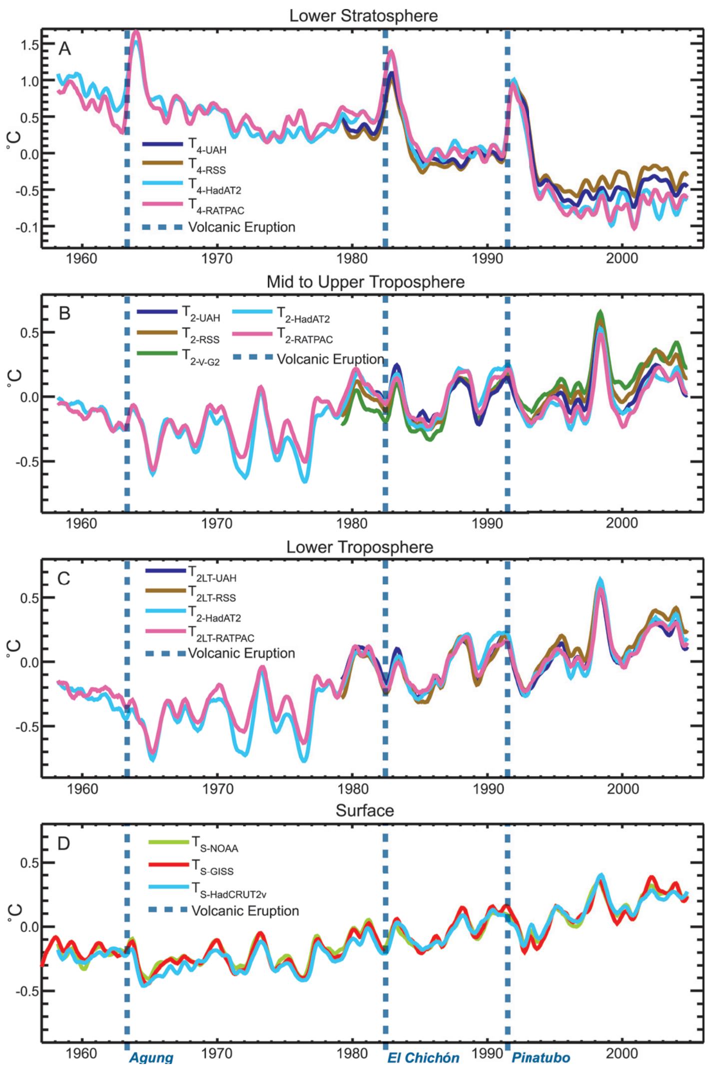


Figure TS.7. *Observed surface (D) and upper air temperatures for the lower troposphere (C), mid- to upper troposphere (B) and lower stratosphere (A), shown as monthly mean anomalies relative to the period 1979 to 1997 smoothed with a seven-month running mean filter. Dashed lines indicate the times of major volcanic eruptions. {Figure 3.17}*

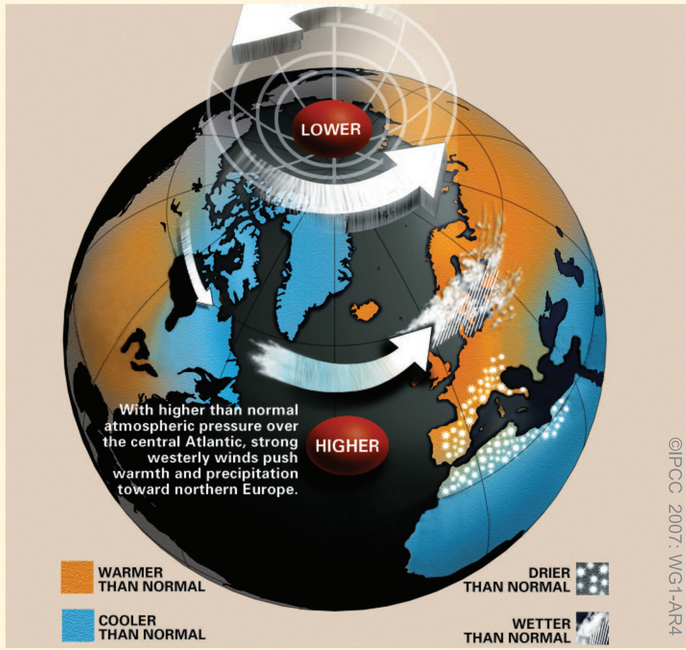
Many regional climate changes can be described in terms of preferred patterns of climate variability and therefore as changes in the occurrence of indices that characterise the strength and phase of these patterns. The importance, over all time scales, of fluctuations in the westerlies and storm tracks in the North Atlantic has often been noted, and these fluctuations are described by the NAO (see Box TS.2 for an explanation of this and other preferred patterns). The characteristics of fluctuations in the zonally averaged westerlies in the two hemispheres have more recently been described by their respective 'annular modes', the Northern and Southern Annular Modes (NAM and SAM). The observed changes can be expressed as a shift of the circulation towards the structure associated with one sign of these preferred patterns. The increased mid-latitude westerlies in the North Atlantic can be largely viewed as reflecting either NAO or NAM changes; multi-decadal variability is also evident in the Atlantic, both in the atmosphere and the ocean. In the SH, changes in circulation related to an increase in the SAM from the 1960s to the present are associated with strong warming over the Antarctic Peninsula and, to a lesser extent, cooling over parts of continental Antarctica. Changes have also been observed in ocean-atmosphere interactions in the Pacific. The ENSO is the dominant mode of global-scale variability on interannual time scales although there have been times when it is less apparent. The 1976–1977 climate shift, related to the phase change in the Pacific Decadal Oscillation (PDO) towards more El Niño events and changes in the evolution of ENSO, has affected many areas, including most tropical monsoons. For instance, over North America, ENSO and Pacific-

Box TS.2: Patterns (Modes) of Climate Variability

Analysis of atmospheric and climatic variability has shown that a significant component of it can be described in terms of fluctuations in the amplitude and sign of indices of a relatively small number of preferred patterns of variability. Some of the best known of these are:

- El Niño-Southern Oscillation (ENSO), a coupled fluctuation in the atmosphere and the equatorial Pacific Ocean, with preferred time scales of two to about seven years. ENSO is often measured by the difference in surface pressure anomalies between Tahiti and Darwin and the SSTs in the central and eastern equatorial Pacific. ENSO has global teleconnections.
- North Atlantic Oscillation (NAO), a measure of the strength of the Icelandic Low and the Azores High, and of the westerly winds between them, mainly in winter. The NAO has associated fluctuations in the storm track, temperature and precipitation from the North Atlantic into Eurasia (see Box TS.2, Figure 1).
- Northern Annular Mode (NAM), a winter fluctuation in the amplitude of a pattern characterised by low surface pressure in the Arctic and strong mid-latitude westerlies. The NAM has links with the northern polar vortex and hence the stratosphere.
- Southern Annular Mode (SAM), the fluctuation of a pattern with low antarctic surface pressure and strong mid-latitude westerlies, analogous to the NAM, but present year round.
- Pacific-North American (PNA) pattern, an atmospheric large-scale wave pattern featuring a sequence of tropospheric high- and low-pressure anomalies stretching from the subtropical west Pacific to the east coast of North America.
- Pacific Decadal Oscillation (PDO), a measure of the SSTs in the North Pacific that has a very strong correlation with the North Pacific Index (NPI) measure of the depth of the Aleutian Low. However, it has a signature throughout much of the Pacific.

Positive Phase of NAO and NAM



Box TS.2, Figure 1. *A schematic of the changes associated with the positive phase of the NAO and NAM. The changes in pressure and winds are shown, along with precipitation changes. Warm colours indicate areas that are warmer than normal and blue indicates areas that are cooler than normal.*

The extent to which all these preferred patterns of variability can be considered to be true modes of the climate system is a topic of active research. However, there is evidence that their existence can lead to larger-amplitude regional responses to forcing than would otherwise be expected. In particular, a number of the observed 20th-century climate changes can be viewed in terms of changes in these patterns. It is therefore important to test the ability of climate models to simulate them (see Section TS.4, Box TS.7) and to consider the extent to which observed changes related to these patterns are linked to internal variability or to anthropogenic climate change. {3.6, 8.4}

North American (PNA) teleconnection-related changes appear to have led to contrasting changes across the continent, as the western part has warmed more than the eastern part, while the latter has become cloudier and wetter. There is substantial low-frequency atmospheric variability in the Pacific sector over the 20th century, with extended periods of weakened (1900–1924; 1947–1976) as well as strengthened (1925–1946; 1977–2003) circulation. {3.2, 3.5, 3.6}

Changes in extremes of temperature are consistent with warming. Observations show widespread reductions in the number of frost days in mid-latitude regions, increases in the number of warm extremes (warmest 10% of days or nights) and a reduction in the number of daily cold extremes (coldest 10% of days or nights) (see Box TS.5). The most marked changes are for cold nights, which have declined over the 1951 to 2003 period for all regions where data are available (76% of the land). {3.8}

Heat waves have increased in duration beginning in the latter half of the 20th century. The record-breaking heat wave over western and central Europe in the summer of 2003 is an example of an exceptional recent extreme. That summer (JJA) was the warmest since comparable instrumental records began around 1780 (1.4°C above the previous warmest in 1807). Spring drying of the land surface over Europe was an important factor in the occurrence of the extreme 2003 temperatures. Evidence suggests that heat waves have also increased in frequency and duration in other locations. The very strong correlation between observed dryness and high temperatures over land in the tropics during summer highlights the important role moisture plays in moderating climate. {3.8, 3.9}

There is insufficient evidence to determine whether trends exist in such events as tornadoes, hail, lightning and dust storms which occur at small spatial scales. {3.8}

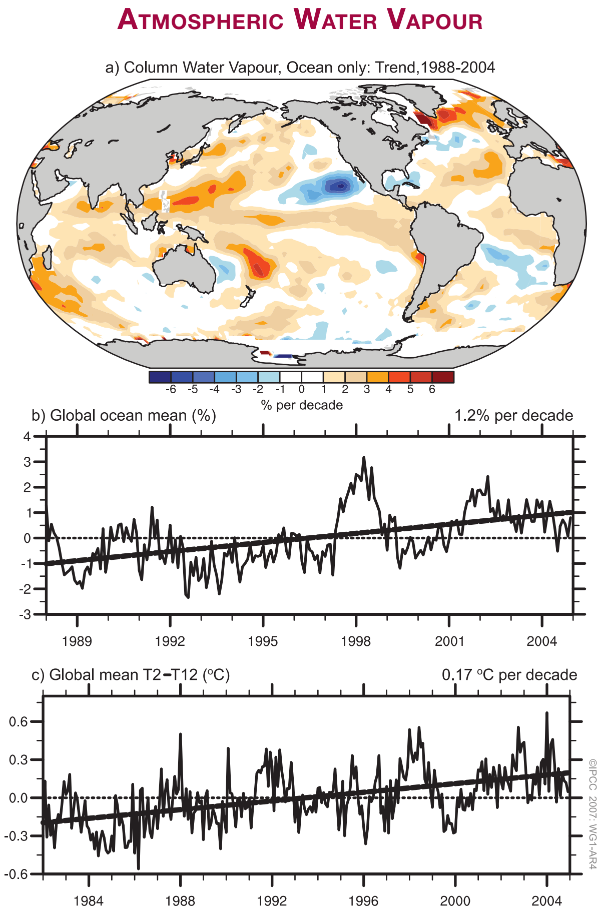


Figure TS.8. *(a) Linear trends in precipitable water (total column water vapour) over the period 1988 to 2004 (% per decade) and (b) the monthly time series of anomalies, relative to the period shown, over the global ocean with linear trend. (c) The global mean (80°N to 80°S) radiative signature of upper-tropospheric moistening is given by monthly time series of combinations of satellite brightness temperature anomalies (°C), relative to the period 1982 to 2004, with the dashed line showing the linear trend of the key brightness temperature in °C per decade. {3.4, Figures 3.20 and 3.21}*

TS.3.1.3 Changes in the Water Cycle: Water Vapour, Clouds, Precipitation and Tropical Storms

Tropospheric water vapour is increasing (Figure TS.8). Surface specific humidity has generally increased since 1976 in close association with higher temperatures over both land and ocean. Total column water vapour has increased over the global oceans by 1.2 ± 0.3% per decade (95% confidence limits) from 1988 to 2004. The observed regional changes are consistent in pattern and amount with the changes in SST and the assumption of a near-constant relative humidity increase in water vapour mixing ratio. The additional atmospheric water vapour implies increased moisture availability for precipitation. {3.4}

Upper-tropospheric water vapour is also increasing. Due to instrumental limitations, it is difficult to assess long-term changes in water vapour in the upper troposphere, where it is of radiative importance. However, the available data now show evidence for global increases in upper-tropospheric specific humidity over the past two decades (Figure TS.8). These observations are consistent with the observed increase in temperatures and represent an important advance since the TAR. {3.4}

Cloud changes are dominated by ENSO. Widespread (but not ubiquitous) decreases in continental DTR have coincided with increases in cloud amounts. Surface and satellite observations disagree on changes in total and low-level cloud changes over the ocean. However, radiation changes at the top of the atmosphere from the 1980s to 1990s (possibly related in part to the ENSO phenomenon) appear to be associated with reductions in tropical upper-level cloud cover, and are consistent with changes in the energy budget and in observed ocean heat content. {3.4}

'Global dimming' is not global in extent and it has not continued after 1990. Reported decreases in solar radiation at the Earth's surface from 1970 to 1990 have an urban bias. Further, there have been increases since about 1990. An increasing aerosol load due to human activities decreases regional air quality and the amount of solar radiation reaching the Earth's surface. In some areas, such as Eastern Europe, recent observations of a reversal in the sign of this effect link changes in solar radiation to concurrent air quality improvements. {3.4}

Long-term trends in precipitation amounts from 1900 to 2005 have been observed in many large regions (Figure TS.9). Significantly increased precipitation has been observed in the eastern parts of North and South America, northern Europe and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Precipitation is highly variable spatially and temporally, and robust long-term trends have not been established for other large regions.[5] {3.3}

Substantial increases in heavy precipitation events have been observed. It is *likely* that there have been increases in the number of heavy precipitation events (e.g., above the 95th percentile) in many land regions since about 1950, even in those regions where there has been a reduction in total precipitation amount. Increases have also been reported for rarer precipitation events (1 in 50 year return period), but only a few regions have sufficient data to assess such trends reliably (see Figure TS.10). {3.8}

There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases in tropical SSTs. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity and there is no clear trend in the annual numbers of tropical cyclones. Estimates of the potential destructiveness of tropical cyclones suggest a substantial upward trend since the mid-1970s, with a trend towards longer lifetimes and greater intensity. Trends are also apparent in SST, a critical variable known to influence

Global Mean Precipitation

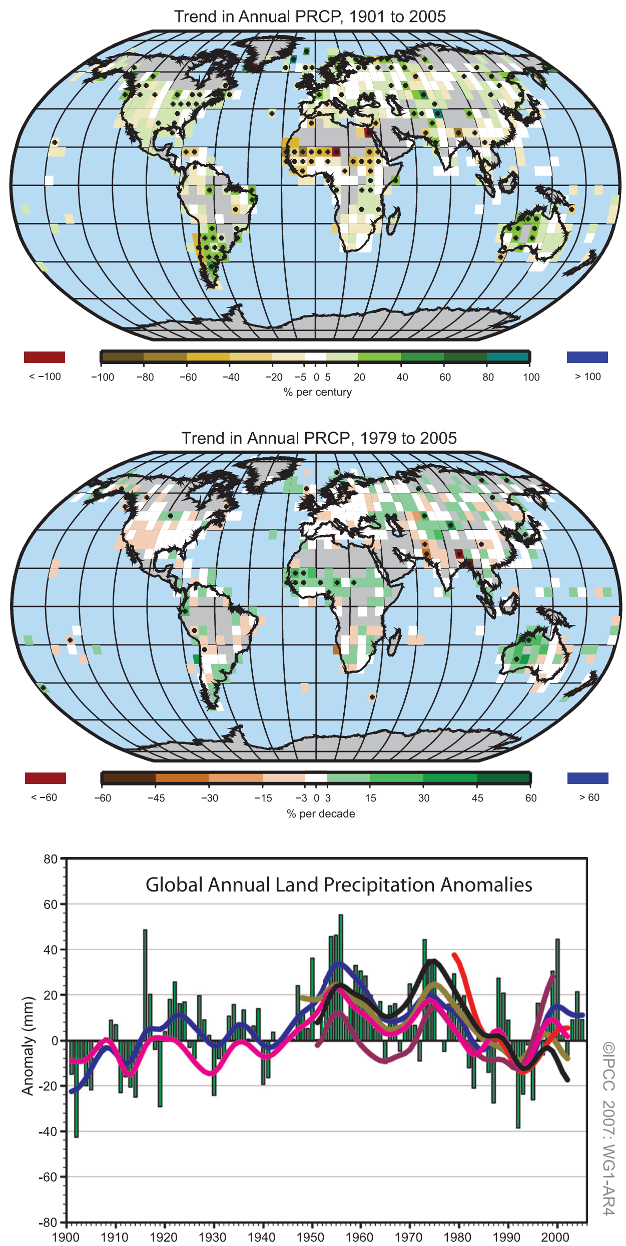


Figure TS.9. *(Top) Distribution of linear trends of annual land precipitation amounts over the period 1901 to 2005 (% per century) and (middle) 1979 to 2005 (% per decade). Areas in grey have insufficient data to produce reliable trends. The percentage is based on the 1961 to 1990 period. (Bottom) Time series of annual global land precipitation anomalies with respect to the 1961 to 1990 base period for 1900 to 2005. The smooth curves show decadal variations (see Appendix 3.A) for different data sets. {3.3, Figures 3.12 and 3.13}*

[5] The assessed regions are those considered in the regional projections chapter of the TAR and in Chapter 11 of this report.

Annual Precipitation Trends

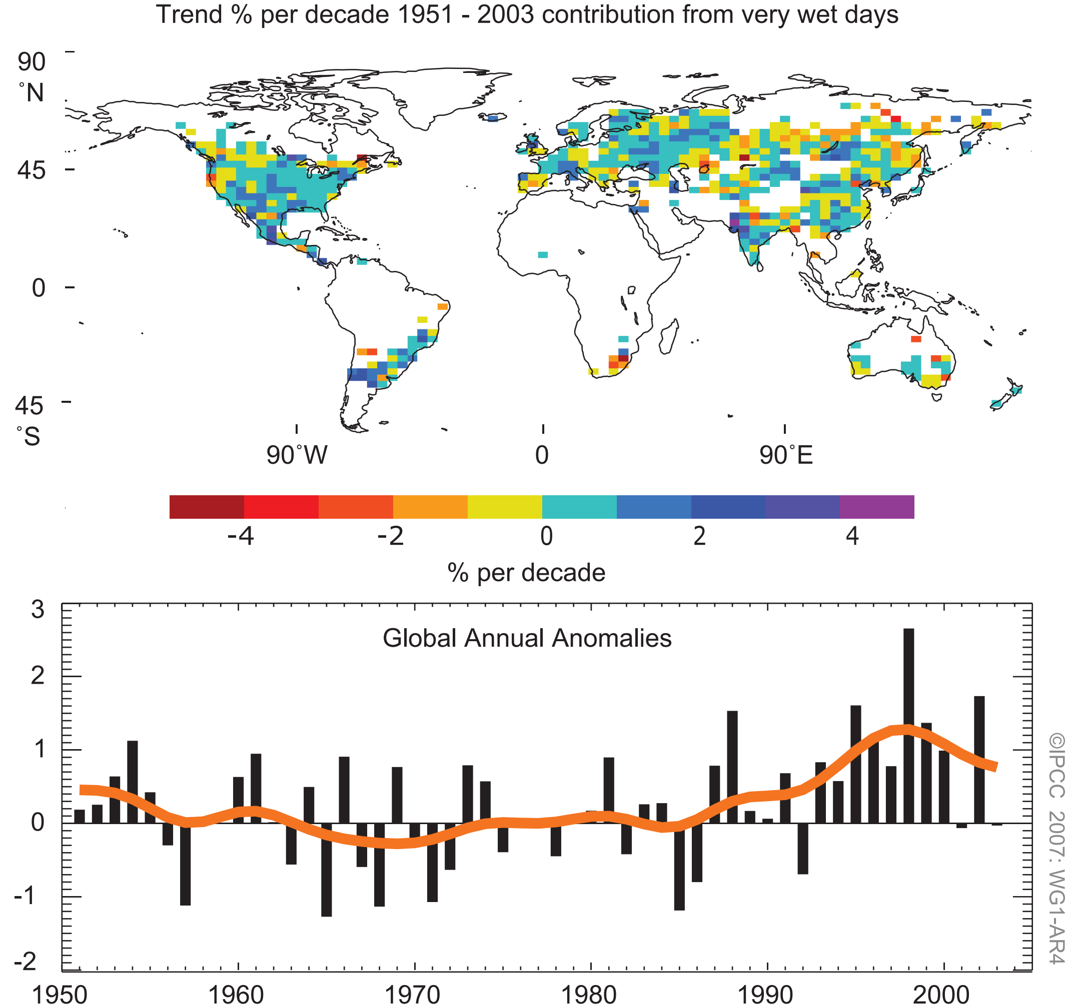


Figure TS.10. *(Top) Observed trends (% per decade) over the period 1951 to 2003 in the contribution to total annual precipitation from very wet days (i.e., corresponding to the 95th percentile and above). White land areas have insufficient data for trend determination. (Bottom) Anomalies (%) of the global (regions with data shown in top panel) annual time series of very wet days (with respect to 1961–1990) defined as the percentage change from the base period average (22.5%). The smooth orange curve shows decadal variations (see Appendix 3.A). {Figure 3.39}*

Annual Sea-Surface Temperature Anomalies

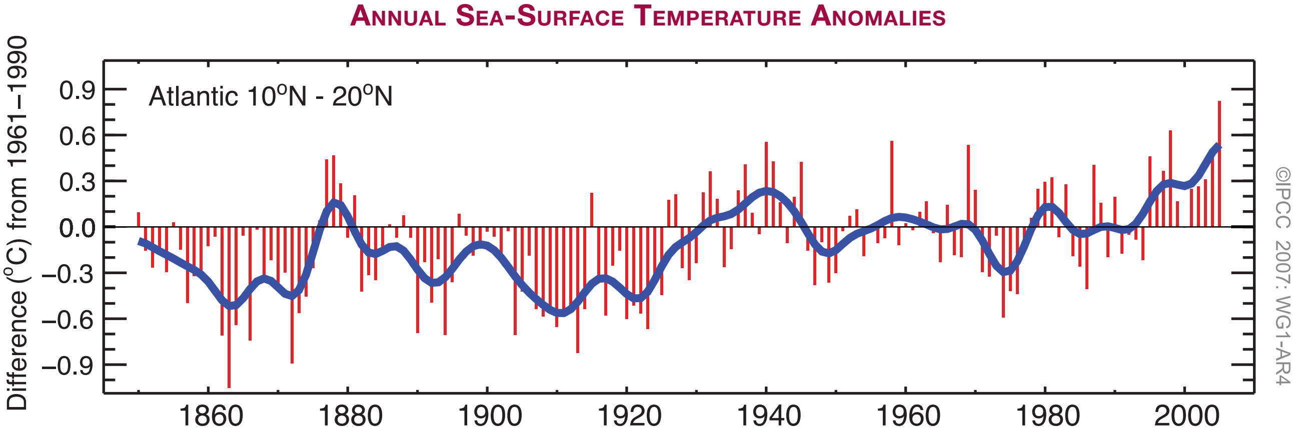


Figure TS.11. *Tropical Atlantic (10°N–20°N) sea surface temperature annual anomalies (°C) in the region of Atlantic hurricane formation, relative to the 1961 to 1990 mean. {Figure 3.33}* tropical cyclone development (see Figure TS.11). Variations in the total numbers of tropical cyclones result from ENSO and decadal variability, which also lead to a redistribution of tropical storm numbers and tracks. The numbers of hurricanes in the North Atlantic have been above normal (based on 1981–2000) in nine of the years from 1995 to 2005. {3.8}

More intense and longer droughts have been observed over wider areas, particularly in the tropics and subtropics since the 1970s. While there are many different measures of drought, many studies use precipitation changes together with temperature.[6] Increased drying due to higher temperatures and decreased land precipitation have contributed to these changes. {3.3}

TS.3.2 Changes in the Cryosphere: Instrumental Record

Currently, ice permanently covers 10% of the land surface, with only a tiny fraction occurring outside Antarctica and Greenland. Ice also covers approximately 7% of the oceans in the annual mean. In midwinter, snow covers approximately 49% of the land surface in the NH. An important property of snow and ice is its high surface albedo. Because up to 90% of the incident solar radiation is reflected by snow and ice surfaces, while only about 10% is reflected by the open ocean or forested lands, changes in snow and ice cover are important feedback mechanisms in climate change. In addition, snow and ice are effective insulators. Seasonally frozen ground is more extensive than snow cover, and its presence is important for energy and moisture fluxes. Therefore, frozen surfaces play important roles in energy and climate processes. {4.1}

The cryosphere stores about 75% of the world's freshwater. At a regional scale, variations in mountain snowpack, glaciers and small ice caps play a crucial role in freshwater availability. Since the change from ice to liquid water occurs at specific temperatures, ice is a component of the climate system that could be subject to abrupt change following sufficient warming. Observations and analyses of changes in ice have expanded and improved since the TAR, including shrinkage of mountain glacier volume, decreases in snow cover, changes in permafrost and frozen ground, reductions in arctic sea ice extent, coastal thinning of the Greenland Ice Sheet exceeding inland thickening from increased snowfall, and reductions in seasonally frozen ground and river and lake ice cover. These allow an improved understanding of how the cryosphere is changing, including its contributions to recent changes in sea level. The periods from 1961 to the present and from 1993 to the present are a focus of this report, due to the availability of directly measured glacier mass balance data and altimetry observations of the ice sheets, respectively. {4.1}

Snow cover has decreased in most regions, especially in spring. Northern Hemisphere snow cover observed by satellite over the 1966 to 2005 period decreased in every month except November and December, with a stepwise drop of 5% in the annual mean in the late 1980s (see Figure TS.12). In the SH, the few long records or proxies mostly show either decreases or no changes in the past 40 years or more. Northern Hemisphere April snow cover extent is strongly correlated with 40°N to 60°N April temperature, reflecting the feedback between snow and temperature. {4.2}

Decreases in snowpack have been documented in several regions worldwide based upon annual time series of mountain snow water equivalent and snow depth. Mountain snow can be sensitive to small changes in temperature, particularly in temperate climatic zones where the transition from rain to snow is generally closely associated with the altitude of the freezing level. Declines in mountain snowpack in western North America and in the Swiss Alps are largest at lower, warmer elevations. Mountain snow water equivalent has declined since 1950 at 75% of the stations monitored in western North America. Mountain snow depth has also declined in the Alps and in southeastern Australia. Direct observations of snow depth are too limited to determine changes in the Andes, but temperature measurements suggest that the altitude where snow occurs (above the snow line) has probably risen in mountainous regions of South America. {4.2}

Permafrost and seasonally frozen ground in most regions display large changes in recent decades. Changes in permafrost conditions can affect river runoff, water supply, carbon exchange and landscape stability, and can cause damage to infrastructure. Temperature increases at the top of the permafrost layer of up to 3°C since the 1980s have been reported. Permafrost warming has also been observed with variable magnitude in the Canadian Arctic, Siberia, the Tibetan Plateau and Europe. The permafrost base is thawing at a rate ranging from 0.04 m yr^{-1} in Alaska to 0.02 m yr^{-1} on the Tibetan Plateau. {4.7}

The maximum area covered by seasonally frozen ground decreased by about 7% in the NH over the

[6] Precipitation and temperature are combined in the Palmer Drought Severity Index (PDSI), considered in this report as one measure of drought. The PDSI does not include variables such as wind speed, solar radiation, cloudiness and water vapour but is a superior measure to precipitation alone.

Box TS.3: Ice Sheet Dynamics and Stability

Ice sheets are thick, broad masses of ice formed mainly from compaction of snow. They spread under their own weight, transferring mass towards their margins where it is lost primarily by runoff of surface melt water or by calving of icebergs into marginal seas or lakes. Ice sheets flow by deformation within the ice or melt water-lubricated sliding over materials beneath. Rapid basal motion requires that the basal temperature be raised to the melting point by heat from the Earth's interior, delivered by melt water transport, or from the 'friction' of ice motion. Sliding velocities under a given gravitational stress can differ by several orders of magnitude, depending on the presence or absence of deformable sediment, the roughness of the substrate and the supply and distribution of water. Basal conditions are generally poorly characterised, introducing important uncertainties to the understanding of ice sheet stability. {4.6}

Ice flow is often channelled into fast-moving ice streams (that flow between slower-moving ice walls) or outlet glaciers (with rock walls). Enhanced flow in ice streams arises either from higher gravitational stress linked to thicker ice in bedrock troughs, or from increased basal lubrication. {4.6}

Ice discharged across the coast often remains attached to the ice sheet to become a floating ice shelf. An ice shelf moves forward, spreading and thinning under its own weight, and fed by snowfall on its surface and ice input from the ice sheet. Friction at ice shelf sides and over local shoals slows the flow of the ice shelf and thus the discharge from the ice sheet. An ice shelf loses mass by calving icebergs from the front and by basal melting into the ocean cavity beneath. Studies suggest an ocean warming of 1°C could increase ice shelf basal melt by 10 m yr^{-1}, but inadequate knowledge of the largely inaccessible ice shelf cavities restricts the accuracy of such estimates. {4.6}

The palaeo-record of previous ice ages indicates that ice sheets shrink in response to warming and grow in response to cooling, and that shrinkage can be far faster than growth. The volumes of the Greenland and Antarctic Ice Sheets are equivalent to approximately 7 m and 57 m of sea level rise, respectively. Palaeoclimatic data indicate that substantial melting of one or both ice sheets has likely occurred in the past. However, ice core data show that neither ice sheet was completely removed during warm periods of at least the past million years. Ice sheets can respond to environmental forcing over very long time scales, implying that commitments to future changes may result from current warming. For example, a surface warming may take more than 10,000 years to penetrate to the bed and change temperatures there. Ice velocity over most of an ice sheet changes slowly in response to changes in the ice sheet shape or surface temperature, but large velocity changes may occur rapidly in ice streams and outlet glaciers in response to changing basal conditions, penetration of surface melt water to the bed or changes in the ice shelves into which they flow. {4.6, 6.4}

Models currently configured for long integrations remain most reliable in their treatment of surface accumulation and ablation, as for the TAR, but do not include full treatments of ice dynamics; thus, analyses of past changes or future projections using such models may underestimate ice flow contributions to sea level rise, but the magnitude of such an effect is unknown. {8.2}

latter half of the 20th century, with a decrease in spring of up to 15%. Its maximum depth has decreased by about 0.3 m in Eurasia since the mid-20th century. In addition, maximum seasonal thaw depth increased by about 0.2 m in the Russian Arctic from 1956 to 1990. {4.7}

On average, the general trend in NH river and lake ice over the past 150 years indicates that the freeze-up date has become later at an average rate of 5.8 ± 1.9 days per century, while the breakup date has occurred earlier, at a rate of 6.5 ± 1.4 days per century. However, considerable spatial variability has also been observed, with some regions showing trends of opposite sign. {4.3}

Annual average arctic sea ice extent has shrunk by about 2.7 ± 0.6% per decade since 1978 based upon satellite observations (see Figure TS.13). The decline in summer extent is larger than in winter extent, with the summer minimum declining at a rate of about 7.4 ± 2.4% per decade. Other data indicate that the summer decline began around 1970. Similar observations in the Antarctic reveal larger interannual variability but no consistent trends during the period of satellite observations. In contrast to changes in continental ice such as ice sheets and glaciers, changes in sea ice do not directly contribute to sea level change (because this ice is already floating), but can contribute to salinity changes through input of freshwater. {4.4}

During the 20th century, glaciers and ice caps have experienced widespread mass losses and have contributed to sea level rise. Mass loss of glaciers and ice caps (excluding those around the ice sheets of Greenland and Antarctica) is estimated to be 0.50 ± 0.18 mm yr^{-1} in sea level equivalent (SLE) between 1961 and 2003, and 0.77 ± 0.22 mm yr^{-1} SLE between 1991 and 2003. The late 20th-century glacier wastage *likely* has been a response to post-1970 warming. {4.5}

Recent observations show evidence for rapid changes in ice flow in some regions, contributing to sea level rise and suggesting that the dynamics of ice

motion may be a key factor in future responses of ice shelves, coastal glaciers and ice sheets to climate change. Thinning or loss of ice shelves in some near-coastal regions of Greenland, the Antarctic Peninsula and West Antarctica has been associated with accelerated flow of nearby glaciers and ice streams, suggesting that ice shelves (including short ice shelves of kilometres or tens of kilometres in length) could play a larger role in stabilising or restraining ice motion than previously thought. Both oceanic and atmospheric temperatures appear to contribute to the observed changes. Large summer warming in the Antarctic Peninsula region *very likely* played a role in the subsequent rapid breakup of the Larsen B Ice Shelf in 2002 by increasing summer melt water, which drained into crevasses and wedged them open. Models do not accurately capture all of the physical processes that appear to be involved in observed iceberg calving (as in the breakup of Larsen B). {4.6}

Changes in Snow Cover

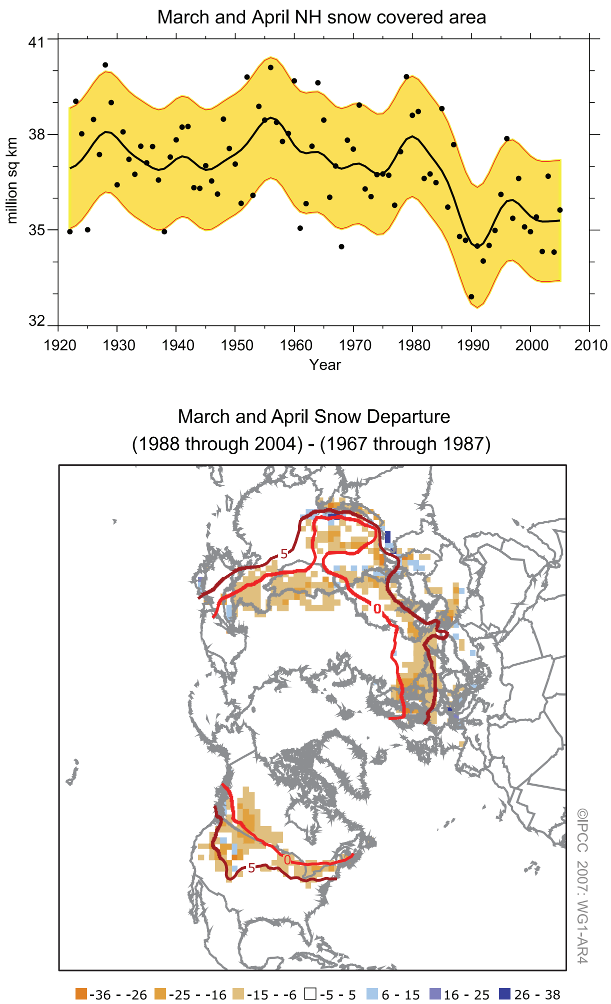


Figure TS.12. *(Top) Northern Hemisphere March-April snow-covered area from a station-derived snow cover index (prior to 1972) and from satellite data (during and after 1972). The smooth curve shows decadal variations (see Appendix 3.A) with the 5 to 95% data range shaded in yellow. (Bottom) Differences in the distribution of March-April snow cover between earlier (1967–1987) and later (1988–2004) portions of the satellite era (expressed in percent coverage). Tan colours show areas where snow cover has declined. Red curves show the 0°C and 5°C isotherms averaged for March-April 1967 to 2004, from the Climatic Research Unit (CRU) gridded land surface temperature version 2 (CRUTEM2v) data. The greatest decline generally tracks the 0°C and 5°C isotherms, reflecting the strong feedback between snow and temperature. {Figures 4.2, 4.3}*

Changes in Sea Ice Extent

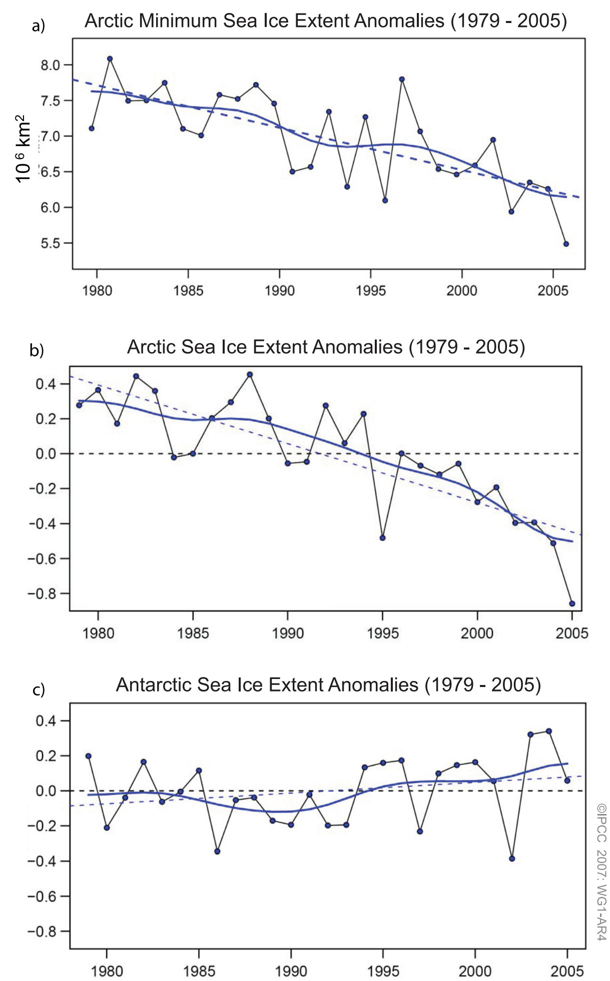


Figure TS.13. *(a) Arctic minimum sea ice extent; (b) arctic sea ice extent anomalies; and (c) antarctic sea ice extent anomalies all for the period 1979 to 2005. Symbols indicate annual values while the smooth blue curves show decadal variations (see Appendix 3.A). The dashed lines indicate the linear trends. (a) Results show a linear trend of –60 ± 20 x 10^3 km^2 yr^{-1}, or approximately -7.4% per decade. (b) The linear trend is –33 ± 7.4 x 10^3 km^2 yr^{-1} (equivalent to approximately –2.7% per decade) and is significant at the 95% confidence level. (c) Antarctic results show a small positive trend of 5.6 ± 9.2 x 10^3 km^2 yr^{-1}, which is not statistically significant. {Figures 4.8 and 4.9}*

The Greenland and Antarctic Ice Sheets taken together have *very likely* contributed to the sea level rise of the past decade. It is *very likely* that the Greenland Ice Sheet shrunk from 1993 to 2003, with thickening in central regions more than offset by increased melting in coastal regions. Whether the ice sheets have been growing or shrinking over time scales of longer than a decade is not well established from observations. Lack of agreement between techniques and the small number of estimates preclude assignment of best estimates or statistically rigorous error bounds for changes in ice sheet mass balances. However, acceleration of outlet glaciers drains ice from the interior and has been observed in both ice sheets (see Figure TS.14). Assessment of the data and techniques suggests a mass balance for the Greenland Ice Sheet of –50 to –100 Gt yr^{-1} (shrinkage contributing to raising global sea level by 0.14 to 0.28 mm yr^{-1}) during 1993 to 2003, with even larger losses in 2005. There are greater uncertainties for earlier time periods and for Antarctica. The estimated range in mass balance for the Greenland Ice Sheet over the period 1961 to 2003 is between growth of 25 Gt yr^{-1} and shrinkage by 60 Gt yr^{-1} (–0.07 to +0.17 mm yr^{-1} SLE). Assessment of all the data yields an estimate for the overall Antarctic Ice Sheet mass balance ranging from growth of 100 Gt yr^{-1} to shrinkage of 200 Gt yr^{-1} (–0.27 to +0.56 mm yr^{-1} SLE) from 1961 to 2003, and from +50 to –200 Gt yr^{-1} (–0.14 to +0.55 mm yr^{-1} SLE) from 1993 to 2003. The recent changes in ice flow are *likely* to be sufficient to explain much or all of the estimated antarctic mass imbalance, with recent changes in ice flow, snowfall and melt water runoff sufficient to explain the mass imbalance of Greenland. {4.6, 4.8}

Rates of Observed Surface Elevation Change

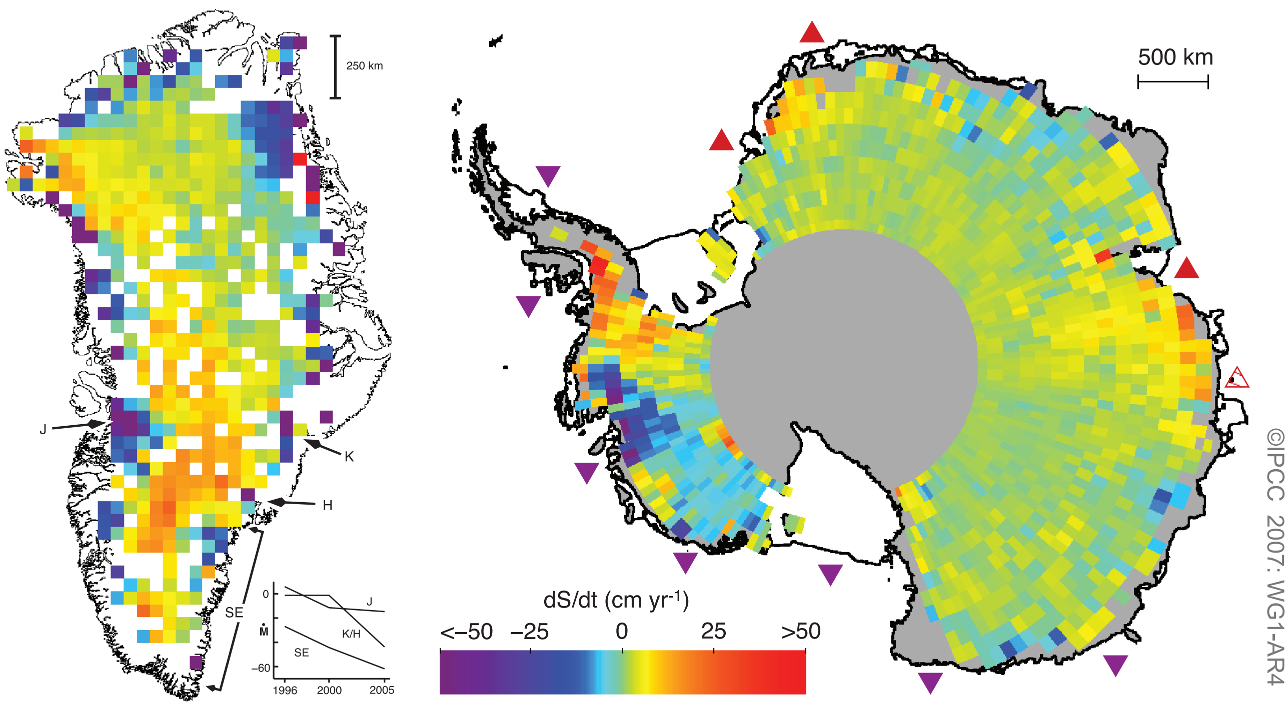


Figure TS.14. *Rates of observed recent surface elevation change for Greenland (left; 1989–2005) and Antarctica (right; 1992–2005). Red hues indicate a rising surface and blue hues a falling surface, which typically indicate an increase or loss in ice mass at a site, although changes over time in bedrock elevation and in near-surface density can be important. For Greenland, the rapidly thinning outlet glaciers Jakobshavn (J), Kangerdlugssuaq (K), Helheim (H) and areas along the southeast coast (SE) are shown, together with their estimated mass balance vs. time (with K and H combined, in Gt yr^{-1}, with negative values indicating loss of mass from the ice sheet to the ocean). For Antarctica, ice shelves estimated to be thickening or thinning by more than 30 cm yr^{-1} are shown by point-down purple triangles (thinning) and point-up red triangles (thickening) plotted just seaward of the relevant ice shelves. {Figures 4.17 and 4.19}*

TS.3.3 Changes in the Ocean: Instrumental Record

The ocean plays an important role in climate and climate change. The ocean is influenced by mass, energy and momentum exchanges with the atmosphere. Its heat capacity is about 1000 times larger than that of the atmosphere and the ocean's net heat uptake is therefore many times greater than that of the atmosphere (see Figure TS.15). Global observations of the heat taken up by the ocean can now be shown to be a definitive test of changes in the global energy budget. Changes in the amount of energy taken up by the upper layers of the ocean also play a crucial role for climate variations on seasonal to interannual time scales, such as El Niño. Changes in the transport of heat and SSTs have important effects upon many regional climates worldwide. Life in the sea is dependent on the biogeochemical status of the ocean and is affected by changes in its physical state and circulation. Changes in ocean biogeochemistry can also feed back into the climate system, for example, through changes in uptake or release of radiatively active gases such as CO_2. {5.1, 7.3}

Energy Content in the Climate System

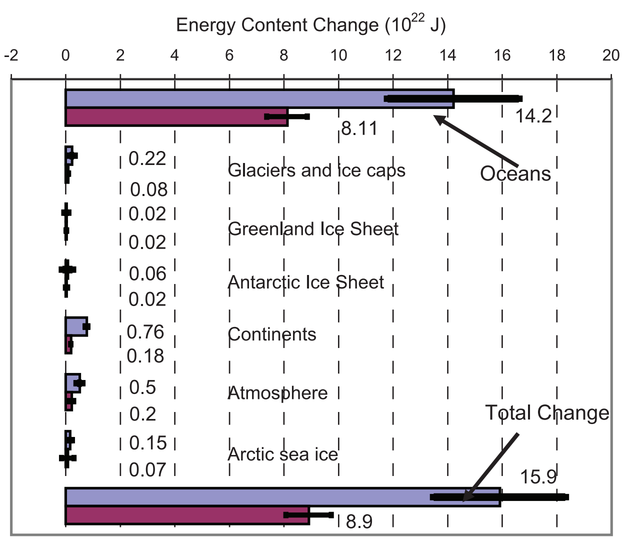


Figure TS.15. *Energy content changes in different components of the Earth system for two periods (1961–2003 and 1993–2003). Blue bars are for 1961 to 2003; burgundy bars are for 1993 to 2003. Positive energy content change means an increase in stored energy (i.e., heat content in oceans, latent heat from reduced ice or sea ice volumes, heat content in the continents excluding latent heat from permafrost changes, and latent and sensible heat and potential and kinetic energy in the atmosphere). All error estimates are 90% confidence intervals. No estimate of confidence is available for the continental heat gain. Some of the results have been scaled from published results for the two respective periods. {Figure 5.4}*

Global mean sea level variations are driven in part by changes in density, through thermal expansion or contraction of the ocean's volume. Local changes in sea level also have a density-related component due to temperature and salinity changes. In addition, exchange of water between oceans and other reservoirs (e.g., ice sheets, mountain glaciers, land water reservoirs and the atmosphere) can change the ocean's mass and hence contribute to changes in sea level. Sea level change is not geographically uniform because processes such as ocean circulation changes are not uniform across the globe (see Box TS.4). {5.5}

Oceanic variables can be useful for climate change detection, in particular temperature and salinity changes below the surface mixed layer where the variability is smaller and signal-to-noise ratio is higher. Observations analysed since the TAR have provided new evidence for changes in global ocean heat content and salinity, sea level, thermal expansion contributions to sea level rise, water mass evolution and biogeochemical cycles. {5.5}

TS.3.3.1 Changes in Ocean Heat Content and Circulation

The world ocean has warmed since 1955, accounting over this period for more than 80% of the changes in the energy content of the Earth's climate system. A total of 7.9 million vertical profiles of ocean temperature allows construction of improved global time series (see Figure TS.16). Analyses of the global oceanic heat budget have been replicated by several independent analysts and are robust to the method used. Data coverage limitations require averaging over decades for the deep ocean and observed decadal variability in the global heat content is not fully understood. However, inadequacies in the distribution of data (particularly coverage in the Southern Ocean and South Pacific) could contribute to the apparent decadal variations in heat content. During the period 1961 to 2003, the 0 to 3000 m ocean layer has taken up about 14.1×10^{22} J, equivalent to an average heating rate of 0.2 W m^{-2} (per unit area of the Earth's surface). During 1993 to 2003, the corresponding rate of warming in the shallower 0 to 700 m ocean layer was higher, about 0.5 ± 0.18 W m^{-2}. Relative to 1961 to 2003, the period 1993 to 2003 had high rates of warming but in 2004 and 2005 there has been some cooling compared to 2003. {5.1–5.3}

Warming is widespread over the upper 700 m of the global ocean. The Atlantic has warmed south of 45°N. The warming is penetrating deeper in the Atlantic Ocean Basin than in the Pacific, Indian and Southern Oceans, due to the

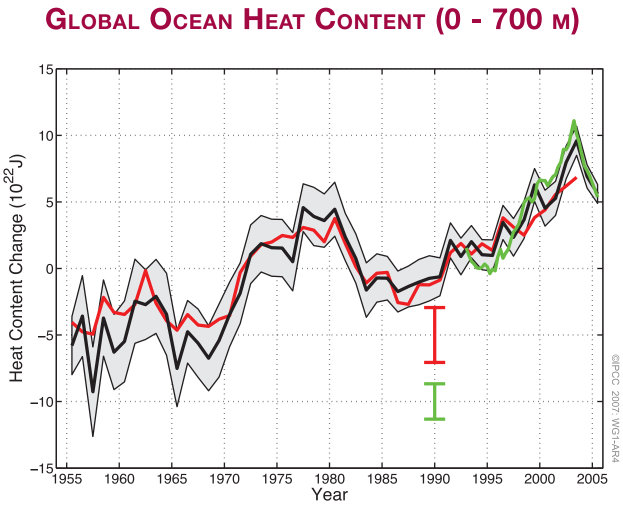


Figure TS.16. *Time series of global ocean heat content (10^{22} J) for the 0 to 700 m layer. The three coloured lines are independent analyses of the oceanographic data. The black and red curves denote the deviation from their 1961 to 1990 average and the shorter green curve denotes the deviation from the average of the black curve for the period 1993 to 2003. The 90% uncertainty range for the black curve is indicated by the grey shading and for the other two curves by the error bars. {Figure 5.1}*

deep overturning circulation cell that occurs in the North Atlantic. The SH deep overturning circulation shows little evidence of change based on available data. However, the upper layers of the Southern Ocean contribute strongly to the overall warming. At least two seas at subtropical latitudes (Mediterranean and Japan/East China Sea) are warming. While the global trend is one of warming, significant decadal variations have been observed in the global time series, and there are large regions where the oceans are cooling. Parts of the North Atlantic, North Pacific and equatorial Pacific have cooled over the last 50 years. The changes in the Pacific Ocean show ENSO-like spatial patterns linked in part to the PDO. {5.2, 5.3}

Parts of the Atlantic meridional overturning circulation exhibit considerable decadal variability, but data do not support a coherent trend in the overturning circulation. {5.3}

TS.3.3.2 Changes in Ocean Biogeochemistry and Salinity

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic, with an average decrease in surface pH of 0.1 units.[7] Uptake of CO_2 by the ocean changes its chemical equilibrium. Dissolved CO_2 forms a weak acid, so as dissolved CO_2 increases, pH decreases (i.e., the ocean becomes more acidic). The overall pH change is computed from estimates of anthropogenic carbon uptake and simple ocean models. Direct observations of pH at available stations for the last 20 years also show trends of decreasing pH, at a rate of about 0.02 pH units per decade. Decreasing ocean pH decreases the depth below which calcium carbonate dissolves and increases the volume of the ocean that is undersaturated with respect to the minerals aragonite (a meta-stable form of calcium carbonate) and calcite, which are used by marine organisms to build their shells. Decreasing surface ocean pH and rising surface temperatures also act to reduce the ocean buffer capacity for CO_2 and the rate at which the ocean can take up excess atmospheric CO_2. {5.4, 7.3}

The oxygen concentration of the ventilated thermocline (about 100 to 1000 m) decreased in most ocean basins between 1970 and 1995. These changes may reflect a reduced rate of ventilation linked to upper-level warming and/or changes in biological activity. {5.4}

There is now widespread evidence for changes in ocean salinity at gyre and basin scales in the past half century (see Figure TS.17) with the near-surface waters in the more evaporative regions increasing in salinity in almost all ocean basins. These changes in salinity imply changes in the hydrological cycle over the oceans. In the high-latitude regions in both hemispheres, the surface waters show an overall freshening consistent with these regions having greater precipitation, although higher runoff, ice melting, advection and changes in the meridional overturning circulation may also contribute. The subtropical latitudes in both hemispheres are characterised by an increase in salinity in the upper 500 m. The patterns are consistent with a change in the Earth's hydrological cycle, in particular with changes in precipitation and inferred larger water transport in the atmosphere from low latitudes to high latitudes and from the Atlantic to the Pacific. {5.2}

TS.3.3.3 Changes in Sea Level

Over the 1961 to 2003 period, the average rate of global mean sea level rise is estimated from tide gauge data to be 1.8 ± 0.5 mm yr^{-1} (see Figure TS.18). For the purpose of examining the sea level budget, best estimates and 5 to 95% confidence intervals are provided for all land ice contributions. The average

[7] Acidity is a measure of the concentration of H^+ ions and is reported in pH units, where pH = –log(H^+). A pH decrease of 1 unit means a 10-fold increase in the concentration of H^+, or acidity.

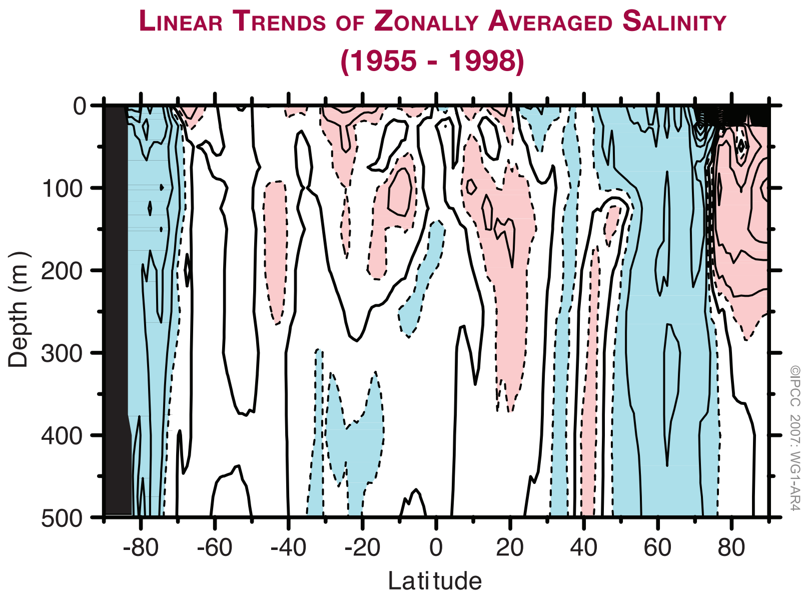


Figure TS.17. *Linear trends (1955–1998) of zonally averaged salinity (Practical Salinity Scale) for the World Ocean. The contour interval is 0.01 per decade and dashed contours are ±0.005 per decade. The dark, solid line is the zero contour. Red shading indicates values equal to or greater than 0.005 per decade and blue shading indicates values equal to or less than –0.005 per decade. {Figure 5.5}*

thermal expansion contribution to sea level rise for this period was 0.42 ± 0.12 mm yr^{-1}, with significant decadal variations, while the contribution from glaciers, ice caps and ice sheets is estimated to have been 0.7 ± 0.5 mm yr^{-1} (see Table TS.3). The sum of these estimated climate-related contributions for about the past four decades thus amounts to 1.1 ± 0.5 mm yr^{-1}, which is less than the best estimate from the tide gauge observations (similar to the discrepancy noted in the TAR). Therefore, the sea level budget for 1961 to 2003 has not been closed satisfactorily. {4.8, 5.5}

The global average rate of sea level rise measured by TOPEX/Poseidon satellite altimetry during 1993 to 2003 is 3.1 ± 0.7 mm yr^{-1}. This observed rate for the recent period is close to the estimated total of 2.8 ± 0.7 mm yr^{-1} for the climate-related contributions due to thermal expansion (1.6 ± 0.5 mm yr^{-1}) and changes in land ice (1.2 ± 0.4 mm yr^{-1}). Hence, the understanding of the budget has improved significantly for this recent period, with the climate contributions constituting the main factors in the sea level budget (which is closed to within known errors). Whether the faster rate for 1993 to 2003 compared to 1961 to 2003 reflects decadal variability or an increase in the longer-term trend is unclear. The tide gauge record indicates that faster rates similar to that observed in 1993 to 2003 have occurred in other decades since 1950. {5.5, 9.5}

There is *high confidence* that the rate of sea level rise accelerated between the mid-19th and the mid-20th centuries based upon tide gauge and geological data. A recent reconstruction of sea level change back to 1870 using the best available tide records provides high confidence that the rate of sea level rise accelerated over the period 1870 to 2000. Geological observations indicate that during the previous 2000 years, sea level change was small, with average rates in the range 0.0 to 0.2 mm yr^{-1}. The use of proxy sea level data from archaeological sources is well established in the Mediterranean and indicates that oscillations in sea level from about AD 1 to AD 1900 did not exceed ±0.25 m. The available evidence indicates that the onset of modern sea level rise started between the mid-19th and mid-20th centuries. {5.5}

Precise satellite measurements since 1993 now provide unambiguous evidence of regional variability of sea level change. In some regions, rates of rise during this period are up to several times the global mean,

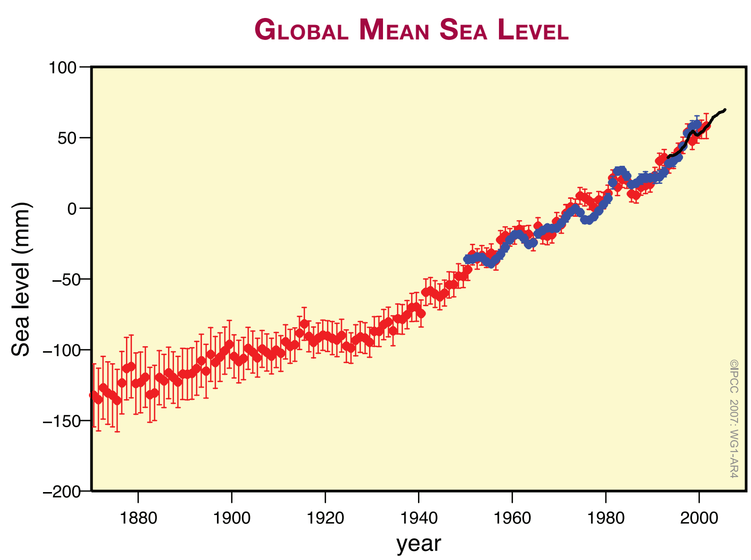


Figure TS.18. *Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals. {Figure 5.13}*

Table TS.3. *Contributions to sea level rise based upon observations (left columns) compared to models used in this assessment (right columns; see Section 9.5 and Appendix 10.A for details). Values are presented for 1993 to 2003 and for the last four decades, including observed totals. {Adapted from Tables 5.3 and 9.2}*

	Sea Level Rise (mm yr^{-1})			
	1961–2003		1993–2003	
Sources of Sea Level Rise	**Observed**	**Modelled**	**Observed**	**Modelled**
Thermal expansion	0.42 ± 0.12	0.5 ± 0.2	1.6 ± 0.5	1.5 ± 0.7
Glaciers and ice caps	0.50 ± 0.18	0.5 ± 0.2	0.77 ± 0.22	0.7 ± 0.3
Greenland Ice Sheet	0.05 ± 0.12[a]		0.21 ± 0.07[a]	
Antarctic Ice Sheet	0.14 ± 0.41[a]		0.21 ± 0.35[a]	
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	1.2 ± 0.5	2.8 ± 0.7	2.6 ± 0.8
Observed total sea level rise	1.8 ± 0.5 (tide gauges)		3.1 ± 0.7 (satellite altimeter)	
Difference (Observed total minus the sum of observed climate contributions)	0.7 ± 0.7		0.3 ± 1.0	

Notes:
[a] prescribed based upon observations (see Section 9.5)

while in other regions sea level is falling. The largest sea level rise since 1992 has taken place in the western Pacific and eastern Indian Oceans (see Figure TS.19). Nearly all of the Atlantic Ocean shows sea level rise during the past decade, while sea level in the eastern Pacific and western Indian Oceans has been falling. These temporal and spatial variations in regional sea level rise are influenced in part by patterns of coupled ocean-atmosphere variability, including ENSO and the NAO. The pattern of observed sea level change since 1992 is similar to the thermal expansion computed from ocean temperature changes, but different from the thermal expansion pattern of the last 50 years, indicating the importance of regional decadal variability. {5.5}

Observations suggest increases in extreme high water at a broad range of sites worldwide since 1975. Longer records are limited in space and under-sampled in time, so a global analysis over the entire 20th century is not feasible. In many locations, the secular changes in extremes were similar to those in mean sea level. At others, changes in atmospheric conditions such as storminess were more important in determining long-term trends. Interannual variability in high water extremes was positively correlated with regional mean sea level, as well as to indices of regional climate such as ENSO in the Pacific and NAO in the Atlantic. {5.5}

Sea Level Change Patterns

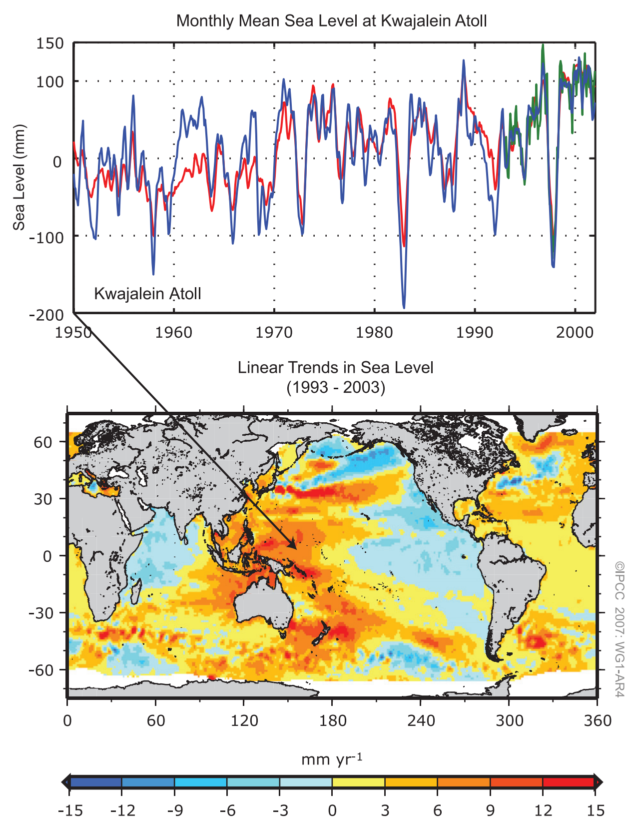


Figure TS.19. *(Top) Monthly mean sea level (mm) curve for 1950 to 2000 at Kwajalein (8°44'N, 167°44'E). The observed sea level (from tide gauge measurements) is in blue, the reconstructed sea level in red and the satellite altimetry record in green. Annual and semiannual signals have been removed from each time series and the tide gauge data have been smoothed. (Bottom) Geographic distribution of short-term linear trends in mean sea level for 1993 to 2003 (mm yr^{-1}) based on TOPEX/Poseidon satellite altimetry. {Figures 5.15 and 5.18}*

Box TS.4: Sea Level

The level of the sea at the shoreline is determined by many factors that operate over a great range of temporal scales: hours to days (tides and weather), years to millennia (climate), and longer. The land itself can rise and fall and such regional land movements need to be accounted for when using tide gauge measurements for evaluating the effect of oceanic climate change on coastal sea level. Coastal tide gauges indicate that global average sea level rose during the 20th century. Since the early 1990s, sea level has also been observed continuously by satellites with near-global coverage. Satellite and tide gauge data agree at a wide range of spatial scales and show that global average sea level has continued to rise during this period. Sea level changes show geographical variation because of several factors, including the distributions of changes in ocean temperature, salinity, winds and ocean circulation. Regional sea level is affected by climate variability on shorter time scales, for instance associated with El Niño and the NAO, leading to regional interannual variations which can be much greater or weaker than the global trend.

Based on ocean temperature observations, the thermal expansion of seawater as it warms has contributed substantially to sea level rise in recent decades. Climate models are consistent with the ocean observations and indicate that thermal expansion is expected to continue to contribute to sea level rise over the next 100 years. Since deep ocean temperatures change only slowly, thermal expansion would continue for many centuries even if atmospheric concentrations of greenhouse gases were stabilised.

Global average sea level also rises or falls when water is transferred from land to ocean or vice versa. Some human activities can contribute to sea level change, especially by the extraction of groundwater and construction of reservoirs. However, the major land store of freshwater is the water frozen in glaciers, ice caps and ice sheets. Sea level was more than 100 m lower during the glacial periods because of the ice sheets covering large parts of the NH continents. The present-day retreat of glaciers and ice caps is making a substantial contribution to sea level rise. This is expected to continue during the next 100 years. Their contribution should decrease in subsequent centuries as this store of freshwater diminishes.

The Greenland and Antarctic Ice Sheets contain much more ice and could make large contributions over many centuries. In recent years the Greenland Ice Sheet has experienced greater melting, which is projected to increase further. In a warmer climate, models suggest that the ice sheets could accumulate more snowfall, tending to lower sea level. However, in recent years any such tendency has probably been outweighed by accelerated ice flow and greater discharge observed in some marginal areas of the ice sheets. The processes of accelerated ice flow are not yet completely understood but could result in overall net sea level rise from ice sheets in the future.

The greatest climate- and weather-related impacts of sea level are due to extremes on time scales of days and hours, associated with tropical cyclones and mid-latitude storms. Low atmospheric pressure and high winds produce large local sea level excursions called 'storm surges', which are especially serious when they coincide with high tide. Changes in the frequency of occurrence of these extreme sea levels are affected both by changes in mean sea level and in the meteorological phenomena causing the extremes. {5.5}

TS.3.4 Consistency Among Observations

In this section, variability and trends within and across different climate variables including the atmosphere, cryosphere and oceans are examined for consistency based upon conceptual understanding of physical relationships between the variables. For example, increases in temperature will enhance the moisture-holding capacity of the atmosphere. Changes in temperature and/or precipitation should be consistent with those evident in glaciers. Consistency between independent observations using different techniques and variables provides a key test of understanding, and hence enhances confidence. {3.9}

Changes in the atmosphere, cryosphere and ocean show unequivocally that the world is warming. {3.2, 3.9, 4.2, 4.4–4.8, 5.2, 5.5}

Both land surface air temperatures and SSTs show warming. In both hemispheres, land regions have warmed at a faster rate than the oceans in the past few decades, consistent with the much greater thermal inertia of the oceans. {3.2}

The warming of the climate is consistent with observed increases in the number of daily warm extremes, reductions in the number of daily cold extremes and reductions in the number of frost days at mid-latitudes. {3.2, 3.8}

Surface air temperature trends since 1979 are now consistent with those at higher altitudes. It is *likely* that there is slightly greater warming in the troposphere than at the surface, and a higher tropopause, consistent with expectations from basic physical processes and observed increases in greenhouse gases together with depletion of stratospheric ozone. {3.4, 9.4}

Changes in temperature are broadly consistent with the observed nearly worldwide shrinkage of the cryosphere. There have been widespread reductions in mountain glacier mass and extent. Changes in climate consistent with warming are also indicated by decreases in snow cover, snow depth, arctic sea ice extent, permafrost thickness and temperature, the extent of seasonally frozen ground and the length of the freeze season of river and lake ice. {3.2, 3.9, 4.2–4.5, 4.7}

Observations of sea level rise since 1993 are consistent with observed changes in ocean heat content and the cryosphere. Sea level rose by 3.1 ± 0.7 mm yr^{-1} from 1993 to 2003, the period of availability of global altimetry measurements. During this time, a near balance was observed between observed total sea level rise and contributions from glacier, ice cap and ice sheet retreat together with increases in ocean heat content and associated ocean expansion. This balance gives increased

Table TS.4. *Recent trends, assessment of human influence on trends, and projections of extreme weather and climate events for which there is evidence of an observed late 20th-century trend. An asterisk in the column headed 'D' indicates that formal detection and attribution studies were used, along with expert judgement, to assess the likelihood of a discernible human influence. Where this is not available, assessments of likelihood of human influence are based on attribution results for changes in the mean of a variable or changes in physically related variables and/or on the qualitative similarity of observed and simulated changes, combined with expert judgement. {3.8, 5.5, 9.7, 11.2–11.9; Tables 3.7, 3.8, 9.4}*

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post-1960)	Likelihood of a human contribution to observed trend	D	Likelihood of future trend based on projections for 21st century using SRES[b] scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[e]	*	*Virtually certain*[e]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[d]	*Likely* (nights)[e]	*	*Virtually certain*[e]
Warm spells / heat waves: Frequency increases over most land areas	*Likely*	*More likely than not*		*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*		*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*		*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[f]	*Likely*	*More likely than not*[g]		*Likely*[h]

Notes:
[a] See Table 3.7 for further details regarding definitions.
[b] SRES refers to the IPCC Special Report on Emission Scenarios. The SRES scenario families and illustrative cases are summarised in a box at the end of the Summary for Policymakers.
[c] Decreased frequency of cold days and nights (coldest 10%)
[d] Increased frequency of hot days and nights (hottest 10%)
[e] Warming of the most extreme days/nights each year
[f] Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[g] Changes in observed extreme high sea level closely follow the changes in average sea level {5.5.2.6}. It is *very likely* that anthropogenic activity contributed to a rise in average sea level. {9.5.2}
[h] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period {10.6}. The effect of changes in regional weather systems on sea level extremes has not been assessed.

confidence that the observed sea level rise is a strong indicator of warming. However, the sea level budget is not balanced for the longer period 1961 to 2003. {5.5, 3.9}

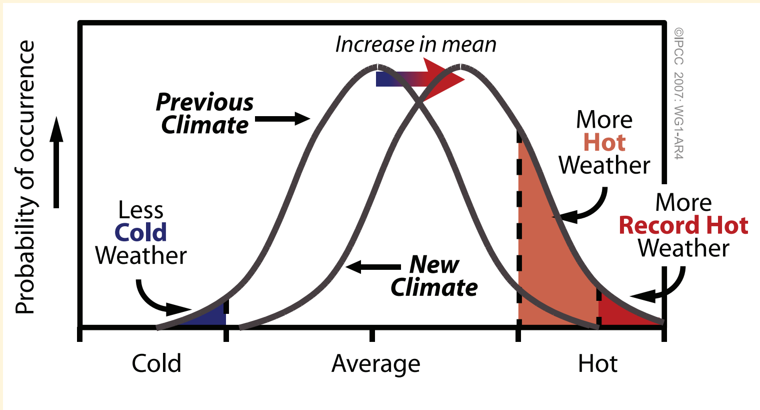
Observations are consistent with physical understanding regarding the expected linkage between water vapour and temperature, and with intensification of precipitation events in a warmer world. Column and upper-tropospheric water vapour have increased, providing important support for the hypothesis of simple physical models that specific humidity increases in a warming world and represents an important positive feedback to climate change. Consistent with rising amounts of water vapour in the atmosphere, there are widespread increases in the numbers of heavy precipitation events and increased likelihood of flooding events in many land regions, even those where there has been a reduction in total precipitation. Observations of changes in ocean salinity independently support the view

Box TS.5: Extreme Weather Events

People affected by an extreme weather event (e.g., the extremely hot summer in Europe in 2003, or the heavy rainfall in Mumbai, India in July 2005) often ask whether human influences on the climate are responsible for the event. A wide range of extreme weather events is expected in most regions even with an unchanging climate, so it is difficult to attribute any individual event to a change in the climate. In most regions, instrumental records of variability typically extend only over about 150 years, so there is limited information to characterise how extreme rare climatic events could be. Further, several factors usually need to combine to produce an extreme event, so linking a particular extreme event to a single, specific cause is problematic. In some cases, it may be possible to estimate the anthropogenic contribution to such changes in the probability of occurrence of extremes.

However, simple statistical reasoning indicates that substantial changes in the frequency of extreme events (and in the maximum feasible extreme, e.g., the maximum possible 24-hour rainfall at a specific location) can result from a relatively small shift of the distribution of a weather or climate variable.

Extremes are the infrequent events at the high and low end of the range of values of a particular variable. The probability of occurrence of values in this range is called a probability distribution function (PDF) that for some variables is shaped similarly to a 'Normal' or 'Gaussian' curve (the familiar 'bell' curve). Box TS.5, Figure 1 shows a schematic of a such a PDF and illustrates the effect a small shift (corresponding to a small change in the average or centre of the distribution) can have on the frequency of extremes at either end of the distribution. An increase in the frequency of one extreme (e.g., the number of hot days) will often be accompanied by a decline in the opposite extreme (in this case the number of cold days such as frosts). Changes in the variability or shape of the distribution can complicate this simple picture.



Box TS.5, Figure 1. *Schematic showing the effect on extreme temperatures when the mean temperature increases, for a normal temperature distribution.*

The IPCC Second Assessment Report noted that data and analyses of extremes related to climate change were sparse. By the time of the TAR, improved monitoring and data for changes in extremes was available, and climate models were being analysed to provide projections of extremes. Since the TAR, the observational basis of analyses of extremes has increased substantially, so that some extremes have now been examined over most land areas (e.g., daily temperature and rainfall extremes). More models have been used in the simulation and projection of extremes, and multiple integrations of models with different starting conditions (ensembles) now provide more robust information about PDFs and extremes. Since the TAR, some climate change detection and attribution studies focussed on changes in the global statistics of extremes have become available (Table TS.4). For some extremes (e.g., tropical cyclone intensity), there are still data concerns and/or inadequate models. Some assessments still rely on simple reasoning about how extremes might be expected to change with global warming (e.g., warming could be expected to lead to more heat waves). Others rely on qualitative similarity between observed and simulated changes. The assessed likelihood of anthropogenic contributions to trends is lower for variables where the assessment is based on indirect evidence.

that the Earth's hydrologic cycle has changed, in a manner consistent with observations showing greater precipitation and river runoff outside the tropics and subtropics, and increased transfer of freshwater from the ocean to the atmosphere at lower latitudes. {3.3, 3.4, 3.9, 5.2}

Although precipitation has increased in many areas of the globe, the area under drought has also increased. Drought duration and intensity has also increased. While regional droughts have occurred in the past, the widespread spatial extent of current droughts is broadly consistent with expected changes in the hydrologic cycle under warming. Water vapour increases with increasing global temperature, due to increased evaporation where surface moisture is available, and this tends to increase precipitation. However, increased continental temperatures are expected to lead to greater evaporation and drying, which is particularly important in dry regions where surface moisture is limited. Changes in snowpack, snow cover and in atmospheric circulation patterns and storm tracks can also reduce available seasonal moisture, and contribute to droughts. Changes in SSTs and associated changes in the atmospheric circulation and precipitation have contributed to changes in drought, particularly at low latitudes. The result is that drought has become more common, especially in the tropics and subtropics, since the 1970s. In Australia and Europe, direct links to global warming have been inferred through the extremes in high temperatures and heat waves accompanying recent droughts. {3.3, 3.8, 9.5}

TS.3.5 A Palaeoclimatic Perspective

Palaeoclimatic studies make use of measurements of past change derived from borehole temperatures, ocean sediment pore-water change and glacier extent changes, as well as proxy measurements involving the changes in chemical, physical and biological parameters that reflect past changes in the environment where the proxy grew or existed. Palaeoclimatic studies rely on multiple proxies so that results can be cross-verified and uncertainties better understood. It is now well accepted and verified that many biological organisms (e.g., trees, corals, plankton, animals) alter their growth and/or population dynamics in response to changing climate, and that these climate-induced changes are well recorded in past growth in living and dead (fossil) specimens or assemblages of organisms. Networks of tree ring width and tree ring density chronologies are used to infer past temperature changes based on calibration with temporally overlapping instrumental data. While these methods are heavily used, there are concerns regarding the distributions of available measurements, how well these sample the globe, and such issues as the degree to which the methods have spatial and seasonal biases or apparent divergence in the relationship with recent climate change. {6.2}

It is *very likely* that average NH temperatures during the second half of the 20th century were warmer than any other 50-year period in the last 500 years and *likely* the warmest in at least the past 1300 years. The data supporting these conclusions are most extensive over summer extratropical land areas (particularly for the longer time period; see Figure TS.20). These conclusions are based upon proxy data such as the width and density of a tree ring, the isotopic composition of various elements in ice or the chemical composition of a growth band in corals, requiring analysis to derive temperature information and associated uncertainties. Among the key uncertainties are that temperature and precipitation are difficult to separate in some cases, or are representative of particular seasons rather than full years. There are now improved and expanded data since the TAR, including, for example, measurements at a larger number of sites, improved analysis of borehole temperature data and more extensive analyses of glaciers, corals and sediments. However, palaeoclimatic data are more limited than the instrumental record since 1850 in both space and time, so that statistical methods are employed to construct global averages, and these are subject to uncertainties as well. Current data are too limited to allow a similar evaluation of the SH temperatures prior to the period of instrumental data. {6.6, 6.7}

Some post-TAR studies indicate greater multi-centennial NH variability than was shown in the TAR, due to the particular proxies used and the specific statistical methods of processing and/or scaling them to represent past temperatures. The additional variability implies cooler conditions, predominantly during the 12th to 14th, the 17th and the 19th centuries; these are *likely* linked to natural forcings due to volcanic eruptions and/or solar activity. For example, reconstructions suggest decreased solar activity and increased volcanic activity in the 17th century as compared to current conditions. One reconstruction suggests slightly warmer conditions in the 11th century than those indicated in the TAR, but within the uncertainties quoted in the TAR. {6.6}

The ice core CO_2 record over the past millennium provides an additional constraint on natural climate variability. The amplitudes of the pre-industrial, decadal-scale NH temperature changes from the proxy-based reconstructions (<1°C) are broadly consistent with the ice core CO_2 record and understanding of the strength

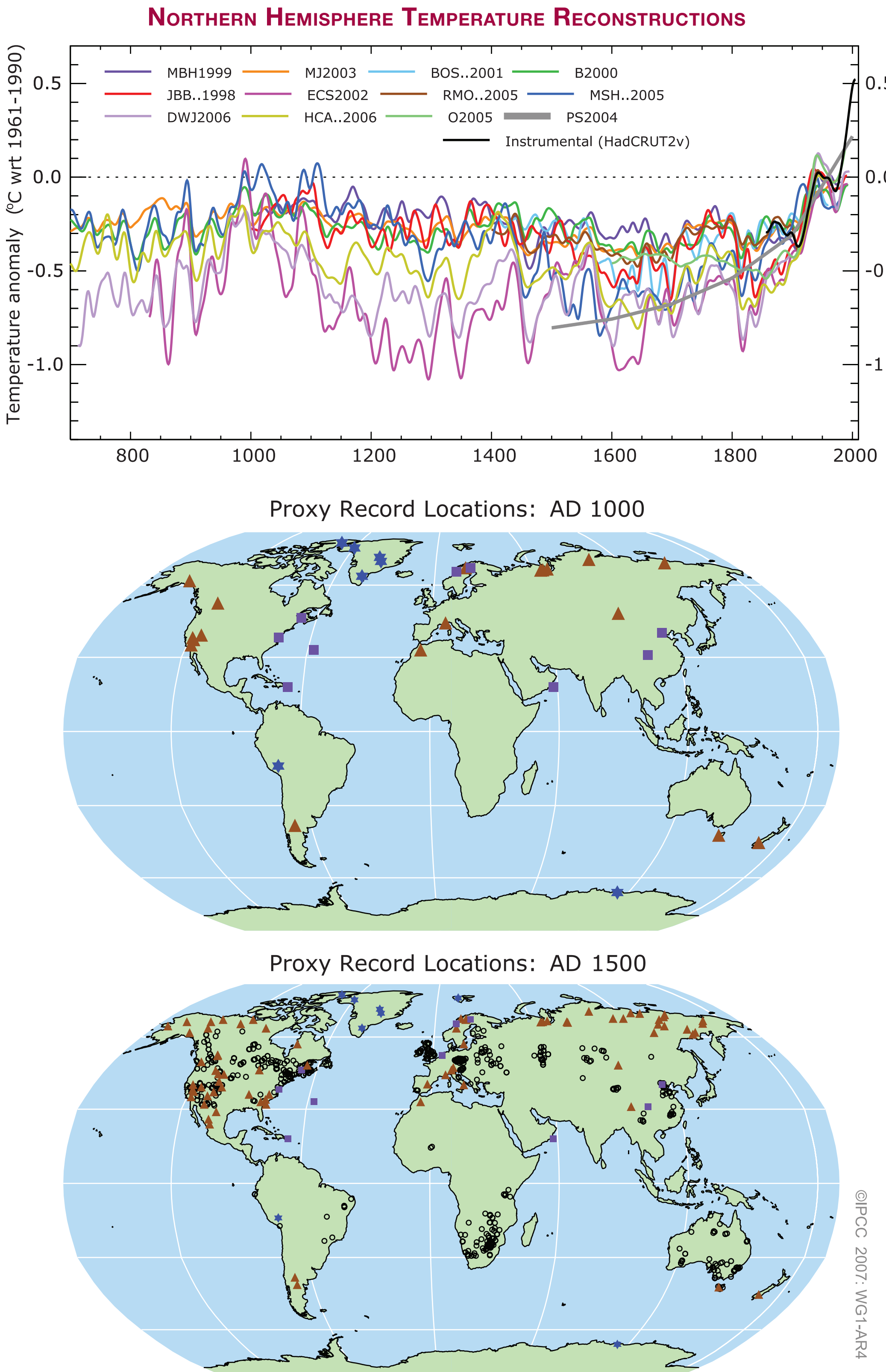


Figure TS.20. *(Top) Records of Northern Hemisphere temperature variation during the last 1300 years with 12 reconstructions using multiple climate proxy records shown in colour and instrumental records shown in black. (Middle and Bottom) Locations of temperature-sensitive proxy records with data back to AD 1000 and AD 1500 (tree rings: brown triangles; boreholes: black circles; ice core/ice boreholes: blue stars; other records including low-resolution records: purple squares). Data sources are given in Table 6.1, Figure 6.10 and are discussed in Chapter 6. {Figures 6.10 and 6.11}*

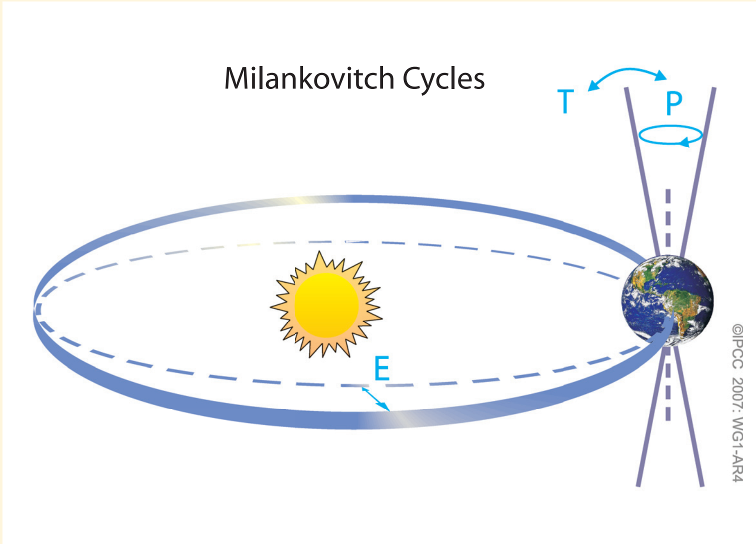
Box TS.6: Orbital Forcing

It is well known from astronomical calculations that periodic changes in characteristics of the Earth's orbit around the Sun control the seasonal and latitudinal distribution of incoming solar radiation at the top of the atmosphere (hereafter called 'insolation'). Past and future changes in insolation can be calculated over several millions of years with a high degree of confidence. {6.4}

Precession refers to changes in the time of the year when the Earth is closest to the Sun, with quasi-periodicities of about 19,000 and 23,000 years. As a result, changes in the position and duration of the seasons on the orbit strongly modulate the latitudinal and seasonal distribution of insolation. Seasonal changes in insolation are much larger than annual mean changes and can reach 60 W m^{-2} (Box TS.6, Figure 1).

The obliquity (tilt) of the Earth's axis varies between about 22° and 24.5° with two neighbouring quasi-periodicities of around 41,000 years. Changes in obliquity modulate seasonal contrasts as well as annual mean insolation changes with opposite effects at low vs. high latitudes (and therefore no effect on global average insolation) {6.4}.

The eccentricity of the Earth's orbit around the Sun has longer quasi-periodicities at 400,000 years and around 100,000 years. Changes in eccentricity alone have limited impacts on insolation, due to the resulting very small changes in the distance between the Sun and the Earth. However, changes in eccentricity interact with seasonal effects induced by obliquity and precession of the equinoxes. During periods of low eccentricity, such as about 400,000 years ago and during the next 100,000 years, seasonal insolation changes induced by precession are not as large as during periods of larger eccentricity (Box TS.6, Figure 1). {6.4}



Box TS.6, Figure 1. *Schematic of the Earth's orbital changes (Milankovitch cycles) that drive the ice age cycles. 'T' denotes changes in the tilt (or obliquity) of the Earth's axis, 'E' denotes changes in the eccentricity of the orbit and 'P' denotes precession, that is, changes in the direction of the axis tilt at a given point of the orbit. {FAQ 6.1, Figure 1}*

The Milankovitch, or 'orbital' theory of the ice ages is now well developed. Ice ages are generally triggered by minima in high-latitude NH summer insolation, enabling winter snowfall to persist through the year and therefore accumulate to build NH glacial ice sheets. Similarly, times with especially intense high-latitude NH summer insolation, determined by orbital changes, are thought to trigger rapid deglaciations, associated climate change and sea level rise. These orbital forcings determine the pacing of climatic changes, while the large responses appear to be determined by strong feedback processes that amplify the orbital forcing. Over multi-millennial time scales, orbital forcing also exerts a major influence on key climate systems such as the Earth's major monsoons, global ocean circulation and the greenhouse gas content of the atmosphere. {6.4}

Available evidence indicates that the current warming will not be mitigated by a natural cooling trend towards glacial conditions. Understanding of the Earth's response to orbital forcing indicates that the Earth would not naturally enter another ice age for at least 30,000 years. {6.4, FAQ 6.1} of the carbon cycle-climate feedback. Atmospheric CO_2 and temperature in Antarctica co-varied over the past 650,000 years. Available data suggest that CO_2 acts as an amplifying feedback. {6.4, 6.6}

Changes in glaciers are evident in Holocene data, but these changes were caused by different processes than the late 20th-century retreat. Glaciers of several mountain regions in the NH retreated in response to orbitally forced regional warmth between 11,000 and 5000 years ago, and were smaller than at the end of the 20th century (or even absent) at times prior to 5000 years ago. The current near-global retreat of mountain glaciers cannot be due to the same causes, because decreased summer insolation during the past few thousand years in the NH should be favourable to the growth of glaciers. {6.5}

Palaeoclimatic data provide evidence for changes in many regional climates. The strength and frequency of ENSO events have varied in past climates. There is evidence that the strength of the Asian monsoon, and hence precipitation amount, can change abruptly. The palaeoclimatic records of northern and eastern Africa and of North America indicate that droughts lasting decades to centuries are a recurrent feature of climate in these regions, so that recent droughts in North America and northern Africa are not unprecedented. Individual decadal-resolution palaeoclimatic data sets support the existence of regional quasi-periodic climate variability, but it is *unlikely* that these regional signals were coherent at the global scale. {6.5, 6.6}

Strong evidence from ocean sediment data and from modelling links abrupt climate changes during the last glacial period and glacial-interglacial transition to changes in the Atlantic Ocean circulation. Current understanding suggests that the ocean circulation can become unstable and change rapidly when critical thresholds are crossed. These events have affected temperature by up to 16°C in Greenland and have influenced tropical rainfall patterns. They were probably associated with a redistribution of heat between the NH and SH rather than with large changes in global mean temperature. Such events have not been observed during the past 8000 years. {6.4}

The Arctic and the Last Interglacial

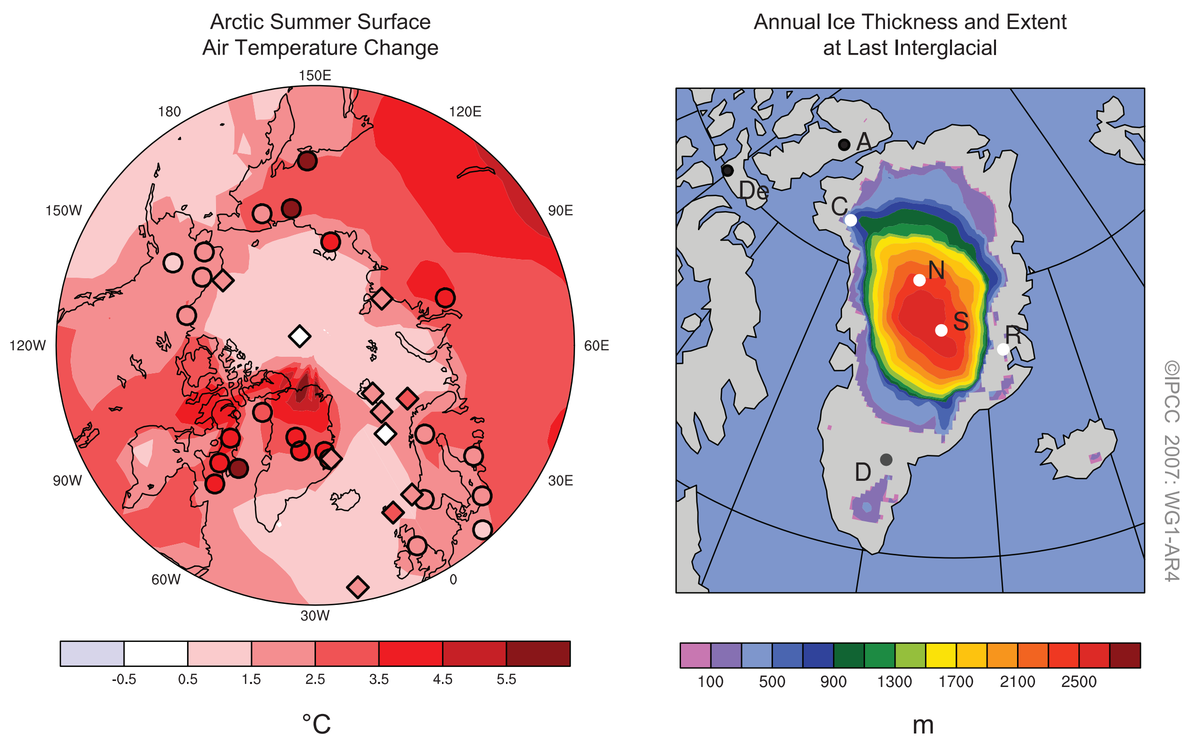


Figure TS.21. *Summer surface air temperature change relative to the present over the Arctic (left) and ice thickness and extent for Greenland and western arctic glaciers (right) for the last interglacial, approximately 125,000 years ago, from a multi-model and multi-proxy synthesis. (Left) A multi-model simulation of summer warming during the last interglacial is overlain by proxy estimates of maximum summer warming from terrestrial (circles) and marine (diamonds) sites. (Right) Extents and thicknesses of the Greenland Ice Sheet and western Canadian and Iceland glaciers at their minimum extent during the last interglacial, shown as a multi-model average from three ice models. Ice core observations indicate ice during the last interglacial at sites (white dots), Renland (R), North Greenland Ice Core Project (N), Summit (S, GRIP and GISP2) and possibly Camp Century (C), but no ice at sites (black dots): Devon (De) and Agassiz (A).Evidence for LIG ice at Dye-3 (D, grey dot) is equivocal. {Figure 6.6}*

Confidence in the understanding of past climate change and changes in orbital forcing is strengthened by the improved ability of current models to simulate past climate conditions. The Last Glacial Maximum (LGM; the last 'ice age' about 21,000 years ago) and the mid-Holocene (6000 years ago) were different from the current climate not because of random variability, but because of altered seasonal and global forcing linked to known differences in the Earth's orbit (see Box TS.6). Biogeochemical and biogeophysical feedbacks amplified the response to orbital forcings. Comparisons between simulated and reconstructed conditions in the LGM demonstrate that models capture the broad features of inferred changes in the temperature and precipitation patterns. For the mid-Holocene, coupled climate models are able to simulate mid-latitude warming and enhanced monsoons, with little change in global mean temperature (<0.4°C), consistent with our understanding of orbital forcing. {6.2, 6.4, 6.5, 9.3}

Global average sea level was likely between 4 and 6 m higher during the last interglacial period, about 125,000 years ago, than during the 20th century, mainly due to the retreat of polar ice (Figure TS.21). Ice core data suggest that the Greenland Summit region was ice-covered during this period, but reductions in the ice sheet extent are indicated in parts of southern Greenland. Ice core data also indicate that average polar temperatures at that time were 3°C to 5°C warmer than the 20th century because of differences in the Earth's orbit. The Greenland Ice Sheet and other arctic ice fields likely contributed no more than 4 m of the observed sea level rise, implying that there may also have been a contribution from Antarctica. {6.4}

TS.4 Understanding and Attributing Climate Change

Attribution evaluates whether observed changes are consistent with quantitative responses to different forcings obtained in well-tested models, and are not consistent with alternative physically plausible explanations. The first IPCC Assessment Report (FAR) contained little observational evidence of a detectable anthropogenic influence on climate. Six years later, the IPCC Second Assessment Report (SAR) concluded that the balance of evidence suggested a discernible human influence on the climate of the 20th century. The TAR concluded that 'most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations'. Confidence in the assessment of the human contributions to recent climate change has increased considerably since the TAR, in part because of stronger signals obtained from longer records, and an expanded and improved range of observations allowing attribution of warming to be more fully addressed jointly with other changes in the climate system. Some apparent inconsistencies in the observational record (e.g., in the vertical profile of temperature changes) have been largely resolved. There have been improvements in the simulation of many aspects of present mean climate and its variability on seasonal to inter-decadal time scales, although uncertainties remain (see Box TS.7). Models now employ more detailed representations of processes related to aerosol and other forcings. Simulations of 20th-century climate change have used many more models and much more complete anthropogenic and natural forcings than were available for the TAR. Available multi-model ensembles increase confidence in attribution results by providing an improved representation of model uncertainty. An anthropogenic signal has now more clearly emerged in formal attribution studies of aspects of the climate system beyond global-scale atmospheric temperature, including changes in global ocean heat content, continental-scale temperature trends, temperature extremes, circulation and arctic sea ice extent. {9.1}

TS.4.1 Advances in Attribution of Changes in Global-Scale Temperature in the Instrumental Period: Atmosphere, Ocean and Ice

Anthropogenic warming of the climate system is widespread and can be detected in temperature observations taken at the surface, in the free atmosphere and in the oceans. {3.2, 3.4, 9.4}

Evidence of the effect of external influences, both anthropogenic and natural, on the climate system has continued to accumulate since the TAR. Model and data improvements, ensemble simulations and improved representations of aerosol and greenhouse gas forcing along with other influences lead to greater confidence that most current models reproduce large-scale forced variability of the atmosphere on decadal and inter-decadal time scales quite well. These advances confirm that past climate variations at large spatial scales have been strongly influenced by external forcings. However, uncertainties still exist in the magnitude and temporal evolution of estimated contributions from individual forcings other than well-mixed greenhouse gases, due, for

Box TS.7: Evaluation of Atmosphere-Ocean General Circulation Models

Atmosphere-ocean general circulation models (AOGCMs) are the primary tool used for understanding and attribution of past climate variations, and for future projections. Since there are no historical perturbations to radiative forcing that are fully analogous to the human-induced perturbations expected over the 21st century, confidence in the models must be built from a number of indirect methods, described below. In each of these areas there have been substantial advances since the TAR, increasing overall confidence in models. {8.1}

Enhanced scrutiny and analysis of model behaviour has been facilitated by internationally coordinated efforts to collect and disseminate output from model experiments performed under common conditions. This has encouraged a more comprehensive and open evaluation of models, encompassing a diversity of perspectives. {8.1}

Projections for different scales and different periods using global climate models. Climate models project the climate for several decades or longer into the future. Since the details of individual weather systems are not being tracked and forecast, the initial atmospheric conditions are much less important than for weather forecast models. For climate projections, the forcings are of much greater importance. These forcings include the amount of solar energy reaching the Earth, the amount of particulate matter from volcanic eruptions in the atmosphere, and the concentrations of anthropogenic gases and particles in the atmosphere. As the area of interest moves from global to regional to local, or the time scale of interest shortens, the amplitude of variability linked to weather increases relative to the signal of long-term climate change. This makes detection of the climate change signal more difficult at smaller scales. Conditions in the oceans are important as well, especially for interannual and decadal time scales. {FAQ 1.2, 9.4, 11.1}

Model formulation. The formulation of AOGCMs has developed through improved spatial resolution and improvements to numerical schemes and parametrizations (e.g., sea ice, atmospheric boundary layer, ocean mixing). More processes have been included in many models, including a number of key processes important for forcing (e.g., aerosols are now modelled interactively in many models). Most models now maintain a stable climate without use of flux adjustments, although some long-term trends remain in AOGCM control integrations, for example, due to slow processes in the ocean. {8.2, 8.3}

Simulation of present climate. As a result of improvements in model formulation, there have been improvements in the simulation of many aspects of present mean climate. Simulations of precipitation, sea level pressure and surface temperature have each improved overall, but deficiencies remain, notably in tropical precipitation. While significant deficiencies remain in the simulation of clouds (and corresponding feedbacks affecting climate sensitivity), some models have demonstrated improvements in the simulation of certain cloud regimes (notably marine stratocumulus). Simulation of extreme events (especially extreme temperature) has improved, but models generally simulate too little precipitation in the most extreme events. Simulation of extratropical cyclones has improved. Some models used for projections of tropical cyclone changes can simulate successfully the observed frequency and distribution of tropical cyclones. Improved simulations have been achieved for ocean water mass structure, the meridional overturning circulation and ocean heat transport. However most models show some biases in their simulation of the Southern Ocean, leading to some uncertainty in modelled ocean heat uptake when climate changes. {8.3, 8.5, 8.6}

Simulation of modes of climate variability. Models simulate dominant modes of extratropical climate variability that resemble the observed ones (NAM/SAM, PNA, PDO) but they still have problems in representing aspects of them. Some models can now simulate important aspects of ENSO, while simulation of the Madden-Julian Oscillation remains generally unsatisfactory. {8.4}

Simulation of past climate variations. Advances have been made in the simulation of past climate variations. Independently of any attribution of those changes, the ability of climate models to provide a physically self-consistent explanation of observed climate variations on various time scales builds confidence that the models are capturing many key processes for the evolution of 21st-century climate. Recent advances include success in modelling observed changes in a wider range of climate variables over the 20th century (e.g., continental-scale surface temperatures and extremes, sea ice extent, ocean heat content trends and land precipitation). There has also been progress in the ability to model many of the general features of past, very different climate states such as the mid-Holocene and the LGM using identical or related models to those used for studying current climate. Information on factors treated as boundary conditions in palaeoclimate calculations include the different states of ice sheets in those periods. The broad predictions of earlier climate models, of increasing global temperatures in response to increasing greenhouse gases, have been borne out by subsequent observations. This strengthens confidence in near-term climate projections and understanding of related climate change commitments. {6.4, 6.5, 8.1, 9.3–9.5}

(continued)

Weather and seasonal prediction using climate models. A few climate models have been tested for (and shown) capability in initial value prediction, on time scales from weather forecasting (a few days) to seasonal climate variations, when initialised with appropriate observations. While the predictive capability of models in this mode of operation does not necessarily imply that they will show the correct response to changes in climate forcing agents such as greenhouse gases, it does increase confidence that they are adequately representing some key processes and teleconnections in the climate system. {8.4}

Measures of model projection accuracy. The possibility of developing model capability measures ('metrics'), based on the above evaluation methods, that can be used to narrow uncertainty by providing quantitative constraints on model climate projections, has been explored for the first time using model ensembles. While these methods show promise, a proven set of measures has yet to be established. {8.1, 9.6, 10.5}

example, to uncertainties in model responses to forcing. Some potentially important forcings such as black carbon aerosols have not yet been considered in most formal detection and attribution studies. Uncertainties remain in estimates of natural internal climate variability. For example, there are discrepancies between estimates of ocean heat content variability from models and observations, although poor sampling of parts of the world ocean may explain this discrepancy. In addition, internal variability is difficult to estimate from available observational records since these are influenced by external forcing, and because records are not long enough in the case of instrumental data, or precise enough in the case of proxy reconstructions, to provide complete descriptions of variability on decadal and longer time scales (see Figure TS.22 and Box TS.7). {8.2–8.4, 8.6, 9.2–9.4}

It is *extremely unlikely* (<5%) that the global pattern of warming observed during the past half century can be explained without external forcing. These changes took place over a time period when non-anthropogenic forcing factors (i.e., the sum of solar and volcanic forcing) would be *likely* to have produced cooling, not warming (see Figure TS.23). Attribution studies show that it is *very likely* that these natural forcing factors alone cannot account for the observed warming (see Figure TS.23). There is also increased confidence that natural internal variability cannot account for the observed changes, due in part to improved studies demonstrating that the warming occurred in both oceans and atmosphere, together with observed ice mass losses. {2.9, 3.2, 5.2, 9.4, 9.5, 9.7}

It is *very likely* that anthropogenic greenhouse gas increases caused most of the observed increase in global average temperatures since the mid-20th century. Without the cooling effect of atmospheric aerosols, it is *likely* that greenhouse gases alone would have caused a greater global mean temperature rise than that observed during the last 50 years. A key factor in identifying the aerosol fingerprint, and therefore the amount of cooling counteracting greenhouse warming, is the temperature change through time (see Figure TS.23), as well as the hemispheric warming contrast. The conclusion that greenhouse gas forcing has been dominant takes into account observational and forcing uncertainties, and is robust to the use of different climate models, different methods for estimating the responses to external forcing and different analysis techniques. It also allows for possible amplification of the response to solar forcing. {2.9, 6.6, 9.1, 9.2, 9.4}

Widespread warming has been detected in ocean temperatures. Formal attribution studies now suggest that it is *likely* that anthropogenic forcing has contributed to the observed warming of the upper several hundred metres of the global ocean during the latter half of the 20th century. {5.2, 9.5}

Anthropogenic forcing has *likely* contributed to recent decreases in arctic sea ice extent. Changes in arctic sea ice are expected given the observed enhanced arctic warming. Attribution studies and improvements in the modelled representation of sea ice and ocean heat transport strengthen the confidence in this conclusion. {3.3, 4.4, 8.2, 8.3, 9.5}

It is *very likely* that the response to anthropogenic forcing contributed to sea level rise during the latter half of the 20th century, but decadal variability in sea level rise remains poorly understood. Modelled estimates of the contribution to sea level rise from thermal expansion are in good agreement with estimates based on observations during 1961 to 2003, although the budget for sea level rise over that interval is not closed. The observed increase in the rate of loss of mass from glaciers and ice caps is proportional to the global average temperature rise, as expected qualitatively from physical considerations (see Table TS.3). The greater rate of sea level rise in 1993 to 2003 than in 1961 to 2003 may be linked to increasing anthropogenic forcing, which has

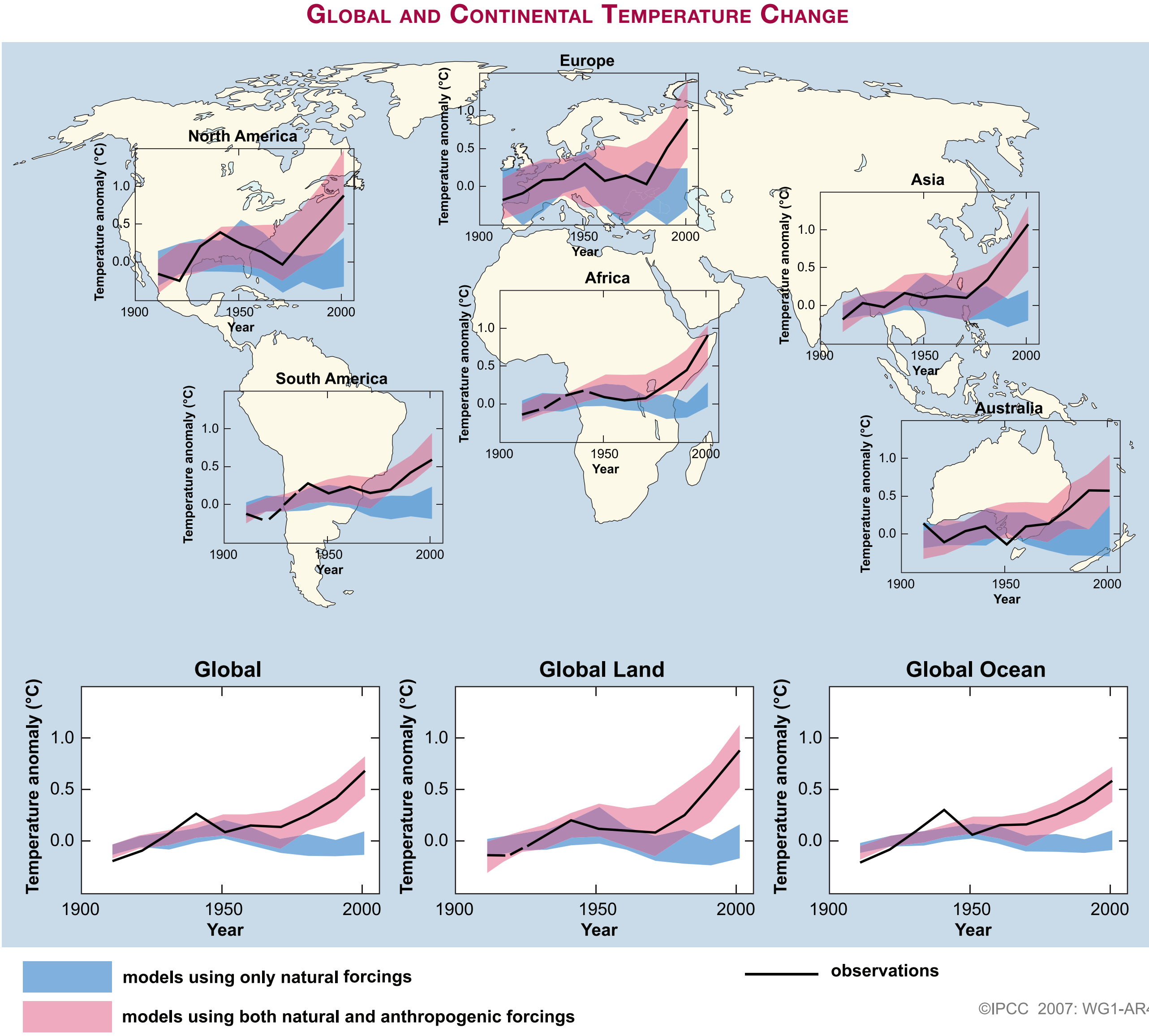


Figure TS.22. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901 to 1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5% to 95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5% to 95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. Data sources and models used are described in Section 9.4, FAQ 9.2, Table 8.1 and the supplementary information for Chapter 9. {FAQ 9.2, Figure 1}*

likely contributed to the observed warming of the upper ocean and widespread glacier retreat. On the other hand, the tide gauge record of global mean sea level suggests that similarly large rates may have occurred in previous 10-year periods since 1950, implying that natural internal variability could also be a factor in the high rates for 1993 to 2003 period. Observed decadal variability in the tide gauge record is larger than can be explained by variability in observationally based estimates of thermal expansion and land ice changes. Further, the observed decadal variability in thermal expansion is larger than simulated by models for the 20th century. Thus, the physical causes of the variability seen in the tide gauge record are uncertain. These unresolved issues relating to sea level change and its decadal variability during 1961 to 2003 make it unclear how much of the higher rate of sea level rise in 1993 to 2003 is due to natural internal variability and how much to anthropogenic climate change. {5.5, 9.5}

TS.4.2 Attribution of Spatial and Temporal Changes in Temperature

The observed pattern of tropospheric warming and stratospheric cooling is *very likely* due to the influence of anthropogenic forcing, particularly that due to greenhouse gas increases and stratospheric ozone depletion. New analyses since the TAR show that this pattern corresponds to an increase in the height of the tropopause that is *likely* due largely to greenhouse gas and stratospheric ozone changes. Significant uncertainty remains in the estimation of tropospheric temperature trends, particularly from the radiosonde record. {3.2, 3.4, 9.4}

It is *likely* that there has been a substantial anthropogenic contribution to surface temperature increases averaged over every continent except Antarctica since the middle of the 20th century. Antarctica has insufficient observational coverage to make an assessment. Anthropogenic warming has also been identified in some sub-continental land areas. The ability of coupled climate models to simulate the temperature evolution on each of six continents provides stronger evidence of human influence on the global climate than was available in the TAR. No coupled global climate model that has used natural forcing only has reproduced the observed global mean warming trend, or the continental mean warming trends in individual

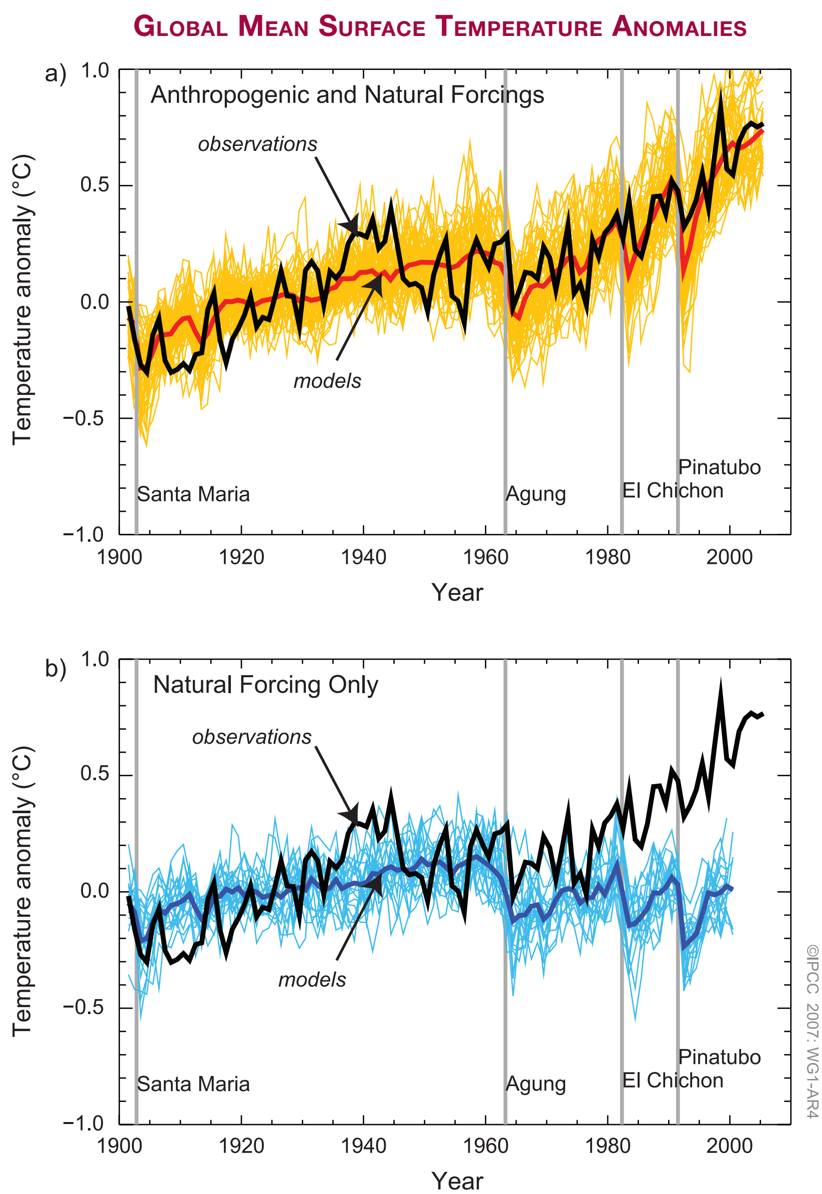


Figure TS.23. *(a) Global mean surface temperature anomalies relative to the period 1901 to 1950, as observed (black line) and as obtained from simulations with both anthropogenic and natural forcings. The thick red curve shows the multi-model ensemble mean and the thin yellow curves show the individual simulations. Vertical grey lines indicate the timing of major volcanic events. (b) As in (a), except that the simulated global mean temperature anomalies are for natural forcings only. The thick blue curve shows the multi-model ensemble mean and the thin lighter blue curves show individual simulations. Each simulation was sampled so that coverage corresponds to that of the observations. {Figure 9.5}* continents (except Antarctica) over the second half of the 20th century. {9.4}

Difficulties remain in attributing temperature changes at smaller than continental scales and over time scales of less than 50 years. Attribution results at these scales have, with limited exceptions, not been established. Averaging over smaller regions reduces the natural variability less than does averaging over large regions, making it more difficult to distinguish between changes expected from external forcing and variability. In addition, temperature changes associated with some modes of variability are poorly simulated by models in some regions and seasons. Furthermore, the small-scale details of external forcing and the response simulated by models are less credible than large-scale features. {8.3, 9.4}

Surface temperature extremes have *likely* been affected by anthropogenic forcing. Many indicators of extremes, including the annual numbers and most extreme values of warm and cold days and nights, as well as numbers of frost days, show changes that are consistent with warming. Anthropogenic influence has been detected in some of these indices, and there is evidence that anthropogenic forcing may have substantially increased the risk of extremely warm summer conditions regionally, such as the 2003 European heat wave. {9.4}

December - February Sea Level Pressure Trends

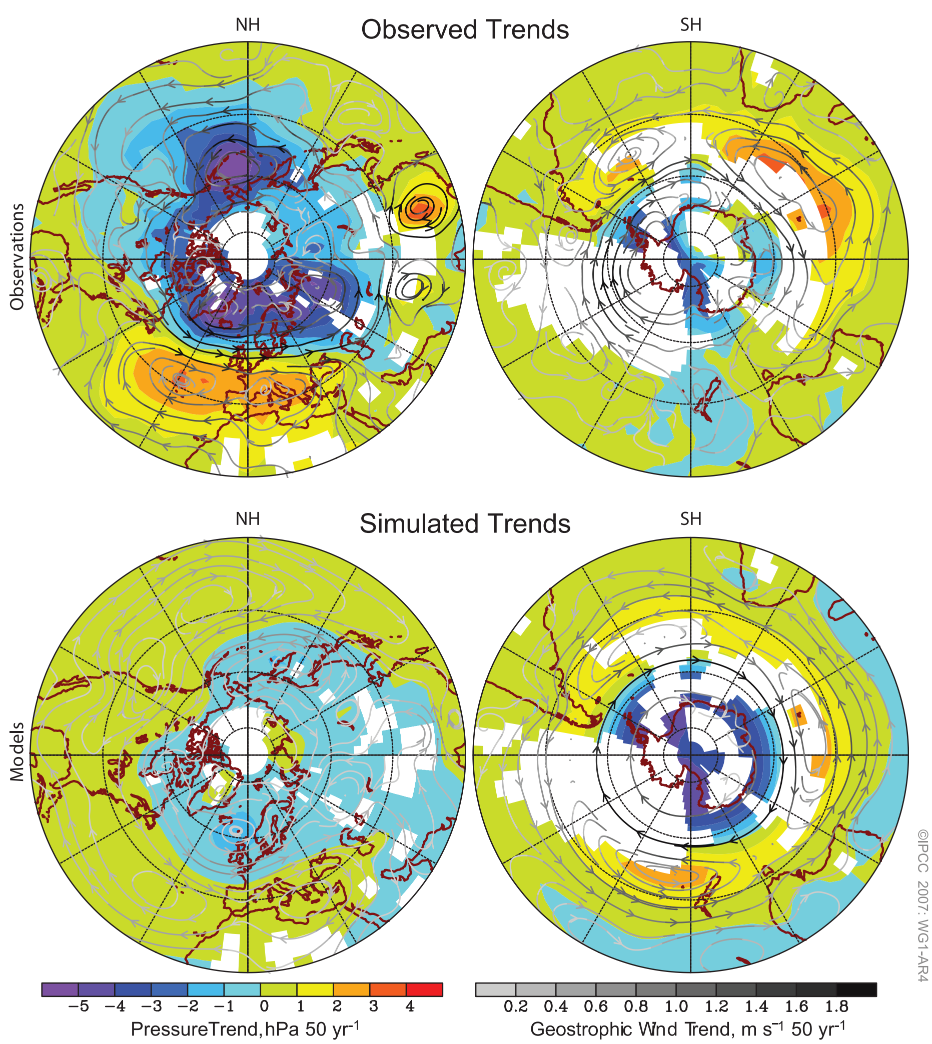


Figure TS.24. *December through February sea level pressure trends based on decadal means for the period 1955 to 2005. (Top) Trends estimated from an observational data set and displayed in regions where there is observational coverage. (Bottom) Mean trends simulated in response to natural and anthropogenic forcing changes in eight coupled models. The model-simulated trends are displayed only where observationally based trends are displayed. Streamlines, which are not masked, indicate the direction of the trends in the geostrophic wind derived from the trends in sea level pressure, and the shading of the streamlines indicates the magnitude of the change, with darker streamlines corresponding to larger changes in geostrophic wind. Data sources and models are described in Chapter 9 and its supplementary material, and Table 8.1 provides model details. {Figure 9.16}*

TS.4.3 Attribution of Changes in Circulation, Precipitation and Other Climate Variables

Trends in the Northern and Southern Annular Modes over recent decades, which correspond to sea level pressure reductions over the poles and related changes in atmospheric circulation, are *likely* related in part to human activity (see Figure TS.24). Models reproduce the sign of the NAM trend, but the simulated response is smaller than observed. Models including both greenhouse gas and stratospheric ozone changes simulate a realistic trend in the SAM, leading to a detectable human influence on global sea level pressure that is also consistent with the observed cooling trend in surface climate over parts of Antarctica. These changes in hemispheric circulation and their attribution to human activity imply that anthropogenic effects have *likely* contributed to changes in mid- and high-latitude patterns of circulation and temperature, as well as changes in winds and storm tracks. However, quantitative effects are uncertain because simulated responses to 20th century forcing change for the NH agree only qualitatively and not quantitatively with observations of these variables. {3.6, 9.5, 10.3}

There is some evidence of the impact of external influences on the hydrological cycle. The observed large-scale pattern of changes in land precipitation over the 20th century is qualitatively consistent with simulations, suggestive of a human influence. An observed global trend towards increases in drought in the second half of the 20th century has been reproduced with a model by taking anthropogenic and natural forcing into account. A number of studies have now demonstrated that changes in land use, due for example to overgrazing and conversion of woodland to agriculture, are *unlikely* to have been the primary cause of Sahelian and Australian droughts. Comparisons between observations and models suggest that changes in monsoons, storm intensities and Sahelian rainfall are related at least in part to changes in observed SSTs. Changes in global SSTs are expected to be affected by anthropogenic forcing, but an association of regional SST changes with forcing has not been established. Changes in rainfall depend not just upon SSTs but also upon changes in the spatial and temporal SST patterns and regional changes in atmospheric circulation, making attribution to human influences difficult. {3.3, 9.5, 10.3, 11.2}

TS.4.4 Palaeoclimate Studies of Attribution

It is *very likely* that climate changes of at least the seven centuries prior to 1950 were not due to unforced variability alone. Detection and attribution studies indicate that a substantial fraction of pre-industrial NH inter-decadal temperature variability contained in reconstructions for those centuries is *very likely* attributable to natural external forcing. Such forcing includes episodic cooling due to known volcanic eruptions, a number of which were larger than those of the 20th century (based on evidence such as ice cores), and long-term variations in solar irradiance, such as reduced radiation during the Maunder Minimum. Further, it is *likely* that anthropogenic forcing contributed to the early 20th-century warming evident in these records. Uncertainties are unlikely to lead to a spurious agreement between temperature reconstructions and forcing reconstructions as they are derived from independent proxies. Insufficient data are available to make a similar SH evaluation. {6.6, 9.3}

TS.4.5 Climate Response to Radiative Forcing

Specification of a *likely* range and a most *likely* value for equilibrium climate sensitivity[8] in this report represents significant progress in quantifying the climate system response to radiative forcing since the TAR and an advance in challenges to understanding that have persisted for over 30 years. A range for equilibrium climate sensitivity – the equilibrium global average warming expected if CO_2 concentrations were to be sustained at double their pre-industrial values (about 550 ppm) – was given in the TAR as between 1.5°C and 4.5°C. It has not been possible previously to provide a best estimate or to estimate the probability that climate sensitivity might fall outside that quoted range. Several approaches are used in this assessment to constrain climate sensitivity, including the use of AOGCMs, examination of the transient evolution of temperature (surface, upper air and ocean) over the last 150 years and examination of the rapid response of the global climate system to changes in the forcing caused by volcanic eruptions (see Figure TS.25). These are complemented by estimates based upon palaeoclimate studies such as reconstructions of the NH temperature record of the past millennium and the LGM. Large ensembles of climate model simulations have shown that the ability of models to simulate present climate has value in constraining climate sensitivity. {8.1, 8.6, 9.6, Box 10.2}

8 See the Glossary for a detailed definition of climate sensitivity.

Analysis of models together with constraints from observations suggest that the equilibrium climate sensitivity is *likely* to be in the range 2°C to 4.5°C, with a best estimate value of about 3°C. It is *very unlikely* to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement with observations is not as good for those values. Probability density functions derived from different information and approaches generally tend to have a long tail towards high values exceeding 4.5°C. Analysis of climate and forcing evolution over previous centuries and model ensemble studies do not rule out climate sensitivity being as high as 6°C or more. One factor in this is the possibility of small net radiative forcing over the 20th century if aerosol indirect cooling effects were at the upper end of their uncertainty range, thus cancelling most of the positive forcing due to greenhouse gases. However, there is no well-established way of estimating a single probability distribution function from individual results taking account of the different assumptions in each study. The lack of strong constraints limiting high climate sensitivities prevents the specification of a 95th percentile bound or a very likely range for climate sensitivity. {Box 10.2}

There is now increased confidence in the understanding of key climate processes that are important to climate sensitivity due to improved analyses and comparisons of models to one another and to observations. Water vapour changes dominate the feedbacks affecting climate sensitivity and are now better understood. New observational and modelling evidence strongly favours a combined water vapour-lapse rate[9] feedback of around the strength found in General Circulation Models (GCMs), that is, approximately 1 W m^{-2} per degree global temperature increase, corresponding to about a 50% amplification of global mean warming. Such GCMs have demonstrated an ability to simulate seasonal to inter-decadal humidity variations in the upper troposphere over land and ocean, and have successfully simulated the observed surface temperature and humidity changes associated with volcanic eruptions. Cloud feedbacks (particularly from low clouds) remain the largest source of uncertainty. Cryospheric feedbacks such as changes in snow cover have been shown to contribute less to the spread in model estimates of climate sensitivity than cloud or water vapour feedbacks, but they

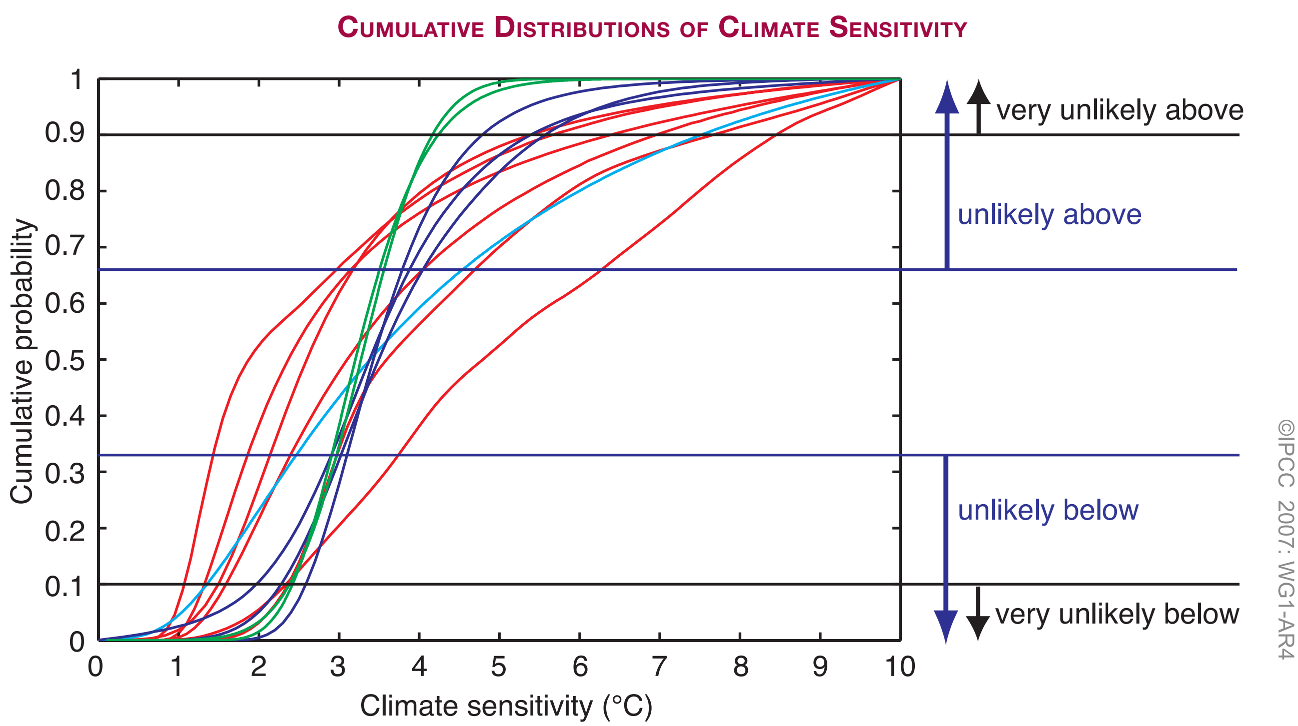


Figure TS.25. *Cumulative distributions of climate sensitivity derived from observed 20th-century warming (red), model climatology (blue), proxy evidence (cyan) and from climate sensitivities of AOGCMs (green). Horizontal lines and arrows mark the boundaries of the likelihood estimates defined in the IPCC Fourth Assessment Uncertainty Guidance Note (see Box TS.1). {Box 10.2, Figures 1 and 2}*

[9] The rate at which air temperature decreases with altitude.

can be important for regional climate responses at mid- and high latitudes. A new model intercomparison suggests that differences in radiative transfer formulations also contribute to the range. {3.4, 8.6, 9.3, 9.4, 9.6, 10.2, Box 10.2}

Improved quantification of climate sensitivity allows estimation of best estimate equilibrium temperatures and ranges that could be expected if concentrations of CO_2 were to be stabilised at various levels based on global energy balance considerations (see Table TS.5). As in the estimate of climate sensitivity, a very likely upper bound cannot be established. Limitations to the concept of radiative forcing and climate sensitivity should be noted. Only a few AOGCMs have been run to equilibrium under elevated CO_2 concentrations, and some results show that climate feedbacks may change over long time scales, resulting in substantial deviations from estimates of warming based on equilibrium climate sensitivity inferred from mixed layer ocean models and past climate change. {10.7}

Agreement among models for projected transient climate change has also improved since the TAR. The range of transient climate responses (defined as the global average surface air temperature averaged over a 20-year period centred at the time of CO_2 doubling in a 1% yr^{-1} increase experiment) among models is smaller than the range in the equilibrium climate sensitivity. This parameter is now better constrained by multi-model ensembles and comparisons with observations; it is *very likely* to be greater than 1°C and *very unlikely* to be greater than 3°C. The transient climate response is related to sensitivity in a nonlinear way such that high sensitivities are not immediately manifested in the short-term response. Transient climate response is strongly affected by the rate of ocean heat uptake. Although the ocean models have improved, systematic model biases and limited ocean temperature data to evaluate transient ocean heat uptake affect the accuracy of current estimates. {8.3, 8.6, 9.4, 9.6, 10.5}

Table TS.5. *Best estimate, likely ranges and very likely lower bounds of global mean equilibrium surface temperature increase (°C) over pre-industrial temperatures for different levels of CO_2-equivalent radiative forcing, as derived from the climate sensitivity.*

Equilibrium CO_2–eq (ppm)	Temperature Increase (°C)		
	Best Estimate	*Very Likely* Above	*Likely* in the Range
350	1.0	0.5	0.6–1.4
450	2.1	1.0	1.4–3.1
550	2.9	1.5	1.9–4.4
650	3.6	1.8	2.4–5.5
750	4.3	2.1	2.8–6.4
1000	5.5	2.8	3.7–8.3
1200	6.3	3.1	4.2–9.4

TS.5 Projections of Future Changes in Climate

Since the TAR, there have been many important advances in the science of climate change projections. An unprecedented effort has been initiated to make new model results available for prompt scrutiny by researchers outside of the modelling centres. A set of coordinated, standard experiments was performed by 14 AOGCM modelling groups from 10 countries using 23 models. The resulting multi-model database of outputs, analysed by hundreds of researchers worldwide, forms the basis for much of this assessment of model results. Many advances have come from the use of multi-member ensembles from single models (e.g., to test the sensitivity of response to initial conditions) and from multi-model ensembles. These two different types of ensembles allow more robust studies of the range of model results and more quantitative model evaluation against observations, and provide new information on simulated statistical variability. {8.1, 8.3, 9.4, 9.5, 10.1}

A number of methods for providing probabilistic climate change projections, both for global means and geographical depictions, have emerged since the TAR and are a focus of this report. These include methods based on results of AOGCM ensembles without formal application of observational constraints as well as methods based on detection algorithms and on large model ensembles that provide projections consistent with observations of climate change and their uncertainties. Some methods now explicitly account for key uncertainty sources such as climate feedbacks, ocean heat uptake, radiative forcing and the carbon cycle. Short-term projections are similarly constrained by observations of recent trends. Some studies have probed additional probabilistic issues, such as the likelihood of future changes in extremes such as heat waves that could occur due to human influences. Advances have also occurred since the TAR through broader ranges of studies of committed climate change and of carbon-climate feedbacks. {8.6, 9.6, 10.1, 10.3, 10.5}

These advances in the science of climate change modelling provide a probabilistic basis for distinguishing projections of climate change for different SRES marker scenarios. This is in contrast to the TAR where ranges for different marker scenarios could not be given in probabilistic terms. As a result, this assessment identifies and quantifies the difference in character between uncertainties that arise in climate modelling and those that arise from a lack of prior knowledge of decisions that will affect greenhouse gas emissions. A loss of policy-relevant information would result from combining probabilistic projections. For these reasons, projections for different emission scenarios are not combined in this report.

Model simulations used here consider the response of the physical climate system to a range of possible future conditions through use of idealised emissions or concentration assumptions. These include experiments with greenhouse gases and aerosols held constant at year 2000 levels, CO_2 doubling and quadrupling experiments, SRES marker scenarios for the 2000 to 2100 period, and experiments with greenhouse gases and aerosols held constant after 2100, providing new information on the physical aspects of long-term climate change and stabilisation. The SRES scenarios did not include climate initiatives. This Working Group I assessment does not evaluate the plausibility or likelihood of any specific emission scenario. {10.1, 10.3}

A new multi-model data set using Earth System Models of Intermediate Complexity (EMICs) complements AOGCM experiments to extend the time horizon for several more centuries in the future. This provides a more comprehensive range of model responses in this assessment as well as new information on climate change over long time scales when greenhouse gas and aerosol concentrations are held constant. Some AOGCMs and EMICs contain prognostic carbon cycle components, which permit estimation of the likely effects and associated uncertainties of carbon cycle feedbacks. {10.1}

Box TS.8: Hierarchy of Global Climate Models

Estimates of change in global mean temperature and sea level rise due to thermal expansion can be made using Simple Climate Models (SCMs) that represent the ocean-atmosphere system as a set of global or hemispheric boxes, and predict global surface temperature using an energy balance equation, a prescribed value of climate sensitivity and a basic representation of ocean heat uptake. Such models can also be coupled to simplified models of biogeochemical cycles and allow rapid estimation of the climate response to a wide range of emission scenarios. {8.8, 10.5}

Earth System Models of Intermediate Complexity (EMICs) include some dynamics of the atmospheric and oceanic circulations, or parametrizations thereof, and often include representations of biogeochemical cycles, but they commonly have reduced spatial resolution. These models can be used to investigate continental-scale climate change and long-term, large-scale effects of coupling between Earth system components using large ensembles of model runs or runs over many centuries. For both SCMs and EMICs it is computationally feasible to sample parameter spaces thoroughly, taking account of parameter uncertainties derived from tuning to more comprehensive climate models, matching observations and use of expert judgment. Thus, both types of model are well suited to the generation of probabilistic projections of future climate and allow a comparison of the 'response uncertainty' arising from uncertainty in climate model parameters with the 'scenario range' arising from the range of emission scenarios being considered. Earth System Models of Intermediate Complexity have been evaluated in greater depth than previously and intercomparison exercises have demonstrated that they are useful for studying questions involving long time scales or requiring large ensembles of simulations. {8.8, 10.5, 10.7}

The most comprehensive climate models are the AOGCMs. They include dynamical components describing atmospheric, oceanic and land surface processes, as well as sea ice and other components. Much progress has been made since the TAR (see Box TS.7), and there are over 20 models from different centres available for climate simulations. Although the large-scale dynamics of these models are comprehensive, parametrizations are still used to represent unresolved physical processes such as the formation of clouds and precipitation, ocean mixing due to wave processes and the formation of water masses, etc. Uncertainty in parametrizations is the primary reason why climate projections differ between different AOGCMs. While the resolution of AOGCMs is rapidly improving, it is often insufficient to capture the fine-scale structure of climatic variables in many regions. In such cases, the output from AOGCMs can be used to drive limited-area (or regional climate) models that combine the comprehensiveness of process representations comparable to AOGCMs with much higher spatial resolution. {8.2}

TS.5.1 Understanding Near-Term Climate Change

Knowledge of the climate system together with model simulations confirm that past changes in greenhouse gas concentrations will lead to a committed warming (see Box TS.9 for a definition) and future climate change. New model results for experiments in which concentrations of all forcing agents were held constant provide better estimates of the committed changes in atmospheric variables that would follow because of the long response time of the climate system, particularly the oceans. {10.3, 10.7}

Previous IPCC projections of future climate changes can now be compared to recent observations, increasing confidence in short-term projections and the underlying physical understanding of committed climate change over a few decades. Projections for 1990 to 2005 carried out for the FAR and the SAR suggested global mean temperature increases of about 0.3°C and 0.15°C per decade, respectively.[10] The difference between the two was due primarily to the inclusion of aerosol cooling effects in the SAR, whereas there was no quantitative basis for doing so in the FAR. Projections given in the TAR were similar to those of the SAR. These results are comparable to observed values of about 0.2°C per decade, as shown in Figure TS.26, providing broad confidence in such short-term projections. Some of this warming is the committed effect of changes in the concentrations of greenhouse gases prior to the times of those earlier assessments. {1.2, 3.2}

Committed climate change (see Box TS.9) due to atmospheric composition in the year 2000 corresponds to a warming trend of about 0.1°C per decade over the next two decades, in the absence of large changes in volcanic or solar forcing. About twice as much warming (0.2°C per decade) would be expected if emissions were to fall within the range of the SRES marker scenarios. This result is insensitive to the choice among the SRES marker scenarios, none of which considered climate initiatives. By 2050, the range of expected warming shows limited sensitivity to the choice among SRES scenarios (1.3°C to 1.7°C relative to 1980–1999) with about a quarter being due to the committed climate change if all radiative forcing agents were stabilised today. {10.3, 10.5, 10.7}

Sea level is expected to continue to rise over the next several decades. During 2000 to 2020 under the SRES A1B scenario in the ensemble of AOGCMs, the rate of thermal expansion is projected to be 1.3 ± 0.7 mm yr^{-1}, and is not significantly different under the A2 or B1 scenarios. These projected rates are within the uncertainty of the observed contribution of thermal expansion for 1993 to 2003 of 1.6 ± 0.6 mm yr^{-1}. The ratio of committed thermal expansion, caused by constant atmospheric composition at year 2000 values, to total thermal expansion (that is the ratio of expansion occurring after year 2000 to that occurring before and after) is larger than the corresponding ratio for global average surface temperature. {10.6, 10.7}

Box TS.9: Committed Climate Change

If the concentrations of greenhouse gases and aerosols were held fixed after a period of change, the climate system would continue to respond due to the thermal inertia of the oceans and ice sheets and their long time scales for adjustment. 'Committed warming' is defined here as the further change in global mean temperature after atmospheric composition, and hence radiative forcing, is held constant. Committed change also involves other aspects of the climate system, in particular sea level. Note that holding concentrations of radiatively active species constant would imply that ongoing emissions match natural removal rates, which for most species would be equivalent to a large reduction in emissions, although the corresponding model experiments are not intended to be considered as emission scenarios. {FAQ 10.3}

The troposphere adjusts to changes in its boundary conditions over time scales shorter than a month or so. The upper ocean responds over time scales of several years to decades, and the deep ocean and ice sheet response time scales are from centuries to millennia. When the radiative forcing changes, internal properties of the atmosphere tend to adjust quickly. However, because the atmosphere is strongly coupled to the oceanic mixed layer, which in turn is coupled to the deeper oceanic layer, it takes a very long time for the atmospheric variables to come to an equilibrium. During the long periods where the surface climate is changing very slowly, one can consider that the atmosphere is in a quasi-equilibrium state, and most energy is being absorbed by the ocean, so that ocean heat uptake is a key measure of climate change. {10.7}

[10] See IPCC First Assessment Report, Policymakers Summary, and Second Assessment Report, Technical Summary, Figure 18.

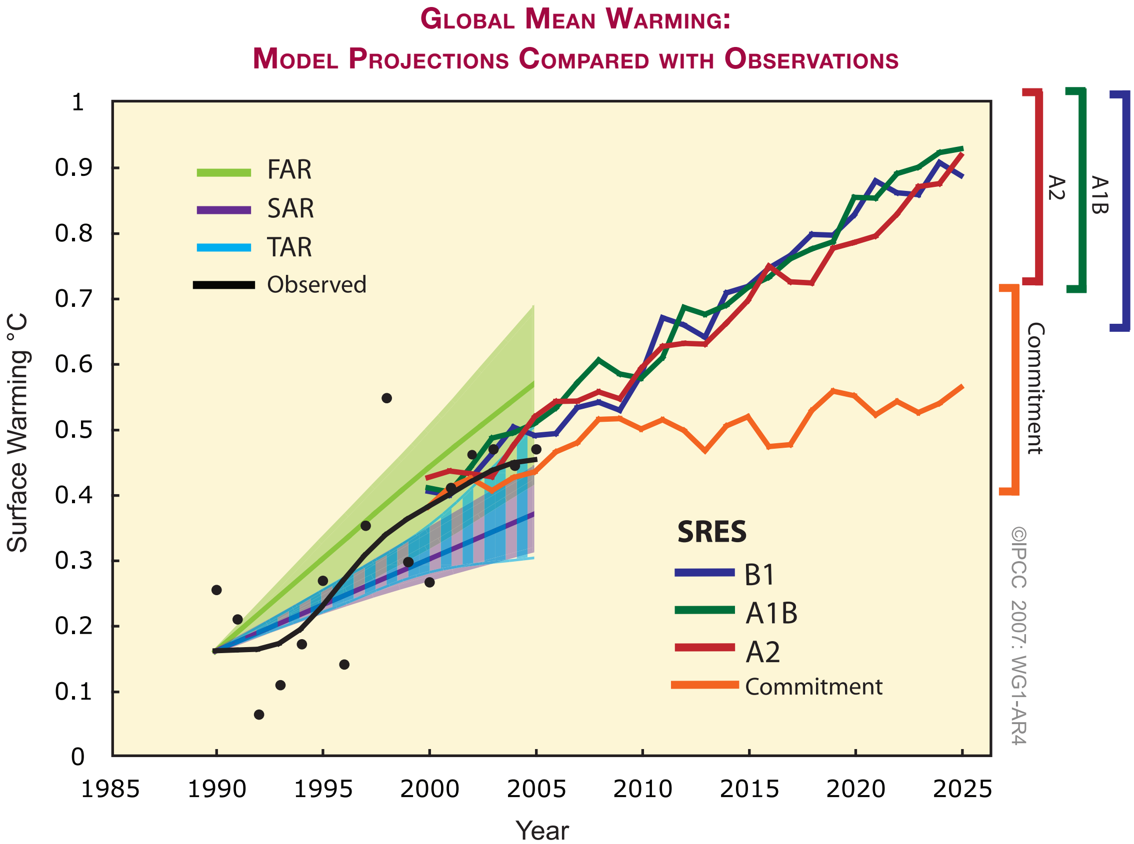


Figure TS.26. *Model projections of global mean warming compared to observed warming. Observed temperature anomalies, as in Figure TS.6, are shown as annual (black dots) and decadal average values (black line). Projected trends and their ranges from the IPCC First (FAR) and Second (SAR) Assessment Reports are shown as green and magenta solid lines and shaded areas, and the projected range from the TAR is shown by vertical blue bars. These projections were adjusted to start at the observed decadal average value in 1990. Multi-model mean projections from this report for the SRES B1, A1B and A2 scenarios, as in Figure TS.32, are shown for the period 2000 to 2025 as blue, green and red curves with uncertainty ranges indicated against the right-hand axis. The orange curve shows model projections of warming if greenhouse gas and aerosol concentrations were held constant from the year 2000 – that is, the committed warming. {Figures 1.1 and 10.4}*

TS.5.2 Large-Scale Projections for the 21st Century

This section covers advances in understanding global-scale climate projections and the processes that will influence their large-scale patterns in the 21st century. More specific discussion of regional-scale changes follows in TS.5.3.

Projected global average surface warming for the end of the 21st century (2090–2099) is scenario-dependent and the actual warming will be significantly affected by the actual emissions that occur. Warmings compared to 1980 to 1999 for six SRES scenarios[11] and for constant year 2000 concentrations, given as best estimates and corresponding *likely* ranges, are shown in Table TS.6. These results are based on AOGCMs, observational constraints and other methods to quantify the range of model response (see Figure TS.27). The combination of multiple lines of evidence allows likelihoods to be assigned to the resulting ranges, representing an important advance since the TAR. {10.5}

Assessed uncertainty ranges are larger than those given in the TAR because they consider a more complete range of models and climate-carbon cycle feedbacks. Warming tends to reduce land and ocean uptake of atmospheric CO_2, increasing the fraction of anthropogenic emissions that remains in the atmosphere. For the A2 scenario for example, the CO_2 feedback increases the corresponding global average warming in 2100 by more than 1°C. {7.3, 10.5}

[11] Approximate CO_2 equivalent concentrations corresponding to the computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100 (see p. 823 of the TAR) for the SRES B1, A1T, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1,250 and 1,550 ppm respectively. Constant emission at year 2000 levels would lead to a concentration for CO_2 alone of about 520 ppm by 2100.

Table TS.6. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a] Best estimate	*Likely* range	Sea Level Rise (m at 2090-2099 relative to 1980-1999) Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth Models of Intermediate Complexity (EMICs), and a large number of Atmosphere-Ocean Global Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

Projected global-average sea level rise at the end of the 21st century (2090 to 2099), relative to 1980 to 1999 for the six SRES marker scenarios, given as 5% to 95% ranges based on the spread of model results, are shown in Table TS.6. Thermal expansion contributes 70 to 75% to the best estimate for each scenario. An improvement since the TAR is the use of AOGCMs to evaluate ocean heat uptake and thermal expansion. This has also reduced the projections as compared to the simple model used in the TAR. In all the SRES marker scenarios except B1, the average rate of sea level rise during the 21st century *very likely* exceeds the 1961–2003 average rate (1.8 ± 0.5 mm yr^{-1}). For an average model, the scenario spread in sea level rise is only 0.02 m by the middle of the century, but by the end of the century it is 0.15 m. These ranges do not include uncertainties in carbon-cycle feedbacks or ice flow processes because a basis in published literature is lacking. {10.6, 10.7}

For each scenario, the midpoint of the range given here is within 10% of the TAR model average for 2090–2099, noting that the TAR projections were given for 2100, whereas projections in this report are for 2090–2099. The uncertainty in these projections is less than in the TAR for several reasons: uncertainty in land ice models is assumed independent of uncertainty in temperature and expansion projections; improved observations of recent mass loss from glaciers provide a better observational constraint; and the present report gives uncertainties as 5% to 95% ranges, equivalent to ±1.65 standard deviations, whereas the TAR gave uncertainty ranges of ±2 standard deviations. The TAR would have had similar ranges for sea level projections to those in this report if it had treated the uncertainties in the same way. {10.6, 10.7}

Changes in the cryosphere will continue to affect sea level rise during the 21st century. Glaciers, ice caps and the Greenland Ice Sheet are projected to lose mass in the 21st century because increased melting will exceed increased snowfall. Current models suggest that the Antarctic Ice Sheet will remain too cold for widespread melting and may gain mass in future through increased snowfall, acting to reduce sea level rise. However, changes in ice dynamics could increase the contributions of both Greenland and Antarctica to 21st-century sea level rise. Recent observations of some Greenland outlet glaciers give strong evidence for enhanced flow when ice shelves are removed. The observations in west-central Greenland of seasonal variation in ice flow rate and of a correlation with summer temperature variation suggest that surface melt water may join a sub-glacially routed drainage system lubricating the ice flow. By both of these mechanisms, greater surface melting during the 21st century could cause acceleration of ice flow and discharge and increase the sea level contribution. In some parts of West Antarctica, large accelerations of ice flow have recently occurred, which may have been caused by thinning of ice shelves due to ocean warming. Although this has not been formally attributed to anthropogenic climate change due to greenhouse gases, it suggests that future warming could cause faster mass loss and greater

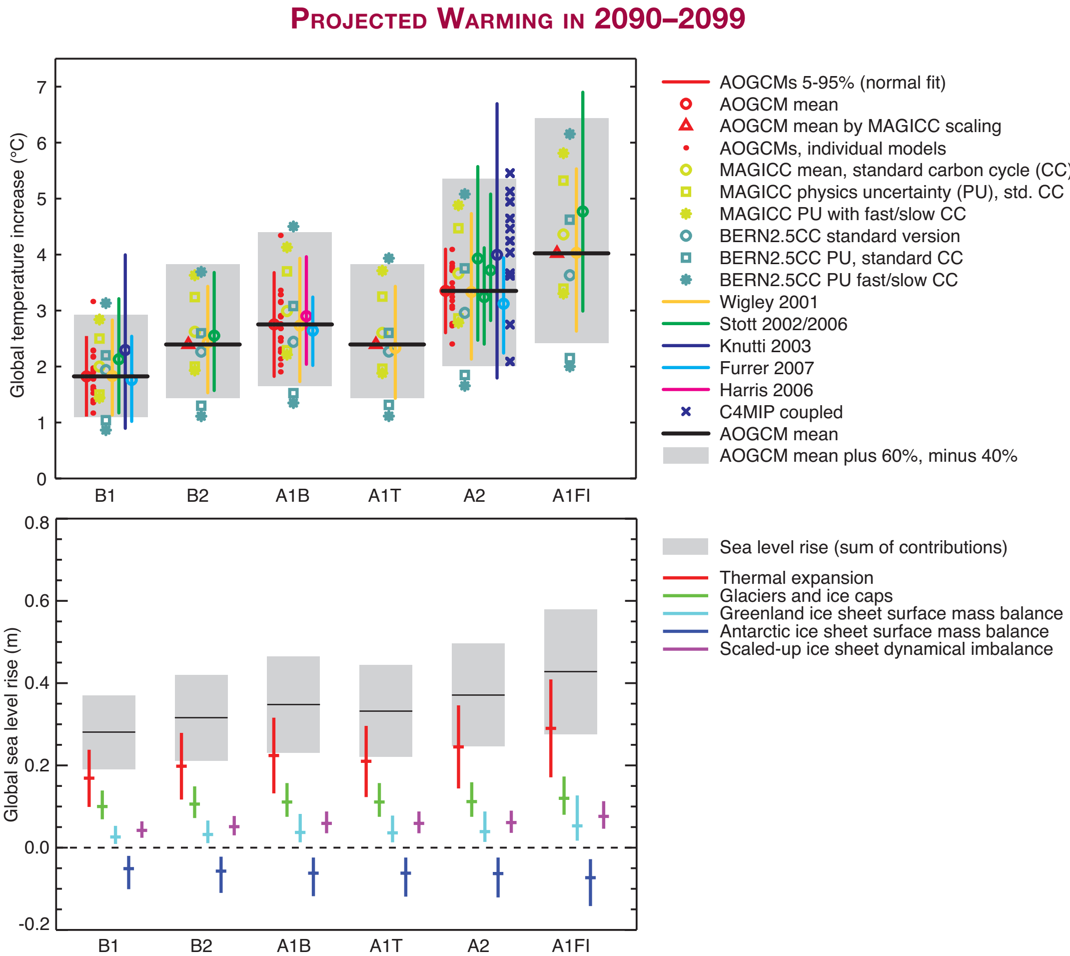


Figure TS.27. *(Top) Projected global mean temperature change in 2090 to 2099 relative to 1980 to 1999 for the six SRES marker scenarios based on results from different and independent models. The multi-model AOGCM mean and the range of the mean minus 40% to the mean plus 60% are shown as black horizontal solid lines and grey bars, respectively. Carbon cycle uncertainties are estimated for scenario A2 based on Coupled Carbon Cycle Climate Model Intercomparison Project (C⁴MIP) models (dark blue crosses), and for all marker scenarios using an EMIC (pale blue symbols). Other symbols represent individual studies (see Figure 10.29 for details of specific models). (Bottom) Projected global average sea level rise and its components in 2090 to 2099 (relative to 1980–1999) for the six SRES marker scenarios. The uncertainties denote 5 to 95% ranges, based on the spread of model results, and not including carbon cycle uncertainties. The contributions are derived by scaling AOGCM results and estimating land ice changes from temperature changes (see Appendix 10.A for details). Individual contributions are added to give the total sea level rise, which does not include the contribution shown for ice sheet dynamical imbalance, for which the current level of understanding prevents a best estimate from being given. {Figures 10.29 and 10.33}*

sea level rise. Quantitative projections of this effect cannot be made with confidence. If recently observed increases in ice discharge rates from the Greenland and Antarctic Ice Sheets were to increase linearly with global average temperature change, that would add 0.1 to 0.2 m to the upper bound of sea level rise. Understanding of these effects is too limited to assess their likelihood or to give a best estimate. {4.6, 10.6}

Many of the global and regional patterns of temperature and precipitation seen in the TAR projections remain in the new generation of models and across ensemble results (see Figure TS.28). Confidence in the robustness of these patterns is increased by the fact that they have remained largely unchanged while overall model simulations have improved (Box TS.7). This adds to confidence that these patterns reflect basic physical constraints on the climate system as it warms. {8.3–8.5, 10.3, 11.2–11.9}

The projected 21st-century temperature change is positive everywhere. It is greatest over land and at most high latitudes in the NH during winter, and increases going from the coasts into the continental interiors. In otherwise geographically similar areas, warming is typically larger in arid than in moist regions. {10.3, 11.2–11.9}

In contrast, warming is least over the southern oceans and parts of the North Atlantic Ocean. Temperatures are projected to increase, including over the North Atlantic and Europe, despite a projected slowdown of the meridional overturning circulation (MOC) in most models, due to the much larger influence of the increase in greenhouse gases. The projected pattern of zonal mean temperature change in the atmosphere displays a maximum warming in the upper tropical troposphere and cooling in the stratosphere. Further zonal mean warming in the ocean is expected to occur first near the surface and in the northern mid-latitudes, with the warming gradually reaching the ocean interior, most evident at high latitudes where vertical mixing is greatest. The projected pattern of change is very similar among the late-century cases irrespective of the scenario. Zonally averaged fields normalised by the mean warming are very similar for the scenarios examined (see Figure TS.28). {10.3}

It is *very likely* that the Atlantic MOC will slow down over the course of the 21st century. The multi-model average reduction by 2100 is 25% (range from zero to about 50%) for SRES emission scenario A1B. Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases of greenhouse gases. The projected reduction of the Atlantic MOC is due to the combined effects of an increase in high latitude temperatures and precipitation, which reduce the density of the surface waters in the North Atlantic. This could lead to a significant reduction in Labrador Sea Water formation. Very few AOGCM studies have included the impact of additional freshwater from melting of the Greenland Ice Sheet, but those that have do not suggest that this will lead to a complete MOC shutdown. Taken together, it is *very likely* that the MOC will reduce, but very *unlikely* that the MOC will undergo a large abrupt transition during the course of the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. {8.7, 10.3}

Projections of Surface Temperatures

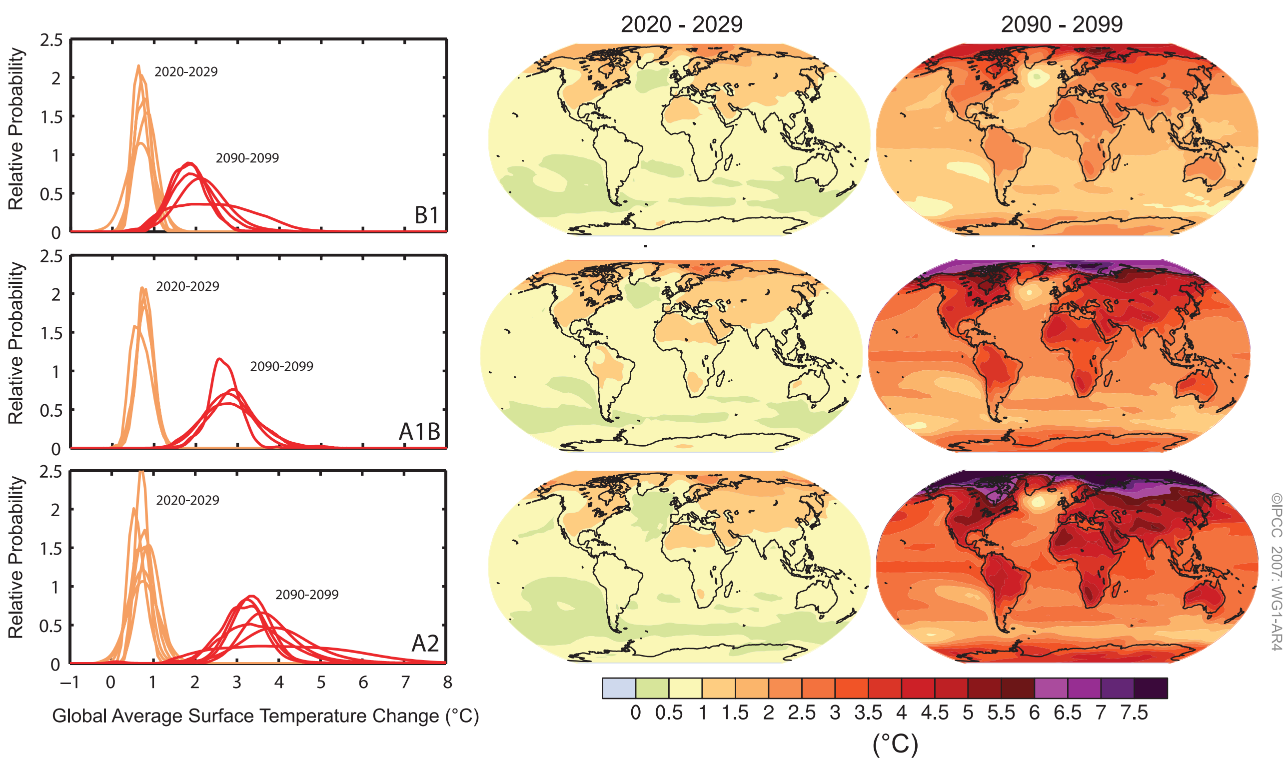


Figure TS.28. *Projected surface temperature changes for the early and late 21st century relative to the period 1980 to 1999. The central and right panels show the AOGCM multi-model average projections (°C) for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020 to 2029 (centre) and 2090 to 2099 (right). The left panel shows corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and EMIC studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves, shown in the left-hand panels, is due only to differences in the availability of results. {Adapted from Figures 10.8 and 10.28}*

Models indicate that sea level rise during the 21st century will not be geographically uniform. Under scenario A1B for 2070 to 2099, AOGCMs give a median spatial standard deviation of 0.08 m, which is about 25% of the central estimate of the global average sea level rise. The geographic patterns of future sea level change arise mainly from changes in the distribution of heat and salinity in the ocean and consequent changes in ocean circulation. Projected patterns display more similarity across models than those analysed in the TAR. Common features are a smaller than average sea level rise in the Southern Ocean, larger than average sea level rise in the Arctic and a narrow band of pronounced sea level rise stretching across the southern Atlantic and Indian Oceans. {10.6}

Projections of changes in extremes such as the frequency of heat waves are better quantified than in the TAR, due to improved models and a better assessment of model spread based on multi-model ensembles. The TAR concluded that there was a risk of increased temperature extremes, with more extreme heat episodes in a future climate. This result has been confirmed and expanded in more recent studies. Future increases in temperature extremes are projected to follow increases in mean temperature over most of the world except where surface properties (e.g., snow cover or soil moisture) change. A multi-model analysis, based on simulations of 14 models for three scenarios, investigated changes in extreme seasonal (DJF and JJA) temperatures where 'extreme' is defined as lying above the 95th percentile of the simulated temperature distribution for the 20th century. By the end of the 21st century, the projected probability of extreme warm seasons rises above 90% in many tropical areas, and reaches around 40% elsewhere. Several recent studies have addressed possible future changes in heat waves, and found that, in a future climate, heat waves are expected to be more intense, longer lasting and more frequent. Based on an eight-member multi-model ensemble, heat waves are simulated to have been increasing for the latter part of the 20th century, and are projected to increase globally and over most regions. {8.5, 10.3}

For a future warmer climate, models project a 50 to 100% decline in the frequency of cold air outbreaks relative to the present in NH winters in most areas. Results from a nine-member multi-model ensemble show simulated decreases in frost days for the 20th century continuing into the 21st century globally and in most regions. Growing season length is related to frost days and is projected to increase in future climates. {10.3, FAQ 10.1}

Snow cover is projected to decrease. Widespread increases in thaw depth are projected to occur over most permafrost regions. {10.3}

Under several different scenarios (SRES A1B, A2 and B1), large parts of the Arctic Ocean are expected to no longer have year-round ice cover by the end of the 21st century. Arctic sea ice responds sensitively to warming. While projected changes in winter sea ice extent are moderate, late-summer sea ice is projected to disappear almost completely towards the end of the 21st century under the A2 scenario in some models. The reduction is accelerated by a number of positive feedbacks in the climate system. The ice-albedo feedback allows open water to receive more heat from the Sun during summer, the insulating effect of sea ice is reduced and the increase in ocean heat transport to the Arctic further reduces ice cover. Model simulations indicate that the late-summer sea ice cover decreases substantially and generally evolves over the same time scale as global warming. Antarctic sea ice extent is also projected to decrease in the 21st century. {8.6, 10.3, Box 10.1}

Sea level pressure is projected to increase over the subtropics and mid-latitudes, and decrease over high latitudes associated with an expansion of the Hadley Circulation and annular mode changes (NAM/NAO and SAM, see Box TS.2). A positive trend in the NAM/NAO as well as the SAM index is projected by many models. The magnitude of the projected increase is generally greater for the SAM, and there is considerable spread among the models. As a result of these changes, storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns outside the tropics, continuing the broad pattern of observed trends over the last half century. Some studies suggest fewer storms in mid-latitude regions. There are also indications of changes in extreme wave height associated with changing storm tracks and circulation. {3.6, 10.3}

In most models, the central and eastern equatorial Pacific SSTs warm more than those in the western equatorial Pacific, with a corresponding mean eastward shift in precipitation. ENSO interannual variability is projected to continue in all models, although changes differ from model to model. Large inter-model differences in projected changes in El Niño amplitude, and the inherent centennial time-scale variability of El Niño in the models, preclude a definitive projection of trends in ENSO variability. {10.3}

Recent studies with improved global models, ranging in resolution from about 100 to 20 km, suggest future changes in the number and intensity of future tropical cyclones (typhoons and hurricanes).

A synthesis of the model results to date indicates, for a warmer future climate, increased peak wind intensities and increased mean and peak precipitation intensities in future tropical cyclones, with the possibility of a decrease in the number of relatively weak hurricanes, and increased numbers of intense hurricanes. However, the total number of tropical cyclones globally is projected to decrease. The apparent observed increase in the proportion of very intense hurricanes since 1970 in some regions is in the same direction but much larger than predicted by theoretical models. {10.3, 8.5, 3.8}

Since the TAR, there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* at high latitudes while decreases are *likely* in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100). Poleward of 50°, mean precipitation is projected to increase due to the increase in water vapour in the atmosphere and the resulting increase in vapour transport from lower latitudes. Moving equatorward, there is a transition to mostly decreasing precipitation in the subtropics (20°–40° latitude). Due to increased water vapour transport out of the subtropics and a poleward expansion of the subtropical high-pressure systems, the drying tendency is especially pronounced at the higher-latitude margins of the subtropics (see Figure TS.30). {8.3, 10.3, 11.2–11.9}

Models suggest that changes in mean precipitation amount, even where robust, will rise above natural variability more slowly than the temperature signal. {10.3, 11.1}

Available research indicates a tendency for an increase in heavy daily rainfall events in many regions, including some in which the mean rainfall is projected to decrease. In the latter cases, the rainfall decrease is often attributable to a reduction in the number of rain days rather than the intensity of rain when it occurs. {11.2–11.9}

TS.5.3 Regional-Scale Projections

For each of the continental regions, the projected warming over 2000 to 2050 resulting from the SRES emissions scenarios is greater than the global average and greater than the observed warming over the past century. The warming projected for the next few decades of the 21st century, when averaged over the continents individually, would substantially exceed estimated 20th-century natural forced and unforced variability in all cases except Antarctica (Figure TS.29). Model best-estimate projections indicate that decadal average warming over each continent except Antarctica by 2030 is *very likely* to be at least twice as large as the corresponding model-estimated natural variability during the 20th century. The simulated warming over this period is not very sensitive to the choice of scenarios across the SRES set as is illustrated in Figure TS.32. Over longer time scales, the choice of scenario is more important, as shown in Figure TS.28. The projected warming in the SRES scenarios over 2000 to 2050 also exceeds estimates of natural variability when averaged over most sub-continental regions. {11.1}

Box TS.10. Regional Downscaling

Simulation of regional climates has improved in AOGCMs and, as a consequence, in nested regional climate models and in empirical downscaling techniques. Both dynamic and empirical downscaling methodologies show improving skill in simulating local features in present-day climates when the observed state of the atmosphere at scales resolved by current AOGCMs is used as input. The availability of downscaling and other regionally focused studies remains uneven geographically, causing unevenness in the assessments that can be provided, particularly for extreme weather events. Downscaling studies demonstrate that local precipitation changes can vary significantly from those expected from the large-scale hydrological response pattern, particularly in areas of complex topography. {11.10}

There remain a number of important sources of uncertainty limiting the ability to project regional climate change. While hydrological responses are relatively robust in certain core subpolar and subtropical regions, there is uncertainty in the precise location of these boundaries between increasing and decreasing precipitation. There are some important climate processes that have a significant effect on regional climate, but for which the climate change response is still poorly known. These include ENSO, the NAO, blocking, the thermohaline circulation and changes in tropical cyclone distribution. For those regions that have strong topographical controls on their climatic patterns, there is often insufficient climate change information at the fine spatial resolution of the topography. In some regions there has been only very limited research on extreme weather events. Further, the projected climate change signal becomes comparable to larger internal variability at smaller spatial and temporal scales, making it more difficult to utilise recent trends to evaluate model performance. {Box 11.1, 11.2–11.9}

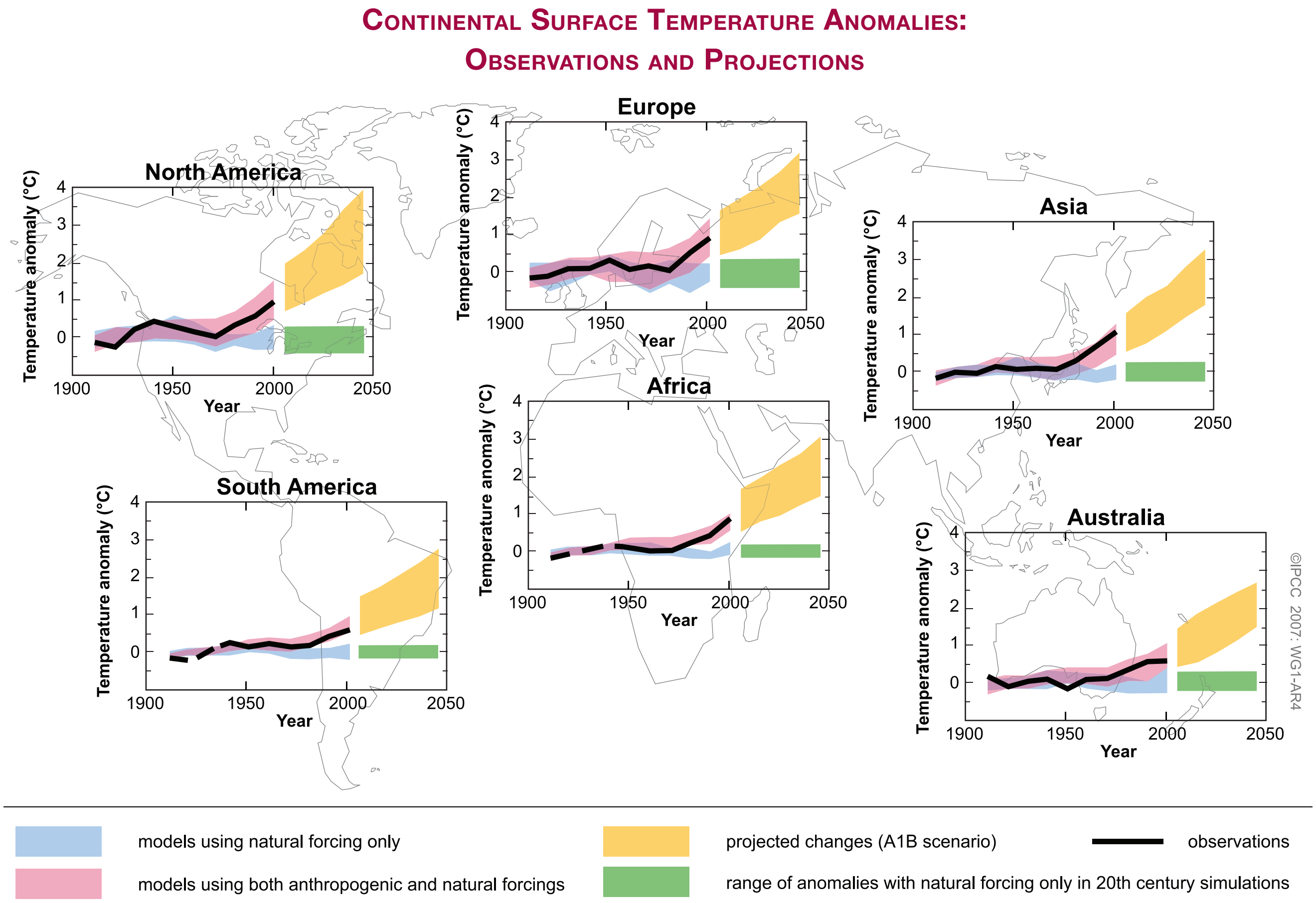


Figure TS.29. *Decadal mean continental surface temperature anomalies (°C) in observations and simulations for the period 1906 to 2005 and in projections for 2001 to 2050. Anomalies are calculated from the 1901 to 1950 average. The black lines represent the observations and the red and blue bands show simulated average temperature anomalies as in Figure TS.22 for the 20th century (i.e., red includes anthropogenic and natural forcings and blue includes only natural forcings). The yellow shading represents the 5th to 95th percentile range of projected changes according to the SRES A1B emissions scenario. The green bar denotes the 5th to 95th percentile range of decadal mean anomalies from the 20th-century simulations with only natural forcings (i.e., a measure of the natural decadal variability). For the observed part of these graphs, the decadal averages are centred on calendar decade boundaries (i.e., the last point is at 2000 for 1996 to 2005), whereas for the future period they are centred on calendar decade mid-points (i.e., the first point is at 2005 for 2001 to 2010). To construct the ranges, all simulations from the set of models involved were considered independent realisations of the possible evolution of the climate given the forcings applied. This involved 58 simulations from 14 models for the red curve, 19 simulations from 5 models (a subset of the 14) for the blue curve and green bar and 47 simulations from 18 models for the yellow curve. {FAQ 9.2.1, Figure 1 and Box 11.1, Figure 1}*

In the NH a robust pattern of increased subpolar and decreased subtropical precipitation dominates the projected precipitation pattern for the 21st century over North America and Europe, while subtropical drying is less evident over Asia (see Figure TS.30). Nearly all models project increased precipitation over most of northern North America and decreased precipitation over Central America, with much of the continental USA and northern Mexico in a more uncertain transition zone that moves north and south following the seasons. Decreased precipitation is confidently projected for southern Europe and Mediterranean Africa, with a transition to increased precipitation in northern Europe. In both continents, summer drying is extensive due both to the poleward movement of this transition zone in summer and to increased evaporation. Subpolar increases in precipitation are projected over much of northern Asia but with the subtropical drying spreading from the Mediterranean displaced by distinctive monsoonal signatures as one moves from central Asia eastward. {11.2–11.5}

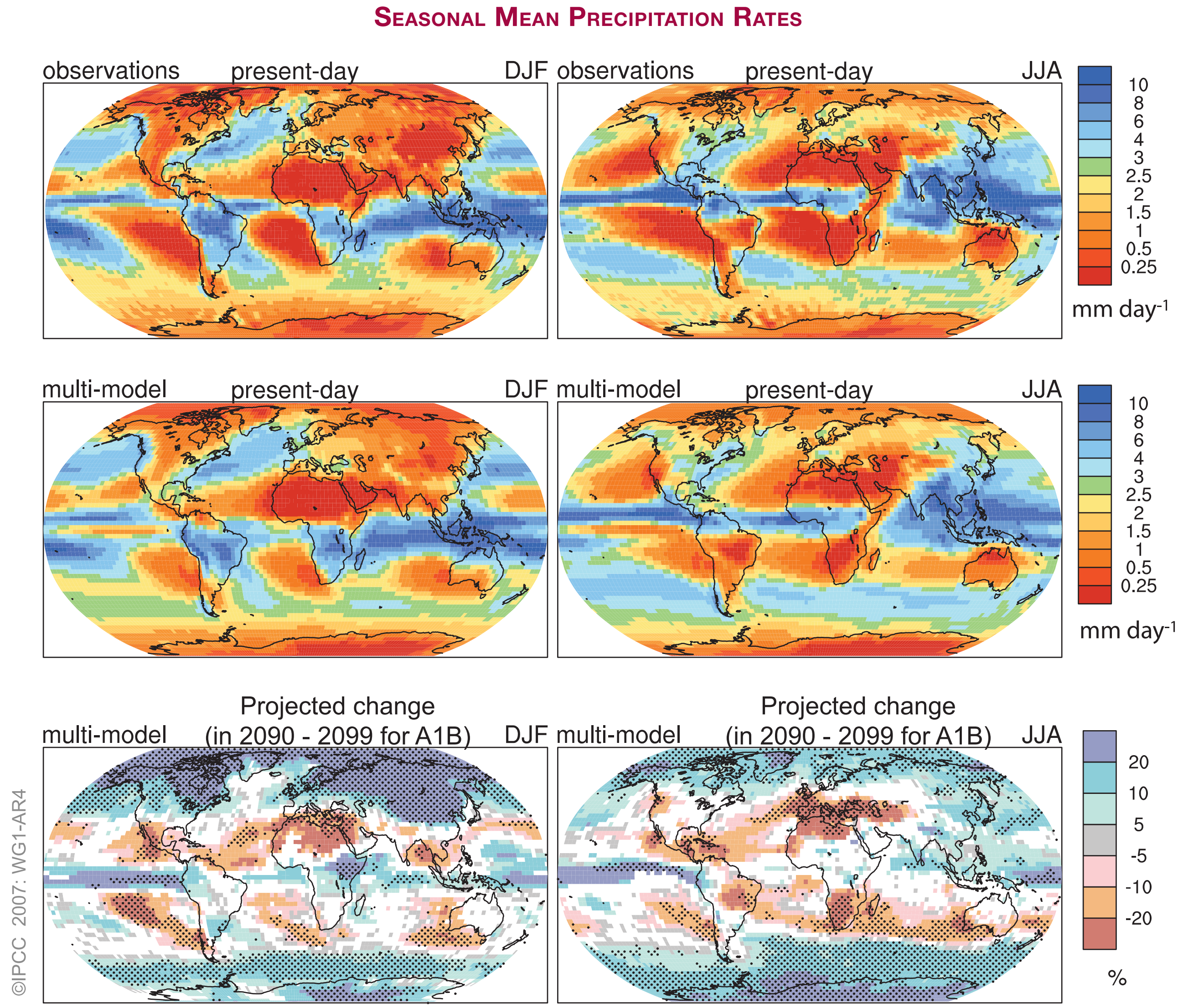


Figure TS.30. *Spatial patterns of observed (top row) and multi-model mean (middle row) seasonal mean precipitation rate (mm day^{-1}) for the period 1979 to 1993 and the multi-model mean for changes by the period 2090 to 2099 relative to 1980 to 1999 (% change) based on the SRES A1B scenario (bottom row). December to February means are in the left column, June to August means in the right column. In the bottom panel, changes are plotted only where more than 66% of the models agree on the sign of the change. The stippling indicates areas where more than 90% of the models agree on the sign of the change. {Based on same datasets as shown in Figures 8.5 and 10.9}*

In the SH, there are few land areas in the zone of projected subpolar moistening during the 21st century, with the subtropical drying more prominent (see Figure TS.30). The South Island of New Zealand and Tierra del Fuego fall within the subpolar precipitation increase zone, with southernmost Africa, the southern Andes in South America and southern Australia experiencing the drying tendency typical of the subtropics. {11.2, 11.6, 11.7}

Projections of precipitation over tropical land regions are more uncertain than those at higher latitudes, but, despite significant inadequacies in modelling tropical convection and atmosphere-ocean interactions, and the added uncertainty associated with tropical cyclones, some robust features emerge in models. Rainfall in the summer monsoon season of South and Southeast Asia increases in most models, as does rainfall in East Africa. The sign of the precipitation response is considered less certain over both the Amazon and the African Sahel. These are regions in which there is added uncertainty due to potential vegetation-climate links, and there is less robustness across models even when vegetation feedbacks are not included. {8.3, 11.2, 11.4, 11.6}

TS.5.4 Coupling Between Climate Change and Changes in Biogeochemical Cycles

All models that treat the coupling of the carbon cycle to climate change indicate a positive feedback effect with warming acting to suppress land and ocean uptake of CO_2, leading to larger atmospheric CO_2 increases and greater climate change for a given emissions scenario, but the strength of this feedback effect varies markedly among models. Since the TAR, several new projections based on fully coupled carbon cycle-climate models have been performed and compared. For the SRES A2 scenario, and based on a range of model results, the projected increase in atmospheric CO_2 concentration over the 21st century is *likely* between 10 and 25% higher than projections without this feedback, adding more than 1°C to projected mean warming by 2100 for higher emission SRES scenarios. Correspondingly, the reduced CO_2 uptake caused by this effect reduces the CO_2 emissions that are consistent with a target stabilisation level. However, there are still significant uncertainties due, for example, to limitations in the understanding of the dynamics of land ecosystems and soils. {7.3, 10.4}

Increasing atmospheric CO_2 concentrations lead directly to increasing acidification of the surface ocean. Projections based on SRES scenarios give reductions in pH of between 0.14 and 0.35 units in the 21st century (depending on scenario), extending the present decrease of 0.1 units from pre-industrial times. Ocean acidification would lead to dissolution of shallow-water carbonate sediments. Southern Ocean surface waters are projected to exhibit undersaturation with regard to calcium carbonate ($CaCO_3$) for CO_2 concentrations higher than 600 ppm, a level exceeded during the second half of the 21st century in most of the SRES scenarios. Low-latitude regions and the deep ocean will be affected as well. These changes could affect marine organisms that form their exoskeletons out of $CaCO_3$, but the net effect on the biological cycling of carbon in the oceans is not well understood. {Box 7.3, 10.4}

Committed climate change due to past emissions varies considerably for different forcing agents because of differing lifetimes in the Earth's atmosphere (see Box TS.9). The committed climate change due to past emissions takes account of both (i) the time lags in the responses of the climate system to changes in radiative forcing; and (ii) the time scales over which different forcing agents persist in the atmosphere after their emission because of their differing lifetimes. Typically the committed climate change due to past emissions includes an initial period of further increase in temperature, for the reasons discussed above, followed by a long-term decrease as radiative forcing decreases. Some greenhouse gases have relatively short atmospheric lifetimes (decades or less), such as CH_4 and carbon monoxide, while others such as N_2O have lifetimes of the order of a century, and some have lifetimes of millennia, such as SF_6 and PFCs. Atmospheric concentrations of CO_2 do not decay with a single well-defined lifetime if emissions are stopped. Removal of CO_2 emitted to the atmosphere occurs over multiple time scales, but some CO_2 will stay in the atmosphere for many thousands of years, so that emissions lead to a very long commitment to climate change. The slow long-term buffering of the ocean, including $CaCO_3$-sediment feedback, requires 30,000 to 35,000 years for atmospheric CO_2 concentrations to reach equilibrium. Using coupled carbon cycle components, EMICs show that the committed climate change due to past CO_2 emissions persists for more than 1000 years, so that even over these very long time scales, temperature and sea level do not return to pre-industrial values. An indication of the long time scales of committed climate change is obtained by prescribing anthropogenic CO_2 emissions following a path towards stabilisation at 750 ppm, but arbitrarily setting emissions to zero at year 2100. In this test case, it takes about 100 to 400 years in the different models for the atmospheric CO_2 concentration to drop from the maximum (ranges between 650 to 700 ppm) to below the level of two times the pre-industrial CO_2 concentration (about 560 ppm), owing to a continuous but slow transfer of carbon from the atmosphere and terrestrial reservoirs to the ocean (see Figure TS.31). {7.3, 10.7}

Future concentrations of many non-CO_2 greenhouse gases and their precursors are expected to be coupled to future climate change. Insufficient understanding of the causes of recent variations in the CH_4 growth rate suggests large uncertainties in future projections for this gas in particular. Emissions of CH_4 from wetlands are *likely* to increase in a warmer and wetter climate and to decrease in a warmer and drier climate. Observations also suggest increases in CH_4 released from northern peatlands that are experiencing permafrost melt, although the large-scale magnitude of this effect is not well quantified. Changes in temperature, humidity and clouds could also affect biogenic emissions of ozone precursors, such as volatile organic compounds. Climate change is also expected to affect tropospheric ozone through changes in chemistry and transport. Climate change could induce changes in OH through changes in humidity, and could alter stratospheric ozone concentrations and hence solar ultraviolet radiation in the troposphere. {7.4, 4.7}

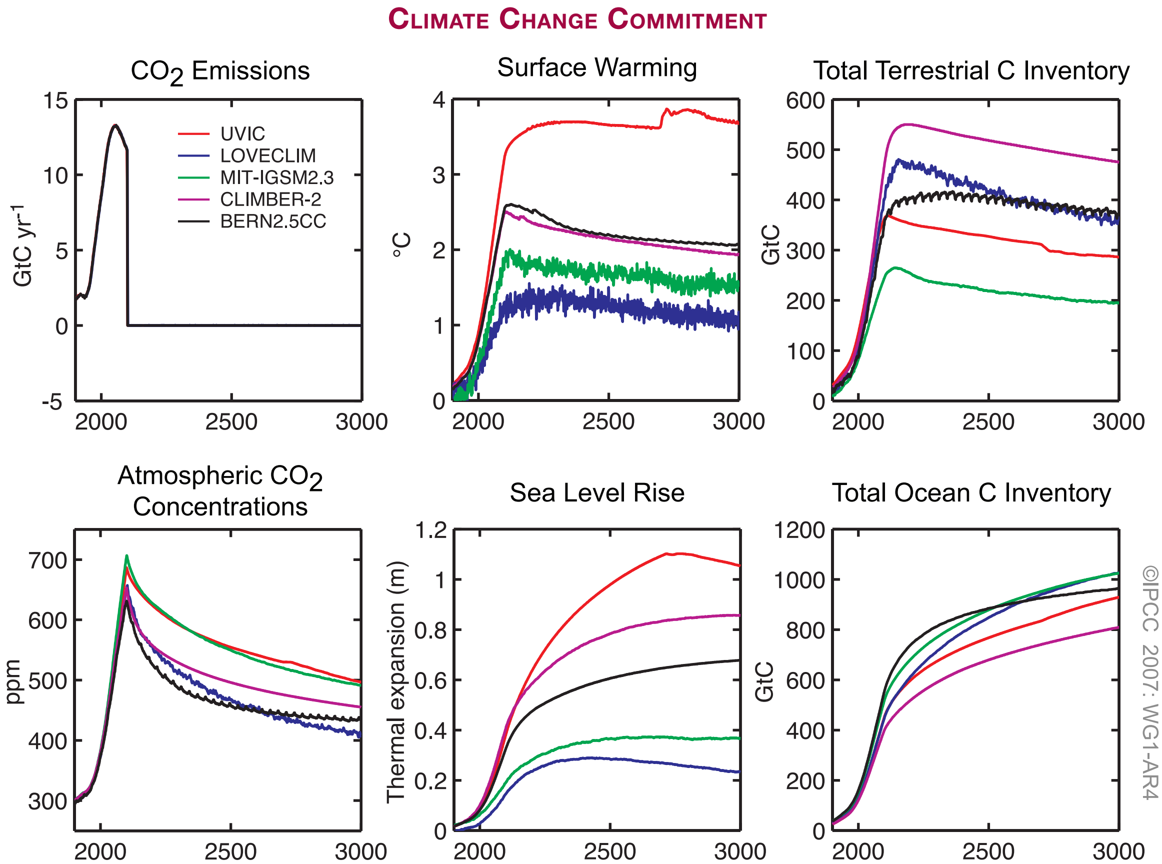


Figure TS.31. *Calculation of climate change commitment due to past emissions for five different EMICs and an idealised scenario where emissions follow a pathway leading to stabilisation of atmospheric CO_2 at 750 ppm, but before reaching this target, emissions are reduced to zero instantly at year 2100. (Left) CO_2 emissions and atmospheric CO_2 concentrations; (centre) surface warming and sea level rise due to thermal expansion; (right) change in total terrestrial and oceanic carbon inventory since the pre-industrial era. {Figure 10.35}*

Future emissions of many aerosols and their precursors are expected to be affected by climate change. Estimates of future changes in dust emissions under several climate and land use scenarios suggest that the effects of climate change are more important in controlling future dust emissions than changes in land use. Results from one study suggest that meteorology and climate have a greater influence on future Asian dust emissions and associated Asian dust storm occurrences than desertification. The biogenic emission of volatile organic compounds, a significant source of secondary organic aerosols, is known to be highly sensitive to (and increase with) temperature. However, aerosol yields decrease with temperature and the effects of changing precipitation and physiological adaptation are uncertain. Thus, change in biogenic secondary organic aerosol production in a warmer climate could be considerably lower than the response of biogenic volatile organic carbon emissions. Climate change may affect fluxes from the ocean of dimethyl sulphide (which is a precursor for some sulphate aerosols) and sea salt aerosols, however, the effects on temperature and precipitation remain very uncertain. {7.5}

While the warming effect of CO_2 represents a commitment over many centuries, aerosols are removed from the atmosphere over time scales of only a few days, so that the negative radiative forcing due to aerosols could change rapidly in response to any changes in emissions of aerosols or aerosol precursors. Because sulphate aerosols are *very likely* exerting a substantial negative radiative forcing at present, future net forcing is very sensitive to changes in sulphate emissions. One study suggests that the hypothetical removal from the atmosphere of the entire current burden of anthropogenic sulphate aerosol particles would produce a rapid increase in global mean temperature of about 0.8°C within a decade or two. Changes in aerosols are also likely to influence precipitation. Thus, the effect of environmental strategies aimed at mitigating climate change requires consideration of changes in both greenhouse gas and aerosol emissions.

Changes in aerosol emissions may result from measures implemented to improve air quality which may therefore have consequences for climate change. {Box 7.4, 7.6, 10.7}

Climate change would modify a number of chemical and physical processes that control air quality and the net effects are *likely* to vary from one region to another. Climate change can affect air quality by modifying the rates at which pollutants are dispersed, the rate at which aerosols and soluble species are removed from the atmosphere, the general chemical environment for pollutant generation and the strength of emissions from the biosphere, fires and dust. Climate change is also expected to decrease the global ozone background. Overall, the net effect of climate change on air quality is highly uncertain. {Box 7.4}

TS.5.5 Implications of Climate Processes and their Time Scales for Long-Term Projections

The commitments to climate change after stabilisation of radiative forcing are expected to be about 0.5 to 0.6°C, mostly within the following century. The multi-model average when stabilising concentrations of greenhouse gases and aerosols at year 2000 values after a 20th-century climate simulation, and running an additional 100 years, is about 0.6°C of warming (relative to 1980–1999) at year 2100 (see Figure TS.32). If the B1 or A1B scenarios were to characterise 21st-century emissions followed by stabilisation at those levels, the additional warming after stabilisation is similar, about 0.5°C, mostly in the subsequent hundred years. {10.3, 10.7}

The magnitude of the positive feedback between climate change and the carbon cycle is uncertain. This leads to uncertainty in the trajectory of CO_2 emissions required to achieve a particular stabilization level of atmospheric CO_2 concentration. Based upon current understanding of climate-carbon cycle feedback, model studies suggest that, in order to stabilise CO_2 at 450 ppm, cumulative emissions in the 21st century could be reduced from a model average of approximately 670 [630 to 710] GtC to approximately 490 [375 to 600] GtC. Similarly, to stabilise CO_2 at 1000 ppm, the cumulative emissions could be reduced by this feedback from a model average of

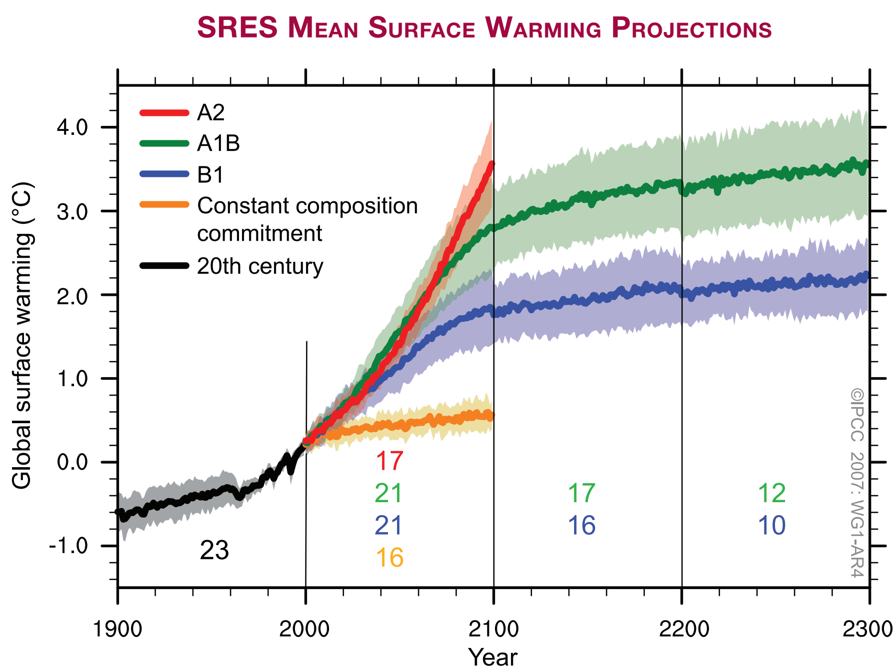


Figure TS.32. *Multi-model means of surface warming (compared to the 1980–1999 base period) for the SRES scenarios A2 (red), A1B (green) and B1 (blue), shown as continuations of the 20th-century simulation. The latter two scenarios are continued beyond the year 2100 with forcing kept constant (committed climate change as it is defined in Box TS.9). An additional experiment, in which the forcing is kept at the year 2000 level is also shown (orange). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi-model means, shading denotes the ±1 standard deviation range. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario (numbers indicated in figure). For the same reason, uncertainty across scenarios should not be interpreted from this figure (see Section 10.5 for uncertainty estimates). {Figure 10.4}* approximately 1415 [1340 to 1490] GtC to approximately 1100 [980 to 1250] GtC. {7.3, 10.4}

If radiative forcing were to be stabilised in 2100 at A1B concentrations, thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999) and would continue at decreasing rates for many centuries, due to slow processes that mix heat into the deep ocean. {10.7}

Contraction of the Greenland Ice Sheet is projected to continue to contribute to sea level rise after 2100. For stabilisation at A1B concentrations in 2100, a rate of 0.03 to 0.21 m per century due to thermal expansion is projected. If a global average warming of 1.9°C to 4.6°C relative to pre-industrial temperatures were maintained for millennia, the Greenland Ice Sheet would largely be eliminated except for remnant glaciers in the mountains. This would raise sea level by about 7 m and could be irreversible. These temperatures are comparable to those inferred for the last interglacial period 125,000 years ago, when palaeoclimatic information suggests reductions of polar ice extent and 4 to 6 m of sea level rise. {6.4, 10.7}

Dynamical processes not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their likely magnitude. {4.6, 10.7}

Current global model studies project that the Antarctic Ice Sheet will remain too cold for widespread surface melting and will gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. {10.7}

While no models run for this assessment suggest an abrupt MOC shutdown during the 21st century, some models of reduced complexity suggest MOC shutdown as a possible long-term response to sufficiently strong warming. However, the likelihood of this occurring cannot be evaluated with confidence. The few available simulations with models of different complexity rather suggest a centennial-scale slowdown. Recovery of the MOC is *likely* if the radiative forcing is stabilised but would take several centuries. Systematic model comparison studies have helped establish some key processes that are responsible for variations between models in the response of the ocean to climate change (especially ocean heat uptake). {8.7, FAQ 10.2, 10.3}

TS.6 Robust Findings and Key Uncertainties

TS.6.1 Changes in Human and Natural Drivers of Climate

Robust Findings:

Current atmospheric concentrations of CO_2 and CH_4, and their associated positive radiative forcing, far exceed those determined from ice core measurements spanning the last 650,000 years. {6.4}

Fossil fuel use, agriculture and land use have been the dominant cause of increases in greenhouse gases over the last 250 years. {2.3, 7.3, 7.4}

Annual emissions of CO_2 from fossil fuel burning, cement production and gas flaring increased from a mean of 6.4 ± 0.4 GtC yr^{-1} in the 1990s to 7.2 ± 0.3 GtC yr^{-1} for 2000 to 2005. {7.3}

The sustained rate of increase in radiative forcing from CO_2, CH_4 and N_2O over the past 40 years is larger than at any time during at least the past 2000 years. {6.4}

Natural processes of CO_2 uptake by the oceans and terrestrial biosphere remove about 50 to 60% of anthropogenic emissions (i.e., fossil CO_2 emissions and land use change flux). Uptake by the oceans and the terrestrial biosphere are similar in magnitude over recent decades but that by the terrestrial biosphere is more variable. {7.3}

It is *virtually certain* that anthropogenic aerosols produce a net negative radiative forcing (cooling influence) with a greater magnitude in the NH than in the SH. {2.9, 9.2}

From new estimates of the combined anthropogenic forcing due to greenhouse gases, aerosols and land surface changes, it is *extremely likely* that human activities have exerted a substantial net warming influence on climate since 1750. {2.9}

Solar irradiance contributions to global average radiative forcing are considerably smaller than the contribution of increases in greenhouse gases over the industrial period. {2.5, 2.7}

Key Uncertainties:

The full range of processes leading to modification of cloud properties by aerosols is not well understood and the magnitudes of associated indirect radiative effects are poorly determined. {2.4, 7.5}

The causes of, and radiative forcing due to stratospheric water vapour changes are not well quantified. {2.3}

The geographical distribution and time evolution of the radiative forcing due to changes in aerosols during the 20th century are not well characterised. {2.4}

The causes of recent changes in the growth rate of atmospheric CH_4 are not well understood. {7.4}

The roles of different factors increasing tropospheric ozone concentrations since pre-industrial times are not well characterised. {2.3}

Land surface properties and land-atmosphere interactions that lead to radiative forcing are not well quantified. {2.5}

Knowledge of the contribution of past solar changes to radiative forcing on the time scale of centuries is not based upon direct measurements and is hence strongly dependent upon physical understanding. {2.7}

TS.6.2 Observations of Changes in Climate

TS.6.2.1 Atmosphere and Surface

Robust Findings:

Global mean surface temperatures continue to rise. Eleven of the last 12 years rank among the 12 warmest years on record since 1850. {3.2}

Rates of surface warming increased in the mid-1970s and the global land surface has been warming at about double the rate of ocean surface warming since then. {3.2}

Changes in surface temperature extremes are consistent with warming of the climate. {3.8}

Estimates of mid- and lower-tropospheric temperature trends have substantially improved. Lower-tropospheric temperatures have slightly greater warming rates than the surface from 1958 to 2005. {3.4}

Long-term trends from 1900 to 2005 have been observed in precipitation amount in many large regions. {3.3}

Increases have occurred in the number of heavy precipitation events. {3.8}

Droughts have become more common, especially in the tropics and subtropics, since the 1970s. {3.3}

Tropospheric water vapour has increased, at least since the 1980s. {3.4}

Key Uncertainties:

Radiosonde records are much less complete spatially than surface records and evidence suggests a number of radiosonde records are unreliable, especially in the tropics. It is likely that all records of tropospheric temperature trends still contain residual errors. {3.4}

While changes in large-scale atmospheric circulation are apparent, the quality of analyses is best only after 1979, making analysis of, and discrimination between, change and variability difficult. {3.5, 3.6}

Surface and satellite observations disagree on total and low-level cloud changes over the ocean. {3.4}

Multi-decadal changes in DTR are not well understood, in part because of limited observations of changes in cloudiness and aerosols. {3.2}

Difficulties in the measurement of precipitation remain an area of concern in quantifying trends in global and regional precipitation. {3.3}

Records of soil moisture and streamflow are often very short, and are available for only a few regions, which impedes complete analyses of changes in droughts. {3.3}

The availability of observational data restricts the types of extremes that can be analysed. The rarer the event, the more difficult it is to identify long-term changes because there are fewer cases available. {3.8}

Information on hurricane frequency and intensity is limited prior to the satellite era. There are questions about the interpretation of the satellite record. {3.8}

There is insufficient evidence to determine whether trends exist in tornadoes, hail, lightning and dust storms at small spatial scales. {3.8}

TS.6.2.2 Snow, Ice and Frozen Ground

Robust Findings:

The amount of ice on the Earth is decreasing. There has been widespread retreat of mountain glaciers since the end of the 19th century. The rate of mass loss from glaciers and the Greenland Ice Sheet is increasing. {4.5, 4.6}

The extent of NH snow cover has declined. Seasonal river and lake ice duration has decreased over the past 150 years. {4.2, 4.3}

Since 1978, annual mean arctic sea ice extent has been declining and summer minimum arctic ice extent has decreased. {4.4}

Ice thinning occurred in the Antarctic Peninsula and Amundsen shelf ice during the 1990s. Tributary glaciers have accelerated and complete breakup of the Larsen B Ice Shelf occurred in 2002. {4.6}

Temperature at the top of the permafrost layer has increased by up to 3°C since the 1980s in the Arctic. The maximum extent of seasonally frozen ground has decreased by about 7% in the NH since 1900, and its maximum depth has decreased by about 0.3 m in Eurasia since the mid-20th century. {4.7}

Key Uncertainties:

There is no global compilation of *in situ* snow data prior to 1960. Well-calibrated snow water equivalent data are not available for the satellite era. {4.2}

There are insufficient data to draw any conclusions about trends in the thickness of antarctic sea ice. {4.4}

Uncertainties in estimates of glacier mass loss arise from limited global inventory data, incomplete area-volume relationships and imbalance in geographic coverage. {4.5}

Mass balance estimates for ice shelves and ice sheets, especially for Antarctica, are limited by calibration and validation of changes detected by satellite altimetry and gravity measurements. {4.6}

Limited knowledge of basal processes and of ice shelf dynamics leads to large uncertainties in the understanding of ice flow processes and ice sheet stability. {4.6}

TS.6.2.3 Oceans and Sea Level

Robust Findings:

The global temperature (or heat content) of the oceans has increased since 1955. {5.2}

Large-scale regionally coherent trends in salinity have been observed over recent decades with freshening in subpolar regions and increased salinity in the shallower parts of the tropics and subtropics. These trends are consistent with changes in precipitation and inferred larger water transport in the atmosphere from low latitudes to high latitudes and from the Atlantic to the Pacific. {5.2}

Global average sea level rose during the 20th century. There is high confidence that the rate of sea level rise increased between the mid-19th and mid-20th centuries. During 1993 to 2003, sea level rose more rapidly than during 1961 to 2003. {5.5}

Thermal expansion of the ocean and loss of mass from glaciers and ice caps made substantial contributions to the observed sea level rise. {5.5}

The observed rate of sea level rise from 1993 to 2003 is consistent with the sum of observed contributions from thermal expansion and loss of land ice. {5.5}

The rate of sea level change over recent decades has not been geographically uniform. {5.5}

As a result of uptake of anthropogenic CO_2 since 1750, the acidity of the surface ocean has increased. {5.4, 7.3}

Key Uncertainties:

Limitations in ocean sampling imply that decadal variability in global heat content, salinity and sea level changes can only be evaluated with moderate confidence. {5.2, 5.5}

There is low confidence in observations of trends in the MOC. {Box 5.1}

Global average sea level rise from 1961 to 2003 appears to be larger than can be explained by thermal expansion and land ice melting. {5.5}

TS.6.2.4 Palaeoclimate

Robust Findings:

During the last interglacial, about 125,000 years ago, global sea level was *likely* 4 to 6 m higher than present, due primarily to retreat of polar ice. {6.4}

A number of past abrupt climate changes were *very likely* linked to changes in Atlantic Ocean circulation and affected the climate broadly across the NH. {6.4}

It is *very unlikely* that the Earth would naturally enter another ice age for at least 30,000 years. {6.4}

Biogeochemical and biogeophysical feedbacks have amplified climatic changes in the past. {6.4}

It is *very likely* that average NH temperatures during the second half of the 20th century were warmer than in any other 50-year period in the last 500 years and *likely* that this was also the warmest 50-year period in the past 1300 years. {6.6}

Palaeoclimate records indicate with high confidence that droughts lasting decades or longer were a recurrent feature of climate in several regions over the last 2000 years. {6.6}

Key Uncertainties:

Mechanisms of onset and evolution of past abrupt climate change and associated climate thresholds are not well understood. This limits confidence in the ability of climate models to simulate realistic abrupt change. {6.4}

The degree to which ice sheets retreated in the past, the rates of such change and the processes involved are not well known. {6.4}

Knowledge of climate variability over more than the last few hundred years in the SH and tropics is limited by the lack of palaeoclimatic records. {6.6}

Differing amplitudes and variability observed in available millennial-length NH temperature reconstructions, as well as the relation of these differences to choice of proxy data and statistical calibration methods, still need to be reconciled. {6.6}

The lack of extensive networks of proxy data for temperature in the last 20 years limits understanding of how such proxies respond to rapid global warming and of the influence of other environmental changes. {6.6}

TS.6.3 Understanding and Attributing Climate Change

Robust Findings:

Greenhouse gas forcing has *very likely* caused most of the observed global warming over the last 50 years. Greenhouse gas forcing alone during the past half century would *likely* have resulted in greater than the observed warming if there had not been an offsetting cooling effect from aerosol and other forcings. {9.4}

It is *extremely unlikely* (<5%) that the global pattern of warming during the past half century can be explained without external forcing, and *very unlikely* that it is due to known natural external causes alone. The warming occurred in both the ocean and the atmosphere and took place at a time when natural external forcing factors would *likely* have produced cooling. {9.4, 9.7}

It is *likely* that anthropogenic forcing has contributed to the general warming observed in the upper several hundred metres of the ocean during the latter half of the 20th century. Anthropogenic forcing, resulting in thermal expansion from ocean warming and glacier mass loss, has *very likely* contributed to sea level rise during the latter half of the 20th century. {9.5}

A substantial fraction of the reconstructed NH inter-decadal temperature variability of the past seven centuries is *very likely* attributable to natural external forcing (volcanic eruptions and solar variability). {9.3}

Key Uncertainties:

Confidence in attributing some climate change phenomena to anthropogenic influences is currently limited by uncertainties in radiative forcing, as well as uncertainties in feedbacks and in observations. {9.4, 9.5}

Attribution at scales smaller than continental and over time scales of less than 50 years is limited by larger climate variability on smaller scales, by uncertainties in the small-scale details of external forcing and the response simulated by models, as well as uncertainties in simulation of internal variability on small scales, including in relation to modes of variability. {9.4}

There is less confidence in understanding of forced changes in precipitation and surface pressure than there is of temperature. {9.5}

The range of attribution statements is limited by the absence of formal detection and attribution studies, or their very limited number, for some phenomena (e.g., some types of extreme events). {9.5}

Incomplete global data sets for extremes analysis and model uncertainties still restrict the regions and types of detection studies of extremes that can be performed. {9.4, 9.5}

Despite improved understanding, uncertainties in model-simulated internal climate variability limit some aspects of attribution studies. For example, there are apparent discrepancies between estimates of ocean heat content variability from models and observations. {5.2, 9.5}

Lack of studies quantifying the contributions of anthropogenic forcing to ocean heat content increase or glacier melting together with the open part of the sea level budget for 1961 to 2003 are among the uncertainties in quantifying the anthropogenic contribution to sea level rise. {9.5}

TS.6.4 Projections of Future Changes in Climate

TS.6.4.1 Model Evaluation

Robust Findings:

Climate models are based on well-established physical principles and have been demonstrated to reproduce observed features of recent climate and past climate changes. There is considerable confidence that AOGCMs provide credible quantitative estimates of future climate change, particularly at continental scales and above. Confidence in these estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). {FAQ 8.1}

Confidence in models has increased due to:

- improvements in the simulation of many aspects of present climate, including important modes of climate variability and extreme hot and cold spells;
- improved model resolution, computational methods and parametrizations and inclusion of additional processes;
- more comprehensive diagnostic tests, including tests of model ability to forecast on time scales from days to a year when initialised with observed conditions; and
- enhanced scrutiny of models and expanded diagnostic analysis of model behaviour facilitated by internationally coordinated efforts to collect and disseminate output from model experiments performed under common conditions. {8.4}

Key Uncertainties:

A proven set of model metrics comparing simulations with observations, that might be used to narrow the range of plausible climate projections, has yet to be developed. {8.2}

Most models continue to have difficulty controlling climate drift, particularly in the deep ocean. This drift must be accounted for when assessing change in many oceanic variables. {8.2}

Models differ considerably in their estimates of the strength of different feedbacks in the climate system. {8.6}

Problems remain in the simulation of some modes of variability, notably the Madden-Julian Oscillation, recurrent atmospheric blocking and extreme precipitation. {8.4}

Systematic biases have been found in most models' simulations of the Southern Ocean that are linked to uncertainty in transient climate response. {8.3}

Climate models remain limited by the spatial resolution that can be achieved with present computer resources, by the need for more extensive ensemble runs and by the need to include some additional processes. {8.1–8.5}

TS.6.4.2 Equilibrium and Transient Climate Sensitivity

Robust Findings:

Equilibrium climate sensitivity is *likely* to be in the range 2°C to 4.5°C with a most likely value of about 3°C, based upon multiple observational and modelling constraints. It is *very unlikely* to be less than 1.5°C. {8.6, 9.6, Box 10.2}

The transient climate response is better constrained than the equilibrium climate sensitivity. It is *very likely* larger than 1°C and *very unlikely* greater than 3°C. {10.5}

There is a good understanding of the origin of differences in equilibrium climate sensitivity found in different models. Cloud feedbacks are the primary source of inter-model differences in equilibrium climate sensitivity, with low cloud being the largest contributor. {8.6}

New observational and modelling evidence strongly supports a combined water vapour-lapse rate feedback of a strength comparable to that found in AOGCMs. {8.6}

Key Uncertainties:

Large uncertainties remain about how clouds might respond to global climate change. {8.6}

TS.6.4.3 Global Projections

Robust Findings:

Even if concentrations of radiative forcing agents were to be stabilised, further committed warming and related climate changes would be expected to occur, largely because of time lags associated with processes in the oceans. {10.7}

Near-term warming projections are little affected by different scenario assumptions or different model sensitivities, and are consistent with that observed for the past few decades. The multi-model mean warming, averaged over 2011 to 2030 relative to 1980 to 1999 for all AOGCMs considered here, lies in a narrow range of 0.64°C to 0.69°C for the three different SRES emission scenarios B1, A1B and A2. {10.3}

Geographic patterns of projected warming show the greatest temperature increases at high northern latitudes and over land, with less warming over the southern oceans and North Atlantic. {10.3}

Changes in precipitation show robust large-scale patterns: precipitation generally increases in the tropical precipitation maxima, decreases in the subtropics and increases at high latitudes as a consequence of a general intensification of the global hydrological cycle. {10.3}

As the climate warms, snow cover and sea ice extent decrease; glaciers and ice caps lose mass and contribute to sea level rise. Sea ice extent decreases in the 21st century in both the Arctic and Antarctic. Snow cover reduction is accelerated in the Arctic by positive feedbacks and widespread increases in thaw depth occur over much of the permafrost regions. {10.3}

Based on current simulations, it is *very likely* that the Atlantic Ocean MOC will slow down by 2100. However, it is *very unlikely* that the MOC will undergo a large abrupt transition during the course of the 21st century. {10.3}

Heat waves become more frequent and longer lasting in a future warmer climate. Decreases in frost days are projected to occur almost everywhere in the mid- and high latitudes, with an increase in growing season length. There is a tendency for summer drying of the mid-continental areas during summer, indicating a greater risk of droughts in those regions. {10.3, FAQ 10.1}

Future warming would tend to reduce the capacity of the Earth system (land and ocean) to absorb anthropogenic CO_2. As a result, an increasingly large fraction of anthropogenic CO_2 would stay in the atmosphere under a warmer climate. This feedback requires reductions in the cumulative emissions consistent with stabilisation at a given atmospheric CO_2 level compared to the hypothetical case of no such feedback. The higher the stabilisation scenario, the larger the amount of climate change and the larger the required reductions. {7.3, 10.4}

Key Uncertainties:

The likelihood of a large abrupt change in the MOC beyond the end of the 21st century cannot yet be assessed reliably. For low and medium emission scenarios with atmospheric greenhouse gas concentrations stabilised beyond 2100, the MOC recovers from initial weakening within one to several centuries. A permanent reduction in the MOC cannot be excluded if the forcing is strong and long enough. {10.7}

The model projections for extremes of precipitation show larger ranges in amplitude and geographical locations than for temperature. {10.3, 11.1}

The response of some major modes of climate variability such as ENSO still differs from model to model, which may be associated with differences in the spatial and temporal representation of present-day conditions. {10.3}

The robustness of many model responses of tropical cyclones to climate change is still limited by the resolution of typical climate models. {10.3}

Changes in key processes that drive some global and regional climate changes are poorly known (e.g., ENSO, NAO, blocking, MOC, land surface feedbacks, tropical cyclone distribution). {11.2–11.9}

The magnitude of future carbon cycle feedbacks is still poorly determined. {7.3, 10.4}

TS.6.4.4 Sea Level

Robust Findings:

Sea level will continue to rise in the 21st century because of thermal expansion and loss of land ice. Sea level rise was not geographically uniform in the past and will not be in the future. {10.6}

Projected warming due to emission of greenhouse gases during the 21st century will continue to contribute to sea level rise for many centuries. {10.7}

Sea level rise due to thermal expansion and loss of mass from ice sheets would continue for centuries or millennia even if radiative forcing were to be stabilised. {10.7}

Key Uncertainties:

Models do not yet exist that address key processes that could contribute to large rapid dynamical changes in the Antarctic and Greenland Ice Sheets that could increase the discharge of ice into the ocean. {10.6}

The sensitivity of ice sheet surface mass balance (melting and precipitation) to global climate change is not well constrained by observations and has a large spread in models. There is consequently a large uncertainty in the magnitude of global warming that, if sustained, would lead to the elimination of the Greenland Ice Sheet. {10.7}

TS.6.4.5 Regional Projections

Robust Findings:

Temperatures averaged over all habitable continents and over many sub-continental land regions will *very likely* rise at greater than the global average rate in the next 50 years and by an amount substantially in excess of natural variability. {10.3, 11.2–11.9}

Precipitation is *likely* to increase in most subpolar and polar regions. The increase is considered especially robust, and *very likely* to occur, in annual precipitation in most of northern Europe, Canada, the northeast USA and the Arctic, and in winter precipitation in northern Asia and the Tibetan Plateau. {11.2–11.9}

Precipitation is *likely* to decrease in many subtropical regions, especially at the poleward margins of the subtropics. The decrease is considered especially robust, and *very likely* to occur, in annual precipitation in European and African regions bordering the Mediterranean and in winter rainfall in south-western Australia. {11.2–11.9}

Extremes of daily precipitation are *likely* to increase in many regions. The increase is considered as *very likely* in northern Europe, south Asia, East Asia, Australia and New Zealand – this list in part reflecting uneven geographic coverage in existing published research. {11.2–11.9}

Key Uncertainties:

In some regions there has been only very limited study of key aspects of regional climate change, particularly with regard to extreme events. {11.2–11.9}

Atmosphere-Ocean General Circulation Models show no consistency in simulated regional precipitation change in some key regions (e.g., northern South America, northern Australia and the Sahel). {10.3, 11.2–11.9}

In many regions where fine spatial scales in climate are generated by topography, there is insufficient information on how climate change will be expressed at these scales. {11.2–11.9}

Climate Change 2007: Synthesis Report

Summary for Policymakers

An Assessment of the Intergovernmental Panel on Climate Change

This summary, approved in detail at IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007), represents the formally agreed statement of the IPCC concerning key findings and uncertainties contained in the Working Group contributions to the Fourth Assessment Report.

Based on a draft prepared by:

Lenny Bernstein, Peter Bosch, Osvaldo Canziani, Zhenlin Chen, Renate Christ, Ogunlade Davidson, William Hare, Saleemul Huq, David Karoly, Vladimir Kattsov, Zbigniew Kundzewicz, Jian Liu, Ulrike Lohmann, Martin Manning, Taroh Matsuno, Bettina Menne, Bert Metz, Monirul Mirza, Neville Nicholls, Leonard Nurse, Rajendra Pachauri, Jean Palutikof, Martin Parry, Dahe Qin, Nijavalli Ravindranath, Andy Reisinger, Jiawen Ren, Keywan Riahi, Cynthia Rosenzweig, Matilde Rusticucci, Stephen Schneider, Youba Sokona, Susan Solomon, Peter Stott, Ronald Stouffer, Taishi Sugiyama, Rob Swart, Dennis Tirpak, Coleen Vogel, Gary Yohe

2. Causes of change

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system. *{2.2}*

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004 (Figure SPM.3).[5] *{2.1}*

Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000. *{2.1}*

Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. *{2.2}*

Atmospheric concentrations of CO_2 (379ppm) and CH_4 (1774ppb) in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is *very likely* that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. CH_4 growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. The increase in N_2O concentration is primarily due to agriculture. *{2.2}*

There is *very high confidence* that the net effect of human activities since 1750 has been one of warming.[6] *{2.2}*

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations.[7] It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica) (Figure SPM.4). *{2.4}*

During the past 50 years, the sum of solar and volcanic forcings would *likely* have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcings. Difficulties remain in simulating and attributing observed temperature changes at smaller than continental scales. *{2.4}*

Global anthropogenic GHG emissions

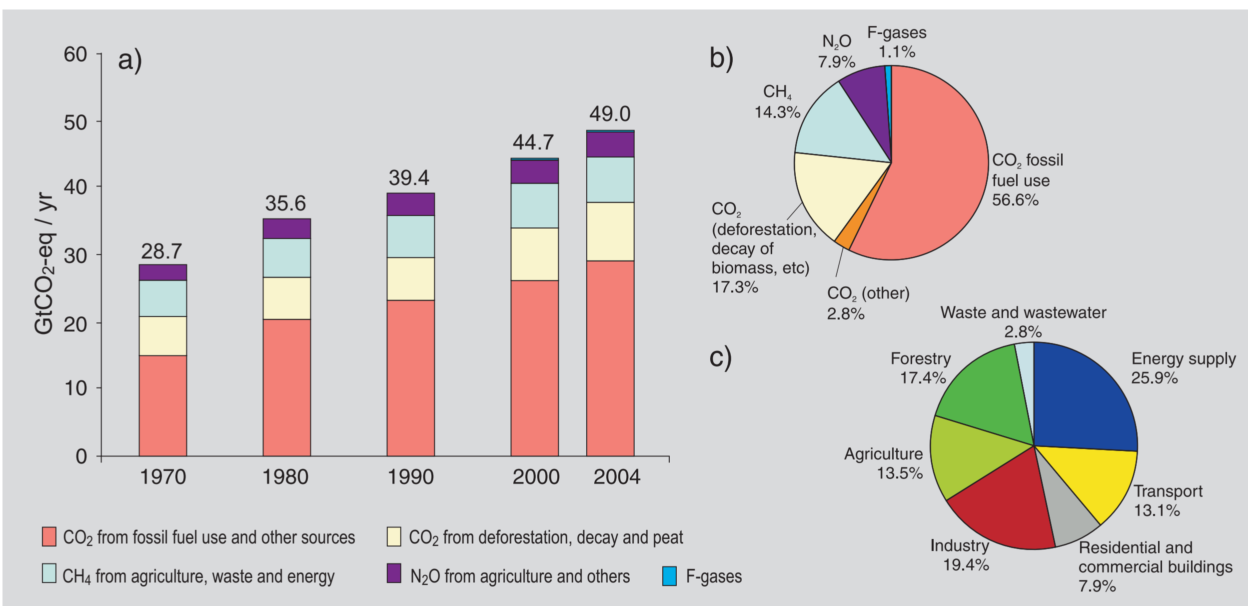


Figure SPM.3. *(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.[5] (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of carbon dioxide equivalents (CO_2-eq). (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (Forestry includes deforestation.) {Figure 2.1}*

[5] Includes only carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphurhexafluoride (SF_6), whose emissions are covered by the United Nations Framework Convention on Climate Change (UNFCCC). These GHGs are weighted by their 100-year Global Warming Potentials, using values consistent with reporting under the UNFCCC.

[6] Increases in GHGs tend to warm the surface while the net effect of increases in aerosols tends to cool it. The net effect due to human activities since the pre-industrial era is one of warming (+1.6 [+0.6 to +2.4] W/m^2). In comparison, changes in solar irradiance are estimated to have caused a small warming effect (+0.12 [+0.06 to +0.30] W/m^2).

[7] Consideration of remaining uncertainty is based on current methodologies.

Appendix A. Construction Emissions

TABLES

☑	0.0	0.0	Other General Industrial	238.00	0.510	8.0	avg
☑	0.0	0.0	Other Material Handling	191.00	0.590	8.0	avg
☑	0.0	0.0	Pavers	100.00	0.620	8.0	avg
☑	0.0	0.0	Paving Equipment	104.00	0.530	8.0	avg
☑	0.0	0.0	Plate Compactors	8.00	0.430	8.0	avg
☑	0.0	0.0	Pressure Washers	1.00	0.600	8.0	avg
☑	0.0	0.0	Pumps	53.00	0.740	8.0	avg
☑	0.0	0.0	Rollers	95.00	0.560	8.0	avg
☑	0.0	0.0	Rough Terrain Forklifts	93.00	0.600	8.0	avg
☑	0.0	0.0	Rubber Tired Loaders	164.00	0.540	8.0	avg
☑	0.0	0.0	Scrapers	313.00	0.720	8.0	avg
☑	0.0	0.0	Signal Boards	15.00	0.780	8.0	avg
☑	0.0	0.0	Skid Steer Loaders	44.00	0.550	8.0	avg
☑	0.0	0.0	Surfacing Eqipment	362.00	0.450	8.0	avg
☑	0.0	0.0	Sweepers/Scrubbers	91.00	0.680	8.0	avg
☑	0.0	0.0	Trenchers	63.00	0.750	8.0	avg
☑	0.0	0.0	Welders	45.00	0.450	8.0	avg
☑	1.0	1.0	Graders	174.00	0.610	6.0	avg
☑	1.0	1.0	Rubber Tired Dozers	357.00	0.590	6.0	avg
☑	1.0	1.0	Tractors/Loaders/Backhoes	108.00	0.550	7.0	avg
☑	1.0	1.0	Water Trucks	189.00	0.500	8.0	avg

For each piece of equipment selected, URBEMIS generates an emission estimate. The emission equation used by URBEMIS for each piece of equipment is as follows:

Equipment Emissions (pounds/day) = # of pieces of equipment * grams per brake horsepower-hour * equipment horsepower * hours/day * load factor

Where: ***grams per brake-horsepower hour is based on the construction year and represents a statewide average for each piece of equipment. Grams per brake horsepower per hour emissions are based on the California Air Resources Board's OFFROAD2007 model (California Air Resources Board, 2006). The pounds per day emission factors are found in Appendix I.***

Demolition Worker Commute Trips

Demolition worker commute trips assume that the number of workers equals 125% of the total pieces of construction equipment selected. The emission estimates assume a construction worker commute fleet mix of 50% light duty autos and 50% light duty trucks. The worker commute travel distance, speed, and temperature are based on the worker commute speed information included in the Operational Trip Characteristics screen.

2005		g/hp/hr	g/hp/hr	g/hp/hr	g/hp/hr	g/hp/hr	g/hp/hr
Equipment	**MaxHP**	ROG	CO	NOX	SOX	PM	CO2
	1000	0.542	2.580	5.471	0.034	0.195	364.039
Crushing/Proc. Equipment	50	2.742	6.051	4.979	0.052	0.619	443.672
	120	1.144	3.276	6.553	0.047	0.601	443.672
	175	0.751	2.615	5.987	0.045	0.331	443.672
	250	0.518	1.434	5.633	0.045	0.205	443.672
	500	0.458	1.800	5.047	0.039	0.184	443.672
	750	0.462	1.726	5.167	0.041	0.184	443.672
	9999	0.573	2.193	6.122	0.041	0.200	443.672
Dumpers/Tenders	25	0.440	1.175	2.094	0.025	0.152	216.148
Excavators	25	0.419	1.342	2.812	0.037	0.179	324.222
	50	2.114	4.737	3.670	0.038	0.477	324.222
	120	0.844	2.453	4.727	0.034	0.463	324.222
	175	0.555	1.960	4.314	0.033	0.251	324.222
	250	0.378	1.010	4.072	0.033	0.146	324.222
	500	0.337	1.149	3.550	0.029	0.132	324.222
	750	0.342	1.148	3.661	0.030	0.134	324.222
Forklifts	50	1.162	2.554	1.949	0.020	0.258	170.643
	120	0.457	1.292	2.483	0.018	0.253	170.643
	175	0.303	1.022	2.286	0.017	0.137	170.643
	250	0.184	0.466	2.118	0.017	0.069	170.643
	500	0.164	0.480	1.852	0.015	0.063	170.643
Generator Sets	15	0.852	3.183	5.429	0.059	0.359	420.920
	25	0.875	2.799	4.364	0.048	0.311	420.920
	50	1.841	4.286	4.445	0.049	0.461	420.920
	120	0.923	2.822	5.727	0.045	0.454	420.920
	175	0.602	2.255	5.233	0.043	0.250	420.920
	250	0.417	1.249	4.929	0.043	0.159	420.920
	500	0.374	1.504	4.535	0.037	0.147	420.920
	750	0.386	1.504	4.640	0.038	0.149	420.920
	9999	0.503	1.876	5.458	0.038	0.180	420.920
Graders	50	2.312	5.089	3.970	0.041	0.514	346.974
	120	0.934	2.653	5.299	0.037	0.498	346.974
	175	0.615	2.129	4.834	0.035	0.275	346.974
	250	0.449	1.244	4.599	0.035	0.179	346.974
	500	0.398	1.610	4.086	0.031	0.160	346.974
	750	0.403	1.608	4.185	0.032	0.162	346.974
Off-Highway Tractors	120	1.163	3.084	6.557	0.039	0.590	369.727
	175	0.781	2.535	5.981	0.038	0.345	369.727
	250	0.638	1.817	5.777	0.038	0.263	369.727
	750	0.568	3.043	5.323	0.034	0.231	369.727
	1000	0.608	3.279	5.887	0.034	0.224	369.727
Off-Highway Trucks	175	0.579	2.004	4.418	0.033	0.261	324.222
	250	0.401	1.057	4.176	0.033	0.154	324.222
	500	0.361	1.220	3.644	0.029	0.139	324.222
	750	0.364	1.219	3.754	0.030	0.141	324.222
	1000	0.416	1.472	4.502	0.030	0.145	324.222
Other Construction Equipment	15	0.447	2.153	2.945	0.050	0.211	352.662

The Costs and Financial Benefits of Green Buildings

A Report to California's
Sustainable Building Task Force

October 2003

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This report was developed for the Sustainable Building Task Force, a group of over 40 California state government agencies. Funding for this study was provided by the Air Resources Board (ARB), California Integrated Waste Management Board CIWMB), Department of Finance (DOF), Department of General Services (DGS), Department of Transportation (Caltrans), Department of Water Resources (DWR), and Division of the State Architect (DSA). This collaborative effort was made possible through the contributions of Capital E, Future Resources Associates, Task Force members, and the United States Green Building Council.

October 3, 2003

Dear Colleagues,

This study, *The Costs and Financial Benefits of Green Building,* represents the most definitive cost benefit analysis of green building ever conducted. It demonstrates conclusively that sustainable building is a cost-effective investment, and its findings should encourage communities across the country to "build green."

In August 2000, Governor Davis issued Executive Order D-16-00, establishing sustainable building as a primary goal for state construction and tasking the State and Consumer Services Agency with its implementation. Our agency established the Sustainable Building Task Force, a unique partnership among more than 40 governmental agencies, whose combined building, environmental, and fiscal expertise has produced outstanding results, including funding for this report.

Since its inception, the Sustainable Building Task Force has worked diligently to incorporate green building principles into California's capital outlay process. Our many successes include:

- Building the first LEED Gold state owned office building in the country, the Education Headquarters Building, which is saving taxpayers $500,000 a year in energy costs alone;
- Including sustainable building performance standards, such as energy efficiency, in over $2 billion of state construction and renovation contracts;
- Constructing many high visibility state "leadership buildings," which are models of sustainability, including the Caltrans District 7 Office building in Los Angeles;
- Promoting on-site renewable energy, such as the installation of over an acre of photovoltaic panels on the roof of the Franchise Tax Board Building in Rancho Cordova – which is the largest array on any state office building in the country;
- Assisting the Chancellor of the new 10th University of California campus, UC Merced, in her goal to construct the greenest campus in the country with an initial target of LEED Silver for all construction;
- Impacting the sustainability of K-12 bond funded school construction throughout the state by providing funding and technical assistance to support the work of the Collaborative for High Performance Schools (CHPS), including the construction of 13 demonstration high performance schools; and
- Confirming through rigorous emissions testing that the careful selection of building materials in concert with environmentally responsive cleaning practices results in cleaner and healthier indoor environments.

While the environmental and human health benefits of green building have been widely recognized, this comprehensive report confirms that minimal increases in upfront costs of about 2% to support green design would, on average, result in life cycle savings of 20% of total construction costs -- more than ten times the initial investment. For example, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of $1 million in today's dollars over the life of the building. These findings clearly support the work of the Sustainable Building Task Force and reinforce our commitment to build the greenest state facilities possible.

This report was funded by several Sustainable Building Task Force member agencies, including the Air Resources Board, the Department of Finance, the Department of General Services, the Department of Transportation, the Department of Water Resources, the Division of the State Architect, and the Integrated Waste Management Board. Their resources and staff support have helped to increase our collective knowledge of the true costs and benefits of green building. In addition, I would like to recognize the contributions of Undersecretary Arnold Sowell and Senior Consultant Amanda Eichel of the State and Consumer Services Agency. Their leadership, as well as their commitment to this subject, made this project possible.

With the signing of Executive Order D-16-00 by Governor Davis, California embarked on a road to sustainability. Since that time many cities, counties, and school districts, as well as the Board of Regents for the University of California, have established similar sustainable building goals. It is extremely rewarding not only to note the major accomplishments of this Task Force, including this first of a kind study documenting the cost-effectiveness of green building, but also to witness the national impact of these extraordinary interagency efforts.

Best regards,

Aileen Adams
Secretary

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Executive Summary

Integrating "sustainable" or "green" building practices into the construction of state buildings is a solid financial investment. In the most comprehensive analysis of the financial costs and benefits of green building conducted to date, this report finds that a minimal upfront investment of about two percent of construction costs typically yields life cycle savings of over ten times the initial investment. For example, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of at least $1 million over the life of the building, assumed conservatively to be 20 years.[1]

The financial benefits of green buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits). Energy and water savings can be predicted with reasonable precision, measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy.

There is now a very large body of research, reviewed in this report, which demonstrates significant and causal correlation between improvements in building comfort and control measures, and worker health and productivity. However, these studies vary widely in specific measured correlations. Further, there has been relatively little work completed to evaluate specific, measurable benefits from green building design in California. Clearly, the benefits are significant and not zero, but the data supports a broad range of calculated benefits – in contrast to the more precisely measurable energy, water, and waste savings.

The financial benefits conclusions in this report should therefore be understood in this context. Energy, waste, and water savings as well as emissions reductions can be viewed as fairly precise, reasonably conservative estimates of direct benefits that alone significantly exceed the marginal cost of building green. Health and productivity benefits can be viewed as reasonably conservative estimates within a large range of uncertainty. Further research is necessary to better quantify and capture the precise savings associated with these benefits. Additional studies might include such measures as evaluating green building effects on insured and uninsured health effects, employee turnover, worker well being and, where relevant (e.g. in schools), test scores.

Background

"Green" or "sustainable" buildings use key resources like energy, water, materials, and land much more efficiently than buildings that are simply built to code. They also create healthier work, learning, and living environments, with more natural light and cleaner air, and contribute to improved employee and student health, comfort, and productivity. Sustainable buildings are cost-effective, saving taxpayer dollars by reducing operations and maintenance costs, as well as by lowering utility bills.

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[1] Although this report was written with specific regard to California state buildings, data is national in scope and conclusions are broadly applicable to other types of buildings and for other public and private sector entities.

Over the last few years, the green building movement has gained tremendous momentum. The United States Green Building Council (USGBC), a national non-profit organization, has grown dramatically in membership. The USGBC's Leadership in Energy and Environmental Design (LEED) rating system has been widely embraced both nationally and internationally as the green building design standard. Public and private sector entities, including the cities of Santa Monica, San Diego, San Francisco, San Jose, Long Beach, Los Angeles, Seattle, and Portland; San Mateo County; the University of California; the Department of the Navy; the federal General Services Administration; and the states of Oregon, New York and Maryland have all adopted green building policies and clean energy standards. In addition, corporate entities, including Steelcase, Herman Miller, Johnson Controls, Interface, IBM, PNC Financial Services, Southern California Gas Company, Toyota, and Ford Motor Company, have constructed green buildings.

Recognizing the tremendous opportunity for California state government to provide leadership in the area of exemplary building design and construction methods, several years ago Governor Davis issued two Executive Orders that address the siting and building of state facilities:

- Executive Order D-16-00 establishes the Governor's sustainable building goal: "to site, design, deconstruct, construct, renovate, operate, and maintain state buildings that are models of energy, water, and materials efficiency; while providing healthy, productive and comfortable indoor environments and long-term benefits to Californians...The objectives are to implement the sustainable building goal in a cost effective manner…; use extended life cycle costing; and adopt an integrated systems approach.[2]"
- Executive Order D-46-01 provides guidance on the process the Department of General Services will use to locate and lease space, including such considerations as proximity to public transit and affordable housing, preserving structures of historic, cultural, and architectural significance, opportunities for economic renewal; and sensitivity to neighborhood and community concerns.[3]

The Issue of Cost

To implement the Executive Orders, the Secretary of the State and Consumer Services Agency, Aileen Adams, formally convened an interagency Sustainable Building Task Force (Task Force) comprised of over 40 state agencies, including representatives with energy, environmental, fiscal, construction, property management, and historic preservation expertise. As the Task Force set about its implementation work, the uncertainty about the "cost" of green buildings became an issue of growing importance and increased discussions.

While there seems to be consensus on the environmental and social benefits of green building, there is a consistent concern, both within and outside the green building community, over the lack of accurate and thorough financial and economic information. Recognizing that the cost issue was becoming more and more of a prohibitive factor in the mainstreaming of green building not only within California but across the country, several members of the Task Force funded an Economic Analysis Project to determine more definitively the costs and benefits of sustainable

[2] State of California, Governor's Executive Order D-16-00. August 2000. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.
[3] State of California, Governor's Executive Order D-46-01. October 2001. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.

building.[4] Sustainable buildings generally incur a "green premium" above the costs of standard construction. They also provide an array of financial and environmental benefits that conventional buildings do not. These benefits, such as energy savings, should be looked at through a life cycle cost methodology, not just evaluated in terms of upfront costs. From a life cycle savings standpoint, savings resulting from investment in sustainable design and construction dramatically exceed any additional upfront costs.

It is generally recognized that buildings consume a large portion of water, wood, energy, and other resources used in the economy. Green buildings provide a potentially promising way to help address a range of challenges facing California, such as:

- The high cost of electric power.
- Worsening electric grid constraints, with associated power quality and availability problems.
- Pending water shortage and waste disposal issues.
- Continued state and federal pressure to cut criteria pollutants.
- Growing concern over the cost of global warming.
- The rising incidence of allergies and asthma, especially in children.
- The health and productivity of workers.
- The effect of the physical school environment on children's abilities to learn.
- Increasing expenses of maintaining and operating state facilities over time.

Benefits include some elements that are relatively easy to quantify, such as energy and water savings, as well as those that are less easily quantified, such as the use of recycled content materials and improved indoor environmental quality. Prior to this report, no comprehensive analysis of the actual costs and financial benefits of green buildings had been completed, although there are a number of studies that do begin to address this very important issue.

- In October 2002, the David and Lucille Packard Foundation released their Sustainability Matrix and Sustainability Report, developed to consider environmental goals for a new 90,000 square foot office facility. The study found that with each increasing level of sustainability (including various levels of LEED), short-term costs increased, but long-term costs decreased dramatically.[5]

- A second, older study conducted by Xenergy for the City of Portland identified a 15% lifecycle savings associated with bringing three standard buildings up to USGBC LEED certification levels (with primary opportunities to save money associated with energy efficiency, water efficiency and use of salvaged materials).[6]

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[4] Funding agencies include the Air Resources Board (ARB), California Integrated Waste Management Board (CIWMB), Department of Finance (DOF), Department of General Services (DGS), Department of Transportation (CalTrans) Department of Water Resources (DWR), and Division of the State Architect (DSA).

[5] "Building for Sustainability: Six Scenarios for the David and Lucille Packard Foundation Los Altos Project," prepared for the David and Lucille Packard Foundation, October 2002. Available on-line at: http://www.packard.org/pdf/2002Report.pdf.

[6] "Green City Buildings: Applying the LEED Rating System," prepared for the Portland Energy Office by Xenergy, Inc and SERA Architects, June 18, 2000. Available at: http://www.sustainableportland.org/CityLEED.pdf.

In addition, a number of other studies document measurable benefits for enhanced daylighting, natural ventilation, and improved indoor air quality in buildings. Benefits associated with these "green" features include enhanced worker and student productivity, as well as reduced absenteeism and illness.

For example:

- One study performed by the Heschong-Mahone group looked at students in three cities and found that students in classrooms with the greatest amount of daylighting performed up to 20% better than those in classrooms that had little daylight.[7]
- A study at Herman-Miller showed up to a 7% increase in worker productivity following a move to a green, daylit facility.[8]
- A Lawrence Berkeley National Laboratory study found that U.S. businesses could save as much as $58 billion in lost sick time and an additional $200 billion in worker performance if improvements were made to indoor air quality.[9]

Report Methodology and Format

This report is the first of its kind to fully aggregate the costs and benefits of green buildings. Specifically, the bulk of this report reviews and analyzes a large quantity of existing data about the costs and financial benefits of green buildings in California. Several dozen building representatives and architects were contacted to secure the cost of 33 green buildings compared to conventional designs for those buildings. The average premium for these green buildings is slightly less than 2% (or $3-5/ ft^2, see *Implications for California,* pg.18), substantially lower than is commonly perceived. The majority of this cost is due to the increased architectural and engineering (A&E) design time necessary to integrate sustainable building practices into projects. Generally, the earlier green building gets incorporated into the design process, the lower the cost.

A literature review conducted for this report revealed that there is sufficient data from which to construct reasonable estimates about the value of many green building attributes. Historically, both private firms and public agencies do not recognize the full financial value of green buildings. They usually acknowledge some benefits from lower energy and water use, but completely ignore or critically undervalue other, often significant, financial benefits of green buildings during the design and construction decision-making process.[10] For most of these benefits, such as emissions reductions and employee productivity, there are multiple methods that can be used to derive values of benefits, as well as a large range of values that can be assigned to them. In most cases, there is no single "right" answer. Nonetheless, the report underscores that based on the body of

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[7] Heschong Mahone Group, "Daylighting in Schools: An Investigation into the Relationship Between Daylight and Human Performance," 1999. Available at: http://www.h-m-g.com; Follow up studies verified the rigor of analysis and subsequent research continues to show positive correlation between daylighting and student performance.

[8] Judith Heerwagen, "Do Green Buildings Enhance the Well Being of Workers?" *Environmental Design and Construction Magazine*. July/August 2000. Available at: http://www.edcmag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,4118,19794,00.html.

[9] William Fisk, "Health and Productivity Gains from Better Indoor Environments," summary of prior publications (see Appendix J), with figures inflation-adjusted for 2002 dollars and rounded.

[10] See, for example "CEC Environmental Performance Report." Available at: http://www.energy.ca.gov/reports/2001-11-20_700-01-001.PDF. 2003 EPR will be finalized and available in October 2003 as part of the *Integrated Energy Policy Report*.

existing data, it is possible to determine reasonable, conservative estimates of financial benefits for a range of green building attributes.

The report also reveals the need for further research and analysis. In all areas, consistently conservative assumptions were made in view of data limitations. Additional research will help to refine cost and benefit estimates and likely lead to increased financial benefit calculations for green building. Additionally, throughout the report, the reader is directed to online databases and publications for the most accurate and relevant information. In many instances, these referenced documents are available online, and URLs are provided in the footnotes.

Conclusion

The benefits of building green include cost savings from reduced energy, water, and waste; lower operations and maintenance costs; and enhanced occupant productivity and health. As Figure ES-1 shows, analysis of these areas indicates that total financial benefits of green buildings are over ten times the average initial investment required to design and construct a green building. Energy savings alone exceed the average increased cost associated with building green.

Additionally, the relatively large impact of productivity and health gains reflects the fact that the direct and indirect cost of employees is far larger than the cost of construction or energy. Consequently, even small changes in productivity and health translate into large financial benefits.

Figure ES-1. Financial Benefits of Green Buildings Summary of Findings (per ft^2)

Category	20-year NPV
Energy Value	$5.79
Emissions Value	$1.18
Water Value	$0.51
Waste Value (construction only) - 1 year	$0.03
Commissioning O&M Value	$8.47
Productivity and Health Value (Certified and Silver)	$36.89
Productivity and Health Value (Gold and Platinum)	$55.33
Less Green Cost Premium	($4.00)
Total 20-year NPV (Certified and Silver)	**$48.87**
Total 20-year NPV (Gold and Platinum)	**$67.31**

Source: Capital E Analysis

Despite data limitations and the need for additional research in various areas, the findings of this report point to a clear conclusion: building green is cost-effective and makes financial sense today.

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[11] Lead author contact information: gkats@cap-e.com, www.cap-e.com, or 202 463-8469. For purposes of disclosure, Greg Kats co-founded and until 2001 served as Chair of the IPMVP, the national standard for monitoring and managing building energy and environmental performance. LEED and IPMVP are referred to frequently in this report.

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I. Overview of Project

In September 2002, California's Sustainable Buildings Task Force (SBTF)[12] – composed of representatives from over 40 state agencies – with funding from seven of its constituent agencies,[13] hired a team, lead by Capital E, to undertake an economic analysis project to aid in the effort to evaluate the cost and benefits of sustainable building.

This report is intended to provide immediately useful analytic support for making informed and cost-effective building design decisions. Identification of gaps and recommendations for additional research are mentioned throughout the text and compiled in Section XII – Recommended Next Steps. These are intended to provide guidance to the SBTF in identifying opportunities to further improve understanding of the full costs and benefits of green buildings.

What is a Green Building?

"Green" or "sustainable" buildings are sensitive to:

- Environment.
- Resource & energy consumption.
- Impact on people (quality and healthiness of work environment).
- Financial impact (cost-effectiveness from a full financial cost-return perspective).
- The world at large (a broader set of issues, such as ground water recharge and global warming, that a government is typically concerned about).

California's Executive Order D-16-00 establishes a solid set of sustainable building objectives: "to site, design, deconstruct, construct, renovate, operate, and maintain state buildings that are models of energy, water and materials efficiency; while providing healthy, productive and comfortable indoor environments and long-term benefits to Californians." [14] This green building Executive Order requires consideration of externalities, economic and environmental performance measures, life cycle costing, and a whole building integrated systems approach when making sustainable building funding decisions. These objectives for sustainable building design include not only tangible savings associated with energy, water and waste efficiencies, but also "softer" benefits, such as human health and productivity, impact on the environment and incorporation of recycled content materials.

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[12] See: http://www.ciwmb.ca.gov/GreenBuilding/TaskForce/, State of California Sustainable Building Task Force website.

[13] The seven CA state agencies that funded this study are the California Air Resources Board (ARB), California Integrated Waste Management Board (CIWMB), Department of Finance (DOF), Department of General Services (DGS), Department of Transportation (Caltrans), Department of Water Resources (DWR), and Division of the State Architect (DSA).

[14] State of California, Governor's Executive Order D-16-00. August 2000. Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.
The goals of sustainable building practice in California, according to one recent article, are to: a) enhance indoor air quality; b) improve occupant health and productivity; c) increase the efficiency of material, energy, and water resource usage; and d) reduce the environmental impacts associated with the production of raw materials and the construction, deconstruction and long-term operation of buildings. Alevantis et al., "Sustainable Building Practices in California State Buildings," *Proceedings of Indoor Air 2002: The 9th International Conference on Indoor Air Quality and Climate*. Monterey, CA, June 30 – July 5, 2002. Vol. 3, pp. 666-671, Indoor Air 2002, Inc. Available at: http://www.indoorair2002.org.

In December 2001, the SBTF released the report, *Building Better Buildings: A Blueprint for Sustainable State Facilities*,[15] the first in a series of reports that will document the progress of California state government in implementing the Governor's sustainable building goals. The Blueprint notes that sustainable buildings are often called green or high performance buildings. The US Green Building Council (USGBC)[16] uses the term "green" to define a building with the same objectives as those described in the *Blueprint*. Other initiatives, such as New York's High Performance Building Design Guidelines,[17] use the term "high performance" to describe virtually the same set of building characteristics. The High Performance Guidelines draw particular attention to the use of advanced technology, or "smart infrastructure," and its impact on tenant ability to control key building comfort measures (such as temperature and light levels) to increase performance.[18]

This report will use the terms "sustainable" and "green" synonymously and interchangeably.

Sustainable design practices have been applied in American buildings for millennia, as evidenced in the exquisite structures of the Hopi Indians a thousand years ago. However, the term sustainable or green architecture as a modern, integrated design philosophy appears to be very recent. The first references to "green architecture" and "green building label" reportedly appeared in the British publication *The Independent* in London in early 1990, followed by the first American use of the term "green architecture" in mid-1990, on the editor's page of *Architecture* magazine.[19] The American Institute of Architect's Committee on the Environment started in 1989.[20] In 1991, the city of Austin established the first green building program in the United States[21] – there are now dozens of such programs nationally.[22] The Green Building committee of the American Society for Testing and Materials (ASTM) also formed in 1991.[23] Thus, the modern green building movement appears to be little over a decade old. It is therefore impressive that there is already an emerging national consensus on the definition of a green building and a rapidly increasing number of green projects in both the public and private sectors.

While there is no exactly "correct" weighting of green attributes, there is a broad consensus both with regard to the general attributes that constitute greenness, as well as the approximate

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15 California State and Consumer Services and Sustainable Building Task Force. "Building Better Buildings: A Blueprint for Sustainable State Facilities," December 2001. Available at: http://www.ciwmb.ca.gov/GreenBuilding/Blueprint/.

16 See: http://www.usgbc.org, United States Green Building Council website.

17 New York City Department of Design and Construction. "High Performance Building Guidelines*."* April 1999. Available at: http://home.nyc.gov/html/ddc/html/highperf.html.

18 See, for example: Alan Traugott, "Green Building Design = High Performance Building Design," *Consulting-Specifying Engineer*, January 1999, pp. 68-74.

19 Nathan Engstrom, "The Rise of Environmental Awareness in American Architecture: From the Bruntland Commission to LEED," *Platform* (A publication of the School of Architecture at the University of Texas at Austin), Fall 2002. Available at: http://www.ar.utexas.edu/csd/documents/stu-papers/engstrom-1.pdf.

20 See: http://www.aia.org/cote, American Institute of Architect's Committee on the Environment (COTE) website.

21 See: http://www.ci.austin.tx.us/greenbuilder/, The City of Austin Green Building Program.

22 For a useful summary table (with URLs) of two dozen green building programs in the US, see: Peter Yost, "Green Building Programs – An Overview," *Building Standards*, March – April 2002, p. 13. Available at: http://www.buildingscience.com/resources/articles/default.htm. The Table was adapted from a longer article in *Environmental Building News*.

23 See: http://www.astm.org, ASTM "Sustainability" Subcommittee E06.71 of Committee E06 "Performance of Buildings."

weighting that these different attributes should receive.[24] However, the definition of a sustainable building is innately subjective. There is no universally accepted way to compare such diverse green attributes as, for example, improved human health, reduced water pollution and reduced forest cutting. Different green building programs balance various dimensions of "greenness" through a necessarily subjective weighting. For example, Green Globes, a US online assessment tool for benchmarking the greenness of building performance, attributes 34% of the weighting of building greenness to energy use, more than the USGBC's Leadership in Energy and Environmental Design (LEED) Rating System's 29%.[25] Because of the wide range of "green" attributes considered, no single scientific denominator exists, and weighting reflects consensus best judgment rather than scientific determination.

The range of definitions of what constitutes a green or sustainable building includes:

- The British Research Establishment Environmental Assessment Method (BREEAM) was launched in 1990 and is increasing in use.[26]
- Canada's Building Environmental Performance Assessment Criteria (BEPAC) began in 1994.[27] This system was never fully implemented due to its complexity.
- The Hong Kong Building Environmental Assessment Method (HK-BEAM) is currently in pilot form.[28]
- The US Green Building Council (established in 1993) began development of the Leadership in Environmental and Energy Design (LEED) Green Building Rating System™ in 1994. Version 2.0 of the LEED standard was formally released in May 2000; Version 2.1 was released in November 2002.[29]

US state or regional green building guidelines include:

- New York's High Performance Building Guidelines (1999).[30]
- Pennsylvania's Guidelines for Creating High Performance buildings (1999).[31]

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[24] For an elegant review of green building design evolution, see:
"Building for Sustainability: Six Scenarios for the David and Lucille Packard Foundation Los Altos Project," October 2002. Available on-line at: http://www.packard.org/pdf/2002Report.pdf.
This comprehensive study evaluates the life cycle cost of six increasingly green designs, each built to a different standard of sustainability. Increases in initial capital costs are weighed against decreases in operating costs to determine net present value (NPV) for each building type over a 30, 60 and 100 year period. The study concludes, even without taking into account most externalities, that life cycle cost for a green building is considerably lower than for a conventional one.

[25] Green Globes – Environmental Assessment of Buildings. Energy Criteria. Available at: http://www2.energyefficiency.org/crit-energy.asp; US Green Building Council's LEED Rating System Energy Criteria. Slide 28, LEED™ Point Distribution, http://www.usgbc.org/Docs/About/usgbc_intro.ppt.

[26] British Research Establishment. BREEAM Environmental Assessment Tool. Information Available at: http://products.bre.co.uk/breeam/.

[27] See: http://www.bepac.dmu.ac.uk/, BEPAC website.

[28] HK-BEAM Society. Hong Kong Building Environmental Assessment Method, Version 4/03 Pilot. May 2003. Available at: http://www.bse.polyu.edu.hk/Research_Centre/BEP/hkbeam/main.html.

[29] US Green Building Council. LEED™ Version 2.1Rating System. November 2002. Available at: http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf.

[30] New York City Department of Design and Construction High Performance Building Guidelines. April 1999. Available at: http://home.nyc.gov/html/ddc/html/highperf.html.

[31] State of Pennsylvania Guidelines for Creating High Performance Buildings, 1999. Available at: http://www.gggc.state.pa.us/publictn/gbguides.html.

In addition, there are a dozen or more local applications of LEED, generally adding more stringent requirements as part of state certification. Federal work on green buildings, coordinated by DOE's Federal Energy Management Program, has also developed important programs and resources on green building best practices. [32]

LEED as the US Green Building Standard

The United States Green Building Council (USGBC), a national non-profit entity, developed the Leadership in Energy and Environmental Design (LEED) Green Building Rating System™[33] to rate new and existing commercial, institutional, and high-rise residential buildings according to their environmental attributes and sustainable features. The LEED system utilizes a list of 34 potential performance based "credits" worth up to 69 points, as well as 7 prerequisite criteria, divided into six categories:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation & Design Process

LEED allows the project team to choose the most effective and appropriate sustainable building measures for a given location and/or project. These "points" are then tallied to determine the appropriate level of LEED certification. See Appendix A for a full list of LEED Version 2.1 prerequisites and credits.

Four levels of LEED certification are possible; depending on the number of criteria met, and indicate increasingly sustainable building practices:

LEED Certified	26-32	points
LEED Silver	33-38	points
LEED Gold	39-51	points
LEED Platinum	52+	points

There is a general perception that LEED is becoming the standard for US green building design. As the industry magazine *Health Facilities Management* described in October 2002, "LEED has become the common benchmark for sustainability."[34] Although imperfect and still evolving, LEED has rapidly become the largest and most widely recognized green building design and certification program in the US, and probably in the world.

LEED was first introduced through a Pilot Program, and twelve buildings received version 1.0 certification in March 2000. Version 2.0 was released shortly thereafter for use as a design and certification tool. At the end of 2000, about 8 million square feet of buildings were undergoing

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[32] See for example: "Greening Federal Facilities", second edition, May 2001, produced by BuildingGreen, Inc. See: http://www.eere.energy.gov/femp/techassist/green_fed_facilities.html.
[33] US Green Building Council. LEED Rating System, Version 2.1. November 2002. Available at: http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf.
[34] Craig Applegath and Jane Wigle, "Turning Green," *Health Facilities Management*, October 2002, pp. 22-27.

LEED certification. By early 2003, this number had jumped to over 100 million square feet. As of December 2002, of all new construction projects in the United States, an estimated 3% had applied for LEED certification, including 4% of schools, 16.5% of government buildings and 1.1% of commercial projects.[35] In addition, many buildings use LEED as a design tool without going through the certification process.[36] LEED's use and impact is therefore more pervasive than the figures suggest. All indications are that this explosive growth will continue. Despite its limitations, the strength and likely future durability of LEED and its definition of green buildings derives from several factors:

- LEED is broad and democratic in nature, currently with 3000 organizations representing all sectors of the building industry. Membership has roughly doubled annually over the last three years. [37]
- LEED continues to change through large, professional, voluntary committees, and a staff that is responsive to the evolving needs of its large and diverse membership. New products are being developed, including: LEED for Existing Buildings, LEED for Commercial Interiors, LEED for Core and Shell, LEED for Homes, LEED for Neighborhood Developments, and LEED for Multiple Buildings.[38]
- The USGBC spends millions of dollars each year to support LEED in a number of ways, including: an extensive training program; the LEED Accredited Professional exam; a Resource guide; LEED templates; an extensive LEED website for registered projects, technical data and scientific committees; and a growing staff of professionals dedicated to LEED.

States and municipalities can create local applications of LEED, generally adding more stringent regional requirements. This approach has been used in Portland, Oregon[39] and Seattle, Washington.[40] These programs require buildings to receive LEED certification, but are tailored to meet the specific resource concerns of the region.[41]

Many other jurisdictions are currently creating LEED-based guidelines and ordinances. Some have developed guidelines that closely follow LEED but are not viewed as LEED compatible,

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[35] US Green Building Council, Urban Land Institute and The Real Estate Roundtable. "Making the Business Case for High Performance Green Buildings." 2002. Available at: https://www.usgbc.org/Docs/Member_Resource_Docs/makingthebusinesscase.pdf.
All percentages based on square footage not on number of buildings. For total LEED square footage see also: www.usgbc.org.

[36] See for example: Larry Flynn, Senior Editor, "Sustainability," *Building Design and Construction*, April 2001.

[37] US Green Building Council. USGBC Member Directory. 2003. Available at: https://www.usgbc.org/Members/members_directory.asp.

[38] LEED™ Green Building Rating System Committees, US Green Building Council. 2003. Available at: https://www.usgbc.org/Members/member_committees.asp.

[39] Portland Office of Sustainable Development, Green Building Division. "City of Portland Supplement to the LEED Rating System." 2002. Available at: http://www.sustainableportland.org/portland_leed.pdf.

[40] City of Seattle Green Building Team. "City of Seattle CIP Supplements to the LEED Green Building Rating System™." 2001. Available at: http://www.cityofseattle.net/sustainablebuilding/Leeds/docs/LEEDSupplements.PDF.

[41] Darren Bouton and Geof Syphers, "Creating Green Building Criteria for Local Governments: Recommendations for San Jose LEED," paper presented at the USGBC International Green Building Conference, October 2002.
Available at: http://www.usgbc.org/expo2002/schedule/documents/DS509_Bouton_P324.pdf.

such as the High Performance Guidelines of North Carolina's Triangle Region.[42] The USGBC's recent publication, *Making the Business Case for High Performance Green Buildings*, co-produced with the Urban Land Institute and The Real Estate Roundtable, provides a useful overview of green building benefits as well as a list of cities, states and other entities that have adopted LEED.[43]

LEED in California

There are more LEED registered projects within California – over 140 as of August 2003[44] – than in any other state. In 2001, in support of state greening efforts, California's Sustainable Building Task Force developed the LEED Supplement for California State Facilities.[45] This regionalized supplement to LEED V.2.0 is intended for guidance purposes and is not required for use in state projects. It provides information on California codes, policies and practices and is hosted on the CIWMB's website[46] for public use, though it has not been officially adopted.

On the local level, LEED has been adopted in a number of California municipalities. The city of San Jose,[47] San Francisco city and county,[48] the city of San Diego,[49] the city of Santa Monica,[50] San Mateo County,[51] and Los Angeles city and county[52] have all made commitments to LEED. The city of Oakland[53] and Alameda County[54] and have developed their own LEED-based green building guidelines. The city of Pleasanton recently passed an ordinance requiring both public and private buildings to meet the standards of LEED Certified level, subject to a few modifications.[55]
As an interim step towards the adoption of LEED at the state level, the California Sustainable Building Task Force, in collaboration with the Department of General Services, has developed

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[42] Triangle J Council of Governments. "High Performance Guidelines: Triangle Region Public Facilities." September 2001. Available at: http://www.tjcog.dst.nc.us/hpgtrpf.htm.
[43] USGBC. 2002. Op. Cit.
[44] LEED Registered Project List, US Green Building Council, April 2, 2003. https://www.usgbc.org/LEED/Project/project_list_registered.asp.
[45] For California application of LEED, see: http://www.ciwmb.ca.gov/GreenBuilding/Design/LEEDforCA.doc.
[46] See: http://www.ciwmb.ca.gov/GreenBuilding/, California Integrated Waste Management Board Green Building Website.
[47] City of San Jose. "Green Building Policy." 2001. Available at: http://www.ci.san-jose.ca.us/esd/gb-policy.htm.
[48] City and County of San Francisco. "Resource Efficient City Buildings Ordinance." 1999. Available at: http://www.sfgov.org/sfenvironment/aboutus/policy/legislation/efficient.htm.
[49] City of San Diego. "Policy No. 900-14: Sustainable Building Practices." 2002. Available at: http://clerkdoc.sannet.gov/RightSite/getcontent/local.pdf?DMW_OBJECTID=09001451800850ad.
[50] City of Santa Monica. "Green Building Guidelines." 1997. Available at: http://greenbuildings.santa-monica.org/introduction/introduction.html.
[51] San Mateo County. Green Building. See: http://www.co.sanmateo.ca.us/smc/county/content/0,,1774_2126_13802237,00.html.
[52] City of Los Angeles. "Sustainable Building Initiative: An Action Plan for Advancing Sustainable Design Practices." 2001. Available at: http://www.lacity.org/SAN/lasp/sbi-draft-nov2001-300.pdf.
[53] City of Oakland. "Oakland Sustainable Design Guide." 2001. Available at: http://www.oaklandpw.com/greenbuilding/.
[54] Alameda County Waste Management Authority. "New Construction Green Buildings Guidelines." 2001. Available at: http://www.stopwaste.org/nhguide.html.
[55] City Council of the City of Pleasanton. "Ordinance No. 1873." Adopted December 2002. Available at: http://www.ci.pleasanton.ca.us/pdf/greenbldg.pdf.

two lists of technologies that are intended to guide development of new buildings.[56] The Tier 1 list includes many green technologies – such as "cool roofs" (described in Section IX) – that have been predetermined as cost-effective by the Department of Finance and are expected to be included in new construction. The Tier 2 list includes technologies that should be included in new designs as long as they are cost justified, and as the project budget allows.

In reality Tier 1 and Tier 2 technologies are inconsistently included in construction. Part of the reason is that the benefits of green design are best achieved when green technologies and practices are adopted as part of an integrated design rather than on a piecemeal basis. An integrated green building design approach – such as LEED – provides a way to incorporate green technologies and practices in a way that is more likely to be cost-effective. [57]

In addition to LEED, another rating system has been developed specific to K-12 schools in California. The Collaborative for High Performance Schools, or CHPS, is a diverse group of government, utility, and non-profit organizations with a unifying mission to improve the quality of education for California's children.[58] The goal of the CHPS is to create a new generation of high performance school facilities in California. The focus is on public schools and levels K-12, although many of the design principals apply to private schools and higher education facilities as well. High performance schools are healthy, comfortable, resource efficient, safe, secure, adaptable, and easy to operate and maintain. They promote higher test scores, help school districts retain quality teachers and staff, reduce operating costs, increase average daily attendance (ADA), reduce liability, and promote environmental stewardship and joint use opportunities.

CHPS has developed a three volume Best Practices Manual for High Performance Schools, including a set of design criteria to "rate" CHPS schools.[59] Different from LEED, CHPS is self-certifying, and CHPS schools must score 28 out of 81 possible points for eligibility.

[56] State of California, Real Estate Services Division,"Exhibit C – Tiers: Energy Efficiency and Sustainable Building Measures," July 1, 2002. Available at: http://www.ciwmb.ca.gov/GreenBuilding/Design/Tiers.pdf.

[57] The benefits and process of green design are extensively documented in RMIs "Green Development: Integrating Ecology and Real Estate." See www.rmi.org.

[58] See: http://www.chps.net, The Collaborative for High Performance Schools website.

[59]The Collaborative for High Performance Schools. "CHPS Best Practices Manual, Volumes I-III, 2002." Available at: http://www.chps.net/manual/index.htm#score.

II. Important Assumptions

Life Cycle Assessment (LCA)

This report uses a life cycle costing (LCC) approach to evaluate and integrate the benefits and costs associated with sustainable buildings. Life cycle costing, often confused with the more rigorous life cycle assessment (LCA) analysis, looks at costs and benefits over the life of a particular product, technology or system. LCA, in contrast, involves accounting for all upstream and downstream costs of a particular activity, and integrating them through a consistent application of financial discounting. The result – if data is available -- is a current "cradle to grave" inventory, impact assessment and interpretation (e.g., a net present value estimate). However, the art and science of calculating true life cycle impacts and costs of green buildings is still evolving and is generally not practiced. Currently, decisions on whether or not to invest in a green building are typically based only on first costs plus, in some cases, a discounted value of lowered energy and water bills. This report seeks an approach that draws on the discipline of LCC practices to identify and clearly document the benefits and costs of the most important green building attributes, including some that are generally not explicitly considered in building investment decisions.

There are a number of international green building assessment programs that provide tools for evaluating building performance across a large range of green performance criteria.[60] European LCA work is extensive and some of it ties into the internationally accepted ISO quality certification process.[61] A popular Canadian core and shell assessment tool – Athena [62] – was recently used in designing the Clearview Elementary School in Pennsylvania[63] and the Battery Park City residential construction project in New York City.[64] BEES, a building materials selection tool developed by the U.S. Government's National Institute of Standards and Technology (NIST), is useful for specifying materials and can be used with Athena to create a whole building life cycle analysis.[65] Some of the most rigorous science-based LCA tools are not available in English – these include LEGOE from Germany, an LCA program that runs in the background with CAD software,[66] and EcoQuantum from Holland.[67]

Altogether, there are a dozen or more life cycle tools each with various strengths and limitations – Athena, for example, despite its strengths, is currently based only on Canadian data.[68]

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[60] For an extensive international listing of green building evaluation and life-cycle related tools and programs with related URLs, go to: http://buildlca.rmit.edu.au/links.html.

[61] For European life cycle work see: http://www.ecotec.com/sharedopet/password/rhrsum13.htm.

[62] Athena Version 2.0 Environmental Impact Estimator. 2003. Available at: See http://www.athenasmi.ca/.

[63] Clearview Elementary School Athena Model Output, 7Group. Available at: http://www.sevengroup.com/pdf/Athena.PDF.

[64] The Athena Sustainable Materials Institute Members Newsletter. Volume 3, Number 1. June 2002. See: "Updates Green Building Challenge 2002." Available At: http://www.athenasmi.ca/news/down/Ath_vol_3_1.pdf.

[65] BEES 3.0 Software Download available at: http://www.bfrl.nist.gov/oae/software/bees.html.

[66] Available only in German at: http://www.legoe.de.

[67] Available only in Dutch from the Environmental Institute at the University of Amsterdam (IVAM). A demo of an older version is available in English at: http://www.ivambv.uva.nl/uk/index.htm.

[68] For a valuable recent review of life cycle tools, see: Gregory Norris and Peter Yost, "A Transparent, Interactive Software Environment for Communicating Life-Cycle Assessment Results," *Journal of Industrial Ecology*, 2002, Volume 5, Number 4. For a good overview of international life cycle development, see: "Evolution and Development of the Conceptual Framework and Methodology of Life-

This report does not use any of these specific tools. Rather, it follows the general life cycle approach in evaluating a broad spectrum of costs and benefits using the limited data available. There are many substantial information gaps preventing a full life cycle cost assessment of green buildings. To cite just two examples: data on the full cost of water is incomplete, and available data on emissions from energy use should (but generally does not) reflect the life cycle emissions from energy extraction, transportation, use and disposal, as well as from energy generation. The objective of this report is to aggregate the available data about green buildings, and to develop a reasonable net present value estimate of their future associated costs and benefits.

Use of Present Value (PV) and Net Present Value (NPV)

The overarching purpose of this report is to answer the following question: Does it make financial and economic sense to build a green building? Green buildings may cost more to build than conventional buildings, especially when incorporating more advanced technologies and higher levels of LEED, or sustainability. However, they also offer significant cost savings over time.

This report will seek to calculate the current value of green buildings and components on a present value (PV) or net present value (NPV) basis. PV is the present value of a future stream of financial benefits. NPV reflects a stream of current and future benefits and costs, and results in a value in today's dollars that represents the present value of an investment's future financial benefits minus any initial investment. If positive, the investment should be made (unless an even better investment exists), otherwise it should not.[69] This report assumes a suitable discount rate over an appropriate term to derive an informed rationale for making sustainable building funding decisions. Typically, financial benefits for individual elements are calculated on a present value basis and then combined in the conclusion with net costs to arrive at a net present value estimate.

Net present value can be calculated using Microsoft's standard Excel formula:

$$NPV = \sum_{i=1}^{n} \frac{values_i}{(1+rate)^i}$$

The formula requires the following:

- **Rate**: Interest Rate per time period (5% real)
- **Nper (n)**: The number of time periods (20 years)
- **Pmt (values):** The constant sized payment made each time period (annual financial benefit)

This provides a calculation of the value in today's dollars for the stream of 20 years of financial benefits discounted by the 5% real interest rate. It is possible to calculate the net present value of the entire investment - both initial green cost premium and the stream of future discounted financial benefits - by subtracting the former from the latter.

Cycle Assessment," *SETAC Press*, January 1998. Available as an addendum to *Life-Cycle Impact Assessment: The State-of-the-Art*. See: http://www.setac.org. Environmental Building News, Dec 2002, p 14, by Nadav Malin (BEES review), and Environmental Building News, Nov 2002, p 15, by Nadav Malin (ATHENA review).

[69] See: http://www.investorwords.com/cgi-bin/getword.cgi?3257.

Discount Rate
To arrive at present value and net present value estimates, projected future costs and benefits must be discounted to give a fair value in today's dollars. The discount rate used in this report is 5% real. This rate is stipulated for use by the California Energy Commission[70] and is somewhat higher than the rate at which the state of California borrows money through bond issuance.[71] It is also representative of discount rates used by other public sector entities.[72]

Term
California's Executive Order D-16-00, committing California to provide energy efficiency and environmental leadership in its building design and operation, stipulates that "a building's energy, water, and waste disposal costs are computed over a twenty-five year period, or for the life of the building."[73] Buildings typically operate for over 25 years. A recent report for the Packard Foundation shows building life increasing with increasing levels of greenness. According to the Packard study, a conventional building is expected to last 40 years, a LEED Silver level building for 60 years and Gold or Platinum level buildings even longer.[74] In buildings, different energy systems and technologies last for different lengths of time – some energy equipment is upgraded every 8 to 15 years while some building energy systems may last the life of a building. This analysis conservatively assumes that the benefits of more efficient/sustainable energy, water, and waste components in green buildings will last 20 years, or roughly the average between envelope and equipment expected life.

Inflation

This report assumes an inflation rate of 2% per year, in line with most conventional inflation projections.[75] Unless otherwise indicated, this report makes a conventional assumption that costs (including energy and labor) as well as benefits rise at the rate of inflation – and so present value calculations are made on the basis of a conservative real 5% discount rate absent any inflation effects. In reality, this is quite an oversimplification and a more detailed analysis might attempt to make more accurate but complicated predictions of future costs. In particular, energy costs are relatively volatile, although electricity prices are less volatile than primary fuels, especially gas.

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[70] California Energy Commission. "Life Cycle Cost Methodology: 2005 California Building Energy Efficiency Standards." March 2002. Available at: http://www.energy.ca.gov/2005_standards/documents/2002-04-02_workshop/2002-03-20_LIFE_CYCLE.PDF.
[71] See for example: "Analysis of GARVEE Bonding Capacity, Attachment D: Detailed Assumptions for Sensitivity Analysis." California State Treasurer's Office. Prepared for California Department of Transportation. 2003. Available at: http://www.treasurer.ca.gov/Bonds/garvee.pdf.
[72] The Wall Street Journal lists discount rates daily, dependent upon credit rating. See Market Data and Resources. Available at: http://online.wsj.com/public/site_map?page=Site+Map.
[73] California Executive Order D-16-00, August 2000. Op. Cit.
[74] A conventional building design for the Packard Foundation envisages a building life of 40 years. A silver building is expected to last 60 years, gold rated building is designed to last 80 years, while a platinum or "living building" – an extremely sustainable design – is projected to last for 100 years. See *"Building For Sustainability Report: Six Scenarios for The David and Lucile Packard Foundation,"* Los Altos Project, October 2002. Available at: http://hpsarch.com/TitlePageSpecial/2002-Report.pdf.
[75] See, for example: http://oregonstate.edu/Dept/pol_sci/fac/sahr/cf166503.pdf and http://www.jsc.nasa.gov/bu2/inflateGDP.html.

LEED as a Basis

Although this report will look at the lessons offered from a range of green design programs, LEED is used as the common basis for comparison because it has become the dominant definition of green buildings in the United States. For example, in seeking to quantify a building's "greenness," it will be described by its LEED level or equivalent (e.g., LEED Silver, representing 33 to 38 points).

A Note about Data Sources

The last few years have seen the emergence of meta-studies that screen, select, and provide up-to-date and well-linked compilations of important data sets related to green building benefits. For example, the Carnegie Mellon BIDS program has screened over one thousand studies to come up with approximately 90 of the most rigorous studies on the productivity impacts from green and high performance building designs.[76] Similarly, the US Green Building Council keeps a regularly updated list of all the cities and municipalities that use LEED or some version of LEED. Some areas, notably water and waste, lack comprehensive on-line databases. A brief annotated review of sources is included as an appendix for these two sections (Appendix L).

In many cases there is no recent reliable California data. For example, there appears to be no California-specific study on the environmental benefits of waste reduction. Similarly, in the last decade there have been no publicly available, comprehensive studies on California that calculate the full benefits (such as avoided transmission and distribution costs) of reduced energy demand, e.g., from measures such as on-site generation and energy efficiency. These gaps are noted in the text and are reflected in recommendations at the end of the report for additional research.

[76]Carnegie Mellon University Department of Architecture. Building Investment Decision Support Tool. 2002. Available at: http://www.arc.cmu.edu/cbpd/.

III. The Cost of Building Green

The Problems of Determining Cost

There has been a widespread perception in the real-estate industry that building green is significantly more expensive than traditional methods of development. A half dozen California developers interviewed in 2001 estimated that green buildings cost 10% to 15% more than conventional buildings.[77] The Sustainable Building Task Force *Blueprint*[78] identifies several obstacles to sustainable buildings, including:

- Incomplete integration within and between projects.
- Lack of life cycle costing.
- Insufficient technical information.

The *Blueprint* notes that because of these barriers, "many sustainable building applications are prematurely labeled as 'unproven' or 'too costly.'" [79] *Consulting – Specifying Engineer* echoed this view in its October 2002 issue, indicating that: "the perception that green design is more expensive is pervasive among developers and will take time to overcome" and "inhibiting green design is the perception that 'green' costs more and does not have an economically attractive payback." [80]

There is a growing body of performance documentation and online resources related to green building. For example, a new online source developed through a partnership of the US Department of Energy, Environmental Building News, the US Green Building Council, Rocky Mountain Institute, and the AIA Committee on the Environment includes 42 green building case studies, 13 of which are located in California.[81] Despite these advances, there is still little published data about actual cost premiums for green buildings. This information gap is compounded by the fact that the USGBC does not require that cost information be included with submissions for LEED certification.

Many developers keep cost information proprietary. In addition, even if developers are willing to share their cost data, determining a precise "green premium" for a given project is often very difficult for several reasons:

- Developers typically only issue specifications and costs for the designed building, not for other green options. Individual green items are sometimes priced out in comparison to non-green ones, but this is not the norm and does not provide a basis for cost comparison between green and conventional whole building design.

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[77] Berman, Adam. "Green Buildings: Sustainable Profits from Sustainable Development," unpublished report, *Tilden Consulting*. July 30, 2001. Available from the author: adam@isabellafreedman.org.
[78] California State and Consumer Services Agency and Sustainable Building Task Force, December 2001. Op. Cit.
[79] *Ibid*, p. VI.
[80] Scott Siddens, Senior Editor, "Verdant Horizon," *Consulting –Specifying Engineer*, October 2002, pp. 30-34. Available at: http://www.syska.com/Sustainable/news/index.asp.
[81] US Department of Energy, Office of Energy Efficiency and Renewable Energy. High Performance Buildings Database. Available at: http://www.eere.energy.gov/buildings/highperformance/case_studies.

- Some green buildings being built today are showcase projects that may include additional and sometimes costly "finish" upgrades that are unrelated to greenness but that nonetheless are counted toward the green building cost increase.
- The design and construction process for the first green building of a client or design/architectural firm is often characterized by significant learning curve costs, and design schedule problems such as late and costly change orders.
- The relative newness of green technologies and systems can make designers, architects and clients conservative when using them. They may oversize green building systems and not fully integrate them into the building, thereby reducing cost savings and other benefits. Similarly, cost estimators may add uncertainty factors for new green technologies they are not familiar with, and these can compound, further inflating cost estimates.

National Green Building Leaders

Although more members and registered projects are located in California than in any other state, Pennsylvania, Massachusetts, Washington and Oregon have the most extensive, documented experience with green building and LEED.[82] Therefore, despite the general deficiency of published data on the cost of building green, there is substantial recent evidence from these and other entities to indicate that building green is less expensive than many developers think. In particular, this data comes in part from two municipalities with extensive experience building LEED projects: Pennsylvania and Seattle, WA.

Pennsylvania

Over the past several years, the state of Pennsylvania has constructed five LEED registered projects (three will be completed in 2003). Pennsylvania's green building experience now enables it to build LEED Silver buildings that cost virtually the same as traditional buildings.[83] The state's first LEED Gold level green building, a 40,000 square foot office building in Cambria, PA, was built at $90 per square foot, just under comparable market rates for conventional buildings (See Appendix C).[84] Much of Pennsylvania's success comes from the state's ability to negotiate better prices from green manufacturers. Most green materials used in this project cost the same or less than the traditional alternative, reinforcing the fact that green design has matured and broadened into the mainstream and is no longer a cutting edge trend.[85]

Seattle, WA

Seattle was the first municipality in the nation to adopt a LEED Silver requirement for larger (over 5000 ft^2 occupied space) construction projects. The city currently has 11 LEED registered projects.

[82] Pennsylvania, Oregon and Washington have more projects per capita, per Gross State Product, and per Construction Gross State Product than California or other states across the country. See Appendix B for a Graphical Representation.

[83] Governor's Green Government Council, State of Pennsylvania. See: "Building Green in Pennsylvania," CD-ROM available at http://www.gggc.state.pa.us.

[84] Commonwealth of Pennsylvania Department of Environmental Protection, Cambria Office Building. 2001. Available at: http://www.gggc.state.pa.us/building/Cambria/2300DEPCambriaDOBldg.pdf.

[85] Governor's Green Government Council, State of Pennsylvania. "Building Green in Pennsylvania: Making the Case." Video available at: http://www.greenworks.tv/green_building/archives.htm.

Detailed cost data from these projects has not yet been released, but according to a draft report, LEED Silver certification should not add cost to a project provided the following: [86]

- LEED Silver is made a requirement in the Request for Qualification for the Design Team and embedded within the construction documents, building construction, and commissioning.
- The selected Design Team has sustainable design embedded within the firm's design culture.
- Contractors, Property Managers, Real Estate Analysts, Budget Analysts, Crew Chiefs and Custodians are included on the Design Team.
- Selected sustainable design strategies are "whole system" in nature and integrated design solutions are pursued that cannot be peeled off from the base project as "add alternates."

A Cost Analysis of 33 LEED Projects

Cost data was gathered on 33 individual LEED registered projects (25 office buildings and 8 school buildings) with actual or projected dates of completion between 1995 and 2004. These 33 projects were chosen because relatively solid cost data for both actual green design and conventional design was available for the same building.

Virtually no data has been collected on conventional buildings to determine what the building would cost as a green building. And, surprisingly, most green buildings do not have data on what the building would have cost as a conventional building. To be useful for this analysis, cost data must include both green building and conventional design costs for the same building. Typically this data is based on modeling and detailed cost estimates. (As indicated elsewhere, LEED does not currently require that cost data for both conventional and green design be submitted. This report recommends that the USGBC consider making this a prerequisite or offer part of a credit for providing this data).

Attempts to compare the cost of a specific green building – such as a school – with other buildings of similar size and function in a different locality provide little help in understanding the cost of green design. The added cost impact of designing green may be very small compared with other building costs such as the cost of land and infrastructure. Therefore, a meaningful assessment of the cost of building green requires a comparison of conventional and green designs for the same building only.

Consequently, there is very little solid data on the additional costs associated with green design. Information for this report was collected primarily through a broad literature review; from several dozen interviews with architects and other senior building personnel; written and verbal communications with California's Sustainable Building Task Force members, USGBC staff, attendees at the Austin green building conference, and members of the Green Building Valuation Advisory Group; through a query posted in the Environmental Building News; and from others.

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[86] Lucia Athens and Gale Fulton, "Developing a Public Portfolio of LEED™ Projects: The City of Seattle Experience." Electronic copy received from authors on December 20, 2002. Available at: http://www.usgbc.org/expo2002/schedule/documents/DS509_Athens_P126.pdf.

A resulting table containing each project name, location, building type, date of completion, green premium and certification level or equivalent can be found in Appendix C. Note that many of these buildings have not yet been certified by the USGBC. In these cases, the LEED level indicated is an assessment by the architect and/or client team reflecting very detailed analysis and modeling – this is viewed as a relatively accurate prediction of final LEED certification level.

While the size of the data set is not large, analysis provides meaningful insights into the cost premium for green buildings. Figures III-1 and III-2 show that, on average, the premium for green buildings is about 2%. The eight rated Bronze level buildings had an average cost premium of less than 1%. Eighteen Silver-level buildings averaged a 2.1% cost premium. The six Gold buildings had an average premium of 1.8%, and the one Platinum building was at 6.5%. The average reported cost premium for all 33 buildings is somewhat less than 2%.[87]

Figure III-1. Level of Green Standard and Average Green Cost Premium

Level of Green Standard	Average Green Cost Premium
Level 1 – Certified	0.66%
Level 2 – Silver	2.11%
Level 3 – Gold	1.82%
Level 4 – Platinum	6.50%
Average of 33 Buildings	1.84%

Source: USGBC, Capital E Analysis

[87] See Appendix C for a complete list of the 33 projects, their LEED levels, and green premiums.

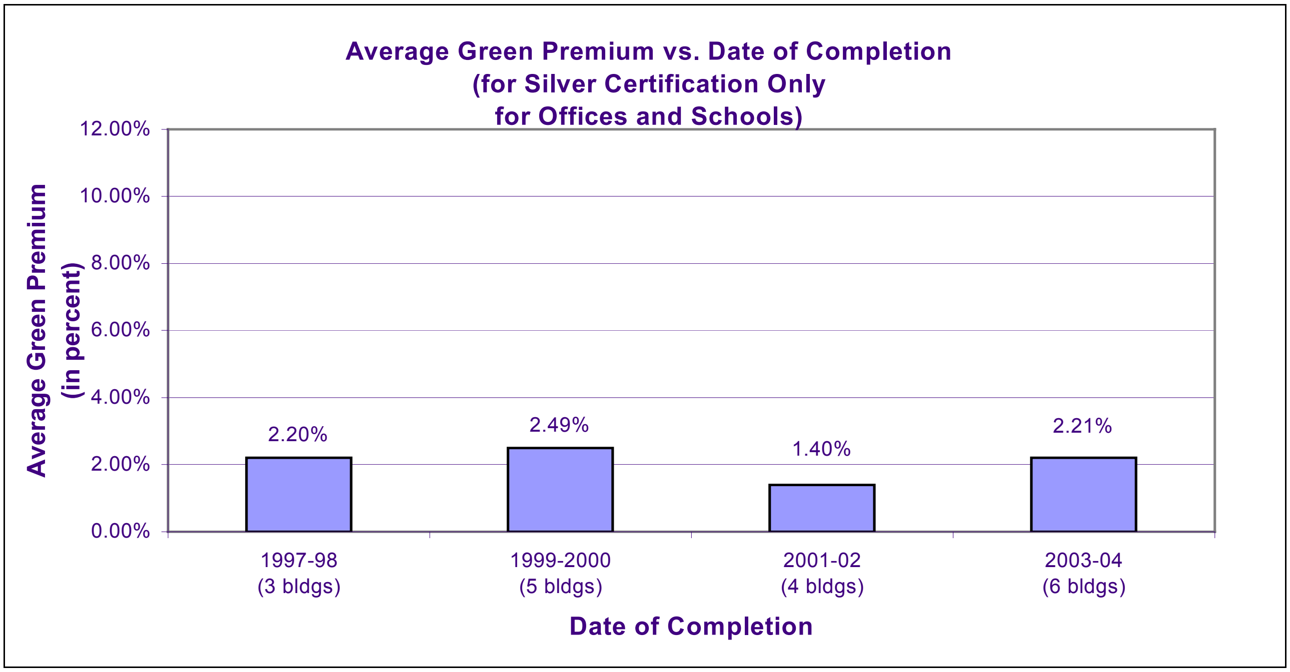
Figure III-2. Average Green Cost Premium vs. Level of Green Certification

Source: USGBC, Capital E Analysis

Figure III-3. Year of Completion and Average Green Cost Premiums for Buildings with Silver Certification

Year of Completion	Average Green Cost Premium
1997-1998	2.20%
1999-2000	2.49%
2001-2002	1.40%
2003-2004	2.21%
Avg. of 18 Silver buildings	2.11%

Figure III-4. Average Green Cost Premium vs. Date of Completion for Buildings with Silver Certification



Source: USGBC, Capital E Analysis

There is evidence that building green gets less expensive over time, with experience. However, an expected downward cost trend of the green cost premium is not clear in this data. The green premium is lowest for the most recently completed buildings (2001-02) and higher for buildings projected to be completed in 2003 and 2004. This data reflects two things. First, 2003-2004 buildings costs are projections and these tend to be slightly high (conservative). It can be expected that as these buildings are completed, the actual cost premium will, on average, be lower than projected in this data. Second and perhaps more importantly, the reported data includes both first time green buildings and buildings that may be the third or fourth green building by the same owner/designer builder team. Thus the data includes both relatively higher cost first timers and the efforts of experienced teams that generally achieve lower cost premiums.

The trend of declining costs associated with increased experience in green building construction has been experienced in Pennsylvania,[88] as well as in Portland and Seattle. Portland's three reported completed LEED Silver buildings (see Appendix C) were finished in 1995, 1997, and

[88] Data provided by John Boecker, L. Robert Kimball and Associates, A/E Firm for the Pennsylvania Department of the Environment Cambria Office Building, Ebensburg, PA, the PA Department of Environmental Protection Southeast Regional Office. Norristown, PA, and the Clearview Elementary School, York, PA.
See: http://www.lrkimball.com/Architecture%20and%20Engineering/ae_experience_green.htm.

2000. They incurred cost premiums of 2%, 1% and 0% respectively.[89] Seattle has seen the cost of LEED Silver buildings drop from 3-4% several years ago to 1-2% today.[90]

A second data anomaly is that reported cost levels for LEED Gold buildings are slightly lower than for Silver buildings, whereas the higher performance level requirements to achieve Gold would be expected to cost more than Silver levels. In part, this anomaly reflects the small data set – the Gold premium is an average across only six buildings. As additional green building data is assembled, costs are likely to more closely follow the rising cost levels associated with more rigorous levels of LEED. Nonetheless, the data indicates that it is possible to build Gold level buildings for little additional cost. The higher performance levels associated with Gold buildings (described below in Health and Productivity and other sections), combined with their potentially low cost premiums – as indicated in this small data set – suggest that, based on available data, LEED Gold may be the most cost effective design objective for green buildings.

Implications for California

The conclusions above indicate that while green buildings generally cost more than conventional buildings, the "green premium" is lower than is commonly perceived. As expected, the cost of green buildings generally rises as the level of greenness increases, while the premium to build green is coming down over time. Importantly, the cost of green buildings tends to decline with experience in design and development, as clients and their design and architecture teams move beyond their first green building. This trend suggests that California develop policies and procedures to favor the hiring of more experienced green building teams, and that this experience be embedded throughout the design team. Additionally, development of multiple green buildings within a particular California state agency or university can be expected to result in declining costs per building to that organization.

Assuming conservative, relatively high California commercial construction costs of $150/ft^2 to 250/ft^2$,[91] a 2% green building premium is equivalent to $3-5/ft^2$. Use of lower construction costs in these calculations would tend to increase the reported cost effectiveness of green construction.

The rest of this report will attempt to quantify the size of financial benefits as compared with the costs of building green buildings.

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[89] Data provided by Heinz Rudolf, BOORA Architects. See Portfolio/Schools at: http://www.boora.com/

[90] Lucia Athens, Seattle Green Building Program, Nov. 2002. See: http://www.cityofseattle.net/light/conserve/sustainability/.
The city is expected to soon release a review of over a dozen green Seattle buildings and specific costs premiums for these buildings.

[91] This is a reasonable, somewhat high (e.g. conservative) estimate as confirmed by Oppenheim Lewis Inc. and Anthony Bernheim, Principal, SMWM. Includes hard and soft costs (including design fees) associated with construction, but not land acquisition.

IV. Energy Use

Energy is a substantial and widely recognized cost of building operations that can be reduced through energy efficiency and related measures that are part of green building design. Therefore, the value of lower energy bills in green buildings can be significant. The average annual cost of energy in state buildings is approximately $1.47/ft^2.[92] On average, green buildings use 30% less energy than conventional buildings[93] – a reduction, for a 100,000 ft^2 state office building, worth $44,000 per year, with the 20-year present value of expected energy savings worth over half a million dollars.[94]

A detailed review of 60 LEED rated buildings, including 5 LEED rated buildings in California, clearly demonstrates that green buildings, when compared to conventional buildings, are:

- On average 25-30% more energy efficient (compared with ASHRAE 90.1-1999 and, for California buildings, Title 24 baselines);[95]
- Characterized by even lower electricity peak consumption;
- More likely to generate renewable energy on-site; and
- More likely to purchase grid power generated from renewable energy sources (green power and/or tradable renewable certificates.

Although the environmental and health costs associated with air pollution caused by non-renewable electric power generation and on-site fossil fuel use are generally externalized (not considered) when making investment decisions, the energy reductions realized through the design and construction of green buildings reduce pollution and lower the environmental impact of conventional power generation.[96] This report seeks to quantify some of the benefits, including the value of peak power reduction (in this section) and the value of emissions reductions (in Section V) associated with the energy strategies integrated into green building design.

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[92] Over 95% of primary energy use in California state buildings is electricity, with the balance natural gas. Data provided by California Department of General Services, Real Estate Services Division, Building Property Management Brach. "Energy Cost Estimates," December 2002. See also *Appendix I*. 2002 energy costs were estimated at $1.60/ft^2/yr, but average California electricity rates are conservatively projected to drop from $0.12/kWh to $0.11/kWh. Energy use and cost data come directly from utility bills.

[93] Note: As a result of the energy crisis in California and various Flex-Your-Power energy efficiency campaigns, the State has already reduced electricity use in most buildings by close to 20%. Absolute energy savings typical of green buildings will be lower for energy efficient state buildings, which have already realized much of the benefit associated with energy efficiency. However the percentage reduction in energy use in these buildings is comparable to less efficient buildings – see subsequent data and discussion.

[94] Using 5% real discount rate over 20 year term, as discussed above. While both improved energy efficiency and on site generation result in lower energy bills, the reduced energy costs only capture a portion of the benefits accrued to the state. See for example: CEC Environmental Performance Report, http://www.energy.ca.gov/reports/2001-11-20_700-01-001.PDF.

[95] Based on analysis of Energy and Atmosphere Credit 1 – Energy Optimization points awarded to all LEED-NC v2 Certified projects.

[96] See: Lovins et al., "Small is Profitable," RMI, 2002. Available at: http://www.rmi.org.

Data on green buildings is somewhat limited because of the relative youth of a quantifiable definition of 'green' (this report uses the U.S. Green Building Council's LEED Green Building Rating System), a limited data set (60 LEED rated Buildings), incomplete reporting and/or insufficient reporting requirements (of the 60 LEED rated buildings, 19 were Certified under the LEED v1.0 Pilot which had different reporting requirements), and client preference for non-disclosure of data. All these limitations are evident in the small data set of five LEED rated buildings in California, including:

- Toyota Motor Sales South Campus Office Development, Torrance – LEED v2.0 Gold, 630,000 ft^2, completed in 2002.
- Ford Motor Company Premier Automotive Group North American HQ, Irvine – LEED v2.0 Certified, 253,000 ft^2, completed in 2001.
- William and Flora Hewlett Foundation Headquarters, Menlo Park - LEED v2.0 Gold, 48,000 ft^2, completed in 2002.
- Capital Area East End Complex 225, Sacramento – LEED v2.0 Gold, 479,000 ft^2, completed in 2003.
- UCSB Donald Bren School of Environmental Science and Management, Santa Barbara – LEED v1.0 Platinum, 90,000 ft^2, completed in 2002.

Data on energy use in these buildings was obtained directly from the USGBC,[97] and included a detailed review of the Energy Cost Budget documents required for award of LEED energy performance. Because some project teams have requested that their project data be kept confidential the data is presented in a format that ensures that the performance characteristics of specific buildings are masked. These California LEED rated buildings on average demonstrate energy efficiency commensurate with the 25-30% national average reduction for green buildings.[98] Energy efficiency (relative to a California Title 24 baseline) improvements for the five buildings (in order of lowest to highest) are 22%, 30%, 30%, 35%, 40%.

The Price of Energy

Calculating the current financial value of lower future energy consumption requires estimating future energy costs, and this is complicated by the rapidly changing tariff structures of California's utilities. California electricity rates have climbed steeply over the past several years, in large part due to surcharges mandated by the CPUC in response to the recent electricity crisis. As indicated in Figure IV-1, peak electricity prices are as high as $0.34 per kWh for buildings (including most state buildings) that are on time-of-use rates. At this time, it is not clear what future electricity prices will be.[99]

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[97] Data provided by the US Green Building Council, December 2002 (Brendan Owens, LEED Engineer).

[98] Because the energy performance baseline in California is Title 24, which is more rigorous than the prevailing national ASHRAE standard, it might be expected that energy reduction in California green buildings would be less than for LEED buildings nationally. This does not appear to be the case. Several reasons for this may include relatively high California energy prices (and recent price increases) that would tend to increase incentives for aggressive energy reduction measures, and the existence of California standards in areas other than energy – such as recycling and indoor environmental quality - that provide a higher baseline for non-energy performance for California sustainable buildings, and that may make energy improvements below the Title 24 baseline not more costly *relative* to other dimensions of green design.

[99] McAuliffe, Pat. California Energy Commission, Office of Commissioner Art Rosenfeld, December 2002.

The majority of California state buildings are on tariffs with time-of-use rates. These include relatively high electricity prices during periods of peak grid-wide electricity use, in an attempt to reduce peak consumption. The Pacific Gas & Electric (PG&E) commercial tariff, in Figure IV-1 below, is typical of these time-of-use commercial rates.

Figure IV-1. PG&E A-6 Time of Use Rate Schedule (simplified)

Customer Charge	**Season**	**Time-of-Use Period**	**Energy Charge** (per kWh)	**1/4/01 Energy Surcharge** (per kWh)	**6/1/01 Energy Surcharge** (per kWh)	**Total Energy Charge** (per kWh)	**"Average" Total Rate** (per kWh)
Single phase service per meter/day =$0.26612; Polyphase service per meter/day =$0.39425. Plus Meter charge =$0.22341 per day for A6 or A6X; =$0.06571 per day for A6W	**Summer**	On peak	$0.23258	$0.01000	$0.10064	**$0.34322**	$0.14487
		Part Peak	$0.10288	$0.01000	$0.04551	**$0.15839**	
		Off Peak	$0.05618	$0.01000	$0.03551	**$0.10169**	
	Winter	Part Peak	$0.11562	$0.01000	$0.04551	**$0.17113**	
		Off Peak	$0.07169	$0.01000	$0.03551	**$0.11720**	

Source: http://www.pge.com/tariffs/CommercialCurrent.xls

PG&E's average commercial rate is currently about $0.15 per kWh.[100] San Diego Gas & Electric (SDG&E)[101] and Southern California Edison (SCE)[102] have similar rates. Other utilities, such as Sacramento Municipal Utility District (SMUD) have slightly lower average commercial rates. The current average cost of electricity for state buildings is about $0.12/kWh, reflecting a concentration of state buildings in lower tariff utility districts, such as SMUD.[103] This rate is likely to drop by the end of 2003 as a substantial temporary surcharge (intended to help California utilities regain solvency) is dropped. However, there may be an additional bond surcharge of about $0.005/kWh imposed in 2003. In addition, the CPUC may implement a $0.50+/kWh "super peak" surcharge on the peak hours of 15 of the hottest (and highest peak electricity use) days in the year.[104] The CEC believes that at end of 2003 rates may drop to about $0.11/kWh,

[100] For PG&E rates, see: http://www.pge.com/tariffs/CommercialCurrent.xls and http://www.pge.com/tariffs/GNR2_Current.xls.
[101] For SDG&E rates see: http://www.sdge.com/tariff/elec_commercial.shtml, and http://www.sdge.com/tm2/pdf/GN-3.pdf.
[102] For SCE Rates, see: http://www.sce.com/NR/sc3/tm2/pdf/ce87-12.pdf and http://www.sce.com/sc3/005_regul_info/005a_tariff_book/005a3_rates/005a3b_biz_rates.htm.
[103] Data provided by the California Energy Commission, Office of the Supervisor of Rates, December 2002. See also: Electricity in California. California Energy Commission. Available at: http://www.energy.ca.gov/electricity/index.html#rates.
[104] California Energy Commission. Office of Energy Commissioner Art Rosenfeld. November 2002.

and that this is a good, conservative estimate for future average commercial electricity prices (Note: Higher electricity rates would increase the benefits of green buildings).[105]

This report therefore assumes a real average commercial electricity price for 2003 and beyond of $0.11/kWh. This rate is used for calculations involving schools as well, even though schools are more evenly distributed through higher tariff utility districts (benefits accruing to green schools may therefore be understated in this analysis). Projected future electricity savings are discounted at the 5% (real) rate. However, calculating the full benefits of lower energy costs from green buildings is more complex than this because green buildings tend to use disproportionately less energy during peak times, when electricity is more valuable and expensive.

Cutting Peak Power

The unique integrated design and construction process that green buildings typically follow considers the building holistically. Interactions between competing building systems (lighting vs. cooling, fresh air vs. humidity control, etc.) are therefore analyzed simultaneously, allowing the building designers to reduce peak power demand by downsizing building systems, particularly air conditioning and lighting loads, while providing a comfortable indoor environment. For most of California (except the generally foggy northern coast) and much of the US (especially in the South and Midwest) air conditioning is the dominant energy user during peak load. The largest and third largest electricity demands, respectively, in California during a typical 50,000 MW peak load period are commercial air conditioning – representing 15% of peak load, and commercial lighting – representing 11% of peak load.[106] By encouraging integrated design and awarding credit for optimization of building energy systems, LEED provides strong incentives to cut both of these peak demand uses.

LEED encourages:

- *Integrated design*: Project teams consider building systems in total to optimize competing demands.
- *High Performance Lighting*: Incorporation of more efficient lights, task lighting, use of sensors to cut unnecessary lighting, use of daylight harvesting and other advanced lighting techniques and technologies. These measures can significantly reduce power demand from electric lights. In hot weather, this reduction has the added advantage of reducing cooling loads in a building, which in-turn reduces required air conditioning.
- *Increased Ventilation Effectiveness*: Helps cut air conditioning load during peak through improved system optimization.
- *Underfloor Air Distribution Systems*: Use of a plenum below a raised floor to deliver space conditioning. Typically cuts fan and cooling loads, substantially lowering air conditioning load (see "Underfloor Air" in Section IX).

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[105] Data provided by the California Energy Commission, Office of the Supervisor of Rates, December 2002. See also: California Energy Commission. "2002-2012 Electricity Outlook Report." February 2002. Available at: http://www.energy.ca.gov/reports/2002-02-14_700-01-004F.PDF.

[106] John Wilson, Art Rosenfeld and Mike Jaske, "Using Demand Responsive Loads to Meet California's Reliability Needs," paper presented at 2002 ACEEE summer conference. Available from: jwilson@energy.state.ca.us. Note: the number two user of electricity in California is residential air conditioning.

- *Commissioning*: A systematic process to ensure that building systems are designed, installed and operating as planned. Incorporation of commissioning tends to increase building system performance and cut energy use, helping to ensure that design objectives and performance targets are met and that energy savings persist (see "Commissioning" in Section IX).
- *Heat Island Reduction Measures*: By increasing the reflectivity of roofs and other typically dark surfaces, it is possible to lower building and urban temperatures, in turn reducing air conditioning loads and peak demand (see "Cool Roofs" in Section IX).
- *On-site Generation*: Two of the eight LEED Gold level buildings reviewed use photovoltaics (PV) to generate 20% of their power on site. PV is coincident with peak power usage, and so contributes to peak demand reduction.

Although peak demand reduction data is not provided or is incomplete for some buildings (LEED certification requirements do not currently require peak reduction information), California LEED rated buildings, like non-California buildings, generally show larger reductions in peak demand than in overall energy use. For the three California LEED rated buildings for which peak reduction data was submitted, electricity for space cooling and lighting (of conditioned space) varied widely but indicated an average electricity peak demand reduction of 17%. This average includes a shift from electricity to natural gas for most space cooling in one of the buildings. The fuel switch from electricity to natural gas artificially inflates the electricity peak demand reduction in this building. A fourth California LEED building, for which incomplete data was submitted, indicates a 13% reduction in total building energy use by implementing natural ventilation strategies rather than relying solely on mechanical HVAC.

The very limited California data set indicates that peak demand reduction in California green buildings is significant and consistent with a preliminary estimate of 10% peak demand reduction below average energy reduction in green buildings. The correlation between peak demand reduction in green buildings evident in the limited data set warrants further research. Preliminary discussions, between report authors and the USGBC, are underway to modify LEED credit requirements to require peak demand reduction data in LEED documentation.

It is important to emphasize that there is not yet sufficient data to exactly predict peak demand reduction from green buildings. Uncertainties result from a limited data set, inconsistencies in documentation, incomplete documentation, technical issues such as fuel switching, and the large variability between building designs. Nonetheless the available green building data is significant and collectively indicates that green buildings - including green buildings in California - on average provide peak demand reduction that is significantly larger than average energy reduction.

LEED places a high priority on building energy performance. Energy efficiency (including building commissioning, renewable energy and green power) is the single largest LEED credit category and represents 27% of the total points available in the LEED Green Building Rating System. LEED rated buildings, on average, use 30% less energy than those that meet the standard energy requirements of Title 24 (for California buildings) or ASHRAE 90.1 (in the rest of the country). Additional confirmation comes from analysis of USGBC data for 21 LEED rated buildings (including 6 buildings in California) - 8 Certified buildings, 5 Silver buildings and 8 Gold buildings. Both analyses (looking at a partially overlapping set of buildings) indicate that Gold buildings are generally the most energy efficient and Certified buildings the least efficient.[107] On a weighted average basis, green buildings are 28% more efficient than conventional buildings and generate 2% of their power on-site from photovoltaics (the large

[107] This building data is from USGBC from buildings that have completed the LEED certification process.

majority of green buildings do not have on-site generation and the 2% on site generation average reflects significant on-site generation from a few green buildings).

Figure IV-2. Reduced Energy Use in Green Buildings as Compared with Conventional Buildings

	Certified	Silver	Gold	Average
Energy Efficiency (above standard code)	18%	30%	37%	28%
On-Site Renewable Energy	0%	0%	4%	2%
Green Power	10%	0%	7%	6%
Total	**28%**	**30%**	**48%**	**36%**

S*ource: USGBC, Capital E Analysis*

As discussed above, green buildings use an average of 30% less purchased energy than conventional buildings. In addition, green buildings are more likely to purchase "green power" for electricity generated from renewable energy sources. Green power purchases can take two forms:

- Customers can purchase green power directly from their utility or from a local green power provider. In this case customers are paying for electricity generated from renewable energy sources, typically by a local provider in the state or utility jurisdiction. About 40% of US electricity customers have this option.
- Customers can purchase green certificates, or green tags. In purchasing green certificates, a customer is buying ownership of the reduced emissions (and by implication the environmental and health benefits) associated with renewable power, even though the green generating facility is frequently not in the customer's vicinity. All electricity consumers have this option.

For 21 green buildings on which USGBC has collected data, 6% of the electricity purchased was green.[108] Two factors need to be considered in determining the net impact that green power purchases by green buildings have on emissions (discussed in Section V). First, a small and growing portion – slightly less than 1/2% of the general population – already buys green power.[109] This suggests that adoption of LEED provides a 5.5% net increase in green power purchases compared with conventional buildings. Secondly, LEED recently modified its green power purchase requirement to allow purchase of green certificates. With this change, 100% of LEED buildings now have the ability to get LEED credit for buying green power, providing virtually universal availability. This is in contrast to direct green power purchases, which are currently available in areas containing only 40% of the population. This broadening of the green power credit will therefore significantly increase the portion of LEED buildings that buy green power (an issue that should be explored in more detail).

[108] Data provided by the USGBC. Capital E analysis with USGBC, November and December 2002.
[109] Jan Hamrin. Center for Resource Solutions, communication January 12, 2003. This number includes business as well as residential consumers.

Because all buildings are now able to buy green power, in the form of certificates, this report assumes that the portion of green power purchased by LEED green buildings will rise from 6% to 9% - an increase proportionally less than the doubling in buildings that can buy green power and receive LEED credit for it. A conservative estimate is that the future difference between average green building green power purchase and total average building green power purchase will rise from 5.5% (cited above) to 8.5%. Note that this is equal to 6% of total electricity use in an average non-green building.

This report therefore assumes that an average green building in the near future will purchase 9% of its electricity from green sources, or about 8.5% more than an average conventional building. Since a green building uses only 70% of the electricity that a conventional building does, the emissions reduction value of green power purchases by a green building is effectively reduced to about 6%.

As indicated in figure IV-2, above, average green building use of conventional energy (and the resulting associated emissions) is therefore on average about 36% lower than conventional buildings.

Evaluation of LEED certification documentation for over a dozen buildings,[110] including four California buildings, indicates an approximate average reduction in energy use of 30%, but an average peak reduction of about 40%.[111] While the data set is limited, it nonetheless indicates that green buildings reduce peak demand to a greater degree than total energy consumption: green buildings have proportionately larger reductions in peak demand.

Energy Star, administered by the US EPA and DOE, is the best known national energy performance rating program. It recognizes buildings for superior energy performance – defined as the 25% most energy efficient portion of the market – based on actual energy usage. Unfortunately, like LEED, the Energy Star program does not evaluate peak demand reduction.[112] Both USGBC/LEED and EPA/Energy Star should gather and publish data on the peak demand reduction of, respectively, green and energy efficient buildings.

Value of Peak Power

Utility transmission and distribution (T&D) systems generally run at less than 50% capacity.[113] However, during periods of peak electricity use, the generation and T&D systems may be close to overloaded. The benefits of reduced consumption are largest during periods of peak power consumption – avoided congestion costs, reduced power quality and reliability problems, reduced pollution, and additional capital investment to expand generation and T&D infrastructure. The value of peak reduction is not just in avoided purchase of electricity, but also in avoided capacity

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[110] Data provided by the USGBC, analysis by Capital E with USGBC. November and December, 2002

[111] Because USGBC does not require that peak load reduction data be submitted, the data quality is mixed and includes some buildings that specify peak load demand reduction and some building data that indicates this indirectly (e.g., through large reductions in air conditioning load). Additional building information reviewed provided no useful data on peak demand reductions.

[112] US EPA. Energy Star Technical Description for the Office Model. 2001.
Available at: http://www.energystar.gov/ia/business/evaluate_performance/technicaldescription.pdf.

[113] Electricity generation and distribution assets are less than half utilized most of the time. See: Amory Lovins et al, "Small is Profitable," RMI, 2002. http://www.smallisprofitable.org/.

and T&D costs.[114] Thus, energy benefits of green buildings need to be quantified not solely based on reduced energy use but also on reduced peak electricity demand.

Approaches for determining the value of peak demand reduction include: 1) marginal cost as imposed in time-of-use rates, and 2) the actual marginal cost of peak power – the cost of building peaking power plants, T&D required to deliver additional power, and related costs such as congestion costs.

An alternative, more elegant approach to calculating the full value of energy reduction in green buildings (including reduced peak demand reduction) would be to match energy reduction by time of use to the value of incentives being developed to reduce marginal load through demand reduction for three periods – baseload, shoulder periods and peak periods (up to 1000 hours per year). The California Energy Commission report, "Discussion of Proposed Energy Savings Goals for the Energy Efficiency Programs in California" evaluates the potential to achieve substantial energy efficiency savings by providing per kWh financial incentives for these three periods of $0.058/kWh, $0.10/kWh, and $0.167/kWh, respectively. [115] This spread between peak and average prices is used to estimate peak value below. Green building documentation does not provide energy use modeling data that would be required to precisely match green building energy use profiles to these marginal efficiency cost targets.

It appears that there is no recent, comprehensive, and publicly available analysis of the value of peak reduction in decreasing T&D, congestion, and related costs.[116] The most recent robust data, consisting of eleven utility studies, including four in California, is eight to ten years old. Summarized in Appendix D, these studies calculate the value to the grid of reduced peak demand due to on-site electricity generation.[117] On-site generation and on-site energy efficiency are functionally equivalent since both avoid the cost of additional central power generation, distribution facility capacity, and T&D.

These utility studies indicate an average T&D-related peak reduction value of $600 per kW (see Appendix D for calculations). To be very conservative, this report will reduce this value by 50%, providing an estimated value of T&D related benefits of $300/kW. This is almost certainly quite low and warrants further research. Gas peaking plants in California now have a capital cost of

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[114] McAuliffe, Pat. California Energy Commission. October 2002. See also: Amory Lovins et al, "Small is Profitable," RMI, 2002. http://www.smallisprofitable.org/.

[115] Mike Messenger, "Discussion of Proposed Energy Savings Goals for Energy Efficiency Programs in California," *CEC Staff Paper*, September 2003. See: http://www.energy.ca.gov/reports/2003-09-24_400-03-022D.PDF

[116] Based on research and a range of interviews with experts at the CEC, PUC, utilities and elsewhere.

[117] As indicated, this data has limitations, which may both exaggerate and undervalue estimates. For example:

1) Only 4 out of 11 studies are from California, and these indicate an average T&D benefit of $510 per kW, lower than the average of $605.
2) The data is 8 to 10 years old. Benefits and costs are likely to have changed somewhat – for example, NIMBY (Not In My Back Yard) concerns and the resulting need to run a larger portion of additional transmission capacity underground have generally increased grid congestion and line expansion costs, indicating that current numbers would probably be higher than those calculated here.
3) Other benefits – described in great detail in the new publication, "Small is Profitable, the Hidden Cost Economic Benefits of Making Resources the Right Size" (RMI, 2002) – were not included in these studies and would tend to increase the value of T&D and related benefits.

On balance these issues would tend to make a comprehensive valuation of T&D and related benefits higher today than these studies indicate.

approximately \$600/kW.[118] Combining the current cost of new marginal generating facilities with \$300 T&D costs results in an estimated total value of \$900/kW for reduced peak demand.

Because of increasing congestion and more cumbersome construction restrictions, T&D and related costs are probably more expensive today than when these studies were done. For example, San Diego Gas & Electric has been planning to build a 31 mile, 500,000 volt transmission line in south Riverside County at an expected cost of \$300 million, or nearly \$10 million per mile –higher than historical costs for large transmission line extensions. However, a PUC administrative law judge recently ruled that the line is not cost-justified over the next five years based on projected electricity demand growth.[119] The explicit recognition of the link between projected electricity demand growth and approval of costly new power lines highlights the potential value of green buildings in reducing or even eliminating the large capital costs of line expansion.

Calculation

As discussed above, green buildings provide an average 30% reduction in energy use, as compared with minimum energy code requirements. For energy costs of \$1.47/ft^2/yr, this indicates savings of about \$0.44/ft^2/yr,[120] with a 20-year present value of \$5.48/ft^2. Energy savings alone exceed the average additional cost of green over conventional construction.

In addition, green buildings provide reduction in peak demand. An important area of research is to develop data needed to better calculate average peak demand reduction. Similarly, USGBC should consider requiring or encouraging that this data be provided in LEED certification documentation. USGBC does not currently require peak capacity analysis to be provided in LEED certification submissions, but output data from several commercially available energy models does provide this information. This report does not calculate savings based on peak capacity reduction. Instead, this report develops a peak reduction value based on data provided on peak energy demand reduction. As discussed above, the limited available data set of green building peak demand reduction for both California and non-California LEED rated buildings indicates a peak demand reduction of 10%.

The value of peak demand reduction can be approximated in several ways, including:

1) Based on California state building experience, a 10% reduction in peak demand for one million square feet of state prisons, hospitals or office buildings amounts to 200 kW, or about \$24,000 per year. On a per ft^2 basis this rule of thumb[121] works out to about \$0.024/ ft^2 per year.[122]

[118] California Energy Commission. "Comparative Cost of California Central Station Electricity Generation Technologies." *Final Staff Report*. June 2003. Available at: http://www.energy.ca.gov/reports/2003-06-06_100-03-001F.PDF, esp. Appendix C.
[119] "SDG&E's Plan for Power Line Dealt Blow," *Energy Info Source, California Energy Report* 10/21/02-11/03/02. Available at: http://www.energyinfosource.com/.
[120] 30% of \$1.47/ft^2/yr total energy costs at 5% discount rate over 20 year term – see Appendix I.
[121] Data provided by the California Department of General Services, November 2002.
[122] Data provided by the California Department of General Services, December 2002.

2) On the basis of an average energy use of 10 kWh/ft^2 per year in state buildings and an average spread in cost between average and peak demand price indicated in recent California Energy Commission estimates for incentives required to reduce marginal load (described above) of $0.067/kWh, it is possible to estimate annual savings from lowered peak power consumption. Assuming peak demand is 8% of all hours, it is estimated, conservatively, that an 0.8 kWh shift from peak power, is worth $0.04 per ft^2 per year.

The two estimates – $0.024/$ft^2$/yr and $0.04/$ft^2$/yr – represent a substantial spread, and indicate the need for better data gathering and more detailed modeling.[123] Adopting a conservative estimated annual savings of $0.025/$ft^2$ results in the 20-year present value of the peak demand reduction attribute of green buildings at $0.31/$ft^2$ ($0.025/year, at 5% real discount rate over 20 years). It is important to emphasize that these are preliminary approximations based on limited data and that more rigorous and thorough modeling should be conducted as a larger data set develops. Despite these limitations, the conclusion indicates that green building energy reduction values include both lowered energy costs and some value of peak demand reduction. The value of peak demand and peak capacity reduction may be higher than estimated here.

Conclusion

Green building energy savings primarily come from reduced electricity purchases, and secondarily from reduced peak energy demand. The financial benefits of 30% reduced consumption at an electricity price of $0.11/kWh are about $0.44/$ft^2$/yr, with a 20-year present value of $5.48/$ft^2$. The additional value of peak demand reduction from green buildings is estimated at $0.025/$ft^2$/yr, with 20-year present value of $0.31/$ft^2$. Together, the total 20-year present value of financial energy benefits from a typical green building is $5.79/$ft^2$. Thus, on the basis of energy savings alone, investing in green buildings appears to be cost-effective.

Comment on Green Buildings and Demand Responsive Pricing

California's shift to dynamic electricity pricing and demand responsive buildings indicates an important future role for green buildings in helping to reduce energy and environmental costs. Several utilities across the country, including Georgia Power Company and Gulf Power have successfully provided financial incentives to customers to cut power consumption as a way to reduce and flatten load and avoid or delay the cost of building and/or operating additional generating capacity. However, California has become the national leader, and is developing dynamic pricing policies and programs to cut costs, increase system efficiency, and create a more intelligent and efficiently used electricity grid.[124]

California is helping residents and businesses install metering and control systems to support increased response to price signals to cut power usage through such measures as load shifting, moving air conditioning to before peak periods, and demand reduction measures such as lowering lighting levels. These measures, now proven ways to cut energy costs by rewarding price

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[123] Modeling by Gregg Morris of Future Resources Associates based on A-6 Schedule (Figure IV-1) indicates a range of $0.026 -$0.039/ft2/year, indicating that the $0.025/ft/year estimate is conservative (this analysis is available upon request, gmorris@emf.net).

[124] See: Arthur Rosenfeld, Michael Jaske and Severin Borenstein, "Dynamic Pricing, Advanced Metering and Demand Response in Electricity Markets", Hewlett Foundation Energy Series, October 2002. See: http://ef.org/energyseries_dynamic.cfm

responsive customer load management, are being expanded to increase customer, utility, and state benefits. Green buildings are ideal candidates for demand responsive load management because they already typically include relatively advanced metering and energy management systems. If, as seems likely, green building continues to grow very rapidly, these buildings should comprise an important part of California's strategy to expand demand responsive load management. In addition, the USGBC should consider adopting policies that encourage green buildings to include metering and energy management systems. These systems allow buildings to more readily participate in and secure the financial benefits of demand responsive power pricing and grid management.

V. Emissions from Energy

Energy use in California state buildings is over 95% electricity (See Appendix I). The generation of electricity, particularly from fossil fuels, creates a number of harmful emissions. As indicated in Figure IV-2 (Section IV, above), average green building use of conventional energy (and the resulting associated emissions) is on average about 36% lower than conventional buildings. Adding emissions reductions from green power purchases to overall electricity consumption reduction provides a total emissions reduction of 36% compared to conventional buildings.

Value of Pollution Associated with Energy

Energy use in California state buildings and schools is predominantly electricity. Reduction in electricity use means lower emissions of pollutants (due to avoided burning of fossil fuels to generate electricity) that are damaging to human health, to the environment and to property.[125]

Air pollutants that result from the burning of fossil fuels include:

- Oxides of Nitrogen (NOx) – a principal cause of smog.
- Particulates (including PM10) – a principal cause of respiratory illness (with associated health costs) and an important contributor to smog.
- Sulfur Dioxide (SO2 or SOx) – a principal cause of acid rain. (SOx and SO2 are functionally the same for the purposes of this report.)
- Carbon Dioxide (CO2) – the principal greenhouse gas and the principal product of combustion.

Additional fossil fuel related pollutants include reactive organic compounds (ROC) and carbon monoxide (CO). These pollutants are not evaluated here because California power plant emissions represent 0.24% and 0.33%, respectively, of the statewide emissions totals and their values in other building aspects are small.[126] Volatile Organic Compounds (VOCs) may have significant value but are not calculated in this report. A more comprehensive analysis should evaluate the costs of a fuller set of these additional pollutants, including mercury.

There are at least three ways of valuing the costs of air pollution associated with burning fossil fuels:

1) The direct costs of pollution effects on property, health and environment can be calculated and then allocated on a weighted or a site-specific basis.
2) The cost of avoiding or reducing these pollutants can be used as a way to determine market value of pollutants.
3) The market value of pollutants can be used if there is an established trading market.

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[125] Other forms of power, such as nuclear and hydro, also have environmental costs, though it is not within the scope of this report to evaluate these issues. Note that emissions intensity can vary by time of day, by season and other factors such as peak vs. baseload power (an issue that is addressed elsewhere in this report), although emissions impact is roughly proportional to energy use.

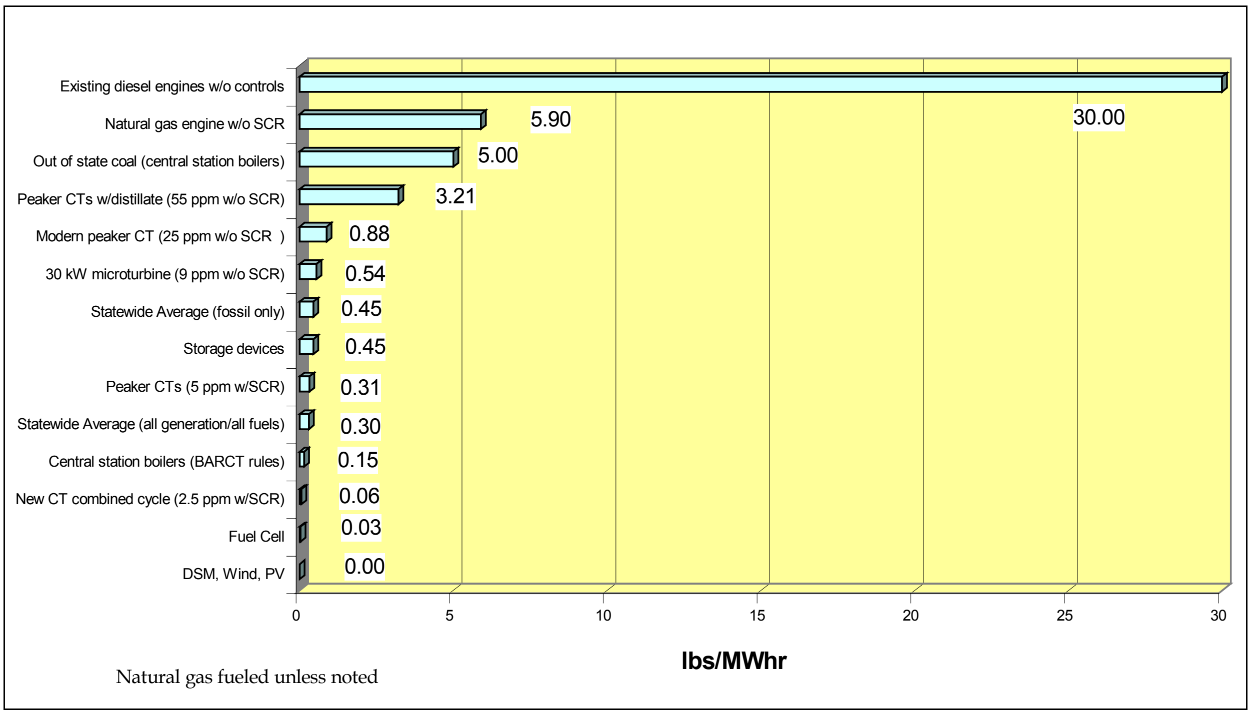
[126] California Energy Commission, "Environmental Performance Report of California's Electric Generation Facilities," July 2001. Available at: http://www.energy.ca.gov/reports/2001-06-28_700-01-001.html.

Each of these approaches has limitations and no one is universally "correct."

Emissions from Energy Use

The emissions reduction from decreased energy use depends on when reduction occurs and what energy source is displaced. Some of the most harmful emissions include NOx, SOx, particulates, and CO2. As indicated in Figure V-1 below, emissions vary vastly from back-up dirty diesel generators (of which the state has 3500 MW[127]) that produce 30 lb of NOx/MWhr,[128] down to zero emissions from renewable energy.[129]

Figure V-1. Generation Technologies Comparative NOx Emissions (lb/MWhr)



Source: "Performance Report of California's Electric Generation Facilities," CEC, July 2001.

Figure V-1 demonstrates that different sources of power are responsible for very different levels of pollution, and consequently different levels of associated health, environmental and property related costs. Benefits derived from the reduction in emissions from green buildings depend in part upon when reductions occur and what type of power (clean or dirty) is displaced. Emissions can vary substantially between California utilities, by season, and by time of use. This report uses an average California emissions factor for electricity to determine the financial value of emissions reductions associated with green buildings. Green buildings also tend to reduce peak

[127] *Ibid.*
[128] *Ibid.*
[129] It should be noted that zero emissions for renewable energy – PV, wind, fuel cells, hydro, etc – refers only to the operation of these generating devices and not to their manufacture.

consumption even more than they reduce overall demand. A more precise estimate would factor in the energy use profile of green buildings and match this to time-of-day power generation and associated pollution. However, this is beyond the scope of this analysis. It should be noted that green buildings can contribute to reducing grid congestion and power reliability and availability problems and can help reduce use of dirty backup/standby generating units. This could be examined in a more detailed analysis.

For a number of reasons – new technology, a shift to renewable energy, improvements in power plant efficiency, emissions control technologies and plant retrofits – emissions of NOx and SOx have dropped sharply and are expected to continue dropping. The CEC Environmental Performance Report notes that, "between 1975 and 2000, NOx and PM10 emissions from power generation declined by 79% and 83% respectively." [130] This decline is summarized in Figure V-2 below.

Figure V-2. Comparison of California Statewide Emissions with Emissions from Power Generation (tons/day)

Pollutant	Source of Emissions	1975	1980	1985	1990	1995	2000	2005 (est.)	2010 (est.)
NO_x	From All Sources	4,761	4,947	4,950	4,929	4,207	3,570	3,008	2,573
	From Power Generation	385	341	161	141	107	79.0	66.5	65.1
	% Power Generation	8.1%	6.9%	3.3%	2.9%	2.5%	2.2%	2.2%	2.5%
PM_{10}	From All Sources	1,864	2,018	2,004	2,240	2,177	2,313	2,467	2,612
	From Power Generation	49.6	29.1	5.7	11.8	8.1	8.62	9.63	9.8
	% Power Generation	2.7%	1.4%	0.28%	0.53%	0.37%	0.37%	0.39%	0.38%

Source: California EPA, Air Resources Board, Emission Reduction Offset Transaction Cost Summary Report for 2001

The state of California accounts for CO2 inconsistently – the California Inventory of Greenhouse Gas Emissions does not require inclusion of out-of-state generation, whereas the California Emissions Inventory Improvement Program does.[131] Typically, California emissions factors calculated by the Energy Information Administration and others reflect only in-state generation. California imports about 20% of its power from out-of-state, and this power has much higher pollution levels. Total coal generation in 2002 for California was 6220 MW, although 3065 MW or slightly less than 50% was imported.[132] In Los Angeles Department of Water and Power territory, coal imports are even more significant: total coal generation owned by LADWP, for

[130] State of California, California Environmental Protection Agency, Air Resources Board, "Emission Reduction Offset Transaction Cost Summary Report for 2001," April 2002, Table 1. Available at: http://www.arb.ca.gov/erco/erc01web.pdf.

[131] Lynn Price et al., "The California Climate Action Registry: Development of Methodologies for Calculating Greenhouse Gas Emissions From Electricity Generation," presented at *Green Building International Conference,* November 2002. Available at: http://eetd.lbl.gov/ea/EMS/reports/50250.pdf.

[132] California Energy Commission. "California Gross System Power for 2002 In Gigawatt-Hours (GWh)." 2002. Available at: http://www.energy.ca.gov/electricity/gross_system_power.html.

example, is 2,235 MW – although almost all of it located out-of-state but sold in the California market.[133]

Figure V-3. California Power Emissions Factors from the Tellus Institute (CO_2 Modified)

	Emission Factors (short tons per GWh)		
Pollutant	**1999**	**2010**	**2020**
Carbon Dioxide	308	308	308
Sulfur Dioxide	0.32	0.281	0.244
Nitrogen Oxides	0.404	0.448	0.399
PM-10	0.235	0.2	0.186

Source: Tellus Institute, 2002, modified by Capital E.

Tellus Institute has undertaken analysis of California power emissions, including out-of-state generation. Modified Tellus estimates are used here, principally because they include all power used in California, not just power generated in-state.[134]

These emissions factors developed by Tellus reflect the likely future average mix of electricity generating technologies and fuels used by the California market. They also reflect likely future trends in emission factors under the EIA's projected business as usual scenario through 2020. The Tellus Institute emissions estimates change over time, including a significant increase in CO_2 intensity in 2010 and 2020, to 452 and 490 tons per GWh, respectively. Given California's continuing concerns about pollution, including global warming, and the state's recent commitment to expanded use of renewable energy, it appears that CO_2 intensity is more likely to remain flat than rise, so this report uses the 1999 CO_2 emissions factor throughout the period of calculation. Use of the higher Tellus numbers would indicate larger financial benefits of green buildings.

Estimated Costs Associated with Pollution from Power Generation

Air pollution from burning fossil fuels to generate electricity imposes very large health, environmental and property damage costs. Demonstrated health costs include increased mortality and increased respiratory ailments.[135] The health, environmental and property damages

[133] Information provided by the California Energy Commission, Systems Assessment and Facilities Siting Division. January 2003. (Matt Layton) See also: LADWP. Power Content Label. Available at: http://www.ladwp.com/power/pwrcontentlbl.pdf; US DOE. Energy Efficiency and Renewable Energy. GreenPower Network. 1999. "LA's New 'Green Power' Program Will Save Customer's Money." Available at: http://www.eere.energy.gov/greenpower/ladwp_599_pr.html.
[134] William W. Dougherty, Senior Scientist, "Characterization of Criteria Air Pollutant and Greenhouse Gas Emission Factors Associated with Energy use in the USA: Sources, Assumptions, Methodology," based on Reference Case of the EIA's AEO200, Tellus Institute, 2002. See also: US Department of Energy, "Carbon Dioxide Emissions from the Generation of Electric Power in the United States," July 2000. Available at: http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2emiss.pdf; U.S. Department of Energy, Energy Information Administration, "Updated State-level Greenhouse Gas Emission Factors for Electricity Generation," Washington, D.C. See DOE EIA site: http://www.eia.doe.gov/env/utility.html.
[135] See, for example: "The Benefits and Costs of Clean Air Act 1990 to 2010," 1991. Available at: http://www.epa.gov/air/sect812/1990-2010/fullrept.pdf and Jonathan Samet et al., "The National

associated with pollution from burning fossil fuels – commonly referred to as externalities – are only partially reflected in the price of energy. Estimating the costs of externalities is technically difficult, politically problematic, and overall an inexact science. There have been dozens of attempts to estimate the external costs of power generation, but these efforts have not produced consensus. [136]

The California Board of Energy Efficiency (CBEE) developed estimates for environmental adders of $0.0072/kWh, or about 3/4 of one cent per kWh.[137] The CEC sought to determine the damage functions (for health, property and environmental impacts) in their Electricity Reports of 1992 and 1994.[138] In the reports, the CEC expressed reservations about use of this data. Given the lack of consensus on the value of externalities, and changing generation profiles (including steep reductions in some pollutants since the CEC analysis), this report will not rely on these damage functions to calculate the value of emissions reductions.

Instead, this report will rely on market values for traded emissions as the least imperfect of the options available for determining emissions values. These prices reflect actual marginal cost of emissions reductions in relatively liquid and well-established trading markets covering the majority of California's population. For some pollutants, including NOx and SOx, there is a well-established, liquid market and these market prices serve as our best measure of both the marginal cost of emissions reductions and the value society places on them. It is important to note that because the current market for emissions is driven by caps set by regulations, and not the morbidity effects of emissions, it does not directly reflect the externalities of health impacts, and therefore the value of reductions may be significantly understated. Some pollutants, including NOx and PM10, have substantial vehicular sources, and it is possible that the true value of reduced emissions for stationary sources is the same as for mobile ones (although this discrepancy is not recognized in the emissions market). In addition, important pollutants, such as mercury and smaller particulates (e.g. PM2.5) have large adverse health effects that are not addressed in this report. A more comprehensive evaluation of a fuller set of pollutants would end to increase the estimated financial benefits associated with lower conventional energy used in green buildings.

The California Air Resources Board (ARB) compiles and publishes annual data on emissions offset transactions[139] from 35 districts. Figure V-4 contains the reported prices for these offsets.[140] The average value of offsets was used in calculations.

Morbidity, Mortality, and Air Pollution Study – Part II: Morbidity and Mortality From Air Pollution In the United States," Health Effects Institute, 2000. Available at: http://www.healtheffects.org/Pubs/Samet2.pdf.

[136] For a valuable introduction and overview of past California and national studies on externality cost and costs of emissions reductions, see Jonathan Koomey and Florentin Krause, "Introduction to Externality Costs," LBNL, 1997. Available at: http://enduse.lbl.gov/Info/Externalities.pdf .

[137] Nick Hall and Jeff Riggert, "Beyond Energy Savings: A Reviews of the Non-Energy Benefits Estimated for Three Low-Income Programs," *ACEEE Conference Proceedings, Program Measurement and Evaluation* – 10.111.

[138] California Energy Commission. "1994 Electricity Report." Available at: http://www.energy.ca.gov/reports/ER94.html.

[139] Prior annual compilations of the offset transactions in California that occurred from 1993 through 2000 can be found at http://www.arb.ca.gov/erco/erco.htm.

[140] California Environmental Protection Agency, Air Resources Board, "Emission Reduction Offset Transaction Cost Summary Report for 2001,"April 2002, Table 1. Available at: http://www.arb.ca.gov/erco/erc01web.pdf. See also: http://www.arb.ca.gov/cgi-bin/swish/search.pl.

Figure V-4. 2001 Prices Paid in Dollars Per Ton for California-based Offsets

	NOx	PM10	SOx
Average (mean)	$ 27,074	$ 46,148	$12,809
Median	$ 22,000	$ 25,000	$ 7,500
High	$104,000	$126,027	$82,192
Low	$ 774	$ 400	$ 15

Source: California EPA Air Resources Board

Because there is no cap on CO2 emissions and no California CO2 market, CO2 price-indexes are not compiled and included. To determine CO2 value it is necessary to look at alternative sources.

The Cost of Carbon: Putting a Price on CO2 Emissions

The vast majority of the world's climate change scientists have concluded that anthropogenic emissions – principally from burning fossil fuels – are the root cause of global warming.[141] The United States is responsible for about 22% of global greenhouse gas (GHG) emissions. Of this 22%, the US building sector is responsible for about 35% of US CO2 emissions. CO2 is the dominant global warming gas, equal to about 9% of global anthropogenic emissions. As a recent study notes, US buildings alone are responsible for more CO2 emissions than those of any other country in the world except China.[142]

A report published in July 2002 for the United Nations Environmental Program's Finance Initiatives Climate Change Working Group, *Climate Change and the Financial Services Industry*, warns of the large risks posed by global warming. The report concludes that the "increasing frequency of severe climatic events, coupled with social trends, has the potential to stress insurers, reinsurers and banks to the point of impaired viability or even insolvency." [143] John Fitzpatrick, CFO and Member of the Executive Board of Swiss Re, maintains, "climate change and substantial emissions reductions – like any other strategic global business challenge – ultimately become a financial issue." [144] The United Nations estimates the potential cost of global warming at over $300 billion per year, and insurance firms are becoming concerned about the possibility of lawsuits due to damage from human-induced global warming.[145]

Global warming is recognized as a potentially very costly issue for California, implying a significant value for CO2 reductions in this state. Projected changes in rainfall patterns and snowmelt will likely reduce both available freshwater supplies and the effectiveness of the state's hydropower infrastructure. If California experiences below average rainfall, it could cut the

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[141] Intergovernmental Panel on Climate Change. World Meterological Association and United Nations Environmental Program. "IPCC Third Assessment Report – Climate Change 2001." Available at: http://www.ipcc.ch/.

[142] Kinzey et al., "The Federal Buildings Research and Development Program: A Sharp Tool for Climate Policy," *2002 ACEEE proceedings*, Section 9.21.

[143] Innovest, for the United Nations Environmental Program. Finance Initiatives Climate Change Working Group. "Climate Change and the Financial Services Industry," 2002. Available at: http://www.unepfi.net/.

[144] "Climate Change Related Perils Could Bankrupt Insurers," *Environmental News Service*, October 7, 2002. Available at: http://www.campaignexxonmobil.org/news/News.OneWorld100802.html.

[145] Katharine Q. Seeley, "Global Warming May Bring New Variety of Class Action", *New York Times*, September 6, 2001. Available at: http://www.commondreams.org/headlines01/0906-03.htm.

amount of power that the state gets from hydroelectricity, currently 20% of total power, by up to half.[146]

California's new climate change legislation, passed in October 2002[147] establishes global warming as an issue of legitimate state concern. In addition, previous legislation requires that the value of emissions reductions be considered in developing a present value assessment of solar energy systems for California state buildings.[148] California's building investment and construction programs should reflect this, probably by assigning a dollar value to avoided GHG emissions achieved through better building design. Even if this value is not based on a single, determinative methodology and even if it is low, recognizing the cost of global warming by assigning a dollar value of some amount is preferable to the current practice of assigning no value – effectively $0 – to CO2 reductions. It is also economically efficient for the state to explicitly recognize a value for CO2 in order to ensure a more cost-effective decision making process about building design choices.

It is important to note that because California is a relatively energy efficient state with relatively clean electricity generation, the emissions associated with energy use in California buildings are relatively low. Balancing this, the value of emissions traded in California markets is high relative to the rest of the US.

Market trading rules for CO2 are not yet established and there is no accepted cap on emissions to drive the creation of a California market. Therefore a range of approaches for determining a fair value for CO2 reductions is discussed below.

Assigning a Cost to Carbon

The large energy use of buildings (more than one third of energy used in the economy) has led to extensive analysis of strategies to cut CO2 emissions from this sector. Countries such as Holland are developing specific programs to reduce energy use and associated greenhouse gas emissions from their buildings sector.[149] Innovative legislation passed in 1997[150] in Oregon mandates that new power plants in the state offset a significant portion (roughly 17%) of their CO2 emissions either by avoiding, sequestering or displacing emissions or by funding projects that do the same.[151] To date, this program has funded projects (including those currently under negotiation)

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[146] William Keese, "Electricity Supply/ Reliability 2000 to 2002," Report for the joint hearing to the California Senate, August 10, 2000. Available at: http://www.energy.ca.gov/papers/2000-08-10_KEESE_TESTIMONY.PDF.

[147] State of California Assembly Bill 1493. Chapter 200, Statutes of 2002. Available at: http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_1451-1500/ab_1493_bill_20020722_chaptered.pdf. For more on CO2 issues in California, see: http://www.arb.ca.gov/gcc/gcc.htm.

[148] State of California Senate Bill 82, Chapter 10, Statutes of 2001-2002, 2nd Extraordinary Session. Available at: http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_0051-0100/sbx2_82_bill_20011007_chaptered.pdf.

[149] Kool et al., "Development of Policy to Reduce CO2 emissions from the Dutch Building Sector," *ACEEE conference proceedings*, 2002, Section 9.23.

[150] State of Oregon House Bill 3283. Oregon Revised Statutes of 1997. Oregon Administrative Rules, Chapter 345, Division 24. Available at: http://www.climatetrust.org/housebill.html.

[151] The Climate Trust. "Funding Innovative Projects to Counter Rapid Climate Change." October 2002. Available at: http://www.climatetrust.org/CTBrochureOct2002.pdf; "2001 Annual Report," Available at: http://www.climatetrust.org/2001AnnualReport.pdf.

that will result in approximately 3.5 million metric tons of CO2 offsets.[152] Within California, legislation has established the California Climate Action Registry, a voluntary registry for businesses and organizations within California to record annual greenhouse gas emissions and track reductions over time.[153] However, there is currently no mandate for state agencies to participate in the Registry. For California, models indicate that achieving a slowdown in growth of CO2 emissions resulting from building energy use would require state taxes on CO2 of $5 per ton in 2005, rising to $14 per ton in 2020.[154]

Determining a value for CO2 reduction is a difficult proposition. For example, a recent Intergovernmental Panel on Climate Change (IPCC) report cites a range of values between $5 and $125 per ton of CO2.[155] CO2 trading programs in the US are emerging,[156] with the value of trades typically ranging from under $1 up to $16 per ton, with most trades at under $5 per ton, but with a general trend of prices rising. The World Bank has participated in 26 emissions reduction projects, with CO2 trading at $3 to $4 per ton.[157] BP has used a price of $10 per ton for internal trading of CO2.

Despite the wide range of current prices for CO2, there is a widespread perception that CO2 prices will rise as the market demand continues to grow, as more private firms and public entities participate, and as the least expensive tons get bought up first. Many macro models project that to meet significant CO2 reduction targets, CO2 prices must be in the $25-$50 per ton range. The exact clearing price depends to a large extent on the size of emissions reductions sought – a political issue that has yet to be resolved. The EU estimates that to achieve the Kyoto Protocol CO2 targets, CO2 cost will need to be about $30 per ton.[158]

A 2002 A.D. Little (ADL) study for the CEC and the ARB includes a detailed analysis of the value of CO2. This study summarizes CO2 values from four emissions trading firms active in the US and two emissions trading institutions, with prices ranging from $0.10 up to $70 per ton. The individual averages of the six institutions are between $2 and $35, with the average of these averages at $13 per ton of CO2 (note that most trades were at lower prices).

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[152] The Climate Trust. "The Climate Trust Fact Sheet." 2003. Available at: http://www.climatetrust.org/aboutus.html.

[153] State of California Senate Bill 527, Chapter 769, Statutes of 2001. Available at: http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_0501-0550/sb_527_bill_20011012_chaptered.pdf.

[154] Kool et al. (all in 1999 dollars) Op. Cit.

[155] IPCC Working Group III, "Summary for Policymakers: The Economic and social Dimensions of Climate Change," 2001. Available at: http://www.ipcc.ch/pub/sarsum3.htm.

[156] Carbon Trade Watch. "Briefing No. 1: The Sky is Not the Limit: The Emerging Market in Greenhouse Gases." January 2003. Available at: http://www.tni.org/reports/ctw/sky.pdf. For a list of existing registry and emissions reductions programs, see also: http://www.nescaum.org/Greenhouse/Registry/state_matrix.html.

[157] "World Carbon Credit Trading Could Triple," *CNN*, October 22, 2002. Available at: http://www.evworld.com/databases/shownews.cfm?pageid=news221002-02.

[158] P. Capros and L. Mantzos, "The Economic Effects of EU-Wide Industry-Level Emission Trading to Reduce Greenhouse Gases," May 2000. Available at: http://europa.eu.int/comm/environment/enveco/climate_change/primes.pdf.

The ADL report concludes by recommending that California adopt a value of $25 per ton of CO2. The CEC estimated that $11 (2002 dollars) must be spent on reforestation to grow enough trees to absorb one ton of carbon dioxide each year.[159] A more recent report, completed by TIAX, LLC for the ARB and CEC completes a similar analysis, but recommends a value of $15 per ton of CO2 emissions.[160]

Given the large range of prices assigned to CO2 by emissions trading markets, policy makers, analysts and others, there is no exactly "right" price per ton of CO2. This analysis recommends that California state agencies adopt a value of $5 or $10 per ton when valuing CO2 emissions. Both of these prices are reasonable figures. These prices are above most current CO2 trades, but well below most medium term estimates for CO2 reduction costs, and below specific price estimates and projections for California. Additional analysis is recommended to arrive at a more thorough valuation of CO2, and this might, for example, include a range of values with probability assigned to each different value. Despite the uncertainties and large credible range of possible prices, some value per ton should be assigned to CO2 for the purposes of calculating the benefits of green buildings, and the relatively conservative prices estimates of $5 and $10 are modeled below.

Conclusion

The average California state building uses electricity at a rate of about 10 $kWh/ft^2/yr$.[161] Converting this to GWh, multiplying by the emissions factors for 2010 from Figure V-3, and then multiplying again by the average prices-per-ton from Figure V-4, yields yearly emissions costs per square foot (Figure V-5). Figure V-6 shows the 20-year PV of a 36% reduction in emissions of the four pollutants discussed above.

Figure V-5. Estimated Annual Cost of Emissions (/ft^2)

Pollutant	Emission Factors (short tons per GWh)	Dollars/ton		Annual Cost of Emissions for 10 kWh	
Carbon Dioxide	308	$5	$10	$0.015	$0.031
Sulfur Dioxide	0.281	$12,809		$0.036	
Nitrogen Oxides	0.448	$27,074		$0.121	
PM-10	0.2	$46,148		$0.092	

Source: Tellus Institute, California ARB, Capital E Analysis

[159] California Energy Commission, Committee Order for Final Policy Analysis, Docket No. 88-ER-8, March 27, 1990, as reported in the Tellus *Packaging Stud,* Report #4, "Impacts of Production and Disposal of Packaging Materials – Methods and Case Studies," p. 1-5. CPI adjusted from $8 in 1990 dollars.
[160] TIAX, LLC, "Benefits of Reducing Demand for Gasoline and Diesel," Report to the CARB and CEC, May 2003. Available at: http://www.energy.ca.gov/fuels/petroleum_dependence/documents/2003-05-07_600-03-005A1.PDF.
[161] Data provided by the California Department of General Services, Real Estate Services Division, Building Property Management Brach. See Appendix I. Energy use and cost numbers come directly from utility bills.

Figure V-6. 20-Year PV of 36% Pollution Reduction for California Buildings (/ft^2)

Pollutant	CO2 PRICE $5/ton	CO2 PRICE $10/ton
NOx	$0.54	$0.54
PM10	$0.41	$0.41
SOx	$0.16	$0.16
CO2	$0.07	$0.14
Total	**$1.18**	**$1.25**

Source: Capital E Analysis

This report will assume the lower $5 per ton value of carbon, indicating a 20-year PV of $1.18/ft^2 for emissions reductions from green buildings.

VI. Water Conservation

California is facing substantial water shortages that are expected to worsen. Drought years can be particularly difficult on Californians. Urban water users have experienced mandatory rationing, small rural communities have seen wells go dry, agricultural lands have been fallowed, and environmental water supplies have been reduced. Without additional facilities, all of these conditions will only deteriorate with California's projected population increase.[162] Thus, water conservation not only saves money for the end user through reduced utility expenditures, but also saves state water districts the costs of facilities construction and expansion and prevents potential environmental damage.

Green building water conservation strategies typically fall into four categories:

- Efficiency of potable water use through better design/technology.
- Capture of gray water – non-fecal waste water from bathroom sinks, bathtubs, showers, washing machines, etc. – and use for irrigation.
- On-site storm water capture for use or groundwater recharge.
- Recycled/reclaimed water use.

Taken together, these strategies can reduce water use below code/common practice by over 30% indoors and over 50% for landscaping.[163] Of 21 reviewed green buildings submitted to the USGBC for LEED certification (including 6 California buildings) all but one used water efficient landscaping, cutting outdoor water use by at least 50%. Seventeen buildings, or 81%, used no potable water for landscaping. Over half cut water use inside buildings by at least 30%.[164]

Current Practice in California State Commercial and Institutional Buildings[165]

The state's current strategy for water conservation in new or renovated buildings generally does not include measures that exceed federal codes. However, the SBTF has developed a 2-tiered list of sustainable building measures, which includes a number of water efficiency elements.[166] While in theory, new projects should include all feasible water efficiency technologies and strategies, in practice this is not done in most projects.[167] Additionally, state projects are not

[162] California Department of Water Resources, "California Water Plan Update BULLETIN 160-98," 1998, Volume 2, Chapter 6, p. 6-2. Available at: http://rubicon.water.ca.gov/. A more current update is expected from DWR in 2003.
[163] US Green Building Council LEED Reference Package, Version 2.0, June 2001, p. 65, and analysis of green buildings submitted to USGBC. Available for purchase at: http://www.usgbc.org/LEED/publications.asp.
[164] Data provided by USGBC.
[165] "Commercial" refers to water use at state office buildings and other commercial facilities. "Institutional" refers to water use at schools, colleges, universities and other non-office government facilities.
[166] California Department of General Services. Real Estate Services Division. "Tier 1 and Tier 2 Energy Efficiency and Sustainable Building Measures Checklists." July 1, 2002. Available at: http://www.ciwmb.ca.gov/GreenBuilding/Design/Tiers.pdf.
[167] California Department of General Services. Real Estate Services Division, Project Management Branch. "Energy Efficiency and Sustainable Building Measures Capital Projects Summary." August 8, 2002.

mandated to follow California's Model Water Efficient Landscape Ordinance of 1993, even when a project is located in an area where the local utility has adopted it. It is therefore assumed that most state buildings are no more water efficient than other private sector commercial projects in California, and that typical strategies employed to reduce water consumption in private sector projects have a similar impact on California state buildings.

The Cost-Effectiveness of Water Conservation and Demand Reduction Strategies[168]

The potential cost savings of water conservation has been documented in the commercial and institutional sectors. Two 1997 studies – one by the Metropolitan Water District (MWD) and one by the US EPA and the California Department of Water Resources (DWR) attempted to estimate this potential specifically in California.[169] The MWD study found that commercial water use volume could be cost-effectively reduced (average payback – 1.7 years) by approximately 23%. The DWR study came to similar conclusions, finding that a 22% reduction in water use could be cost-effectively generated through conservation strategies. Projected savings by building type include: office buildings - 40%, schools - 21%, and hospitals - 22%.[170] In both studies, the authors note that estimates are conservative, and only include relatively simple technologies and/or implementation strategies and short term paybacks.

Water conservation can take several forms. In an urban commercial or institutional setting, significant savings can be achieved through reductions in outdoor water use – with efficient landscape and irrigation design, automatic rain sensors, and landscape water audit programs to ensure that reductions are met – as well as indoors – with better leak detection, more efficient appliances, and aggressive audits (simply ensuring compliance with existing standards and regulations could result in a 3% demand reduction across the commercial, industrial and institutional sectors).[171]

The cost of urban water conservation programs is typically $500-$750/af of conserved water (1 af = 1 acre-foot = 325,851 gallons).[172] Water can also be conserved by increasing the efficiency of the distribution system. Reducing distribution system losses to 5% through full metering, annual water audits, and systematic leak detection and repair programs would cost an estimated $300/af.[173]

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[168] Cost-effectiveness is described earlier in the assumptions section, and is consistent with the definition in "BMP Costs and Savings Study: A Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices," prepared for the California Urban Water Conservation Council by A & N Technical Services, Inc, March 31, 1999. It states, "Cost-effectiveness analysis (CEA) is the comparison of costs of a conservation device or activity with its benefits expressed in physical units (for example, $Costs per AF of savings). Cost-benefit analysis (CBA) is the comparison of costs of a conservation device or activity with its benefits, also expressed in dollar terms (for example, $Net Benefits = $Benefits - $Costs)."
[169] Charles Pike*, "*Study of Potential Water Efficiency Improvement in Commercial Business," US EPA/DWR, April 1997.
[170] Jon Sweeten and Ben Chaput, "Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector*,"* paper delivered to the AWWA, 1997, p.8.
[171] BULLETIN 160-98, p. 6-10. Op. Cit.
[172] A&N Technical Services. "BMP Costs and Savings Study: A Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices*."* July 2000. Available for purchase at: http://www.cuwcc.org/publications.
[173] BULLETIN 160-98, p. 6-10, 6-11. Op. Cit.

Estimated Actual Cost of Water from the State Perspective

A recent empirical study in Canada estimated that the price charged for fresh water was only one-third to one-half the long-run marginal supply cost, and that prices charged for sewage were approximately one-fifth the long-run cost of sewage treatment.[174] Commonly uncounted components of the long-run marginal supply cost include: new marginal water supply expansion and treatment, new marginal wastewater capacity and treatment, and the economic costs caused by environmental damage. Given anticipated population growth and concomitant escalating water demand, these costs are likely to be significant. (For a brief description of California's current water situation including demand, forecasted growth rates, and supply constraints, please see Appendix F). These factors make conservation and demand reduction, as encouraged in green building, all the more attractive – water saved does not need to be treated or disposed.

The California Urban Water Conservation Council (CUWCC) has designed a model to account for all of these factors in determining the total savings of water conservation. Called the Total Society Cost Model,[175] it requires inclusion of all avoided future economic, environmental, and social costs in order to determine a true avoided cost of urban water conservation. It has yet to be implemented by a single agency, perhaps reflecting the fact that determining the true marginal cost of water is difficult.

The following factors contribute to the complexity of determining the true marginal cost of water:

- *Regional Differences*. The current and projected future cost of supplying, treating, delivering and disposing of water vary drastically between and within regions.
- *Future Cost of Water.* To value a water conservation measure today, it is necessary to predict future marginal water costs over the lifetime of the measure. The marginal cost of water in 2012 depends on multiple factors including: demographic changes, weather patterns and public policy choices.
- *Perspective.* Marginal cost depends on perspective. A private building owner, a local utility, a regional utility and a state will all have different marginal cost assumptions.
- *Hard-to-Quantify Environmental Costs*. Although attempts have been made to value some environmental costs (e.g., complying with anticipated regulations), the economic impacts of damages (e.g., habitat destruction, fish losses, local air pollution, greenhouse gas emissions, increased delta salinity, etc.) are generally more difficult to quantify.
- *Unpredictable Political Landscape*. For more than 20 years, California has been taking as much as one million acre-feet per year (1 maf/yr) from the Colorado River above an existing legal limit of 4.4 maf/yr. In January 2003, the Bush administration announced that California would no longer be entitled to this extra water. In 2003, this could mean California will lose as much as 650,000 af of anticipated water supply.[176] This decision will likely increase southern California's marginal cost of water.

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[174] Steven Renzetti, "Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions," *Canadian Journal of Economics*, v32, i3, May 1999, p. 688.
[175] This approach is described in "Guidelines for Preparing Cost-Effectiveness of Urban Water Conservation Best Management Practices," a publication of the CUWCC, Sept. 1996, pp.1-7.
[176] Dean Murphy, "The Politics of Water: California Water War Takes New Turn," *San Francisco Chronicle*, 2003. Available at: http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2003/01/05/MN169799.DTL.

- *Climate Change Impacts*. Recent studies suggest that global warming will have a significant impact on California's water resources. It appears there is no available study that projects the impact of climate change on the cost of future water supplies.

Notwithstanding these challenges, two comprehensive studies have been released over the past several years that attempt to determine appropriate marginal water costs for the state. The more recent, *Urban Water Conservation Potential*, was produced by Gary Fiske and Associates for the California Urban Water Agencies (CUWA) in August 2001.[177] It assigns marginal cost numbers to every region of the state for each year from 2000 – 2040.[178]

Figure VI-1 below shows the present value of avoided marginal water costs over a 20 year period based on the CUWA study. *Supply* is the present value of the marginal price the utility would pay to obtain or develop an acre-foot of water each year. *Wastewater* is the present value of the average cost savings - $73.50/af - from the delay of new wastewater facilities construction over the same time period. *Wastewater O&M* is the present value of the average avoided cost to treat new supplies - $13.50/af - over the specified time period. The *Weighted Average Value* is based on anticipated population growth for each region of the state (see Appendix G for calculations).

Figure VI-1. 20-Year Net Present Value of Avoided Marginal Water Supply and Wastewater Treatment Costs to Local Water Agencies in 2003

	Supply (/af)	Wastewater (/af)	Wastewater O&M	Total (/af)
Bay Area	$8,392	$953	$201	$9,546
Central Coast	$4,423	$953	$201	$5,576
Sacramento	$629	$953	$201	$1,783
San Joaquin	$1,944	$953	$201	$3,098
South Coast	$7,920	$953	$201	$9,074
S. Lahontan	$3,683	$953	$201	$4,837
Tulare	$2,046	$953	$201	$3,200
Average	$5,075	$953	$201	
			Weighted Average Value:	**$6,299**

Source: Gary Fisk and Associates for CUWA, Capital E Analysis

The CUWA study highlights the large differences in marginal water costs between regions (Sacramento's current low cost reflects historical access to low cost water sources) and provides a potential baseline for regional marginal water cost analysis.

A second study, *Economic Evaluation of Water Management Alternatives*, was developed by CALFED in October 1999.[179] It makes predictions of marginal water costs in certain regions of California only for the year 2020, and is thus less useful for determining 20-year PV and yearly

[177] Gary Fiske and Associates, "California Urban Water Agencies Urban Water Conservation Potential*."* *Final Report*, August 2001.
[178] It is assumed that wastewater capacity expansion costs would not begin to accrue until 2005 as projects currently being developed should be counted as fixed, sunk costs.
[179] "Economic Evaluation of Water Management Alternatives," prepared for the CALFED Bay-Delta program, October 1999. Available at: http://calwater.ca.gov/Archives/WaterManagement/adobe_pdf/EconomicEvaluationofWaterManagementAlternatives_Oct99.pdf.

marginal water costs than the CUWA study. The "Unconstrained" scenario, CALFED's preferred/expected option of the seven analyzed, is presented in Figure VI-2 below:[180]

Figure VI-2. Marginal Cost Expectations for One Acre-foot of Water in 2020[181]

	CALFED	CUWA
South Coast	$1,045	$628
San Francisco Bay	$1,123	$867
San Joaquin River	$130	$138
Tulare Lake	$211	$143

Source: CALFED, CUWA

While the CALFED numbers are higher than those from CUWA, a more comprehensive assessment of California's water situation would probably reflect marginal cost numbers higher than both for most regions of the state. The California Water Plan Update from 1998[182] cites a number of water development projects and their costs.[183] According to this report, dam construction alone can cost $2.3 billion to deliver an average of 620,000 af/yr from the San Joaquin River. This excludes property, utility relocation and mitigation costs, as well as maintenance and other water delivery costs. Seawater desalinization, often viewed as the upper bound of economically feasible water, costs $1000-2000/af.[184] The following important factors should be included in order to accurately estimate marginal water cost.

Perspective. The marginal cost numbers from the CUWA study are equal to the price the agency pays for water. From the state's perspective, however, there are additional costs of developing new supplies and delivering water to the end user. These costs can be significant. For example, MWD has now begun accepting proposals from its member agencies to develop desalinization facilities. MWD will pay up to $250/af to subsidize the local construction of desalinization plants.[185] From the perspective of the MWD, the marginal cost of this water is $250/af. However, the actual development cost to the local agencies can be up to $2000/af.[186] Assuming an average annual cost of $1150/af suggests a 20-year PV of $14,332/af of new water capacity construction avoided, or more than 2 times higher than the weighted average cost for California indicated Figure VI-1.

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[180] *Ibid.* Table 8.1.

[181] San Joaquin and Tulare Lake Region numbers are much lower than the Bay Area and South Coast for two primary reasons. First, their marginal need is for agriculture, and agricultural water is much less expensive to develop, treat, and dispose of than urban water. Second, both of these regions are closer to the water sources than the Bay Area and South Coast, sharply reducing pumping costs. Costs include amortized capital and O&M costs for supply measures, plus estimated retail cost components for treatment, distribution and administrative overhead.

[182] BULLETIN 160-98, Volume 2. Op. Cit.

[183] "California Water Plan Update BULLETIN 160-98," Volume 2, Chapter 6.
Download at: http://rubicon.water.ca.gov/pdfs/v2/v2ch6.pdf.

[184] *Ibid*, p.6-34.

[185] CUWA study. Op. Cit.

[186] CUWA study. Op. Cit.

Wastewater Treatment Costs. The authors of the CUWA study acknowledge that their wastewater treatment numbers could be refined.[187] The CUWA study assumes that the marginal cost of wastewater treatment will grow at the rate of inflation, as it has, on average, over the past ten years. However, a recent study released by the EPA suggests that future costs will likely rise much more rapidly than in the past.[188] The city of Portland, Oregon, for example, expects wastewater rates to rise by about 7% annually over the next decade, significantly higher than the 2-3% annual increase experienced over the past several years.[189]

Proposition 50 Supply Projects. This initiative, from the November 2002 ballot, requires California to issue $3.4 billion worth of bonds to fund a variety of water projects over the next several years. A portion of the funds is intended for new supply and advanced treatment projects including desalination and reclaimed water.[190] These relatively expensive projects were not included in the marginal cost assumptions in the CUWA study.

Projections of Environmental Costs. Environmental costs beyond those attributed to anticipated regulatory requirements are difficult to quantify. Not surprisingly, the authors of the CUWA study made no attempt to estimate them. Nevertheless, both water supply expansion and marginal consumption have significant potential environmental impacts. These include: wildlife habitat destruction, fish losses, local air pollution and climate change impacts, among others.[191]

In addition, multiple studies suggest that global warming will likely alter precipitation patterns in the state. A recent report by the Pacific Institute summarized the results of nearly 1,000 peer-reviewed studies on climate change. The report states "with very high confidence":

> *It is likely that reductions in snowfall and earlier snowmelt [caused by global warming] and runoff would increase the probability of flooding early in the year and reduce the runoff of water during late spring and summer. Basins in the western United States are particularly vulnerable to such shifts*.[192]

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[187] Illingworth, Wendy. Economic Insights, Inc., Oct 15, 2002.

[188] The EPA reports that the expected gap between future revenues (based on historical price increase) and infrastructure needs will be approximately $148 billion over the next twenty years. See: US Environmental Protection Agency. "The Clean Water and Drinking Water Infrastructure Gap Analysis," August 2002. Available at: http://www.epa.gov/owm/gapfact.pdf.

[189] Data provided by the city of Portland, Environmental Services Department. October 2002.

[190] Proposition 50 allocates up to $200 million for desalination, treatment capacity expansion, and recycled water projects. "The Official Voter Information Guide to the November 2002 California Elections*.*" http://www.ss.ca.gov.

[191] See, for example, "Proceedings of a Workshop on Economic Non-Market Evaluation of Losses to Fish, Wildlife and Other Environmental Resources," Bay Institute of San Francisco, May 1987.

[192] Peter Gleick, "Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States," September 2000, p. 4.
Available at: http://www.gcrio.org/NationalAssessment/water/water.pdf. A similar UCS study finds that more precipitation will fall as rain, rather than snow, causing massive flooding in the spring and droughts by late summer. Reduced summer runoff of fresh water would also increase summer salinity in San Francisco Bay, requiring less diversion in order to meet ecosystem and bay water quality needs. Christopher Field, "Confronting Climate Change in California: Ecological Impacts on the Golden State*,*" *Union of Concerned Scientist*, 1999.
Available at: http://www.ucsusa.org/publication.cfm?publicationID=7.

According to the California Climate Change Registry, climate change in California will also likely cause the following: a sea level rise of 4-35 inches by 2100, severe salt-water intrusion into coastal aquifers, and greater air pollution.[193]

Exclusion of Reclaimed Water Projects. Reclaimed water projects provide an increasingly large share of "new" water supply. In the Bay Area, for example, reclaimed water is expected to account for 50% of new supply over the next twenty years.[194] Reclaimed water projects typically cost $600-$1100/af – higher than the marginal costs numbers presented in the CUWA study in *every* region of the state. At an average cost of $850/af, the 20-year PV for avoiding new reclaimed water projects is about $10,593/af, or almost 2 times larger than CUWA estimates for the Bay Area.

This report will assume that actual costs are two times higher than indicated by CUWA data, for a state average 20-year PV of $12,598/af. For the reasons described above, even this adjusted cost estimate is likely to be low. Additional work needs to be conducted to obtain more accurate full cost numbers.

Conclusion

Green buildings are designed to conserve water. Taking the avoided cost of water to be only the average retail price paid by state agencies to local utilities, the literature suggests that there is considerable potential for cost-effective water conservation strategies in new and renovated building projects in many regions of the state. However, the actual value of water conservation to the state is not the avoided cost of retail water rates. Rather, it is the region-specific added cost of new marginal water supplies.

The CUWA study cited above advances knowledge of the marginal costs of new water supplies. But it is clear that additional work needs to be done to determine more realistic numbers. More comprehensive assumptions will likely yield higher marginal costs, and thus higher potential savings. Nevertheless, the CUWA study is a good basis for determining average statewide costs, and can be adjusted upward to reflect actual recent water costs.

The modified CUWA findings were applied to a hypothetical new state building project to determine potential savings and include this and a cost doubling to reflect the higher actual costs discussed above. This provides a 20-year PV of $0.51/ft^2 for water savings from green buildings. These costs are very likely conservative (low) for reasons discussed above. Please see Appendix G for the detailed calculations.

This investigation provides a conservative estimate for the value of water savings from green building, but also indicates that more research and analysis needs to be done.

[193] See: http://www.climateregistry.org/.
[194] "Water Conservation Master Plan Annual Report," FY02, East Bay Municipal Utility District. 2002. p.4.

VII. Waste Reduction

Nearly 60% (over 21 million tons in 1998) of waste in the state of California comes from commercial (i.e. non-residential) buildings.[195] Additionally, 57% of the construction and demolition (C&D) debris nationally comes from the non-residential sector.[196] California state buildings generally fall within this category.

Waste reduction strategies such as reuse and recycling, as promoted in green buildings, help to divert some waste from being disposed of in landfills. Diversion strategies result in savings associated with avoided disposal costs as well as in reduced societal costs of landfill creation and maintenance. In addition to diverting waste from landfills, recycling and reuse can catalyze further economic growth in industries that reprocess diverted waste and use recycled raw materials.

Green building waste reduction strategies can occur at time of construction and throughout the life of the building.

Construction waste reduction options include:

- Reuse and minimization of construction and demolition (C&D) debris and diversion of C&D waste from landfills to recycling facilities.
- Source reduction, e.g., (1) use of building materials that are more durable and easier to repair and maintain, (2) design to generate less scrap material through dimensional planning, (3) increased recycled content, (4) use of reclaimed building materials, and (5) use of structural materials in a dual role as finish material (e.g. stained concrete flooring, unfinished ceilings, etc.).
- Reuse of existing building structure and shell in renovation projects.

Building lifetime waste reduction includes:

- Development of indoor recycling program and space.
- Design for deconstruction.
- Design for flexibility through the use of moveable walls, raised floors, modular furniture, moveable task lighting and other reusable building components.

Together, these strategies can have a dramatic impact on reducing landfill disposal. C&D diversion rates have reached as high as 97% on individual state of California projects, and are typically at least 50-75% in green buildings.[197] C&D waste impacts vary greatly depending on the type of building project and whether it is new construction, renovation, or construction on already developed land.

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[195] California Integrated Waste Management Board. "Statewide Waste Characterization Study: Results and Final Report." December 1999. p. ES-2: commercial and self-haul commercial values combined

[196] US Environmental Protection Agency Municipal and Industrial Solid Waste Division, Office of Solid Waste. "Characterization of Building-related Construction and Demolition Debris in the United States." June 1998. p. 2-11, Table 8.

[197] California State and Consumer Services Agency and Sustainable Building Task Force. "Building Better Buildings: A Blueprint for Sustainable State Facilities." December 2001. P.16.

Of 21 green buildings submitted to USGBC for certification, seventeen, or 81%, reduced construction waste by at least 50%, while 38% reduced construction waste by 75% or more.[198] Renovated projects can often utilize 75-100% of a building envelope and shell (excluding windows) and up to 50% of non-shell elements (walls, floor systems, etc.).[199]

Designing indoor recycling systems encourages recycling as part of a building's operational practices. Moveable walls, raised floors, modular furniture, and moveable task lighting can reduce the costs and wastes associated with reconfiguring office spaces (similar to saved churn costs of "Underfloor Air" – see Section IX).

It is clear that green buildings recycle and divert substantially higher levels of waste, and incorporate greater amounts of recycled or "re-used" materials than conventional buildings. However estimating the relative increases in waste recycling, diversion and use of green buildings compared with conventional buildings is difficult and tenuous.

Current Practice in California State Commercial and Institutional Buildings

Currently, there is no standard practice for incorporating all the waste reduction elements into state construction projects, although efforts are underway in each individual category.

C&D diversion requirements are incorporated into state contracts through the use of building performance standards and the Tier sustainable building measures checklists, which specify technologies that should be or can be used in new buildings. Tier 1 requires that all projects develop a recycling plan that results in the diversion of 50% or more of C&D materials, and Tier 2 encourages project teams to consider diverting 75% or more (if economically feasible). Although required, there is little evidence to date that indicates either is regularly done for state projects.[200]

The Tier 1 list also requires projects to "provide for dedicated space in and outside the building for the collection, storage, and loading of recyclable materials." Unfortunately, information is not readily available to indicate how often dedicated recycling space is actually included in space designs. AB 75 does require state agencies and large state facilities (college campuses and prisons) to divert 25% of generated solid waste from landfills by January 1, 2002 and to achieve a 50% diversion rate by January 1, 2004.[201] Regardless of whether or not dedicated space is included in design, state agencies are required to implement recycling programs and many recycling programs are in place and being enhanced to reach this goal.

With respect to the purchase of recycled content products, there is a state mandate through the State Agency Buy Recycled Campaign[202] (SABRC) that requires state agencies to meet recycled content requirements for products in each of 12 categories.[203] Contractors for state agencies must also supply recycled content products that meet the SABRC requirements. Although SABRC has

[198] Data provided by USGBC.
[199] LEED Reference Package. Version 2.0. US Green Building Council. June 2001. pages 170 - 180.
[200] Information provided by the California Integrated Waste Management Board, Green Building Section. November 2002. (Kathy Frevert).
[201] California Assembly Bill 75 (Strom-Martin) Statues of 1999, Chapter 764. Available at: http://www.leginfo.ca.gov/pub/99-00/bill/asm/ab_0051-0100/ab_75_bill_19991010_chaptered.html.
[202] See: http://www.ciwmb.ca.gov/BuyRecycled/StateAgency.
[203] See: http://www.ciwmb.ca.gov/BuyRecycled/StateAgency/Buying.htm.

been in place for approximately 14 years, Block 225 of the Capitol Area East End Project was the first construction project to attempt to implement the mandate. While not all materials used in Block 225 were SABRC compliant, this project was invaluable in helping the state to develop specification language, reporting procedures, and forms that will assist future state projects in their efforts to increase the use of recycled content products.[204] The Tier 1 list does include requirements for the use of recycled content products, promoting the incorporation of these materials into projects when appropriate. Because the checklists were developed considering only material first costs, those products deemed cost-effective are fairly limited.

Since the enactment of the 1989 California Integrated Waste Management Act (AB 939),[205] waste diversion in California has been steadily increasing – from 17% in 1990, to 25% in 1995, to 48% in 2002.[206]

The Retail Cost of Disposal and Diversion

Retail collection and removal fees in California currently range from \$90 – \$150/ton for disposal (including an average tipping fee of \$34/ton)[207] and from \$120 – \$200/ton for recycling.[208] These are the fees paid by customers to waste management companies for waste collection and removal, and are associated with curbside recycling, not generally applicable to many commercial businesses. Higher fees for recycling collection probably result from the necessity to sort and collect separately different types of recycled waste. The range reflects many factors including: tipping fees, type of recycled material, recycled product markets and infrastructure, labor costs, and subsidies. Additionally, hauling costs may be higher for diversion/recycling because the waste must be transported farther in order to be processed.

Because of the relative high quality of many recovered building materials, well established markets, and lower collection costs, C&D recycling is generally less expensive per ton than curbside residential or commercial service. For example, C&D recyclers in the Sacramento region will accept concrete and asphalt for free and clean wood waste for less than \$10 per ton,[209] while the Sacramento County Landfill charges \$26 per ton[210] (hauling costs are not included in these figures). In this instance where the first cost of recycling is less than the first cost of disposal there is a direct financial incentive to divert materials for recycling and reuse.

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[204] Information provided by CIWMB, Recycling Technologies Branch. September 2003 (Clark Williams, JoAnne Jaschke)
[205] California Assembly Bill 939, Sher, Chapter 1095, Statutes of 1989. Public Resources Code (PRC) sections 42920–42928 Available at: http://www.leginfo.ca.gov/cgi-bin/displaycode?section=prc&group=42001-43000&file=42920-42928.
[206] CIWMB, "Solid Waste Generation and Diversion, 1989-2002." Available at: http://www.ciwmb.ca.gov/lgcentral/Rates/Diversion/RateTable.htm
[207] CIWMB, "Active Landfill Profiles," 2003. Available at: http://www.ciwmb.ca.gov/Profiles/Facility/Landfill/Default.asp.
[208] Conversation with Aya Ogishi, Department of Agricultural and Resource Economics, UCB, November 6, 2002. (John Blue, CIWMB).
[209] Telephone inquiry: *California Concrete Crushing and Recycling* (916) 387-5050 and *Allied Waste-Elder Creek Transfer & Recovery Facility* (916) 387-8425)
[210] CIWMB. "2000 Solid Waste Tipping Fee Survey." Available at: http://www.ciwmb.ca.gov/landfills/TipFees/2000/

Estimated Actual Cost and Benefits of Landfill Diversion

From the perspective of the state, the value of diverting materials from landfills should include all quantifiable benefits that accrue to the state. These include direct economic benefits as well as avoided environmental costs.

Direct Economic Value

Two recently published studies have quantified the economic costs and benefits of landfill disposal and diversion in California. The Department of Agriculture and Resource Economics at UC Berkeley (UCB), in conjunction with the California Integrated Waste Management Board (CIWMB), published the first study in April 2001.[211] The second, conducted by the National Recycling Coalition (NRC), was released in July 2001.[212] It is important to note that these studies deal with the economic impacts of waste diversion in general and are not specific to C&D diversion. These studies have been included to show the positive economic impact of diversion as compared to disposal.

The UCB study used 1999 data to compare the economic impacts of waste disposal to diversion in six California regions. For both disposal and diversion, the study calculated Total Sales generated from waste and four multiplier effects:

- *Total Output* – a measure of how the disposal/diversion sector influences total economic activity including direct (e.g., collection of wastes), indirect (e.g., collection/recycling equipment manufacturers, other support businesses) and induced impacts (e.g., engineers/consultants) – not including environmental costs.[213]
- *Total Income* – a measure of the total income earned by all persons in the economy attributed to disposal/diversion.
- *Total Value Added* – a measure of the increase in the value of goods sold by all sectors of the economy, minus the costs of inputs.[214]
- *Number of Jobs* – the number of jobs created by disposal/diversion activities.

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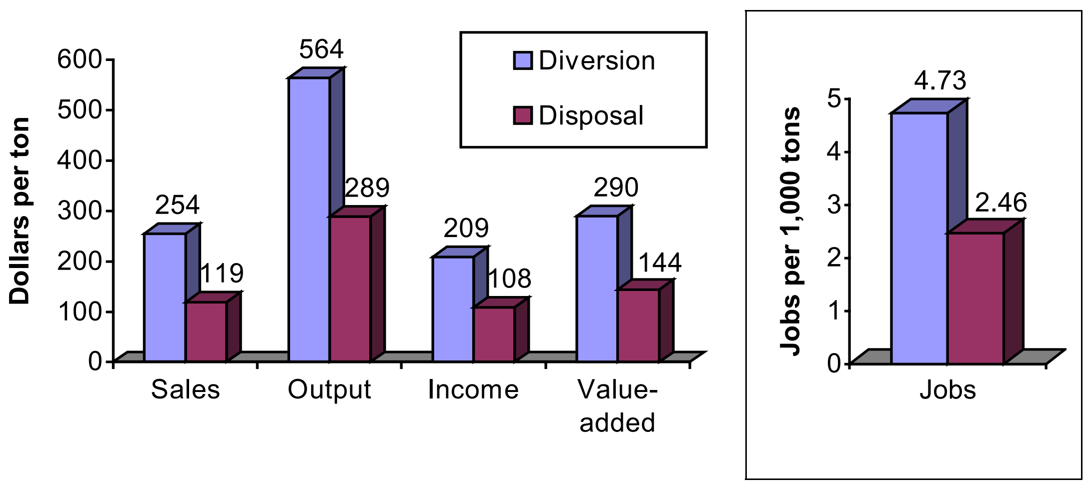
211 *Ibid.*

212 "California Recycling Economic Information Study (REI)," prepared for CIWMB by the National Recycling Coalition in association with R.W. Beck, Inc, July 2001. Available at: http://www.ciwmb.ca.gov/agendas/mtgdocs/2002/01/00007124.pdf.

213 Total Output includes both Total Income and Value Added.

214 Value Added also includes tax revenues.

Figure VII-1. Value of Diversion vs. Disposal in UCB Study



Source: Goldman and Ogishi, April 2001

In general, the UCB study found that total economic impacts from diversion are nearly twice as large as the impacts from disposal. One additional ton of waste disposed in a landfill in California generates $289 of total output in the state economy. One additional ton of waste diverted as recyclables generates an average of $564. Figure VII-1 above shows that only 2.46 jobs are created for every 1,000 tons of waste disposed, while 4.73 jobs are created for waste diverted as recyclables. The study also found that regional variation is significant. The Central Valley's total output impacts are nearly $350 per ton greater when waste is diverted, while the Eastern region is the only place in the state where, due to currently limited infrastructure to support recycling businesses, the average economic impacts for diversion are less than the impacts for disposal.[215]

The NRC study has a broader scope than the UCB study. It compares diversion to other sectors of the economy and shows how the economic impacts from diversion in California fit within the nationwide economy. It also uses different assumptions, input data and methodologies. Despite the differences, the resulting economic impacts per diverted ton are quite similar.

Averaging the results of the two diversion studies show that when material is diverted rather than disposed in a landfill, the marginal impacts are worth:[216]

- $325 per ton in Output Impact
- $70 per ton in Income Impact
- $111 per ton in Value Added Impact
- 2.15 jobs per 1,000 tons

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215 George Goldman and Aya Ogishi, "The Economic Impact of Solid Waste Disposal and Diversion in California." Paper presented at the *Western Agricultural Economic Association Meeting*, Logan Utah, July 20, 2001, p. 14. Available at: http://are.berkeley.edu/extension/EconImpWaste.pdf.

216 These numbers are based on data from "Two Studies on the Economic Impacts for Diversion: A Brief Review by Board Staff" (unpublished document from the CIWMB).

The figures are intended to quantify the economic impacts for the period of one year – the year in which the waste is either disposed of or diverted. They are not 20-year PV numbers. Both studies may under-estimate the full marginal value of diversion. In the Berkeley study, for example, only data from manufacturers that use recycled materials extensively (as identified by the 1997 Census of Manufacturers) were included. In addition, the Census data set does not include all industries. The value of source reduction and reuse were also not included in the study, nor was the value of some common materials such as tires. Consideration of these factors would likely increase the value of diversion.

Avoided Environmental Costs

While no study completed to date has examined and quantified the environmental benefits of recycling in California, several have investigated the subject in other states. The most comprehensive study was conducted in Massachusetts in 2000. The study found average total net environmental benefit of recycling at $63 per ton. According to the study, diversion has two primary benefits compared to disposal:[217]

1) Fewer hazardous substances and greenhouse gases are emitted when products are manufactured with recycled materials instead of virgin wood, metal and petroleum resources.[218]
2) Fewer hazardous substances and other pollutants are released when materials are collected for recycling instead of landfill disposal or incineration.

Just as the economic impact described in the UCB and NRC studies must be further refined to create a more meaningful number, this environmental estimate should be adjusted to reflect California-specific conditions. In addition, projected costs for long-term maintenance of environmental hazards associated with landfill degradation should also be considered.

Conclusion

As discussed above, estimating financial benefits of waste reduction, diversion and recycling from green buildings relative to existing buildings is difficult. At present, the AB75 baseline for waste diversion for California state agencies is 25%, set to increase to 50% in 2004. Although this does not apply directly to specific building construction projects, construction and demolition debris diversion do factor into the overall state agency calculation. Currently, no data exist to indicate whether or not these goals are being met relative to construction projects. However, diversion rates in excess of 75% are commonly met on projects where project managers enforce the Tier 1 & 2 requirements for waste diversion. Improved reporting of diversion and disposal data for state projects would significantly improve the ability to estimate the waste reduction benefits of green buildings.

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[217] Lisa Skumatz and Jeffrey Morris, "Massachusetts Recycle 2000: Baseline Report," prepared for the Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA) Recycle 2000 Task Force, December 1998.

[218] Estimates of net benefits of GHG reductions are based on US EPA, "Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, Final Report," September 1998, Exhibit ES-4. Available at: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BVP7P/$File/r99fina.pdf.

It is possible, with a set of tentative assumptions, to estimate waste benefits associated with green buildings. This report uses the numbers from the UCB and NRC/REI studies, combined with the environmental benefit from the Massachusetts study, to calculate rough conservative values for C&D diversion in for new construction as well as demolition of pre-existing structure before construction:

- $0.03/ft^2 or $3,000 per 100,000 ft^2 building for construction only.
- $0.14/ft^2 or $14,000 per 100,000 ft^2 building for construction preceded by demolition.

Since green buildings attempt to use some of the pre-existing building envelope, it is probable that diversion percentages for the second case will be higher than estimated in this analysis. The details of these calculations are included in Appendix H.

In the absence of good data on present rates of waste diversion in green and conventional buildings during both their construction and operation, it is impossible to quantify the relative advantages of either one. However, it appears probable that the green building waste reduction advantage would not exceed about $0.50/ft^2, because of California's already aggressive waste reduction targets (as set forth in AB 75 and AB 989) – the effectiveness of which is evidenced by the increase in waste diversion from 17% in 1990 to 48% in 2002.[219]

A more thorough study is needed to obtain more realistic financial cost estimates of diversion versus disposal and to generate a California-specific value for the environmental benefits of construction and demolition waste diversion and recycling.

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[219] CIWMB, "Solid Waste Generation and Diversion, 1989-2002." Available at: http://www.ciwmb.ca.gov/lgcentral/Rates/Diversion/RateTable.htm

VIII. Productivity and Health

California's Executive Order D-16-00, which established the Governor's sustainable building goals, includes the statement that sustainable building practices should "enhance indoor air quality; and improve employee health, comfort and productivity,"[220] indicating that health and productivity benefits should be explicitly recognized in the state's building design and funding decisions.

This section contains a brief overview of what is known about health, human comfort and productivity in relation to green building design and operation. The conclusion contains a reasonable and conservative estimate for the monetary value of productivity gains in green buildings. Health and productivity issues, often addressed separately, are combined here because both relate directly to worker well-being and comfort and both can be measured by their impacts on productivity.

The relationship between worker comfort/productivity and building design/operation is complicated.[221] There are thousands of studies, reports and articles on the subject. This report relies in large part on recent meta-studies that have screened tens or hundreds of other studies and have evaluated and synthesized their findings.

Potential Savings

The cost to the state of California for state employees is ten times larger than the cost of property. The following chart (Figure VIII-1) and supporting data (see Appendix I) represent state costs for 27,428 state employees in 38 state-owned buildings. Note that operations and maintenance (O&M) costs are allocated 44% for labor and 56% for property related expenses.[222] Average annual employee costs ($66,478 in salary and benefits - $65,141 - plus allocated operations and maintenance costs - $1,337), are 10.25 times larger than the cost of space per employee ($6,477).[223] Thus, measures that increase employee costs by 1% are equivalent, from a state cost perspective, to an increase in property related costs of about 10%. *In other words, if green design measures can increase productivity by 1%, this would, over time, have a fiscal impact roughly equal to reducing property costs by 10%.*

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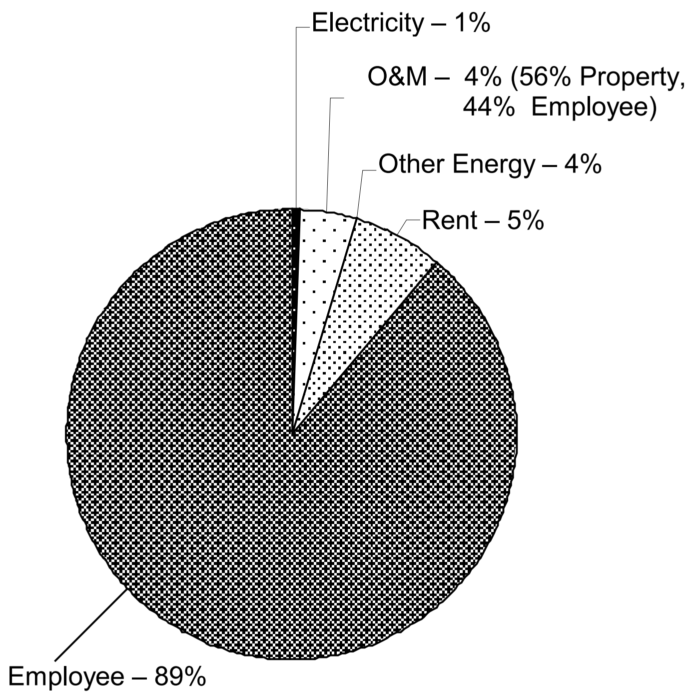
[220] State of California. Governor's Executive Order D-16-00, August 2000.
Available at: http://www.governor.ca.gov/state/govsite/gov_homepage.jsp.

[221] One approach to address this complexity is offered by comprehensive building performance scoring tools for evaluating building design and operation benefits. One example of this type of scoring methodology is called the Balanced Scorecard. This approach evaluates four categories of building performance: Financial Results (cost of absenteeism, turnover, etc), Business Processes (innovation, product quality, etc), Customer Satisfaction (stakeholder relations - including public image and local economic impact), and Learning and Growth (human capital development - including work satisfaction and productivity). These kinds of broad systems approaches are valuable for explicitly demonstrating how green buildings support health, productivity and other benefits and meeting larger corporate objectives. However, these types of approaches are less helpful for quantifying the benefits of green building design. See for example: http://www.balancedscorecard.org/bscand/bsckm.html.

[222] Operations and Maintenance cost ($3,039) are allocated 44% for labor and 56% for property related expenses. Data provided by the California Department of General Services, Real Estate Services Division. December 2002.

[223] See Appendix I.

Figure VIII-1. Costs in California State Employee-Occupied Office Buildings
(December 2001 - September 2002 with projections for November-December 2002)



Source: Real Estate Services Division of Department of General Services.[224]

Increased productivity is closely linked to improved worker health. Companies with a demonstrably healthier work environment can also experience reduced insurance premiums – a topic covered in Section X.

The Building-Productivity Link

There is growing recognition of the large health and productivity costs imposed by poor indoor environmental quality (IEQ) in commercial buildings – estimated variously at up to hundreds of billions of dollars per year. This is not surprising as people spend 90% of their time indoors, and

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224 Data provided by the California Department of General Services. November 2002. Note that these include state owned buildings leased to state agencies and that on average these rental rates are slightly below market average – perhaps by about 10%. The data were not adjusted to account for this (by about 3%) because doing so has no significant effect on calculations or conclusions. Conditioned area per employee is assumed to be $225ft^2$ – the number indicated by the California Department of General Services, Real Estate Services Division. This is significantly below the aggregate data summarized in Appendix I, provided by DGS, reflecting the fact that a substantial portion of building space is not conditioned occupied. Annual average energy cost is about \$1.60, conservatively projected to decline to $\$1.47/ft^2$. (Also see discussion of this data in Energy Use section.)

the concentration of pollutants indoors is typically higher than outdoors, sometimes by as much as 10 or even 100 times.[225]

Measuring the exact financial impact of healthier, more comfortable and greener buildings is difficult. The costs of poor indoor environmental and air quality – including higher absenteeism and increased respiratory ailments, allergies and asthma – are hard to measure and have generally been "hidden" in sick days, lower productivity, unemployment insurance and medical costs.

The discussion of IEQ and productivity issues in industry publications has expanded rapidly in the last decade to become a common theme, and has spilled over into popular media. Business Week's cover for its June 5, 2000 issue features a picture of a large menacing office building to accompany the feature story: "Is Your Office Killing You? The Dangers of Sick Buildings." [226] The article cites potential benefits of up to $250 billion per year from improved indoor air quality in US office buildings.

There are now hundreds of published testimonials about the health and productivity benefits that result from adopting green design strategies. For example:

- William Pape, the cofounder of VeriFone, reports that eighteen months after VeriFone employees began working in a building retrofitted to cut indoor pollutants and improve indoor environmental quality, absenteeism rates were down 40% and productivity was up by more than 5%. Pape notes that healthy workplaces have "done more to boost productivity than all the bandwidth in the world." [227]
- Gary Jay Saulson, the Senior VP and Director of Corporate Real Estate for PNC Realty Services, describes the benefits of the LEED Silver PNC Firstside Center building in Pittsburgh as follows: "people want to work here, even to the point of seeking employment just to work in our building. Absenteeism has decreased, productivity has increased, recruitment is better and turnover less." Two business units experienced 83% and 57% reductions in voluntary terminations after moving into the new Firstside facility.[228]

The relationship between green building strategies and productivity has been studied and documented extensively. There are number of substantial databases that aggregate and screen studies on the relationship between specific building performance attributes and productivity and worker well-being.[229]

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[225] US Environmental Protection Agency, "Indoor Air Quality," January 6, 2003. Available at: http://www.epa.gov/iaq/.

[226] Michelle Conlin, "Is Your Office Killing You?" *Business Week*, June 5, 2000, http://www.businessweek.com/2000/00_23/b3684001.htm.

[227] William Pape, "Healthy, Wealthy, and Wise," *Inc*, 1998, No. 2, pp. 25-26. Available at: http://www.inc.com/articles/ops/office_management/office_design/1075-print.html. See also William Browning, "Boosting Productivity with IEQ Improvements," *Buildings Design & Construction*, April 1997.

[228] Compared with a control group that experiences an 11% reduction. "Shades of Green: 2002 Report of the Pittsburgh Green Building Alliance," http://www.gbapgh.org. This report provides a clear overview of green building benefits and valuable references and quotes on productivity and related green building benefits. See also: William Browning, "Successful Strategies for Planning a Green Building" *Planning for Higher Education*, Society of College and University Planners, March-May 2003, pp. 78-86.

[229] The Rocky Mountain Institute has been a pioneer in developing and publishing studies on green buildings and productivity, including both original research and reviews of studies on the impact of green buildings on productivity, sales and other worker performance measures. See Rocky Mountain Institute website, "Buildings & Land," Available at: http://www.rmi.org/sitepages/pid174.php. These include:

What Do Tenants Want?

Given the large impact that poor IEQ has on the health and comfort of office workers, it is not surprising that recent surveys of workers suggest that IEQ is one of the most important components of job satisfaction. For example, the study, *What Office Tenants Want: 1999 BOMA/ULI Office Tenant Survey Report*[230] is based on questionnaires from 1800 office tenant surveys in 126 metropolitan areas. Conducted by the Building Owners and Managers Association (BOMA) and the Urban Land Institute, the study affirms that office tenants highly value comfort in office buildings. Survey respondents attributed the highest importance to tenant comfort features, including comfortable air temperature (95%) and indoor air quality (94%). Office temperature and the ability to control temperature are the only features that were both "most important" and also on the list of things with which tenants are least satisfied. The BOMA/ULI study found that the number one reason that tenants move out is because of HVAC heating/cooling problems.

The BOMA/ULI survey found that office tenants also highly value intelligent building features. These include modern energy-efficient HVAC systems and automatic sensors for lighting. According to the BOMA/ULI study, over 75% of office buildings do not have these intelligent features. The survey found that 72% of tenants who want an intelligent feature would be willing to pay additional rent to have the feature made available.

This and other studies make it clear that a high percentage of office tenants are dissatisfied with the indoor air quality (IAQ) and comfort of their work environment and express a willingness to pay for a greener, more comfortable and productive one.

California has developed its own requirements for IAQ that differ from and are in some ways more stringent than IAQ prerequisites contained in LEED. Although the new California IAQ requirements have been adopted for use in the East End complex, they are not required in new construction and have, as yet, not been generally applied. Until these new standards are incorporated, the LEED approach to IAQ offers a significant improvement over current California practices.

"Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design," a compilation of widely quoted original research and review of 20 case studies on documented productivity gains, (Joseph Romm and Bill Browning, "Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design," RMI, 1994. Available at: http://www.rmi.org/images/other/GDS-GBBL.pdf. See also: Joseph Romm, "Cool Companies," *Island Press*, 1999 for a useful set of business case studies), and "Green Development: Integrating Ecology & Real Estate," a general overview of green building case studies with a focus on productivity and health in green buildings (Excerpts from "Green Development: Integrating Ecology & Real Estate" available at: http://www.rmi.org/sitepages/pid219.php).
Some good general databases on the subject include: http://www.ciwmb.ca.gov/GreenBuilding/Basics.htm; http://www.gbapgh.org/On%20Green%20Building/ogb_economic_benefits.html; http://www.conservationeconomy.net/content.cfm?PatternID=30; and http://www.ci.sf.ca.us/sfenvironment/aboutus/greenbldg/gb_productivity.pdf.
See also EPA's excellent database on indoor air quality: http://www.epa.gov/iaq/largebldgs/i-beam_html/bibliography.htm.

[230] "What Office Tenants Want: 1999 BOMA/ULI Office Tenant Survey Report." To order, call 1-800-426-6292, or order on-line at www.boma.org, item #159-TENANT-029.

While the full range of design practices encouraged by LEED is available in Appendix A, the following are some relevant attributes common in green buildings that promote healthier work environments:

1) Much lower source emissions from measures such as better siting (e.g., avoiding locating air intakes next to outlets, such as parking garages, and avoiding recirculation), and better building material source controls (e.g., required attention to storage). Certified and Silver level green buildings achieved 55% and Gold level LEED buildings achieved 88% of possible LEED credits for use of the following:[231]

    a. less toxic materials
    b. low-emitting adhesives & sealants
    c. low-emitting paints
    d. low-emitting carpets
    e. low-emitting composite wood
    f. indoor chemical & pollutant source control

2) Significantly better lighting quality including: more daylighting (half of 21 LEED green buildings reviewed provide daylighting to at least 75% of building space[232]), better daylight harvesting and use of shading, greater occupancy control over light levels and less glare.

3) Generally improved thermal comfort and better ventilation – especially in buildings that use underfloor air for space conditioning (see Section IX).

4) Commissioning, use of measurement and verification, and CO2 monitoring to ensure better performance of systems such as ventilation, heating and air conditioning (see Section IX).

The links between specific LEED credits and productivity are reviewed in other publications.[233]

One of the most authoritative studies to date quantifying potential health and productivity benefits from improved indoor environments was undertaken by William Fisk, head of the Indoor Environment Department at Lawrence Berkeley National Laboratory, and colleagues. Their findings, estimated across the US, are summarized below and reflect analyses and syntheses of a large number of prior studies. Fisk et al. divided the health benefits provided by better buildings into four principal areas: acute respiratory illness, allergies and asthma, sick building syndrome symptoms, and direct productivity gains. A summary of the rationale and supporting data and assumptions underlying Fisk's calculations is included as Appendix J.

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[231] Capital E analysis of USGBC data (based on analysis of points actually achieved in building performance data submitted to USGBC), November and December 2002. For more detail on achievable reductions from some of these indoor emissions sources, please see: Hodgson AT. "Common Indoor Sources of Volatile Organic Compounds: Emissions Rates and Techniques for Reducing Consumer Exposures." University of California, Lawrence Berkeley National Laboratory. 1999.
Prepared for California Air Resources Board.
Available at: http://www.arb.ca.gov/research/apr/past/indoor.htm#Toxic%20Air%20Contaminants.

[232] Capital E analysis of USGBC data, November and December 2002.

[233] See for example: Jonathan Weiss, Kath Williams and Judith Heerwagen, "Human Centered Design for Sustainable Facilities," Available from authors: j.heerwagen@att.net or williams@global.net.

Figure VIII-2. Potential Productivity Gains from Improvements in Indoor Environments

Source of Productivity Gain	Potential Annual Health Benefits	Potential U.S. Annual Savings or Productivity Gain (2002 dollars)
1) Reduced respiratory illness	16 to 37 million avoided cases of common cold or influenza	\$7 - \$16 billion
2) Reduced allergies and asthma	8% to 25% decrease in symptoms within 53 million allergy sufferers and 16 million asthmatics	\$1 - \$5 billion
3) Reduced sick building syndrome symptoms	20% to 50% reduction in SBS health symptoms experienced frequently at work by ~15 million workers	\$10 - \$35 billion
4) Sub-total		*\$18 - \$56 billion*
5) Improved worker performance from changes in thermal environment and lighting	Not applicable	\$25 - \$180 billion
6) Total		*\$43 - \$235 billion*

Adapted from: William Fisk, "Health and Productivity Gains from Better Indoor Environments"[234]

The first two sources of productivity gain outlined in Figure VIII-2 are only partially attributable to the work environment, so this report assumes that potential health benefits are therefore reduced to a range of \$12 to \$45 billion annually. Productivity benefits from both health improvement and from improvement in thermal environment and lighting are reduced to a range of \$35 to \$225 billion. Note that there are other, less substantial sources of potential health related benefits that are not included in Figure VIII-2, making these estimates of benefits potentially low.

Assuming a low value of \$25 billion, this translates into \$385 in direct health improvement potential for each of the 65 million full time office workers and teachers in the US.[235] If one third of these benefits can be achieved in a green building, this translates into about \$130 per year in health-related financial benefits. With 225 ft^2 in average space per worker, this suggests a potential annual productivity gain of $\$0.58/ft^2$.

If we assume a mid-range value of \$140 billion in potential productivity benefits (line 6 in Figure VIII-2), and assume that 1/3 of these benefits could be achieved from respiratory health benefits

[234] William Fisk, "Health and Productivity Gains from Better Indoor Environments," summary of prior publications (see Appendix J), with figures inflation-adjusted for 2002 dollars and rounded.
See also:
W.J. Fisk, "Health and Productivity Gains from Better Indoor Environments and Their Relationship with Building Energy Efficiency," *Annual Review of Energy and Environment* 25(1): pp. 537-566.
W.J. Fisk and A.H. Rosenfeld. "Estimates of Improved Productivity and Health from Better Indoor Environments," *Indoor Air* 7(3), 1997: pp. 158-172.

[235] Adjusted up from 63.5 million in Fisk. Note that Fisk includes ½ of military personnel, who are assumed to be office workers. For more on the size and composition of the US workforce, see: *Statistical Abstract of the United States*, US Census Bureau, 2001.
Available at: http://www.census.gov/prod/2002pubs/01statab/stat-ab01.html.

and thermal and lighting improvements in green buildings, this translates into about $718 per worker per year. This suggests a potential annual productivity gain of $3.19/ft^2$ per worker, or slightly over 1% per year.

A review published by ASHRAE compares commonly used measures of productivity with HVAC system performance. In the study, the authors evaluate 262 references and feature the 53 most rigorous and significant ones. These demonstrate a positive correlation between measures common to green buildings and productivity, absenteeism, and related issues.[236]

A National Science and Technology Council project entitled *Indoor Health & Productivity* was established to collect and communicate research findings relating workplace attributes – including lighting, thermal comfort, air quality and ventilation – to human health and productivity. The database contains over 900 papers from more than 100 journals and conferences. There are abstracts for about 700 of these articles, and the entire database is searchable by fields such as author and category (e.g., acoustics, humidity, ventilation) or by keywords such as sick building, visual comfort or HVAC.[237] There is a very large body of technically sound studies and documentation linking health and productivity with specific building design operation attributes – e.g., indoor air quality and tenant control over work environment, including lighting levels, air flow, humidity and temperature. It is clear that green building measures that improve these attributes increase worker comfort, health, well-being and measured productivity.

Two studies of over 11,000 workers in 107 European buildings analyzed the health effect of worker-controlled temperature and ventilation. They found significantly reduced illness symptoms, reduced absenteeism and increases in perceived productivity over workers in a group that lacked these features.[238]

Seattle City Light has compiled over 30 projects that document productivity, increased retail sales and increased student learning resulting from incorporation of green design elements.[239] The program intends to create a database documenting the impact of green features on worker comfort, health, productivity and related measures for all municipal buildings that meet or exceed LEED Silver level and is preparing to release a study of a dozen Seattle green buildings, including costs and benefits.

Productivity Benefits for Specific Worker Control/Comfort Upgrades

One of the leading national centers of expertise on the benefits of high performance buildings is the Center for Building Performance at Carnegie Mellon University. The Center's Building Investment Decision Support (BIDS) program has reviewed over 1000 studies that relate

[236] Sensharma et al., "Relationships Between the Indoor Environment and Productivity: A Literature Review," published in *ASHRAE Transactions* 1998, Vol. 104.

[237] An online bibliography as well as more information about this project can be found at http://www.dc.lbl.gov/IHP/. The website includes 5 useful brief reviews of key findings in the area of health, productivity and school test scores that were published in ASHRAE Journal, May 2002.

[238] Judith Heerwagen, "Sustainable Design Can Be an Asset to the Bottom Line - expanded internet edition," *Environmental Design & Construction*, Posted 07/15/02. Available at: http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,80724,00.html.

[239] See "High Performance Building Delivers Results," *The Sustainable Demand Project – A Project of the Urban Consortium Energy Task Force of Public Technology*, City of Seattle, Seattle City Light, December 2000. Available at: http://www.cityofseattle.net/light/conserve/sustainability/SDPFRa.pdf.

technical characteristics of buildings, in areas such as lighting and ventilation, to tenant responses, such as productivity. Of these studies, the Center has identified 95 that are sufficiently rigorous and quantitative to meet their criteria for inclusion in the BIDS database and decision making tool, making it perhaps the most valuable database of its kind.[240]

Collectively, these studies demonstrate that better building design and performance in areas such as lighting, ventilation and thermal control correlate to increases in tenant/worker well-being and productivity. The BIDS data set includes a number of controlled laboratory studies where speed and accuracy at specific tasks was measured in low and high performance ventilation, thermal control and lighting control environments. These studies used a range of speed and accuracy performance measures including: typing, addition, proof reading, paragraph completion, reading comprehension, and creative thinking.[241]

Increases in tenant control over ventilation, temperature and lighting each provide measured benefits from 0.5% up to 34%, with average measured workforce productivity gains of 7.1% with lighting control, 1.8% with ventilation control, and 1.2% with thermal control. Additionally, measured improvements have been found with increased daylighting, as discussed in the following section.

Figures VIII-3, VIII-4 and VIII-5 on the subsequent pages were supplied by the Department of Architecture at Carnegie Mellon University. They represent ongoing research, and as such should be considered interim.[242]

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[240] Vivian Loftness et al., "Building Investment Decisions Support (BIDS)," *ABSIC Research 2001-2002 Year End report.* See: http://nodem.pc.cc.cmu.edu/bids. Carnegie Mellon's BIDS™, for Building Investment Decision Support, is a case-based decision-making tool that calculates the economic value added of investing in high performance building systems, based on the findings of building owners and researchers around the world.

[241] Communication with Vivian Loftness, CMU, February 2003.

[242] Data extracted from BIDS™. Carnegie Mellon University Department of Architecture. February 2003. (Vivan Loftness).

Figure VIII-3: Increased Ventilation Control

The 13 studies summarized below by CMU show a consistently significant positive correlation between increased control over ventilation and increased productivity – ranging between 0.5 % and 11%, with most studies clustering around 1% and an average of 1.8%.

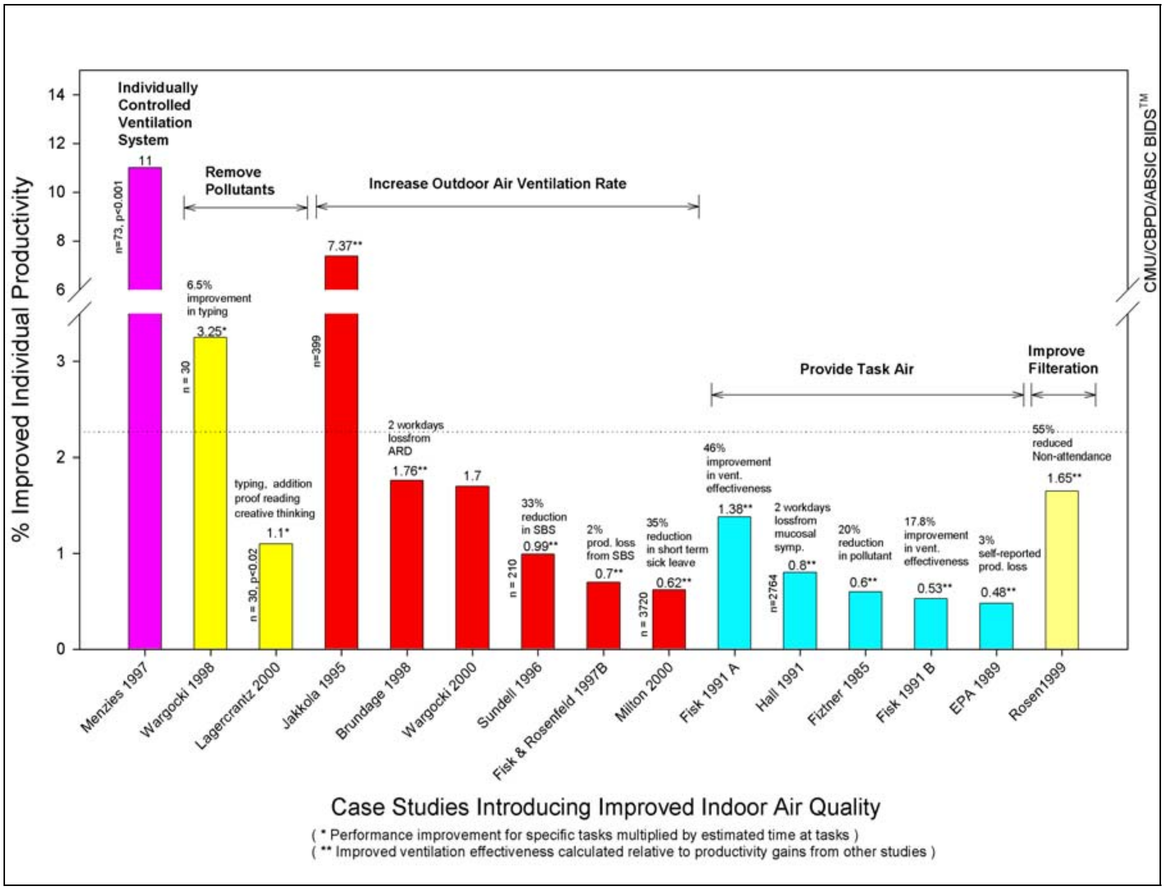


Figure VIII-4: Increased Temperature Control

The Center also looked at studies examining productivity impacts of worker control over temperature. As noted earlier, the BOMA/ULI study found that lack of control over temperature was one of only two features considered by respondents as both most important and of lowest tenant satisfaction. The mean productivity increase for temperature control in these seven studies is 1.2%.

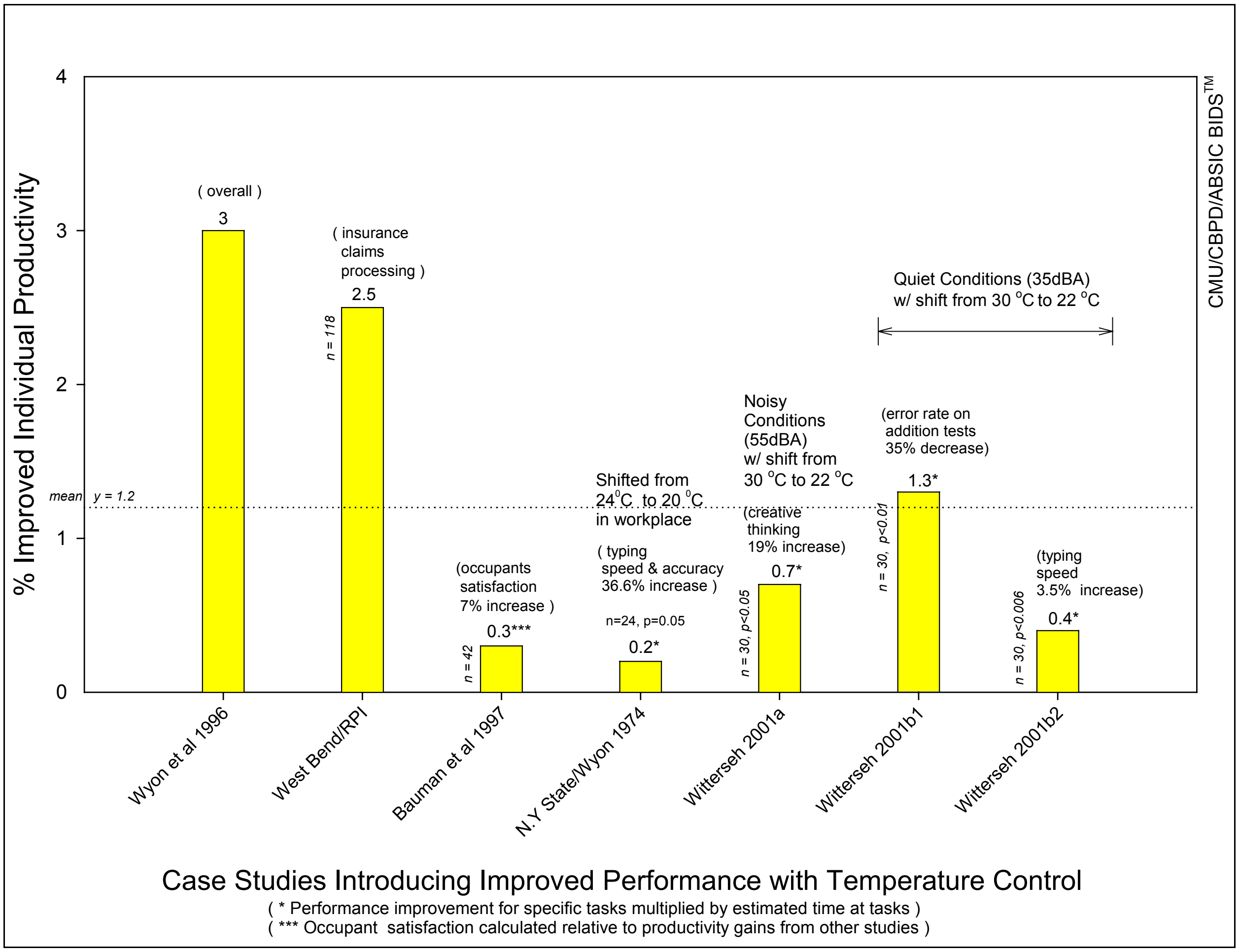
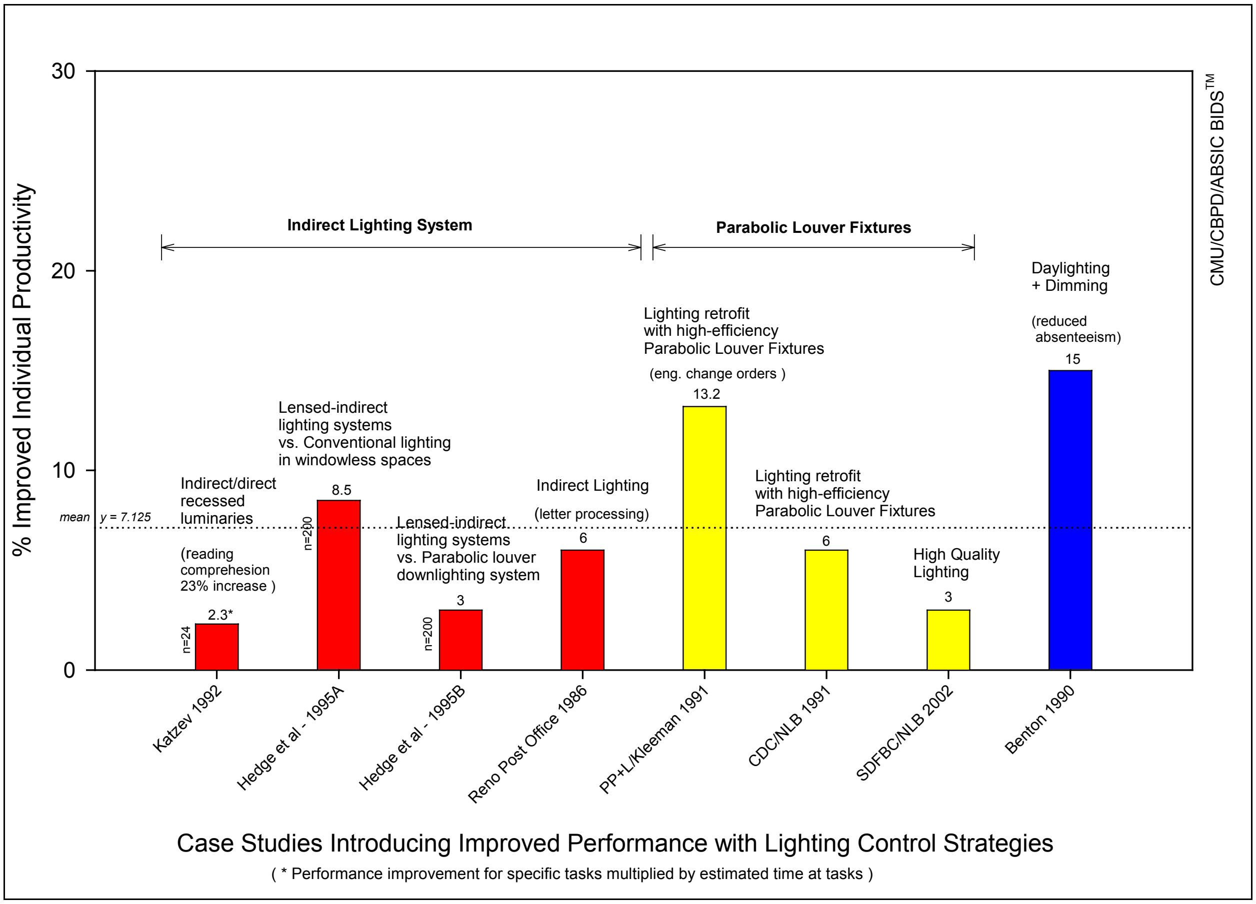


Figure VIII-5: Increased Lighting Control

Eight studies measured the relationship between increased lighting control and productivity, finding productivity gains ranging from 3% up to 34%, with a mean of 7.1%.



Increased Daylighting

A study by the Heschong Mahone Group evaluated the test score performance of over 21,000 students in three school districts in San Juan Capistrano, CA; Seattle, WA; and Fort Collins, CO. The study found that in classrooms with the most daylighting, students' learning progressed 20% faster in math and 26% faster in reading than similar students in classrooms with the least daylighting. The overall findings show that increased daylighting and generally improving quality of lighting significantly improves student test performance.[243] The study's results have been widely quoted, although the large impact of daylighting quality surprised some people and raised questions about the technical thoroughness of the report. To ensure the study's validity, California's Public Interest Energy Research (PIER) program, administered by the CEC, funded a follow up study, employing an independent technical advisory group to reanalyze the data. The reanalysis confirmed the initial study's findings with a 99.9% confidence level.[244]

The kind of work done by "knowledge workers" – most state employees – is very similar to the work students do. Tasks include: reading comprehension, synthesis of information, writing, calculations, and communications. Large-scale studies correlating daylighting with student performance on standard tests therefore provide relevant insight about the impact of increased daylighting on state employees.

This study is important for its size, rigor and the large measured impact of lighting quality on standardized test performance. Note that the study compares performance between students with the greatest amount of daylighting and those with the least daylighting – two extremes. Therefore it is difficult to use this study to predict benefits of enhanced daylighting common in green buildings relative to conventional buildings. The productivity benefits that could conservatively be expected are much less than 26% (which reflects extremes in daylighting), perhaps on the order of 2% to 6%.

Sick Building Syndrome

Following (see text box, *The cost of sick building syndrome for California state and school employees,* below) are the results of an analysis of the cost of sick building syndrome (SBS) for California state and school employees.[245] It assumes a "conservative" 2% productivity decrease due to SBS symptoms. By comparison, a 2000 evaluation of three buildings with a total of over 600 occupants for the Portland Energy Office estimated a 1% increase in productivity and noted that this is "a very conservative estimate." [246] A National Energy Management Institute (NEMI) study entitled *Productivity and Indoor Environmental Quality*, estimates that productivity gains

[243] Heschong Mahone Group, "Daylighting in Schools: An Investigation into the Relationship Between Daylight and Human Performance," 1999. Available at: http://www.h-m-g.com; Follow up studies verified the rigor of analysis and subsequent research continues to show positive correlation between daylighting and student performance.
[244] Heschong Mahone Group. 2002. "Daylighting in Schools Re-Analysis." Available at: http://www.newbuildings.org/pier/index.html.
[245] Original report by Leon Alevantis, Deputy Chief of Indoor Air Quality Section, California Department of Health Services, updated for this report by the author.
[246] "Green City Buildings: Applying the LEED Rating System," prepared for the Portland Energy Office by Xenergy, Inc and SERA Architects, June 18, 2000.
Available at: http://www.sustainableportland.org/CityLEED.pdf.

of 1.5% in "generally healthy" buildings are possible and even conservative.[247] As part of the state of California's Block 225 Capitol Area East End project, the Center for the Built Environment will be conducting a productivity analysis of workers related to indoor environmental quality efforts in that building. However, results from this study are not expected for approximately 2-3 years.[248]

The cost of sick building syndrome for California state and school employees
By Leon Alevantis, California Department of Health Services

SBS symptoms are most commonly reported by office and classroom workers. These workers make up about half of the state workforce. The impact of SBS to California office and classroom workers may be calculated as follows:

California office and classroom workers:

A telephone-based, state-wide survey of 14,729 adults (18 years or older) conducted in 1999 on behalf of the California Department of Health Services (DHS),[1] found that 54% of the adult population worked indoors. According to the 1999 California Current Population Survey, there were about 24 million adults living in California. Therefore, in 1999 there were about 13 million adults working indoors. Of those working indoors, according to the DHS survey, 54% or 7 million worked in an office or a classroom. This is about 44% of the annual average employment for 1999 (which was about 16 million).

SBS costs to California office and classroom workers:

Multiplying the number of California office and classroom workers by an annual average compensation of $43,000 (which was the annual average for these professions in 1998 according to data from the California Employment Development Department, excluding benefits and allocated O&M costs) and an estimated conservative decrease of 2% in productivity caused by SBS symptoms[2] the resulting cost of SBS symptoms to California is about $6 billion. Assuming that the average cost for benefits plus allocated O&M costs is an additional 50% of each worker's annual compensation, the resulting overall cost of SBS to California employers is about $9 billion.

Furthermore, published data indicate that 23% of office workers and teachers reported two or more frequent symptoms that improve when they leave their workplace. This implies that about 2 million California office workers and teachers are frequently affected by at least two SBS symptoms.

[1] California Department of Health Services, "1999 California Tobacco Surveys (CTS)."
[2] W.J. Fisk, "Health and Productivity Gains From Better Indoor Environments and Their Relationship with Building Energy Efficiency," *Annual Review of Energy and the Environment,* 25 (1): 537-566.

[247] Thomas Kelly, "Measuring the ROI of IAQ", *Buildings*, March 1999. And see: http://www.nemionline.org/.
[248] Field Study of Capitol Area East End Complex. Center for the Built Environment. See: http://www.cbe.berkeley.edu/research/briefs%2Deastend.htm.

Conclusion

There is no standard for estimating the exact productivity impact of a green building. Each green building has a different set of technologies and design attributes, and each building population has different health attributes and comfort needs.

However, four of the attributes associated with green building design – increased ventilation control, increased temperature control, increased lighting control and increased daylighting – have been positively and significantly correlated with increased productivity. Additionally, there is a large range in potential productivity and health gains from improved indoor environmental quality summarized in Figure VIII-2.

There are also quantifiable green building gains in attracting and retaining a committed workforce – an aspect beyond the scope of this report. Attracting and retaining the best employees can be linked to the quality of benefits that workers receive, including the physical, environmental and technological workplace. Green buildings are designed to be healthier and more enjoyable working environments. Workplace qualities that improve the environment of knowledge workers may also reduce stress and lead to longer lives for multi-disciplinary teams.[249]

It is beneficial for the state of California to maximize health and productivity benefits across a large number of employees and a large number of buildings. The studies cited above indicate significant and measured productivity benefits across a large population of workers and multiple green buildings. Productivity impacts could be even greater in California schools, which often exhibit poor environmental health conditions and a lack of adequate maintenance (and associated maintenance budgets).[250] Therefore improvements in air quality in schools could have significant economic and human health benefits.

LEED rated buildings all address some combination of measures that help reduce the pollutants that cause sickness and increase health care costs; improve quality of lighting and increase use of daylighting; and increase tenant control and comfort. A review of LEED prerequisites and credits (see Appendix A) indicates that LEED is designed to specifically address the materials, designs and operations affecting productivity and health issues discussed above. Credits directly relating to productivity are included in the Indoor Environmental Quality section with two prerequisites and 15 credits (about 22% of total credits available). A preliminary review of green buildings submitted for USGBC certification confirms that these buildings consistently include a range of material, design and operation measures that directly improve human health and productivity. Gold and Platinum level LEED buildings are more comprehensive in applying IEQ-related measures and therefore should be viewed as providing larger productivity and health benefits than Certified or Silver level green buildings.

Calculation

Given the studies and data reviewed above, this report recommends attributing a 1% productivity and health gain to Certified and Silver level buildings and a 1.5% gain to Gold and Platinum level buildings. These percentages are at the low end of the range of productivity gains for each of the

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[249] Communication with Vivian Loftness, CMU, February 2003.
[250] California Air Resources Board and California Department of Health Services. Draft Revised Report to the California Legislature: "Environmental Health Conditions in California's Portable Classrooms." 2003. Available at: http://www.arb.ca.gov/research/indoor/pcs/pcs.htm.

individual specific building measures – ventilation, thermal control, light control and daylighting – analyzed above. They are consistent with or well below the range of additional studies cited above.

For state of California employees, a 1% increase in productivity (equal to about 5 minutes per working day) is equal to $665 per employee per year, or $2.96/ft^2 per year.[251] A 1.5 % increase in productivity (or a little over 7 minutes each working day) is equal to $998 per year, or $4.44/ft^2 per year. At $4.44 per year, over 20 years and at a 5% discount rate (assuming that state employee salaries are unchanged with respect to inflation), the PV of the productivity benefits is about $36.89/ft^2 for Certified and Silver level buildings, and $55.33/ft^2 for Gold and Platinum level buildings. Assuming a longer building operational life, such as 30 or 40 years, would result in substantially larger benefits.

Note on Education [252]

LEED is broadly applicable to most commercial type buildings, and in most cases aspects of LEED will translate easily into other infrastructure areas. However, there are several issues that are specific to education buildings, particularly classrooms and laboratories. The US Environmental Protection Agency and the Department of Energy have collaborated to develop the Laboratories for the 21st Century or Labs21[253] program, which outlines a series of Environmental Performance Critera specific to laboratories. The USGBC is working with Labs21 in the hopes of developing a joint "LEED for Labs." K-12 classrooms also present a special case not specifically addressed by LEED.

California's Collaborative for High Performance Schools (CHPS)[254] has already had a substantial and very positive impact on California schools. For example, the Los Angeles Unified School District is one of five districts throughout the state that have adopted CHPS for all new K-12 school construction.[255] The CHPS program has developed a three volume Best Practices Manual outlining a range of green design technologies and practices.

CHPS and LEED are very compatible, with limited differences between the two programs. CHPS is self-certifying whereas USGBC is responsible for LEED certification. CHPS addresses acoustics, requires greater attention to on-site toxics and requires a higher level of energy performance. LEED includes several measures not in CHPS, including post occupancy requirements such as measurement and verification.[256] CHPS focuses just on schools. While there is currently no direct interchangeability between the CHPS and LEED rating systems, CHPS is working with the USGBC to develop a Memorandum of Understanding, which would formally establish the relationship between CHPS and the USGBC. Internally, the USGBC has

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[251] Average 2002 California employee compensation is $66,469 and average space per employee is 225 ft^2. Both numbers are discussed earlier in this section.

[252] This note on education was reviewed by Nigel Howard, VP of USGBC and Charles Eley, Executive Director of CHPS.

[253] Labs 21 Environmental Performance Criteria, Version 2.0. October 2002. Available at: http://labs21.lbl.gov/EPC/intro.htm.

[254] See page 7 for a more thorough discussion of CHPS. Also see: http://www.chps.net/ and http://www.dsa.dgs.ca.gov/Sustainability.

[255] Los Angeles Unified School District. Board of Education. "Resolution on the Design and Construction of High Performance Schools," November 2002. Available at: http://chps.net/chps_schools/pdfs/LAUSD_res.pdf. See also: http://chps.net/chps_schools/districts.htm.

[256] Discussion with Charles Eley, Eley & Associates, March 26, 2003. See also CHPS Criteria. Available at: http://chps.net/manual/index.htm#vol3.

considered developing a LEED for schools application guide. However, much of this work has already been completed through the development of CHPS performance criteria. Establishing consistency between LEED and CHPS, perhaps with CHPS serving the basis for a national LEED for schools application guide, will help ensure these two complementary programs work together.

Green building and sustainability has also started to influence construction of higher education facilities. In early 2002, the Los Angeles Community College District Board of Trustees committed to a 25% renewable energy standard and adopted a minimum LEED Certified level target for future construction. They allocated $35 million of an overall budget of $1.2 billion, or almost 3%,[257] for green construction.

Most recently, in July of 2003, the University of California Board of Regents, informed in part by an early draft of this report, adopted a green building and clean energy policy for all future new construction on campuses system wide.[258]

It is worth noting that:

- 6.2 million children, teachers and administrators – one fifth of California's population – spend their day inside schools.
- Only 43% of high-volume chemicals have been tested for potential human toxicity, and only 7% have been tested for their effect on children's development.[259]
- Asthma is the leading cause of admission of urban children into hospitals and the leading cause of days absent from school.[260]

LEED Gold design can be expected to provide a significant level of protection against potentially toxic chemicals and against a rising incidence of asthma and allergies. Gold level green buildings typically achieve much higher levels of compliance with LEED IEQ enhancement measures than Certified or Silver buildings. This could include the use of low emitting materials for adhesives and sealants, paints, carpets, and composite woods as well as establishing indoor chemical and pollution source control. As noted in the productivity section, 13 Certified and Silver level green buildings reviewed achieved an average of about 55% of these LEED measures, while 8 Gold level LEED buildings achieved 88% of these credits.

This report recommends that higher education systems target the LEED Gold level, as it will likely be cost-effective to do so. Savings could be expected in energy, waste, and water, and – critically – substantial gains can be expected in student health and productivity.

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[257] Los Angeles Community College District. "Proposition A Sustainable Building Principles and Energy Policy." Available at: http://www.propositiona.org/PropAInfo/SustainableBuildingPrinciples.asp.
[258] See: http://ucop.edu/regents/aar/julyd.pdf.
[259] Philip Landrigan et al, "Environmental Pollutants and Disease in American Children: Estimates of morbidity, Mortality, and Costs of Lead Poisoning, Asthma, Cancer and Developmental Disabilities," *Environmental Health Perspectives*, Volume 110, Number 7, July 2002.
Available at: http://ehpnet1.niehs.nih.gov/docs/2002/110p721-728landrigan/abstract.html.
[260] *Ibid.*

Several recent studies have begun to address the impact of high performance school facilities on student learning and teacher performance:

- As discussed earlier, the Heschong Mahone study examined student performance improvement on standardized tests for 22,000 students in 2000 classrooms in California, Colorado and Washington. Data from California schools (which is considered the most detailed) shows with a 99% statistical certainty that students with the most daylight progressed 20% faster in math and 26% faster in reading than students with the least daylighting.[261]
- A study of Chicago and Washington, DC schools found that better school facilities can add 3-4 percentage points to a school's standardized test scores, even after controlling for demographic factors.[262] This and other studies reviewed in the productivity section confirm a widely held, common sense perception that the physical quality of the classroom environment greatly affects how well children learn.
- An analysis of two school districts in Illinois, one small and one large, found that student attendance improved by 5% after incorporating cost effective indoor air quality improvements – regardless of school size (specifically, each site implemented the US EPA's IAQ Tools for Schools Program[263]).[264]
- A study of several Illinois schools found that 20% of teachers were averaging 4 days per year of sick leave due to IAQ problems.[265]

Green building improvements – especially for new buildings – appear to be very cost effective compared with other available measures to enhance student performance. Under the recently adopted Federal Education Bill, schools and states stand to lose billions of dollars in federal funding if students do not perform well on annual standardized tests. School and university systems should consider adopting whole building green design at the Gold level as a standard requirement in new school design and school retrofits.

Because the school market is relatively heterogeneous, it may be more difficult to quantify financial benefits to schools as compared to state office buildings. Additional research should address specific attributes of schools and university buildings to better refine estimates of financial benefits.

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[261] To view a 30 page condensed version of the study, see:
http://www.pge.com/003_save_energy/003c_edu_train/pec/daylight/di_pubs/SchoolsCondensed820.PDF.
[262] Mark Schneider, "Public School Facilities and Teaching:
Washington, DC and Chicago," November 2002. A Report Prepared for the Neighborhood Capital Budget Group (NCBG). Available at: http://www.ncbg.org/press/press111302.htm.
[263] US Environmental Protection Agency. "IAQ Tools for Schools," December 2000 (Second Edition). Available at: http://www.epa.gov/iaq/schools/.
[264] Illinois Healthy Schools Campaign, "Apparently Size Doesn't Matter: Two Illinois School Districts Show Successful IAQ Management." *School Health Watch*, Summer 2003. Available at: http://www.healthyschoolscampaign.org/school%20health%20watch_summer-2003.pdf.
[265] NCBG, 2002. Op. Cit.

IX. Spotlighted Technologies and Methodologies

This section contains a brief review of the impact of three specific green building features or systems: commissioning, underfloor air distribution systems, and cool roofs. The energy, environmental and health benefits of these technologies and practices are included in the relevant sections above. However, one additional benefit of underfloor air – reduced cost of churn – is not accounted for elsewhere in this report, and is calculated below.

Similarly, commissioning benefits include reduced operations and maintenance (O&M) costs, a benefit not captured above and therefore calculated here. Commissioning is a process that ensures proper system design and installation, and reduces costs by eliminating errors. It is an important part of the integrated design approach and helps ensure that green building systems perform as expected. Since all LEED buildings include commissioning (it is a prerequisite) and are likely to include other measures that help address operations and maintenance issues, the O&M benefits of commissioning can be included in calculations of the full financial benefits of green buildings.

Commissioning, and Measurement and Verification

Commissioning – a methodology to ensure that building systems are installed and operated as planned – is an increasingly common practice.[266] It has been defined as the "process of ensuring that systems are designed, installed, functionally tested and capable of being operated and maintained according to the owner's operational needs." [267]

Commissioning is particularly important for green buildings, because they are expected to achieve better performance (e.g., low energy use, better air quality) than conventional buildings. LEED requires "Fundamental Building Systems Commissioning," which currently entails hiring a commissioning expert, developing a commissioning plan and completing a commissioning report. In addition, LEED provides credits for additional commissioning and for including a building performance measurement and verification program. The measurement protocol referenced in LEED, the International Performance Measurement and Verification Protocol [268] is also used internationally as a way to demonstrate CO2 reductions benefits, providing a potentially helpful way to secure financial value through sale of CO2 reductions associated with green buildings.[269]

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[266] See for example, Karl Sturm, "The Importance of Commissioning Green Buildings," *HPAC Heating/Piping/Air Conditioning Engineering*, Feb. 2000. See also: Jay Enck, "Preserving Our Natural Resources through Design, Maintenance and Commissioning," *Engineered Systems*, May 2002.

[267] "Building Commissioning: The Key to Quality Assurance," *US DOE Rebuild America guide series*, p.9. Available at: http://www.rebuild.org/attachments/guidebooks/commissioningguide.pdf.

[268] See www.ipmvp.org. For purposes of disclosure, the principal author of the present report, Greg Kats, co-founded the IPMVP and served as its Chairman until 2001.

[269] Edward Vine, Gregory Kats, Jayant Sathaye, and Hemant Joshi, "International Greenhouse Gas Trading Programs: A Discussion of Measurement and Accounting Issues," *Energy Policy*, January 2003. Available at: http://www.ipmvp.org.

Commissioning and green buildings share:[270]

- Use of a systems approach.
- Use of life cycle perspective.
- Greater attention to design.

Estimated cost of commissioning as a percentage of construction costs varies with building size and is typically viewed as a higher percentage for smaller buildings. However, there is evidence that resulting savings more than pay for the cost of commissioning for both green and non-green buildings. A recent report found that costs of commissioning, including travel expenses, range from 2% to 4% for buildings costing less than $5 million, down to 0.5 % to 1% for buildings costing over $50 million. The study used nine case studies to illustrate why savings from commissioning exceeded the cost of commissioning even before the projects were complete. Commissioning:[271]

- Helped eliminate costly change orders.
- Reduced requests for cost information.
- Helped ensure proper system/component selection.
- Improved performance of building systems.
- Reduced call backs.

Basic commissioning required for LEED costs even less. In six recent LEED office buildings and schools the average cost of "Fundamental Building Systems Commissioning" required for the LEED prerequisite was equal to 0.3 to 0.6 % of construction costs.[272]

The Portland Energy Conservation study cites cases – including a California commercial property and a California university building – in which commissioning led to identifying substantial design and operating problems, and opportunities for substantial savings.[273] Commissioning can also provide potentially significant insurance related benefits (see Section X).

LEED includes an additional credit for system metering. Detailed analysis of several hundred million dollars of energy building upgrades demonstrate that rigorous measurement and verification of energy and water efficiency and system retrofits tend to:[274]

- Increase initial savings level.
- Increase persistence of savings.
- Reduce variability on energy and water savings.

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[270] Carolyn Dasher, Amanda Potter and Karl Sturm, "Commissioning to Meet Green Expectations." 2000. Available at: http://www.peci.org/cx/CxGreen.pdf.
Dan York, "Commissioning Green Buildings: Two Wisconsin Case Studies," *Proceedings of the 6th National Conference on Building Commissioning*, PECI, 1998.
[271] Chad Dorgan, Robert Cox and Charles Dorgan, "The Value of the Commissioning Process: Costs and Benefits", Farnsworth Group, Madison WI, paper presented at the 2002 *US Green Building Council Conference*, Austin, Texas.
Available at: http://www.usgbc.org/expo2002/schedule/documents/DS506_Dorgan_P152.pdf.
[272] Data provided by Bill Reed, Natural Logic, December 2002. http://www.natlogic.com/.
[273] Carolyn Dasher et al. Op. Cit.
[274] Greg Kats, Art Rosenfeld, and Scott McGaraghan, "Energy Efficiency as a Commodity: The Emergence of a Secondary Market for Efficiency Savings in Commercial Buildings," *1997 ECEEE Conference Proceedings*. Available at: http://www.ipmvp.org/info/ece397.pdf.

Commissioning and metering help ensure that buildings meet and maintain performance targets – including green performance targets. They make it easier to document and claim benefits in such areas as indoor air quality, productivity and emissions reductions. Improved metering allows building mangers to better manage upgrades and maintenance, helping to anticipate and avoid equipment failure, leaks and other costly operations and maintenance (O&M) problems.

Thus, commissioning and metering contribute to lower O&M costs, such as extended equipment life, though how much lower is not known. O&M costs in state buildings – $3,039 per person per year[275] or $12.25/ft^2/yr – are nearly an order of magnitude larger than energy costs. Therefore any reduction in O&M costs has a significant impact on financial benefits. For example, a reduction in O&M costs of 10% is equal to a savings of $304 per person, or $1.35/ft^2 per year. There is not enough data to estimate with any precision the reduction in O&M costs that would occur in green buildings. Clearly the reduction is larger than zero but probably under 25%. To be conservative, this report assumes that green buildings experience an O&M cost decline of 5% per year. This equals a savings of $0.68/ft^2 per year, for a 20-year PV savings of $8.47/ft^2.

Additional research on the O&M impact of green buildings is strongly recommended. Note that the reported savings in areas other than O&M appear to entirely pay for the cost of commissioning, so commissioning costs do not need to be deducted from the O&M-related financial savings.

Underfloor Air

It is estimated that underfloor or raised floor HVAC systems are used in 58% of new commercial buildings in Japan and half of new commercial buildings in Europe, but in only 10% of new commercial buildings in North America.[276] Only 2 of 21 green buildings reviewed included underfloor air,[277] the same percentage as conventional buildings, although there are strong indications that the use of underfloor air is rising in all US construction, and rising more rapidly in new US green building construction. Advocates of underfloor air cite a range of benefits relative to conventional overhead air distribution systems, including:

- Reduced life cycle building costs.
- Improved ventilation efficiency and indoor air quality.
- Reduced energy use.
- Lower cost of churn.
- Quieter working spaces resulting in greater occupant satisfaction.

Underfloor air is "an innovative technology that uses the underfloor plenum below a raised floor to deliver space conditioning in offices and other commercial buildings."[278] Typically this involves either a pressurized underfloor plenum with a central air handler delivering air through

[275] Data provided by the California Department of General Services, Real Estate Services Division, December 2002.
[276] Andy Karvonen, "The Revolution is Underfoot," *Environmental Design & Construction*, posted 01/15/2001. Available at: http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,18731,00.html.
[277] Data provided by the US Green Building Council. January 2003. (Brendan Owens)
[278] Fred Bauman and Tom Webster, "Outlook for Underfloor Air Distribution," *ASHRAE Journal*, June 2001.

passive grills or diffusers, or a zero pressure plenum with air delivered though local fans in combination with a central air handler.[279] The most significant cost savings from underfloor air is the lower cost of "churn" – the cost of moving employees within buildings. There are also significant HVAC energy savings as demonstrated at the Block 225 building in the Capitol Area East End Complex in Sacramento.[280]

Underfloor air has been adopted less rapidly in the United States than some experts had anticipated, due in part to its newness as a technology, limited applicability to retrofit construction and perceived higher costs. Published costs for specific projects range from negative first cost[281] to $3/ft^2$ [282] and higher. The actual costs appear to be very dependent on when the underfloor air systems are integrated into building design and construction. In the case of the state of California's Department of Education building (Block 225 of the East End Complex), underfloor air was added late in the design process through a change order and ended up adding about $4 million to the total construction costs. Block 225 of the East End complex experienced construction costs of only 1.9% above conventional design due to green elements other than underfloor air.[283]

According to Oppenheim Lewis Inc., a well-respected construction cost estimating firm in the San Francisco Bay Area, underfloor air systems, when integrated from the start of design, cost *slightly less* than overhead systems. In these cases, the lowered costs of the architectural, mechanical, and electrical work more than offset the higher materials and installation costs. A more precise breakdown is presented in Figure IX-1 below:

Figure IX-1. Capital Cost Analysis of Overhead (conventional) Air Systems vs. Underfloor Air[284]

Cost Component	Overhead	Underfloor
Architectural Work	$17.00	$14.50
Raised Access Floor	$ N/A	$ 7.00
Mechanical Work	$16.50	$12.40
Electrical	$ 7.00	$ 6.00
Total Cost	**$40.50/ft²**	**$39.90/ft²**

Source: Vivian Loftness, "Energy Savings Potential," June 2002

Perhaps the most comprehensive and authoritative US study to date of underfloor air and its costs and benefits, *Energy Savings Potential of Flexible and Adaptive HVAC Distribution Systems for*

[279] These descriptions are drawn from "Technology Overview" of underfloor air posted on the Berkeley Center for the Built Environment Home Page. Available at: http://www.cbe.berkeley.edu/underfloorair/techOverview.htm.

[280] Data provided by 3D/I, Project consultant on Capitol Area East End Complex. March 2003. (Jim Ogden).

[281] Michael Maybaum, "A Breath of Fresh Air," *Building Operating Management, HVAC*, January 1999, p.21.

[282] Bauman and Webster. Op. Cit.

[283] See also: Anthony Bernheim, "Saving Resources," *Urban Land*, June 2001. Also, See: http://www.ciwmb.ca.gov/GreenBuilding/CaseStudies/GovtOffice/EastEnd.htm; "Greening" of the East End website: http://www.eastend.dgs.ca.gov.

[284] Oppenheim Lewis, Presentation by Kevin Hyde et al., "Life-cycle Cost Analysis & Green Buildings Completing the Picture." Data assembled from V. Loftness et al., "Energy Savings Potential," June 2002.

Office Buildings, was undertaken by a team of six experts from Carnegie Mellon's Center for Building Performance and Diagnostics and the Oak Ridge National Laboratory.[285] The report surveys over 300 relevant case studies worldwide and selects the most rigorous of these. In nine studies with detailed cost estimates, underfloor air came with a premium of \$0 to \$3/ft^2, with one study showing a cost of \$6/ft^2 and two studies showing a cost of \$1 to \$3/ft^2.[286] The churn savings in this study range from \$1 to \$5 per square foot per move, or an annual savings of \$0.40 to \$2.00/ft^2/yr.[287]

The report finds that underfloor air typically provides energy savings in the range of 5% to 30% below conventional overhead systems, and provides measurable benefits in air quality, ventilation effectiveness and productivity. These attributes are part of why underfloor air is promoted in green building design. This section will focus on determining a reasonable and conservative estimate of the benefits associated with reduced cost of churn – a benefit not usually included in building design decisions. Estimating the churn savings from underfloor air can help quantify the full value of green buildings.

Churn Costs

The most significant cost savings from underfloor air is lower cost of "churn" – the cost of moving employees within buildings. As a recent valuable review of churn by Herman Miller describes, with underfloor air "floor layouts can be changed quickly, because power and cabling can be quickly relocated: and simple, easy to use furniture can be used because it does not need to carry large amounts of power and cabling."[288]

In 1995, a study by the International Facility Management Association (IFMA) of its 2200 members found an average churn rate of 35%. [289] This rate rose above 40% in 1997, with a churn rate of 48% reported for service and manufacturing companies.[290] Churn is generally higher for high tech firms and is likely to be lower for government agencies. In California state agencies, the frequency of costly "mass relocation from one building to another" is approximately once every 8 years [291] or 12.5% per year. There appears to be little hard data about churn rate within state buildings or for smaller, less costly, and very probably more frequent moves. In the absence of harder data on churn rate in government agencies, this analysis assumes an average churn rate of 30% for state of California employees, well below the IFMA reported industry average.

In the early 1990s, T.R.York found an average cost premium of \$2.29/ft^2 for underfloor air, but a churn savings of \$257 per year per employee from the greater ease of employee relocation.[292] A

[285] Vivian Loftness et al., "Energy Savings Potential of Flexible and Adaptive HVAC Distribution Systems for Office Buildings," Center for Building Performance and Diagnostics and the Oak Ridge National Laboratory, prepared for the *Air-Conditioning and Refrigeration Technology Institute*, June 2002. Available at: http://www.arti-21cr.org/research/completed/finalreports/30030-final.pdf.

[286] *Ibid,* Figure 10, p. XIII.

[287] *Ibid*, p. 91. This assumes an industry average churn rate of 40%.

[288] "Churn in the Workplace Understanding and Managing Its Impact," Herman Miller, 2001. Available at: http://www.hmeurope.com/WhitePapers/wp_Churn_in_Workpl.pdf.

[289] See: http://www.ifma.org/profdev/research/report16.cfm?actionbig=7&actionlil=166.

[290] IFMA Research Report #18, Benchmakers III, p. 36 and other documents on http://www.ifma.org/. See also: http://www.datathing.com/amaze/Main.asp.

[291] Data provided by the California Department of General Services, Real Estate Services Division, December 2002.

[292] T.R. York, "Can You Afford An Intelligent Building?" *FM Journal*, September/October 1993, pp. 22-27. Summarized in the Carnegie Mellon BIDS database: http://nodem.pc.cc.cmu.edu/bids/index.asp.

1996 study by Flack & Kurtz of an Owens Corning building found a $2/ft^2 first cost savings from raised floor cooling,[293] as well as $1.50/ft^2 in annual savings from the lower cost of churn.[294] DowElanco Corporation (a partnership between Dow Chemical Company and Eli Lilly) found the cost of relocating a workstation in an office with underfloor air to be $2.35/ft^2 compared with $20/ft^2 for hard walled offices.[295]

A more recent detailed examination was made of the Soffer Tech Office Building, a 64,000 ft^2 speculative office building constructed in Pittsburg. A study of this building shows churn savings significantly outweighing the additional costs of installing underfloor air. The combination of high performance design elements – a raised plenum with relocatable diffusers and relocatable wiring – cost $29.03/ft^2, or an additional $0.27/ft^2 over a conventional system, which would cost $28.76.[296] This represents a cost difference of less than 1% between a conventional overhead system and an underfloor air system.[297] The cost savings in of each reconfiguration is estimated at $4.66/ft^2, or about 7 times the initial additional capital cost of the high performance design. Assuming an average churn rate of 0.3 times per year (30% of office workers move each year) an annual churn cost of $1.86/ft^2 is avoided. This indicates a payback ($0.27/$1.86)– assuming a $0.27 initial capital cost increment – of under two months.

Another example of reduced churn costs is provided by the Pennsylvania Department of Environmental Protection. In one conventional office building they measured a cost of about $2,500 per move. (This churn cost is high and reflects the varying costs of moving.) In a new building with raised access flooring, underfloor air, and quick-disconnect manufactured power and teledata cabling, this cost dropped to approximately $250 per workstation, or 90% less.[298]

Conclusions

According to the IFMA 1998 Experience Exchange Report, the average cost of a move is $1063 per employee.[299] Other reports indicate a somewhat lower average cost of moving, reflecting varieties in the definition of moving. According to IFMA, a simple move to and from existing workplaces costs $173, a move including relocation of furniture costs $712 per move, and a move requiring construction costs $2100. Actual yearly moving costs are therefore dependent on what types of moves occur. The reported cost for moving a California state employee is $350, including phone line. Installation of a data line costs $200, so a simple move involving data line installation would cost $550.[300] Larger moves, especially involving construction, cost significantly more. State employees have a 12.5% rate of mass moves to other buildings (cited above), which would typically involve much higher costs, probably on the order of $1000 to $2000 per move. This limited data suggests move costs may be consistent with or somewhat less

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[293] Flack & Kurtz, "Building Design and Construction," November 1996. Summarized in the Carnegie Mellon BIDS database: http://nodem.pc.cc.cmu.edu/bids/index.asp.
[294] Communication with Bill Browning, RMI, March 10, 2003.
[295] Herman Miller, p. 4.Op. Cit.
[296] V. Loftness et al., "Sustainable Development Alternatives for Speculative Office Buildings: A Case Study of The Soffer Tech Office Building," undertaken collaboratively by Carnegie Mellon University, Gardner & Pope Architects, RAY Engineering and the Soffer Organizations, May 26, 1999. Available at: http://www.tate-cheapertobuild.com/pdf/sustainable_development_alternatives.pdf.
[297] Ibid. Appendix B.
[298] Andy Karvonen, 2001. Op. Cit.
[299] "BOMA 1998 Experience Exchange Report." Available at: http://www.energy2001.ee.doe.gov/Technology/S5-Bohsali/tsld028.htm.
[300] Data supplied by the California Department of General Services, Real Estate Services Division. December 2002.

than IFMA reported averages. Absent more specific data about California public employee move costs, estimated savings are $300 per move in a building with underfloor air compared with a conventional building. This estimate is very likely to be low.

Assuming a churn rate of 30% (discussed above), this implies an annual savings of $90 per year per employee, significantly below the estimated costs in other studies, such as those completed by Owens Corning and Ray Engineering.[301]

An average of 225ft^2 per employee implies an annual savings of $0.40/ft^2/yr ($90 per year for each employee's 225ft^2, or $0.40/ft^2/ year). This is significantly below the annual churn savings identified in the York and Souffer studies, and substantially lower than the DowElanco and Pennsylvania DEP estimated savings. This is also at the bottom of the range of the meta-study conducted by Carnegie Mellon/Oak Ridge, which identified average churn cost savings in the range of $0.40 to $2/ft^2/yr.[302] Based on a review of the range of case studies and existing data, this report therefore assumes a conservative value of $0.40/ft^2/yr per employee in reduced churn costs associated with underfloor air, with 20-year PV at 5% discount of $4.98/ft^2. This indicates that it is cost effective to install underfloor air in state buildings where the cost per square foot is less than $5.

Note that there is little data on churn costs in schools, so the above estimate should not be directly applied for schools. It is probable that churn is less frequent and/or less costly in schools, so churn reduction benefits of green buildings would be proportionally less. In the absence of good data, a reasonable estimate for churn reduction benefits in green schools might be about half that for state buildings, or a 20-year PV of $2.50/ft^2. For specific educational buildings such as laboratories and administrative offices, churn costs are likely to be higher. Lack of data indicates the need for additional research in this area.

Additional analysis is recommended to obtain more accurate estimates of frequency and cost of churn, with type of churn (employee-only/phone/rewiring/construction) indicated.

Urban Heat Island Reduction – Cool Roofs

Extensive studies conducted by Lawrence Berkeley National Laboratory (LBNL), the California Energy Commission and others have documented large energy and health benefits from lighter color roofs, lighter color paving and tree planting. Darker surfaces absorb more sunlight, increasing temperature within buildings, and creating "heat islands" and an associated need for air conditioning. More air conditioning requires greater consumption of energy, which in turn leads to the release of more pollutants. In addition to increasing their own temperatures, dark roofs and surfaces also raise the temperatures in surrounding areas, increasing their needs for air conditioning as well. Since 1950, increased absorption of sunlight by dark buildings, roads and loss of tree coverage have played a large role in increasing the average temperature of Los Angeles by about 1ºC every 15 years.[303]

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[301] Conversation with Vivian Loftness, December 2002. Lead author of comprehensive meta study, complete citation above.
[302] V. Loftness et al., June 2002. Op. Cit.
[303] A.H. Rosenfeld et al., "Cool Communities: Strategies for heat island mitigation and smog reduction," *Energy and Buildings*, 28, 1998.

The medical cost of poor air quality in Los Angeles is about $10 billion per year, of which 70% is from particulates and 30%, or $3 billion, is from health costs due to ozone.[304] High temperatures are a primary condition for the creation of smog (ozone). By reducing ambient urban temperatures, heat island reduction directly contributes to reduced ozone creation, in turn reducing the large human health costs associated with smog. For the city of Los Angeles, there are numerous estimated benefits of a comprehensive cool communities program:

- Direct savings of $100 million in annual residential air conditioning costs (A/C needs reduced by 10% to 30% as estimated by various studies). [305]
- $70 million reduction in indirect cooling costs (reduced air conditioning for other buildings due to lowered ambient air temperature).[306]
- $360 million from reduction of smog (12% ozone reduction).[307]

Most of the impacts and benefits of heat island reduction measures have been very extensively modeled and documented by LBNL, utilities such as PG&E,[308] cities and other entities. For example, the Southern California Air Quality Management District undertook an independent evaluation of the benefits of urban heat island mitigation before accepting heat island reduction measures as a legitimate option to meet their strict regulations restricting smog. At the same time, not all the benefits have been fully modeled statewide. The values for direct avoided energy costs have been modeled most extensively, while the health benefit values are somewhat less precise since they have not been fully modeled for all of California.

Potential heat island savings (both air quality and energy) for Northern California have not been fully modeled, but LBNL Senior Scientist Hashem Akbari, a leading expert on heat island reduction, estimates that potential savings from cool roofs in Northern California are at least half that of Southern California. His conservative estimate is that total statewide savings from heat reduction measures are at least $750 million per year, with $500 million from health improvements and $250 million from reduced energy use.[309]

The installation of "cool roofs" on buildings provides both energy and health benefits by reducing heat islanding. The technology is presented here because:

1) The financial benefits for California are significant and well documented.
2) It is an important feature in green building design systems such as LEED (75% of 21 LEED green buildings reviewed achieved one heat island reduction credit and 50% achieved both).
3) Perhaps because it is so simple, it is sometimes overlooked when compared with higher tech solutions.

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[304] J.V. Hall, "Valuing the health benefits of clean air," *Science* 255, 1992.

[305] "Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements, Revised August 2002," Pacific Gas and Electric (2005 Title 24 Building Energy Efficiency Standards Update). Provided by Hashem Akbari.

[306] Data provided by Lawrence Berkeley National Laboratory. November 2002. (Hashem Akbari).

[307] Rosenfeld et al., 1998. Op. Cit.

[308] PG&E. "High Albedo (Cool) Roofs: Codes and Standards Enhancement Study." 2000. Available at: http://www.newbuildings.org/downloads/codes/CoolRoof.pdf.

[309] Data provided by Lawrence Berkeley National Laboratory. October 2002. (Hashem Akbari). See also: http://www.coolroofs.org/.

Cool (high albedo) roofs – roofs that have high thermal emittance (high radiation of heat) and high solar reflectance (high reflection of sunlight) – stay cooler in sunlight. They are also easy to incorporate and have a number of direct and indirect benefits.

Cool roofs come in several forms, including:

- Roofs painted or otherwise covered in a highly reflective surface (of light or metallic color).
- Roofs shaded by neighboring trees, PV panels, etc.
- Green roofs, which are densely planted for high sunlight absorbance and insulation.

In a report issued in 2000, PG&E modeled the effect of cool roofs on the energy usage of 990 California commercial buildings. They found an average 20-year present value energy savings from use of cool roof materials of $0.37/ft^2 for the roof area (not the whole building), resulting from reduced air conditioning requirements.[310]

In addition to energy and heat island impacts, cool roofs also experience less expansion and contraction than dark roofs, which contributes to statistically significant extension of the roof life. Typically, cool roofs last 20% longer than conventional roofs. LBNL has calculated that financial benefits of longer roof life are roughly equal to the value of energy savings.[311] Combining the benefits of direct reduction in air conditioning with the value of a longer roof life provides an estimated 20-year PV of $0.75/ft^2.

As indicated above, the average statewide health value (principally from reduced smog creation) is twice that from direct reduced energy use, or about $0.70/ft^2 in direct health benefits. This report will count one half of the estimated direct health benefits from cool roofs, or $0.35/ft^2. Combined with benefits of direct reduction in air conditioning and longer roof life value (calculated above) of $0.75/ft^2, this provides an estimated 20-year PV savings from cool roofs of $1.10/ft^2 of roof surface. Additional benefits such as lower waste costs due to longer roof life and benefits of reduced temperature on surrounding buildings are not included in this analysis, tending to underestimate the financial benefits of cool roofs.

An additional benefit of cool roofs is that lower cooling demands can allow downsizing of air conditioning in buildings, providing an additional savings of about $0.10/ft^2 in capital costs. This is roughly offset by the additional cost of a cool roof, which is between $0.00 and $0.20/ft^2, though average marginal cost is below $0.10/ft^2.[312] This means that the $1.10/ft^2 value as calculated above can be considered a true 20-year NPV value, where additional cost is subtracted from overall benefits.

Because schools sometimes do not operate in summer months, some of the benefits, especially in reducing air conditioning load, are not achieved. This report conservatively assumes that schools see only 25% of the direct reduction in cooling costs, or $0.09/ft^2, and 50% of the health benefits ($0.35/ft^2). Because schools tend to be located in more wooded areas, roof-life extension benefits will be less, perhaps $0.28/ft^2, or 75% of the estimate for commercial buildings. This set of perhaps overly conservative assumptions indicates 20-year NPV benefits of $0.72/ft^2 for cool roofs on schools.

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310 *Ibid*. Note that a 10 year life is assumed.
311 Data provided by Lawrence Berkeley National Laboratory. December 2002. (Hashem Akbari).
312 Data provided by Lawrence Berkeley National Laboratory. October 2002. (Hashem Akbari).

The large potential health and energy savings have resulted in the promotion of heat reduction measures by a number of organizations. This includes CEC incentives for application of cool roofs, incorporation of heat island reduction measures into the general air quality plans of the South Coast and Bay Area Air Quality Management Districts,[313] adoption of cool roofs in Title 24 as part of its non-residential perspective requirements, and inclusion of the following credits in LEED 2.1:

> Site credit 7.1 - 1 point for shade and/or reflectance and several other options.
>
> Site credit 7.2 - 1 point for energy star light colored/high reflectance roof with various restrictions added.

Despite the financial benefits and the inclusion of cool roofs in Tier 1 and CEC programs to support cool roof implementation, most new California state and school buildings are not built with them.[314] It seems clear that cool roofs and other urban heat island reduction measures are cost- effective and should be applied in new buildings.

To estimate benefits of urban heat island reduction measures for specific buildings, it is necessary to account for the number of floors. On a forty story building the average building-wide benefit of a cool roof is small. In contrast, the cool roof benefit of a one story building is relatively large. The average California state building has about 7 stories,[315] resulting in a cool roof NPV value of $0.15/ft^2 for the total building ($1.10/ft^2 of roof apportioned over seven stories, or about $0.15/ft^2 for the whole building). Note that school savings per square foot will be larger because schools typically have fewer floors. At an average of 2 floors per school,[316] the NPV benefits would be $0.36/ft^2 school-wide.

These estimates are almost certainly low. In addition urban heat island reduction measures other than cool roofs, including shading from tree planting and lighter surfaces surrounding buildings, such as parking lots, also reported to be very cost effective, but are not included in this study. A more thorough analysis should do so.

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[313] Hashem Akbari and Malvin Pomerantz, "Implementation of Heat Island Reduction Measures: Where We Are and Where We Need to Go," *ACEEE Conference Proceedings*, Energy and Environment Policy - 9.1, 2002.
[314] Data provided by Lawrence Berkeley National Laboratory. October 2002. (Hashem Akbari).
[315] Data provided by the California Department of General Services, Real Estate Services Division, December 2002.
[316] Data provided by the California State Architect, Department of General Services, December 2002.

X. Insurance Benefits of Green Buildings[317]

Risk, and associated losses, is costly, with or without formal insurance. With conventional insurance, customer costs include deductibles, premiums and possible excess costs if the insured loss level is capped. If commercial insurance is not used, then the building owner is either formally or informally self-insured. Formal self-insurance implies that a distinct "premium" is paid from internal budgets and accumulated in the form of an earmarked loss reserve. If self-insurance is informal, then the risks are said to be "retained" and losses are paid from general operating budgets, without the creation of an anticipatory loss reserve.[318] Where formal or informal self-insurance is used, risk management is particularly important, since there is no hedge (upper limit) against loss costs.

Considerable untapped opportunities are suggested by the synergies between green-building technologies and risk management (Figure X-1).[319]

Figure X-1. Risk Management Benefits of Green Buildings

- **Worker Health & Safety.** Various benefits, including lower workmen's compensation costs, arise from improved indoor environmental quality, reduced likelihood of moisture damage, and other factors enhancing workplace safety.[320]
- **Property Loss Prevention.** A range of green building technologies reduce the likelihood of physical damages and losses in facilities.[321]
- **Liability Loss Prevention.** Business interruption risks can be reduced by facilities that derive their energy from on-site resources and/or have energy-efficiency features. This includes risks resulting from unplanned power outages.[322]
- **Natural Disaster Preparedness and Recovery.** A subset of energy efficient and renewable energy technologies make facilities less vulnerable to natural disasters, especially heat catastrophes.[323]

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[317] Adapted from a report written by Evan Mills, Senior Scientist, Lawrence Berkeley National Laboratory. "Green Buildings as a Risk Management Strategy," December 2002.

[318] The basic difference between conventional insurance and self-insurance is that self-funded entities take responsibility for financing their own claims. The main advantages of self-insurance are: lower administrative costs, better claims control, meaningful claims statistics and potentially reduced losses through better loss control.

[319] Extensive discussion and references on the subject can be found at http://eetd.lbl.gov/ea/mills/insurance/cifram.html.

[320] Edward Vine et al., "Energy-Efficiency and Renewable Energy Options for Risk Management and Insurance Loss Reduction: An Inventory of Technologies, Research Capabilities, and Research Facilities at the U.S. Department of Energy's National Laboratories," LBNL Report No. 41432, 1998. Available at: http://eetd.lbl.gov/insurance/LBNL-41432.html.

[321] Evan Mills, "The Insurance and Risk Management Industries: New Players in the Delivery of Energy-Efficient Products and Services," *Energy Policy* (in press), 2003. Available at: http://eetd.lbl.gov/emills/PUBS/Insurance_Case_Studies.html.

[322] J. Eto et al., "Scoping Study on Trends in the Economic Value of Electricity Reliability to the U.S. Economy," prepared for the Electric Power Research Institute, 2001. Available at: http://eetd.lbl.gov/ea/EMS/reports/47911.pdf.

Lawrence Berkeley National Laboratory has mapped approximately 80 energy efficiency and renewable energy measures onto specific "lines" of insurance benefited by their use.[324] A number of forward-looking insurers have supported energy-efficient and renewable energy technologies, including 52 insurers and reinsurers, 5 brokers, 7 insurance organizations, and 13 non-insurance organizations in this arena.[325] The approaches can be grouped into eight categories:

- Information, education, and demonstration.
- Financial incentives.
- Specialized policies and products.
- Direct investment to promote energy efficiency and renewables.
- Value-added customer services and inspections.
- Efficient codes, standards, and policies.
- Research and development.
- In-house energy management in insurer-owned properties.

While the list is impressive, it should be stressed that it reflects a small fraction of insurance companies. Most insurers and risk managers have yet to make the connection between green buildings and reduced risk. There are instances where insurance companies have offered premium credits on the order of 10% for insured parties implementing selected energy savings strategies.[326] Little has been done, however, to quantify or monetize the benefits.

A more specific characterization of the potential insurance benefits of green buildings is included in Appendix K, where benefits are mapped onto the credits of the LEED system (Version 2.0). This provides an analysis of the precise insurance-related issues and benefits for the full range of green building attributes. Each LEED prerequisite and credit is evaluated against seven types of risk – property loss; general liability; business interruption; vehicular; health & workers comp; life; and environmental liability, along with related comments. Of the 64 LEED points possible in Design Areas 1-5 (excluding the Innovation and Design Process category, which is non-specific), 49 (77%) are associated with measures that have potential risk-management benefits. A few of these, however, are potentially associated with potential adverse consequences – an issue that merits more attention in the green buildings community.

Insurance and Risk Management in California[327]

Currently, most general government facilities and operations in the state of California do not purchase commercial insurance. The majority of state buildings are informally self-insured. The Capitol building itself is uninsured, as are other well-known properties such as Hearst Castle.

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[323] Evan Mills, "Climate Change, Buildings, and the Insurance Sector: Technological Synergisms between Adaptation and Mitigation," *Building Research and Information* (in press), 2003. Available at: http://eetd.lbl.gov/emills/PUBS/Mitigation_Adaptation.html.
[324] Edward Vine, LBNL Report No. 41432, 1998. Available at: http://eetd.lbl.gov/insurance/LBNL-41432.html.
[325] Evan Mills, *Energy Policy* (in press), 2003. Available at: http://eetd.lbl.gov/emills/PUBS/Insurance_Case_Studies.html.
[326] *Ibid.*
[327] Unless otherwise noted, the observations in this section are taken from conversations between Evan Mills and the California's Office of Risk and Insurance Management (Gary Estrada).

Construction on the Capitol Area East End Complex, the largest state government project in California history and the first state buildings to pursue LEED silver and gold ratings, is now complete. As it is bond-funded, commercial insurance is required. The Office of Risk and Insurance Management (ORIM) is not aware of any insurance/risk-related problems with this project, but subscribes to the notion that green buildings will have happier and healthier occupants.

ORIM is located under the Department of General Services (DGS) and is responsible for all risk and insurance activities in state government. For buildings and other facilities constructed with bond-generated funds, the state purchases property insurance but not liability insurance. In this case, deductibles are generally set high (currently $500,000 - $2.5 million) to minimize the premium. Under California's "Master Policies," there is approximately $1.5 billion of property at 15-20 locations that is commercially insured for property and liability risks, plus roughly $3 billion of additional property currently under construction.[328] Total premiums paid for commercial insurance were $18 million in 2000, of which perhaps 15% were for buildings.[329] The state's primary provider is Affiliated FM, which has, in the past, shown interest in energy efficiency as a tool of risk management.[330]

One of ORIM's most important initiatives at present is their "Owner-Controlled Insurance Program," under which the state buys Workers Comp, General Liability, and Excess Liability coverage for construction projects. Of relevance to the discussion of green buildings, evidence from closed-claims studies suggests that the associated risks can be reduced through the use of building commissioning,[331] and potentially result in lower premiums for the state. Commissioning (see Section IX) is one of the procedures called for in the LEED green building rating system. It is worth noting that state initiatives to promote alternative transportation solutions (one of the criteria of the LEED system) would result in fewer person-miles driven and corresponding reductions in the likelihood of vehicle-related claims.

Lastly, ORIM sees mold as a "growing" issue, and as a potential driver for more proactive risk management and holistic thinking about buildings. According to the Chief Economist at the Insurance Information Institute, most insurers report a tripling of mold-related claims in the last year. More than 9000 claims related to mold are pending the nation's courts, though most involve family homes.[332] A special program provides California state property insurance of $4-5 million for the single family homes of military veterans. While the vast majority of this is for earthquake and flood risks, mold issues have become a real concern in this program. Improved ventilation in green buildings is likely to combat mold problems. Many insurance companies have dropped all coverage for mold and IAQ. Although there are a few policies that cover mold losses, these have become very costly and the state has yet to purchase one.

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[328] Insurance is discontinued once the bond is paid off.
[329] "Annual Report," ORIM. 2001. Available at: http://www.orim.dgs.ca.gov/Publications/default.htm.
[330] D. Avery et al., "Campus Lighting — Lighting Efficiency Options for Student Residential Living Units: A Study at Northeastern University, Boston, Massachusetts," LBNL Report PUB-816, 1998. Available at: http://eetd.lbl.gov/EMills/PUBS/arkwright.html.
[331] R. Brady, "Commissioning Services Can Reduce Professional Liability Losses," Proceedings of the Third National Conference on Building Commissioning, Portland Energy Conservation, Inc., Portland, OR, 1995.
[332] Ray Smith, "Mold Problems Grow in Shops, Hotels, Offices," *Wall Street Journal*, December 4, 2002. Available at: http://www.iuoe.org/cm/iaq_bpconc.asp?Item=356.

XI. Conclusions

This report has sought to define, document and analyze the costs and financial benefits of green buildings. It has attempted to identify gaps in current knowledge about green building costs and benefits and to identify recommended areas of future research and analysis.

The financial benefits estimated in this report are a measure of financial benefits to the state of California as a whole, rather than to specific building tenants or owners. While a government entity should care about the benefits their building may have for society, a private commercial entity may not. Private sector building owners, for example, may be less likely to care about health and environmental impacts, and hence might perceive lower financial benefits of building green. In addition, because of higher capital costs and hurdle rates, future financial benefits are discounted more heavily by private entities than by public ones, potentially further reducing the perceived value of future green building financial benefits for the private sector. These differences help explain the significant disparity between public and private sector adoption of green building design.

This report began with an aggregation of data on actual or modeled costs for 33 green buildings. Largely derived from several dozen conversations with architects, developers and others, the data indicates that the average construction cost premium for green buildings is almost 2%, or about $\$4/ft^2$ in California, substantially less than is generally perceived.

The body of this report focused on determining the financial benefits of a range of green building attributes, with the findings summarized below.

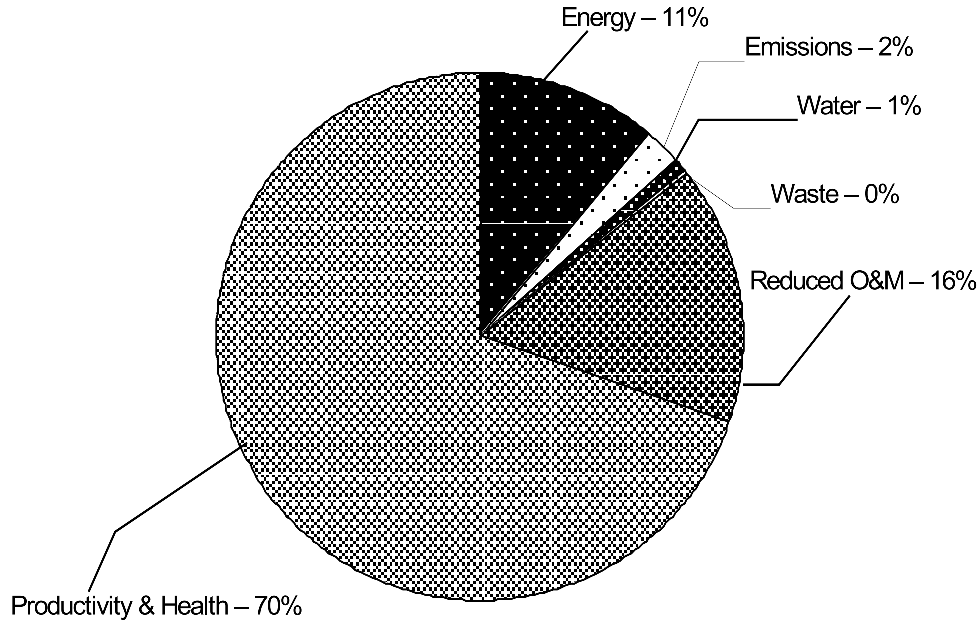
Figure XI-1. Summary of Findings (per ft^2)

Category	20-year NPV
Energy Value	$5.79
Emissions Value	$1.18
Water Value	$0.51
Waste Value (construction only) - 1 year	$0.03
Commissioning O&M Value	$8.47
Productivity and Health Value (Certified and Silver)	$36.89
Productivity and Health Value (Gold and Platinum)	$55.33
Less Green Cost Premium	($4.00)
Total 20-year NPV (Certified and Silver)	**$48.87**
Total 20-year NPV (Gold and Platinum)	**$67.31**

Source: Capital E Analysis

The relative percentages of the different benefit categories are shown in Figure XI-2 below.

Figure XI-2. Percentage Breakdown of Green Building Financial Benefits (LEED Certified and Silver Buildings)



Source: Capital E Analysis

The above pie chart is for Certified and Silver buildings. For Gold and Platinum buildings, a larger portion of benefits are represented by productivity and health, and the percentages of benefits from the other categories reduce correspondingly. The relatively large impact of productivity and health gains reflects the fact that the direct and indirect costs of employees are far larger than the costs of buildings and energy, so even small increases in employee productivity translate into large benefits. Note that this estimate does not include the financial benefits of reduced moving costs (churn) associated with underfloor air distribution systems because most green buildings do not currently use them.

As summarized above, total financial benefits of green design are estimated to be almost $50/ft^2 for Certified and Silver level green buildings, and over $75/ft^2 for Gold and Platinum level buildings. This is over ten times larger than the average 2% cost premium – about $3-5/ft^2 in California – for the 33 green buildings analyzed.

The financial benefits of green buildings include lower energy, waste, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits.) Energy and water savings can be predicted with reasonable precision, measured, and monitored over time, so much so that commercial firms contract to buy streams of future energy and water savings. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy. This is due in part to the complexity of human health and performance issues, the large range in human reactions to indoor environmental quality changes, and the large range of ways that improvements can show up, including lowered insured or uninsured health costs, lower employee turnover or increased productivity.

There is now a very large body of research, reviewed in this report, which demonstrates significant and causal correlation between improvements in building comfort and control measures, and worker health and productivity. However, these studies vary widely in specific measured correlations. Further, there has been relatively little work completed to evaluate specific, measurable benefits from green building design in California in such areas as sick days, health costs, turnover and respiratory impacts such as asthma and allergies. Clearly, the benefits are significant and not zero, but the data supports a broad range of calculated benefits – in contrast to the more precisely measurable energy and water savings.

The financial benefits conclusions in this report should therefore be understood in this context. Energy, waste, and water savings and emissions reductions can be viewed as fairly precise, reasonably conservative estimates of direct benefits that alone significantly exceed the marginal cost of building green. Health and productivity benefits may be viewed as reasonable, conservative estimates within a large range of uncertainty that therefore justify additional research to better quantify and capture the associated benefits. These studies might include such measures as evaluating green building effects on insured and uninsured health effects, employee turnover, worker well being and, where relevant (e.g. in schools), test scores.

Schools are also an ideal application for green building. One-fifth of California's population spends weekdays in schools. Productivity and health are critically important, not just for the well-being of students and teachers, but also in order to enhance the learning environment and student performance. Some green building benefits (e.g., reduced cost of churn) are less relevant for school buildings. However, as discussed in the above *Note on Education*, children's increased vulnerability to toxic chemicals, allergens and other pollutants is a particularly compelling argument for green schools. Green buildings – especially at the Gold level – provide a significant degree of protection against potentially toxic chemicals that can lead to a rising incidence of asthma and allergies. The strong correlation between children's test scores and daylighting illuminates the large benefits available from greener design. Despite uncertainties about benefits of green design in schools, due to limited data and the large range of school building designs, this report concludes that green design up to LEED Gold level is now very cost-effective for school buildings.

There are additional benefits not evaluated in this report. As one example, the recent book *Small is Profitable*, identifies 207 benefits associated with use of distributed generation and energy efficiency,[333] only a few of which are reflected in this report. A range of other potentially significant benefits from building green include reduced medical costs from a healthier work/study environment and avoided school revenue losses due to higher student attendance. Additional studies should evaluate these and other potential benefits. Similarly, there are a few areas of potential health-related costs associated with green buildings. In particular, there is the possibility of higher indoor concentrations of pollution from lower air exchange rates, which are sometimes associated with more efficient buildings. This is addressed in LEED through reducing introduction of pollutants and toxics and enhanced ventilation. These issues should be examined more fully in a future analysis.

Constructing green buildings cost-effectively requires integrated green building design and a careful commissioning process. The commonly higher initial cost of green design and construction can be expected to drop as designers and builders gain experience in building green. The benefits of green buildings are greatest for public entities that have explicit responsibility to be concerned about broader societal benefits such as health.

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[333] See: http://www.smallisprofitable.org/. Op. Cit.

There are a number of areas that warrant additional research to refine our understanding of the costs and financial benefits of green buildings. The following section includes a list of over thirty specific areas for recommended additional research.

Faced with limitations in available data, this report has attempted to make consistently conservative assumptions, and found that the financial benefits of green buildings are approximately ten times larger than the average additional cost of building them. Further research and analysis of areas of potential additional benefits would refine costs and benefits estimates (and probably increase estimated financial benefits). Despite gaps in data and analysis, the findings of this report point to a clear conclusion: building green up to the LEED Gold level makes financial sense today.

XII. Recommended Next Steps

After the general section, recommendations are grouped by category, in alphabetical order, followed by recommendations for research on private sector buildings.

General

1) *Fund Optimized Design.* Green buildings may be more complicated and more expensive (especially when including energy modeling and commissioning) to design than conventional buildings. Ensuring adequate resources for integrated design, use of charettes, modeling, etc., is critical to the construction of cost-effective green buildings. Money spent in the early design phase ensures future financial benefits and optimized building performance. The state should try to understand how to optimize the design process and ensure adequate resources for the early design phase in California green buildings. In doing so, the state should build on work completed by Eley & Associates, Natural Logic and others on performance-based fees – providing a better understanding of the most effective allocation of fees to different phases of the design process. This would allow more cost-effective and fair compensation for all participants including clients and the design team.

2) Support and participate in a more refined evaluation of the cost-effectiveness of adopting a LEED Gold level target for state buildings and academic institutions. Consider whether green building benefits can offset budget limitations, such that operations and productivity savings prevent an increase in expenditures. This could include mapping LEED Gold level points onto financial benefits and other targets specific to the state of California.

3) Evaluate the cost-effectiveness of adopting California's *LEED Supplement for California State Facilities*. Research should address whether additional elements need to be added (e.g., higher minimum energy reduction or peak demand reduction targets).

4) *Baseline Data Collection.* The state does not maintain easily retrievable data about standard design practice for its building projects and generally does not evaluate and catalogue building performance over time. Both of these endeavors are important to gain an accurate understanding of the full value of green building strategies.

5) Identify information sources and tracking mechanisms for green building cost data that are closer to the actual projects, instead of potentially biased second and third-hand sources. This might include obtaining construction records and original estimates, developing a transparent method of interpreting the cost data, and including an explanation of that method with the findings.

6) Support analysis and development of recommendations for the most cost effective policies to promote adoption of green buildings in California.

7) Analysis of data on California and public buildings should be expanded and updated in late 2003 to reflect a growing body of LEED submissions and other data available since this report analysis was undertaken (October-December, 2002). This expanded analysis should identify trends and provide additional cost and financial benefit insights related to green building elements and additional areas of benefits.

Commissioning

8) Support ongoing commissioning efforts at DGS. Encourage evaluation of the cost-effectiveness of commissioning in new non-green buildings as well as advanced commissioning in green buildings in California.

9) Support work to develop a commissioning template, including a checklist of recommended/required commissioning steps that are most important and cost-effective. The checklist could focus on ensuring environmental and health benefits.

10) *Maintenance.* Green buildings provide greater health, productivity, and/or enhanced learning and other benefits than conventional buildings. Green buildings also emphasize the importance of maintenance and periodic planned preventative commissioning. Additional work should be done to develop an approach to improved building maintenance, especially for green buildings, that maintains building benefits and also meets California state budgeting requirements. The cost-effectiveness of periodic re-commissioning as well as improved durability and ease of maintenance of green products and systems should also be examined.

Emissions

11) This paper roughly assumes an "Average California Emissions Factor" (ACEF) approach to quantify cost of emissions from electricity generation. However, a more detailed analysis would look at variations across electricity generators, and assign greater benefit to reducing consumption from the dirtiest sources.

12) Emissions calculations generally cover only pollution at time of generation. However, considerable emissions are created during extraction/production, purification, and other steps in energy life cycle as well. A more thorough analysis would include these. See Appendix E.

13) *Financial Impact of Reduced Non-Fossil Fuel Electricity Generation*. Explore impact of emissions and/or other environmental costs associated with nuclear (16% of California generation) and large hydro (20% of CA generation).[334]

14) Reductions in V

15) olatile Organic Compounds (VOCs), mercury and other emissions from building materials, office machines, nearby traffic and other sources may have significant value but are not explicitly calculated in this preliminary report. A fuller report should quantify the benefits of these reduced emissions including operations and maintenance benefits and the incidence and costs of human productivity and health effects. Specifically, estimate reductions of indoor levels of carcinogens in green buildings and use cancer cost estimates (developed by US EPA) to calculate resultant economic benefit.

16) *Indirect effect of building siting on transportation:* Future work should explore this impact of inappropriate siting of buildings in light of the dominant influence of vehicle emissions on outdoor air quality in California, lost productivity due to gridlock, loss of agricultural land resources, and the growing importance of exposure to high levels of pollutants on or near roadways.

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[334] California electricity generation profile: http://www.green-e.org/your_e_choices/ca.html, April 2003. Data compiled by US Environmental Protection Agency.

Energy

17) *Better Understanding of the Potential of Green Building to Cut Peak Electric Load.* This is an important and largely overlooked issue and it is recommended that additional work be undertaken to more accurately value green building peak demand reduction.

18) *Leased Properties.* The California state government leases one third of the commercial buildings it occupies and provides building performance guidelines to the renting firms. [335] It appears that there is no formal cost analysis for the incorporation of these "green lease" guidelines. Analysis should be done to determine the cost-effectiveness and plausibility of requiring that leased space be green.

    Rising energy costs have a significant impact on the profitability of leasing agencies and therefore on the availability and cost of properties for lease to the state. In 2001, nine of California's eleven real estate investment trusts (REITs) underperformed the market average. One reason for this is California's high energy costs. A survey of California REITs found that for office properties, energy costs amounted to 9.5% of their net operating income, the highest portion for any of the building classes reported. This reflects both high energy costs and lower operating margins for office buildings, underlining the potential value of greater energy efficiency in state-leased office properties.[336]

    Additional work should be undertaken to evaluate the impact of greening on leased properties, including: value of buildings, lease rate impacts, and net operating impacts for the state.

Insurance

19) *Better Quantification of the Insurance-related Benefits of Green Buildings.* The minimal use of commercial insurance in California means that data must be collected from less formal agency-level sources, which may or may not be available. Efforts could be focused on analyzing insurance loss data (often referred to as "data mining") for a broader market, and extrapolating the results to California state-owned buildings and to educational institutions. Specifically, the impact on insurance premiums of reduced mold liability through the construction of moisture resistant buildings, improved quality control of construction and improved maintenance, should be examined.

20) Develop a resource for state risk managers and other decision makers, catalog what is known about the risk and risk-management aspects of green building technologies (expanding on the list of 80 technologies prepared in 1998 for DOE).[337]

21) Use state's purchasing power to negotiate better insurance premiums for existing and future green buildings, e.g., lower premiums for liability insurance under the "Owner-Controlled Insurance Program."

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[335] Exhibit B is now the standard for leased spaces. See: http://www.ciwmb.ca.gov/GreenBuilding/TaskForce/Blueprint/ExhibitB.pdf.
Exhibit C contains the building performance goals used by DGS. See: http://www.ciwmb.ca.gov/GreenBuilding/Design/ExhibitCLEED.doc.

[336] "Are California REITs Getting Zapped by the Electricity Mess?" Green Street Advisors, 2001. Available at: http://www.greenstreetadvisors.com.

[337] The DOE database is available at: http://eetd.lbl.gov/insurance/welcome.html.

22) Identify adverse interactions associated with green building technologies and create corresponding risk-management/reduction protocols to mitigate the risks. A common example is concern over adverse linkages between energy efficiency measures and indoor air quality or moisture problems. Whether real or perceived, these "downside" aspects are a significant barrier to the acceptance of innovative green building strategies. Relay the results to the CEC's Public Interest Energy Research (PIER) Program so that they are better addressed in the state's major energy-efficiency R&D efforts. Current research efforts in the PIER program are attempting to more precisely determine this relationship.

23) Participate in the next Risk Management Conference (sponsored periodically by the California Office of Insurance and Risk Management). Other relevant venues are the Public Agency Risk Mangers Association (PARMA) [338] meeting for state risk managers and the national public sector insurance meeting of Public Risk Management Association (PRIMA).[339]

Productivity and Health

24) Support a team in gathering more data about productivity issues. A study of green buildings might include the measurement of thermal comfort parameters and application of better monitoring – with quality control measures. Other data that could be gathered include: absenteeism, overall satisfaction, health symptoms, and school test scores.

25) Because productivity and health gains can be the dominant benefits of green buildings, more work should be done to assess and expand upon the findings of this report. A greater sensitivity should be paid to variances between specific cases, with error bars attached to benefits to show nominal and worst case conclusions. Consider supporting R&D to develop a set of predictor considerations for what factors specifically impact productivity.

26) California should consider participating in Seattle's "human factors commissioning" database project, which is measuring the impact of greening on worker comfort, health, productivity and related measures for all new or renovated municipal buildings that meet or exceed the LEED Silver level.[340]

27) Expand upon CBE analysis aggregating data from state buildings on:

    - Occupant satisfaction.
    - Absence rates.
    - Number of days actually sick.

    This might involve evaluation and measurement of ventilation rates, pollutants, human output, comfort, absence and sickness in green office buildings. A baseline could be selected (newer, nicer buildings) from the EPA database survey of 100 office buildings.[341]

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[338] See: http://www.parma.com/.
[339] See: http://www.primacentral.org/default.php.
[340] See: http://www.edcmag.com/CDA/ArticleInformation/coverstory/BNPCoverStoryItem/0,4118,19794,00.html.
[341] The "EPA Base Study" measured IAQ parameters and collected data on occupant health symptoms (via questionnaires). William Fisk, Senior Scientist, LBNL, December 2002.

Residential

28) There is no national consensus definition and guide for green residences. Participate in the development of a LEED residential application, including evaluation of cost-effectiveness of applying LEED for residences (including low income housing) with a focus on improving health.

Schools

29) Identify a senior-level state expert on schools to help lead an effort to evaluate the value that a LEED schools application guide might have for California. This would build upon and be coordinated with CHPS.

Water

30) *True Marginal Cost*. Currently available full cost estimates for new water supplies are inadequate. The state should commission a study that re-examines this issue and includes all of the considerations discussed in this document. Any new study examining marginal cost should also consider the marginal cost numbers used by water agencies in their grant applications for Proposition 13 funds. These were scheduled to be submitted to DWR in December 2002.

31) *Impact of Conservation*. The value of a conserved acre-foot varies depending on a range of factors, including: the alternative uses for the conserved water, the location of the conserved water, and timing of the conservation.[342] These factors ought to be examined more closely in any future investigation of value of conserved water.

32) *Cost of Conservation*. Analyze the cost of implementing conservation measures to determine their cost-effectiveness.

Waste

33) *California Environmental Data.* While the Massachusetts report[343] is quite comprehensive in its approach to environmental costs and benefits, its conclusions may or may not be appropriate for the state of California. A comparable California-specific study should be conducted.

34) *Economic Data*. While the UCB and NRC/REI reports provide significant insight into the economic impacts of diversion and disposal in California, they do not evaluate the following important areas: the actual retail price of C&D diversion vs. disposal in all regions of the state, the value to the state of recycled vs. virgin building materials, and cost to the building owner of implementing an office recycling program.

35) *Value of Enforcing Current Ordinances*. Determine the result of meeting current California waste reduction guidelines (Exhibit C – Tiers 1 & 2). Determine the cost to state agencies of implementing recycling and other waste reduction practices.

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[342] Ray Hoagland, DWR, memo to the authors, January 13, 2003.
[343] Lisa Skumatz and Jeffrey Morris, "Massachusetts Recycle 2000: Baseline Report." See Section VII: Waste Reduction.

Research Opportunities for Private Sector Benefits of Green Buildings[344]

- *Increased Rent and Lower Vacancy*. Green buildings are more comfortable and healthier for building occupants, in addition to supporting increases in productivity. Therefore they should be in greater demand than conventional buildings: achievable rents should be higher and vacancies lower. A study that tracks green buildings in the marketplace could confirm or deny this.
- *IRR Case Studies*. Owners need more case studies on the internal rate of return (IRR) of green buildings. The San Diego Ridgehaven building is a good example – showing a 57% IRR on investment. [345]
- *Faster Tenant Lease-Up*. With higher press attention and greater tenant value, it is likely that green buildings will lease-up faster than non-green buildings. If proven, it could demonstrate substantial financial savings to the user.
- *Green Appraisals*. Very few appraisers understand green buildings and their benefits, including potentially increased income, lower expenses, and lower future liability. The state could meet with a few of the largest appraisal firms and discuss the impact of green buildings on their business.

[344] Excerpted from work completed by David Gottfried, Gottfried Technology Inc. Re: Future Green Building Research Needs. January 2003.
[345] See for example: http://www.ciwmb.ca.gov/GreenBuilding/CaseStudies/Commercial/Ridgehaven.htm.

Appendices

Appendix A: The LEED System[346]

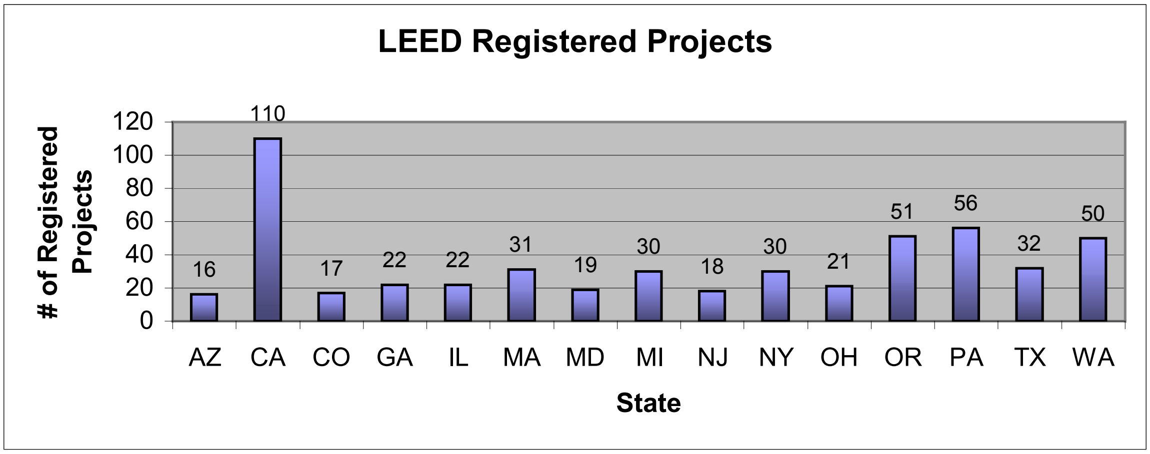
LEED provides four award levels based on the number of environmentally related points achieved by a new building project. The four levels include: Certified (26-32 points) Silver (33-38 points), Gold (39-51 points) and Platinum (52-69 points).

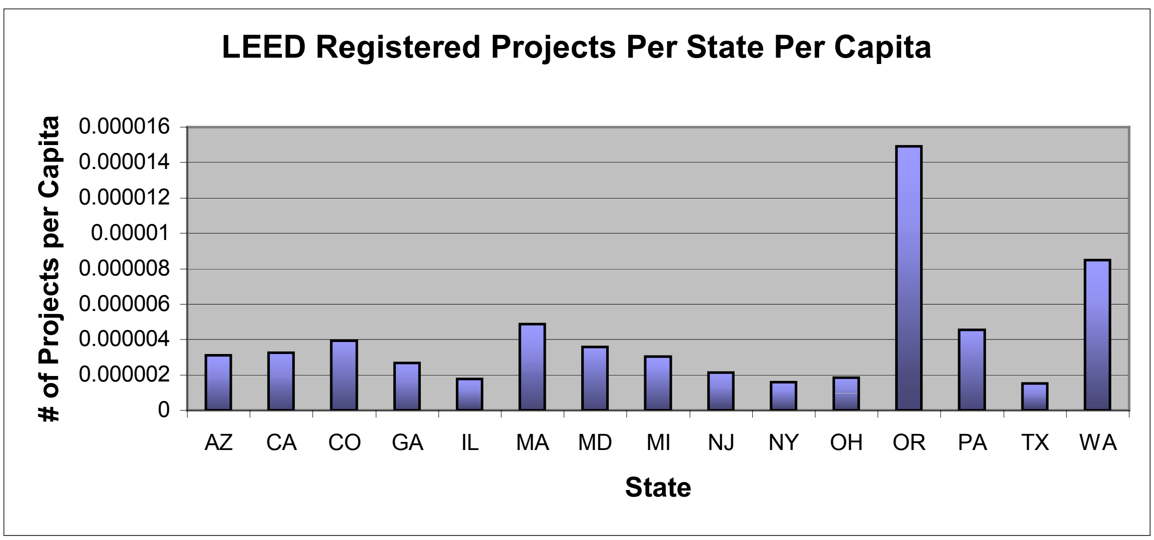
LEED Version 2.1		
Design Area 1	**Sustainable Sites (14 Points possible)**	
	Prereq 1	Erosion & Sedimentation Control (Required)
	Credit 1	Site Selection (1 point)
	Credit 2	Urban Redevelopment (1 point)
	Credit 3	Brownfield Redevelopment (1 point)
	Credit 4.1	Alternative Transportation, Public Transportation Access (1 point)
	Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms (1 point)
	Credit 4.3	Alternative Transportation, Alternative Fuel Vehicles (1 point)
	Credit 4.4	Alternative Transportation, Parking Capacity (1 point)
	Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space (1 point)
	Credit 5.2	Reduced Site Disturbance, Development Footprint (1 point)
	Credit 6.1	Stormwater Management, Rate and Quantity (1 point)
	Credit 6.2	Stormwater Management, Treatment (1 point)
	Credit 7.1	Landscape & Exterior Design to Reduce Heat Islands, Non-Roof (1 point)
	Credit 7.2	Landscape & Exterior Design to Reduce Heat Islands, Roof (1 point)
	Credit 8	Light Pollution Reduction (1 point)
Design Area 2	**Water Efficiency (5 Points possible)**	
	Credit 1.1	Water Efficient Landscaping, Reduce by 50% (1 point)
	Credit 1.2	Water Efficient Landscaping, No Potable Use or No Irrigation (1 point)
	Credit 2	Innovative Wastewater Technologies (1 point)
	Credit 3.1	Water Use Reduction, 20% Reduction (1 point)
	Credit 3.2	Water Use Reduction, 30% Reduction (1 point)
Design Area 3	**Energy & Atmosphere (17 Points possible)**	
	Prereq 1	Fundamental Building Systems Commissioning (Required)
	Prereq 2	Minimum Energy Performance (Required)
	Prereq 3	CFC Reduction in HVAC&R Equipment (Required)
	Credit 1	Optimize Energy Performance (1 to 10 points)
	Credit 2.1	Renewable Energy, 5% (1 point)
	Credit 2.2	Renewable Energy, 10% (1 point)
	Credit 2.3	Renewable Energy, 20% (1 point)
	Credit 3	Additional Commissioning (1 point)
	Credit 4	Ozone Depletion (1 point)
	Credit 5	Measurement & Verification (1 point)
	Credit 6	Green Power (1 point)

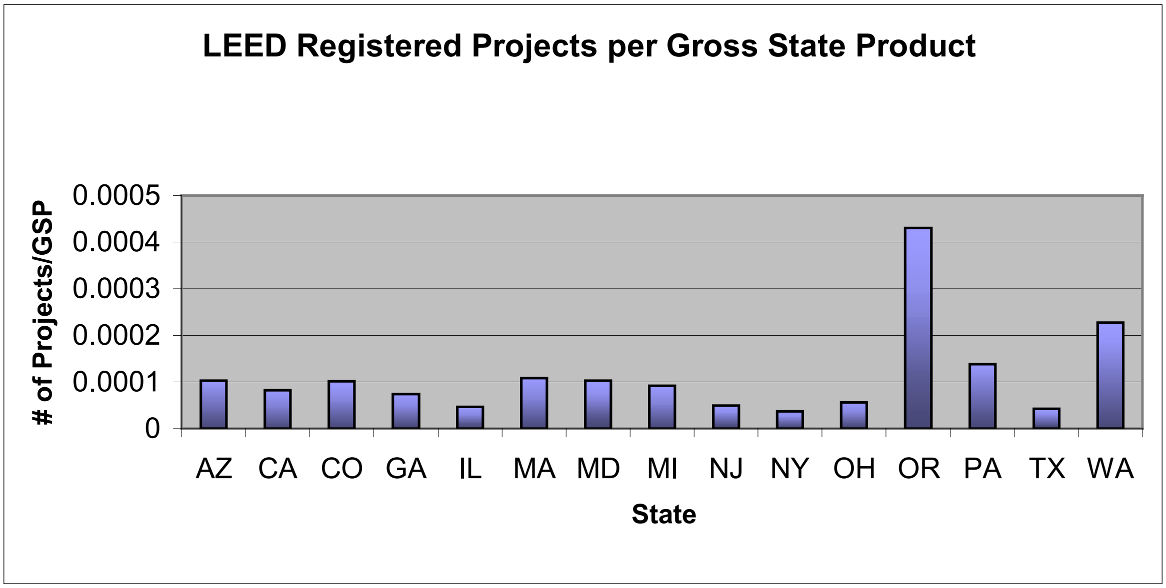
[346] See: www.usgbc.org.

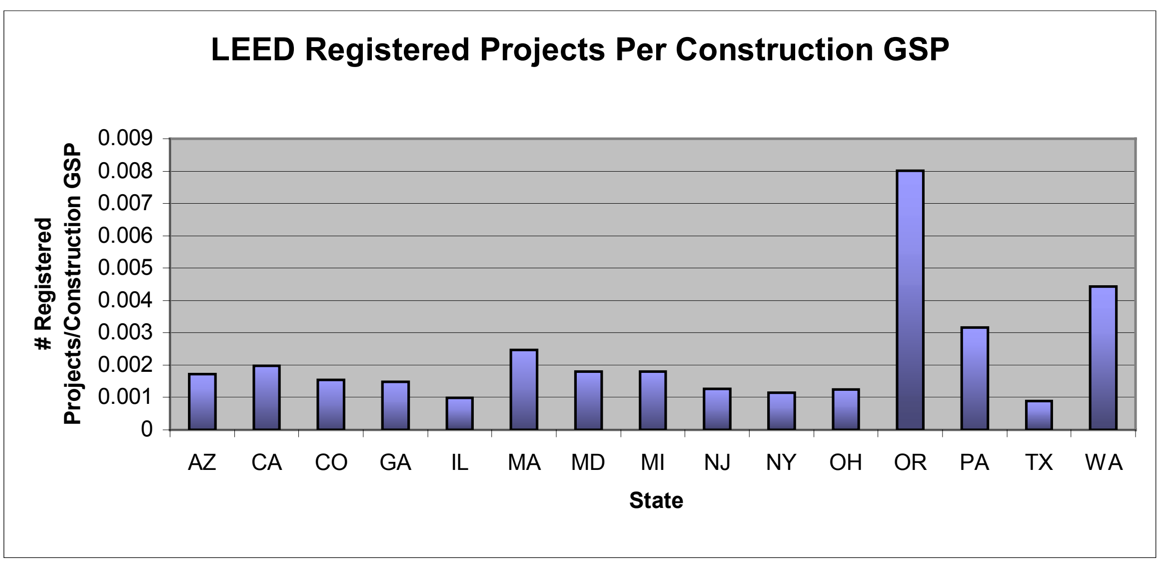
Design Area 4	**Materials & Resources (13 Points possible)**	
	Prereq 1	Storage & Collection of Recyclables (Required)
	Credit 1.1	Building Reuse, Maintain 75% of Existing Shell (1 point)
	Credit 1.2	Building Reuse, Maintain 100% of Shell (1 point)
	Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell (1 point)
	Credit 2.1	Construction Waste Management, Divert 50% (1 point)
	Credit 2.2	Construction Waste Management, Divert 75% (1 point)
	Credit 3.1	Resource Reuse, Specify 5% (1 point)
	Credit 3.2	Resource Reuse, Specify 10% (1 point)
	Credit 4.1	Recycled Content, Specify 5% p.c. or 10% p.c. + 1/2 p.i. (1 point)
	Credit 4.2	Recycled Content, Specify 10% p.c. or 20% p.c. + 1/2 p.i (1 point)
	Credit 5.1	Local/Regional Materials, 20% Manufactured Locally (1 point)
	Credit 5.2	Local/Regional Materials, of 20% Above, 50% Harvested Locally (1 point)
	Credit 6	Rapidly Renewable Materials (1 point)
	Credit 7	Certified Wood (1 point)
Design Area 5	**Indoor Environmental Quality (15 Points possible)**	
	Prereq 1	Minimum IAQ Performance (Required)
	Prereq 2	Environmental Tobacco Smoke (ETS) Control (Required)
	Credit 1	Carbon Dioxide (CO2) Monitoring (1 point)
	Credit 2	Ventilation Effectiveness (1 point)
	Credit 3.1	Construction IAQ Management Plan, During Construction (1 point)
	Credit 3.2	Construction IAQ Management Plan, Before Occupancy (1 point)
	Credit 4.1	Low-Emitting Materials, Adhesives & Sealants (1 point)
	Credit 4.2	Low-Emitting Materials, Paints (1 point)
	Credit 4.3	Low-Emitting Materials, Carpet (1 point)
	Credit 4.4	Low-Emitting Materials, Composite Wood
	Credit 5	Indoor Chemical & Pollutant Source Control (1 point)
	Credit 6.1	Controllability of Systems, Perimeter (1 point)
	Credit 6.2	Controllability of Systems, Non-Perimeter (1 point)
	Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992 (1 point)
	Credit 7.2	Thermal Comfort, Permanent Monitoring System (1 point)
	Credit 8.1	Daylight & Views, Daylight 75% of Spaces (1 point)
	Credit 8.2	Daylight & Views, Views for 90% of Spaces (1 point)
Design Area 6	**Innovation & Design Process (5 Points possible)**	
	Credit 1.1	Innovation in Design: Specific Title (1 point)
	Credit 1.2	Innovation in Design: Specific Title (1 point)
	Credit 1.3	Innovation in Design: Specific Title (1 point)
	Credit 1.4	Innovation in Design: Specific Title (1 point)
	Credit 2	LEED™ Accredited Professional (1 point)

Appendix B: Analysis of LEED Registered Projects






LEED Registered Projects per Gross State Product
# of Projects/GSP
0.0005
0.0004
0.0003
0.0002
0.0001
0
AZ CA CO GA IL MA MD MI NJ NY OH OR PA TX WA
State


LEED Registered Projects Per Construction GSP
Registered Projects/Construction GSP
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
AZ CA CO GA IL MA MD MI NJ NY OH OR PA TX WA
State

Appendix C: List of 33 Green Buildings, Green Cost Premiums, and Level of Green Standard

Project	Location	Type	Date Completed	Green Cost Premium	Green Standard
Energy Resource Center[1]	Downey, CA	Office	1995	0.00%	Level 1-Certified
KSBA Architects[1]	Pittsburgh, PA	Office	1998	0.00%	Level 1-Certified
Brengel Tech Center[1]	Milwaukee, WI	Office	2000	0.00%	Level 1-Certified
Stewart's Building[2]	Baltimore, MD	Office	2003	0.50%	Level 1-Certified
Pier One[3]	San Francisco, CA	Office	2001	0.70%	Level 1-Certified
PA EPA S. Central Regional[1]	Harrisburg, PA	Office	1998	1.00%	Level 1-Certified
Continental Towers[11]	Chicago, IL	Office	1998	1.50%	Level 1-Certified
Cal EPA Headquarters[3]	Sacramento, CA	Office	2000	1.60%	Level 1-Certified
EPA Regional[4]	Kansas City, KS	Office	1999	0.00%	Level 2-Silver
Ash Creek Intermed. School[10]	Independence, OR	School	2002	0.00%	Level 2-Silver
PNC Firstside Center[1]	Pittsburgh, PA	Office	2000	0.25%	Level 2-Silver
Clackamas High School[10]	Clackamas, OR	School	2002	0.30%	Level 2-Silver
Southern Alleghenies Museum[2]	Loretto, PA	Office	2003	0.50%	Level 2-Silver
DPR-ABD Office Building[5]	Sacramento, CA	Office	2003	0.85%	Level 2-Silver
Luhrs Univ. Elementary[2]	Shippensburg, PA	School	2000	1.20%	Level 2-Silver
Clearview Elementary[2]	Hanover, PA	School	2002	1.30%	Level 2-Silver
West Whiteland Township[2]	Exton, PA	Office	2004	1.50%	Level 2-Silver
Twin Valley Elementary[2]	Elverson, PA	School	2004	1.50%	Level 2-Silver
Licking County Vocational[2]	Newark, OH	School	2003	1.80%	Level 2-Silver
3 Portland Public Buildings[1*]	Portland, OR	Office	since 1994	2.20%	Level 2-Silver
Nidus Center of Science[1]	Creve Coeur, MO	Office	1999	3.50%	Level 2-Silver
Municipal Courts[1]	Seattle, WA	Office	2002	4.00%	Level 2-Silver
St. Stephens Cathedral[12]	Harrisburg, PA	School	2003	7.10%	Level 2-Silver
4 Times Square[6]	New York City	Office	1999	7.50%	Level 2-Silver
PA DEP Southeast[2]	Norristown, PA	Office	2003	0.10%	Level 3-Gold
The Dalles Middle School[10]	The Dalles, OR	School	2002	0.50%	Level 3-Gold
Dev. Resource Center[8]	Chattanooga, TN	Office	2001	1.00%	Level 3-Gold
PA DEP Cambria[2]	Ebensburg, PA	Office	2000	1.20%	Level 3-Gold
PA DEP California[2]	California, PA	Office	2003	1.70%	Level 3-Gold
East End Complex-Blk 225[7]	Sacramento, CA	Office	2003	6.41%	Level 3-Gold
Botanical Garden Admin[9]	Queens, NY	Office	2003	6.50%	Level 4-Platinum

1 Cost data from "Resource Guide for Sustainable Development in an Urban Environment: A Case Study in South Lake Union, Seattle, WA," prepared by UEI, Oct 22, 2002, p.42. http://www.usgbc.org/Resources/research.asp. Note that many of these 33 data points typically came from more than one source and/or were checked with more than one source.
2 Cost data from presentation and discussions with John Boecker, Vice President, L. Robert Kimball & Associates, November 20 and December 20, 2002, and May 2003.
3 Cost data from Anthony Bernheim, "Saving Resources," Urban Land, June 2001 and Anthony Bernheim and Scott Lewis, "Measure and Cost of Green Building," presented at the AIA National Convention, May 2000.
4 C. C. Sullivan, "Off-the-Shelf Ecology," Building Design & Construction, May 2001, pp 57-60.
5 Communication with David Gottfried, WorldBuild, December 27, 2002, forwarded information from Craig Greenough, DPR Inc.
6 Communication with Pam Lippe, Environmental Consultant to the Durst Organization, Dec 19, 2002.
7 Cost data from Jim Ogden, 3D/I, "Summary of Green Building Costs - Block 225," 2003.
8 Communication with Randy Croxton, Croxton Collaborative, November 20, 2002.
9 David Kozlowski, "Urban Green," Building Operating Management, December 2001. Indicated cost increase 5-8%.
10 Communication with Heinz Rudolf, Principal, BOORA Architects, November 2002, June 2003. Bill Harper, Assoc. Principal, BOORA Architects, May, 2003. For more info, see: http://www.energy.state.or.us/school/highperform.htm
11 Communication with Kevork Derderian, Continental Offices Ltd., Nov 21, 2002.
12 Communication with Vern McKissick, Architect, McKissick Asssociates. May become gold, but silver for now.
* Without more complete information than that the buildings were completed between 1994-2001, the three were attributed to 1997 in this analysis.

Appendix D: Non-energy Value of Peak Demand Reduction

Below are updated numbers for 11 utility studies on the value of peak demand reduction in lowering T&D and related costs. The result is an average current value of $600/kW for peak power demand reduction. These savings can be realized with peak-shaving energy efficiency improvements and/or the installation of on-site distributed generation, such as solar photovoltaics.

A first set of studies from six utilities (Georgia Power, Florida Power & Light, Green Mountain Energy, New Mexico, and two from Southern California Edison), analyzed by Zaininger Engineering and presented in Figure D-1, indicate an average T&D-related benefit of $549/kW (2002 dollars).

Figure D-1. Non-energy Benefits of Peak Reduction/kW[347]

	Georgia	FPL	Green Mount.	New Mexico	So Cal Ed 1*	So Cal Ed 2*	CA Avg. (*)	Average of all 6
Environmental Externalities					$414	$634	$524	
Distribution facility deferral	$0	$0	$0	$1,033	$227	$0	$113	$210
Distribution Losses	$76	$55	$73	$18	$65	$265	$165	$92
Voltage Regulation	-$5	-$4	-$2	-$4	-$5	-$5	-$5	-$4
Transmission Capacity	$105	$0	$244	$0	$344	$107	$226	$133
Transmission losses	$39	$0	$0	$0	$46	$54	$50	$23
TOTAL NON-ENERGY BENEFITS	$215	$51	$315	$1,048	$677	$421	$549	$454
As % of generation capital cost ($600/kW)	36%	9%	52%	175%	113%	70%	92%	76%

The second set of data are from studies undertaken at five utilities (including two at Southern California Edison in California) and indicate average T&D and line loss benefits of $673/kW (2002 $), or about 110% of the current cost of marginal generation peaking plants.

Figure D-2. Non-energy Value of Peak Reduction[348]

	APS	COA	SRP	PG&E*	SMUD*	CA Avg. (*)	Average of all 5
Losses	$218	$95	$85	$89	$0	$45	$98
Distribution	$780	$18	$637	$62	$172	$117	$334
Transmission	$445	$0	$153	$548	$65	$306	$242
TOTAL NON-ENERGY VALUE	$1,443	$113	$875	$699	$237	$468	$673
% of generation capital cost ($600/kW)	241%	19%	146%	117%	39%	78%	112%

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347 Henry W. Zaininger, Zaininger Engineering Co., Inc., 9959 Granite Crest Ct., Granite Bay, CA 95746, taken from *CEC Energy Innovations '99*, October 25 - 27, 1999. Personal communication with Hank Zaininger, November 2002, CPI inflation adjusted.

348 Howard Wenger, Tom Hoff & Dale Furseth, Pacific Energy Group; Christy Herig, National Renewable Energy Laboratory; John Stevens, Sandia National Laboratory. Data assembled by US DOE. Personal communications with study co-author Tom Hoff, November, 2002, CPI inflation adjusted.

Appendix E: Emissions

Some Assumptions
a) This report focuses on four pollutants: NOx, SO2, PM10 and CO2. While other pollutants impose significant costs and should be evaluated in a more thorough study, these four pollutants probably represent most of the damage from burning fossil fuels. Further research should analyze the value of reducing all emissions, including the waste products of nuclear reactors, which supply 16% of California's power.[349] This report also focuses on electricity and leaves out the cost of using gas in state buildings, both because gas represents a small percentage (<5%) of energy use in commercial buildings and because pollution from gas is well within the range of pollution intensity for the statewide mix of electricity sources.

b) California imports between 20% and 35% of its power (at peak) from out-of-state and this is roughly twice as dirty as in-state generation.[350] Of 50,000 MW total in-state generating capacity, only 500 MW, or 1% is generated from coal. However some 2000 MW of LADWP power that is sold in California is from coal burning power plants located out-of-state.[351] Emissions factors developed by Tellus were used in this analysis because these include out-of-state emissions. (See Section V.)

c) Emissions calculations generally cover only pollution at time of generation. However, considerable emissions are created during the extraction/production, purification and other steps in energy life cycle as well. For example, a recent PhD thesis at the Harvard School of Public Health estimated that a substantial portion of the damaging emissions from natural gas actually occur during extraction and production phases (that is, prior to combustion), but that these emissions are generally not included in calculation of emissions costs associated with energy production. See Figure D-1 below.

Figure E-1. Air Pollutant Emissions from Natural Gas Fuel Cycle (ton/ft^3)[352]

Stage	NOx	SOx	Total PM	CO_2
Extraction/ Production[a]	8.5×10^{-8}	1.4×10^{-6}	1.9×10^{-9}	3.3×10^{-6}
Purification[b]	4.1×10^{-8}	5.4×10^{-12}	1.6×10^{-10}	-
Power plant combustion	1.2×10^{-7}	1.7×10^{-9}	3.5×10^{-9}	6.2×10^{-5}
TOTAL	2.5×10^{-7}	1.4×10^{-6}	5.6×10^{-9}	6.6×10^{-5}
End-use fraction of total	0.49	0.0013	0.63	0.95

[349] Source: http://www.green-e.org/your_e_choices/ca.html, April 2003. Data compiled by the US Environmental Protection Agency.
[350] Communication with Joe Loyer, Environmental Unit of the State Energy Siting Division, on October 23, 2002. jmloyer@energy.state.ca..us. See also Tellus Study. Op. Cit.
[351] Data provided by the California Energy Commission, Systems Assessment and Facilities Siting Division. December 2002.
[352] Jonathan Levy, "Environmental Health Effects of Energy Use: A Damage Function Approach." Thesis submitted to the Faculty of The Harvard School of Public Health in Partial Fulfillment of the Requirements for the Degree of Doctor of Science in the Departments of Environmental Health and Health Policy and Management Boston, Massachusetts, May, 1999, Table 15. This report kindly provided by Bob Berkebile of BNIM.

These and similar studies indicate the need to evaluate the life cycle emissions impact of fossil fuel consumption in order to achieve a more accurate environmental accounting of emissions and costs. It is not within the scope of this study to do so, tending to underestimate the financial benefits associated with lower emissions from reduced issue of purchased electricity in green buildings.

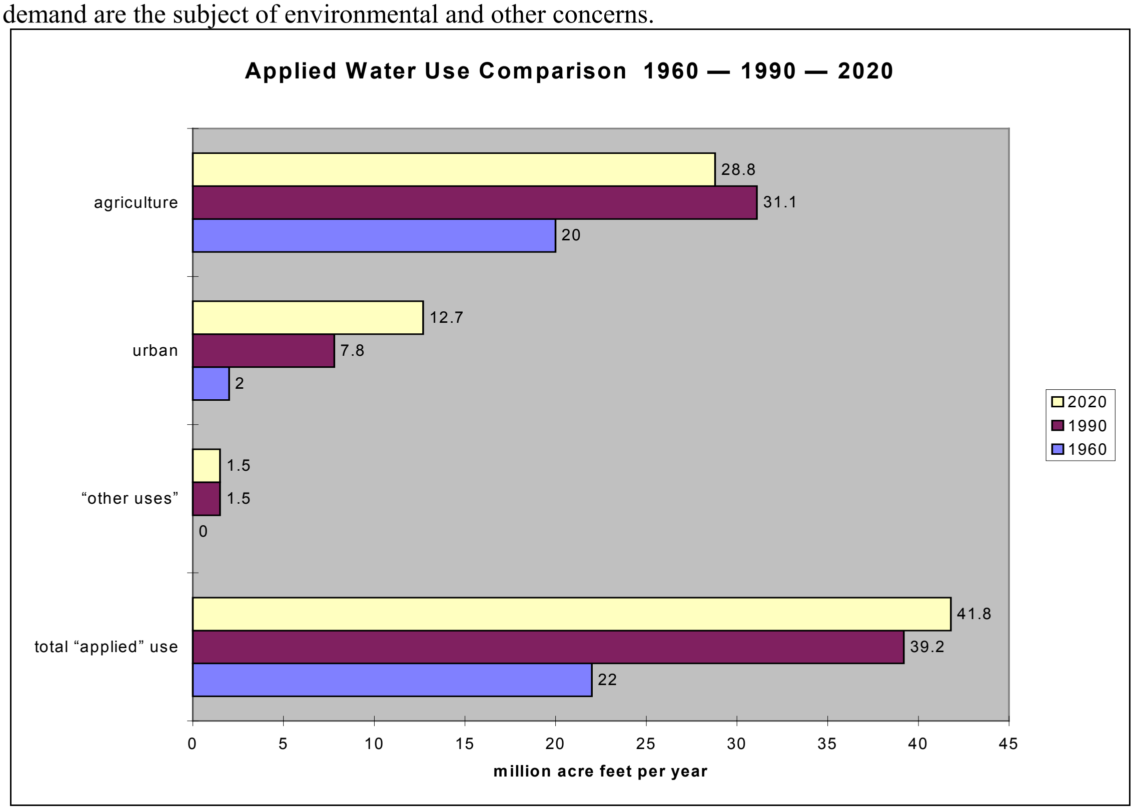
Appendix F: Water Use in California

The following is excerpted and adapted from the work of Bob Wilkinson, UC Santa Barbara.[353]

Water in California is extracted from natural systems primarily for use in the urban and agricultural sectors. The urban water use sector includes residential, commercial, industrial, and institutional uses, as well as municipal uses such landscaping and fire-fighting. As the state's population continues to grow, urban uses of water are steadily increasing. The state now projects a continued decline in water use for agriculture. Land retirement, crop shifting, water transfers, and improved efficiencies in irrigation as well as conveyance and management will all contribute to a reduction in water used for irrigation. Despite this decline, however, total extractions from the state's water systems have increased through the years, with flows for the environment decreasing as a result.

With very real limits to the state's water system, and every major supply source being reduced, the state's water systems may be fairly said to be stressed. Every major water supply source in California is currently beyond the physical or legal capacity to be sustained. California's entitlement to Colorado River water is 4.4 mafy, but it has been taking 5.2 mafy. An average of 1.3 mafy of groundwater extraction is overdraft (extractions exceed recharge by more than 18 percent). In severe drought years, this overdraft may be as high as four to 10 mafy, which drastically depletes economically recoverable groundwater resources.

The municipal and industrial (M&I) sector accounts for approximately 20% of the state's developed water use. The costs of water supply options have increased significantly, and water supplies to meet urban demand are the subject of environmental and other concerns.



* Total of "other outflow" and "environmental," a category which is not disaggregated for 1960. Assumes total water resources of 85 mafy for 2020, consistent with 1960 and 1990 data.

Source: California Department of Water Resources. California Water Plan Update, Bulletin 160-93, 1994.

[353] Robert Wilkinson, "Methodology for Analysis of the Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures," January 2000, p. 16-17. (mafy = million acre-feet per year).

Appendix G: Water Calculations

Weighted Average Value (WAV) Calculation

Population data is based on projections from 1995-2020.[354]

	Total 20-year PV ($/af)	% of CA population	Component of WAV
Bay Area	$9,546	8.1%	$769.36
Central Coast	$5,576	3.9%	$216.24
Sacramento	$1,783	9.3%	$166.35
San Joaquin	$3,098	9.3%	$287.39
South Coast	$9,074	45.5%	$4,128.23
S. Lahontan	$4,837	8.5%	$408.93
Tulare	$3,200	10.1%	$322.71
	Weighted Average Value:		**$6,299.21**

For the following calculations, doubling this WAV number seems to make sense because of the numerous unaccounted for costs in the studies on which these numbers are based, as outlined in Section VI.

Value of Potential Water Savings – An Example

Determining the value of potential water savings in a typical new building project requires making multiple assumptions about the size of the structure, its intended use, and its location within the state and baseline design elements. For the purposes of this example, assume the following:

Building Size:	100,000 ft^2
Building Type:	Standard Commercial Office w/ Cooling Tower
Number of Employees:	400 (250 ft^2/employee)
Baseline Building Practice:	Code
Baseline Indoor Water Usage:	25 gallons per employee per day[355]
Use Reduction through Green Design:	30%[356]
Baseline Landscape Water Usage:	1.46 million gallons per acre per year[357]
Average size of landscaped area:	0.75 acres per building[358]

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[354] Source: "Bulletin 160-98: California Water Plan," California Department of Water Resources, Table 4.1.

[355] The amount of water used in California's commercial buildings varies widely by building type and use. Cooling towers and restaurants have the greatest impact on consumption. Average daily per capita consumption ranges from 15 to 40+ gallons. From conversation with Dale Lessick, Irvine Ranch Water District, October 2, 2002.

[356] Indoor savings of 30% are considered typical when incorporating relatively simple green design features. Source: USGBC, http://www.usgbc.org.

[357] Landscape water usage is even more difficult to generalize than indoor use. Planted landscapes range in size from a few potted plants (mostly in urban centers) to several acres (mostly in the suburbs). In addition, plant types require vastly different amounts of water. From http://www.cimis.water.ca.gov/, the average ETo in California across all 18 zones is 51.6 inches per year. According to the CUWCC, typical turf grass requires roughly 70% of ETo – 36 inches per year. Assuming that water delivery systems, are on average 50% inefficient, this hypothetical turf grass would require 54 inches of water applied per year. Calculations: 4.5 ft^3 x 43,460 ft^2/acre x 7.48 gallons/ft^3 = 1.46 million gallons per year (mgpy). We assume that through more efficient irrigation systems and better plant selection, conservation can achieve a 50% water use reduction, resulting in a required application of 730 mgpy.

Use Reduction through Green Design:	50%[359]
Marginal 20-yr PV cost of water:	$12,598/af

Calculations:
(1 af = 325,851 gallons)

Indoor Water Conserved:
25 gallons x 30% = 7.5 gpd savings
400 people x 7.5 gpd savings x 260 work days/yr = 780,000 gpy (2.39 af)
2.39 af x $12,598/af = $30,109

Irrigation Water Conserved:
(1,460,000 gallons per acre x .75 acres) x 50% = 547,500 gpy (1.68 af)
1.68 af x $12,598/af = $21,164

Figure G-1. 20-Year NPV of Water Savings

Total Value Per 100,000 ft^2 Building		
Indoor	**Irrigation**	**Total**
$30,109	$21, 164	$51,271
Total Value Per ft^2 of Building		
Indoor	**Irrigation**	**Total**
$0.30	$0.21	$0.51

The PV values were calculated by multiplying the PV value of one acre-foot of water, as derived in Section VI, with the amount of savings (in acre-feet) that are achieved in this hypothetical example. The total 20-year PV for both Indoor and Outdoor water savings is calculated as follows:

PV of 1 af = $12,598	(from Section VI)
($12,598 x 2.39 af)	(savings from indoor water reduction)
+ ($12,598 x 1.68 af)	(savings from outdoor water reduction)
= $51,271	
$51,271 / 100,000 ft^2 = **$0.51/ft^2**	(20-year PV)

[358] Conversation with Dale Lessick. This is the average landscaped acreage of over 800 commercial buildings in the Irvine Ranch Water District.
[359] Outdoor landscaping savings of 50% are considered typical when incorporating relatively simple green design features. Source: USGBC, http://www.usgbc.org.

Appendix H: Value of Waste Reduction – A State Building Example

The following example shows the economic impact of C&D diversion in a hypothetical new state green building project. The calculated value is in downstream product manufacture and sales, real tax revenues, and environmental impacts. It is important to note that some of the assumptions in this calculation are based on values for curbside recycling. Due to the relatively higher quality of most C&D materials, C&D recycling is generally more financially beneficial than curbside residential or commercial recycling service. Ultimately, this is a calculation of the benefits of waste diversion, of which recycling is one part.

The Impact of Construction and Demolition Waste Diversion

Assumptions

Building Size:	100,000 ft^2
Construction Waste Generated:	200 tons (400,000 lbs) [360]
Demolition Waste Generated:	775 tons (1,550,000 lbs)
Baseline Case:	50% Diversion Rate[361]
Green Case:	75% Diversion Rate
Value of Ton of Diverted Waste:	
Output Impact:	$325/ton[362]
Income Impact:	$70/ton
Value Added Impact (taxable):	$111/ton
Environmental Impact:	$47/ton[363]
State Income Tax:	3%
State Sales Tax:	8.25%

Calculations

Full Value of Ton Diverted (Output + Environmental): $325 + $47 = $372
Tax Value of Ton Diverted: $2.10 (e.g.$70 x 3%) + $9.16 (e.g.$111 x 8.25%) = $11.25

Conclusions for the whole building, assuming additional 25% diversion over baseline

Construction Diversion		
Full Value:	$18,600	(200 tons x 25% x $372)
Environmental Value:	$2,350	(200 tons x 25% x $47)
Tax Value:	$563	(200 tons x 25% x $11.25)
Demolition Diversion		
Full Value:	$72,075	(775 tons x 25% x $372)
Environmental Value:	$9,106	(775 tons x 25% x $47)
Tax Value:	$2,180	(775 tons x 25% x $11.25)

[360] For nonresidential buildings: 155 lbs/ft^2 demolition waste, about 4 lbs/ft^2 construction waste. US Environmental Protection Agency Municipal and Industrial Solid Waste Division, Office of Solid Waste. *Characterization of Building-related Construction and Demolition Debris in the United States*. June 1998.

[361] Note: Statewide estimated overall diversion rate in 2002 was 48% (CIWMB) – and green buildings can often reach the 75% diversion threshold.

[362] Average Output Impact average from UCB and NRC study.

[363] The environmental cost number for California is probably similar to the environmental cost number from the Massachusetts study plus or minus 25%. A conservative estimate of 75% of the Massachusetts number is used here. This number is similar to the curbside recycling environmental value.

The savings of C&D waste diversion are presented in Figure G-1 below.

Figure H-1. Value of C&D Waste Diversion in 100,000 ft^2 Office Building

		Building	Per ft^2
Construction	**Full Value**	$18,600	$0.19
	Eco Value	$2,350	$0.02
	Tax Value	$563	$0.01
Demolition	**Full Value**	$72,075	$0.72
	Eco Value	$9,106	$0.09
	Tax Value	$2,180	$0.02

For construction on barren land, use only the construction values. For construction on already developed land where an existing structure must first be demolished, use the demolition values plus the construction values.

Which metric is the right one to use?

The most accurate number for the state to use when evaluating the value of waste diversion is the Tax Value[364] plus the Eco-Value, according to the following rationale. The Tax Value is the most precise and conservative metric. It represents actual revenue earned by the state as a result of diversion. The Eco-Value also represents real avoided cost to the state even if it is, in part, speculative (e.g., reduced green house gas emissions). The Full Value includes all the multiplier effects of diversion (e.g., income effects, product value effects, taxes, etc.) – many of which accrue to individual actors within the state, but not to the state itself.

Using this approach, then, the potential values for reaching a 50% C&D diversion rate (25% over baseline) are:

\$0.03/ft^2 or \$3,000 per 100,000 ft^2 building for construction only.

\$0.11/ft^2 or \$11,000 per 100,000 ft^2 building for demolition only.

\$0.14/ft^2 or \$14,000 per 100,000 ft^2 building for construction preceded by demolition.

All numbers reflect the value that occurs in the year of the construction. This is not an NPV calculation. While there undoubtedly are effects from landfill reduction that reverberate through the future years, they are not included in this analysis and assumed to be small. A more thorough study should analyze this further.

Note on Office Recycling

In this example, office recycling has been removed from calculations of green building waste reduction benefits. It is not clear that the tenants of green buildings would reduce disposed waste beyond California's already relatively aggressive statewide recycling goals.

[364] The tax value refers to the additional taxes the state is likely to collect as a result of the economic activity generation through diversion activities.

Appendix I: Total User Costs for California State Buildings

Calculations follow the chart.

Figure I-1. DGS Data for California State Buildings

2002 data for 9.25 million square feet of California state office space with 27,428 employees.

Total User Costs	Annual $/Employee					
BLDG.#	Electricity	O&M	Other Energy	Rent	Employee	Total
001	$555	$22,132	$0	$175	$65,141	$88,003
002	$432	$2,589	$0	$2,477	$65,141	$70,340
003	$557	$3,060	$16	$7,239	$65,141	$75,595
004	$619	$3,585	$0	$0	$65,141	$68,958
006/056	$771	$2,958	$0	$5,747	$65,141	$73,975
008	$406	$2,373	$0	$8,367	$65,141	$75,991
009	$117	$1,812	$0	$932	$65,141	$67,929
010	$189	$1,609	$0	$4,603	$65,141	$71,436
011	$202	$6,476	$0	$4,445	$65,141	$76,247
013	$183	$979	$0	$3,349	$65,141	$69,651
018	$223	$806	$0	$2,962	$65,141	$69,595
019	$351	$1,612	$147	$0	$65,141	$67,018
021	$387	$2,442	$0	$4,959	$65,141	$72,625
025	$725	$5,997	$5	$13,893	$65,141	$85,354
028	$335	$167	$14	$0	$65,141	$66,020
030	$335	$1,166	$24	$5,705	$65,141	$72,371
036	$1,570	$4,563	$5	$0	$65,141	$70,232
039/045	$231	$1,024	$1	$3,061	$65,141	$69,804
075	$516	$1,862	$19	$3,320	$65,141	$71,117
091	$325	$17,112	$0	$0	$65,141	$82,270
330	$376	$6,308	$18	$6,346	$65,141	$77,946
402	$602	$2,631	$0	$15,044	$65,141	$83,869
460	$633	$7,164	$52	$6,275	$65,141	$78,663
461	$290	$1,424	$19	$2,540	$65,141	$69,163
470	$628	$5,486	$0	$5,695	$65,141	$76,479
480	$313	$4,921	$47	$3,226	$65,141	$73,439
512	$397	$2,356	$21	$8,296	$65,141	$76,145
530	$540	$5,177	$31	$6,489	$65,141	$76,972
602	$634	$1,959	$19	$9,063	$65,141	$77,133
701	$515	$3,237	$53	$5,258	$65,141	$73,861
753	$1,039	$3,392	$88	$9,915	$65,141	$78,587
801	$701	$4,999	$96	$6,994	$65,141	$77,391
901	$615	$3,780	$41	$3,995	$65,141	$73,048
Averages	**$408**	**$3,039**	**$12**	**$4,755**	**$65,141**	**$73,355**

Assembled for this report by the California Department of General Services and the Real Estate Services Division.

Energy Use Calculations
For purposes of calculating emissions from energy for Section V, it was necessary to determine a conservative value for electricity used per square foot. This can be derived by first determining electricity consumption per employee, then multiplying electricity consumption per employee by number of employees and dividing by the number of total square feet, as follows:

$408/0.12kWh/ft^2	=	3400 kWh/employee/year
3,400 x 27,428	=	93,255,200 kWh/year (for all building area)
93,255,200/9,250,000	=	**10 kWh/ft^2/yr**

Office energy costs for California state employees in 2002 were about:[365]
$1.60/ft^2 or $360/employee/year

This paper assumes an expected drop in electricity prices from $0.12/kWh to $0.11/kWh.[366] Therefore these figures are discounted to:
$1.47/ft^2/yr or $330/employee/year

Figure H-1 shows total energy costs per employee of $420.
Electricity + Other Energy = Total Energy: $408+$12=$420

Additionally, according to the Real Estate Services Division, average office space per worker is:
225 ft^2/employee

However, the information in Figure H-1 seems to imply more space than this:
9,250,000/27,428 = 337 ft^2/employee

These discrepancies can be explained as follows:

The total energy costs from Figure H-1 are understood to be the total energy consumed by the buildings divided by the number of employees. Therefore, energy costs for all buildings are:

27,428 x $420 = $11,519,760

This doesn't account for two factors:

1. The influence of "transients" or non-employees in the building, thereby increasing the effective number of employees.
2. Non-office space such as stairwells, elevator shafts and hallways, which are communal and generally unconditioned.

State buildings, in providing services, often have many non-employees inside them. Assuming a "transient factor" of 5% (on average there is space for 5% more people in the building than reported employees) results in a higher number of "effective employees":

[365] Data provided by the California Department of General Services, Real Estate Services Division, Building Property Management Brach, December 2002.
[366] California Energy Commission. Office of the Supervisor of Rates. December 2002. $0.11/kWh is a conservative estimate. Higher rates would increase green building benefits.

27,428 x 1.05 = 28,799 effective employees

All office buildings have a significant amount of non-office space. This space is generally both shared by all and less heavily conditioned (requiring less energy in heat and electricity) than office space. Assuming 30% of these state office buildings are non-office space delivers:

9.25 million ft^2 x 70% = 6.475 million ft^2 office space

Assuming non-office space requires 1/3 the energy of office space, this means that, while office space only makes up 70% of the building, it consumes 90% of the energy, thus:

$11,519,760 x 90% = $10,367,784 (energy cost of conditioning office space)

It is only this energy cost that should be attributed to employees, as energy costs of non-office space can't be assumed to scale evenly with number of employees.
Thus, energy costs per effective employee are:

$10,367,784/28,799 = $360/employee/year

Furthermore, office space per employee is:

6,475,000/28,799 = **225 ft^2/employee/year**

And energy costs per square foot are:

$10,367,784/6,475,000 = $1.60/$ft^2$/yr

These numbers are for 2002, when electricity cost (and therefore most of the cost of energy) was $0.12/kWh. However, estimates for future electricity cost are $0.11/kWh. Scaling the above figure down delivers:

$1.60 x (11/12) = **$1.47/ft^2/yr**

This is the number used throughout this report.

Appendix J: Health and Productivity Gains from Better Indoor Environments[367]

This is a direct excerpt from the work of William J. Fisk and Satish Kumar.

Acute Respiratory Illness (ARI)

No high quality studies identified had investigated but failed to find a link between building characteristics and acute respiratory illnesses (ARIs) such as influenza and common colds. Eight studies reported statistically significant 23% to 76% reductions in ARIs among occupants of buildings with higher ventilation rates, reduced space sharing, reduced occupant density, or irradiation of air with ultraviolet light. These changes to buildings or building use were considered technically feasible and practical, given sufficient benefits. One study found a 35% reduction in short-term absence, a surrogate for ARI, in buildings with higher ventilation rates. Because some of these studies took place in unusual building types, such as barracks and a jail, reductions in ARIs were adjusted downwards, and ranged from 9% to 20%. Multiplying this range by the annual cases of common colds and influenza resulted in an estimated 16 million to 37 million potentially avoided cases of common cold and influenza. Given the $70 billion annual cost of ARIs, the associated potential productivity gains were $6 billion to $14 billion.

Allergies and Asthma

The scientific literature reports statistically significant links between prevalence of allergy and asthma symptoms and a variety of changeable building characteristics or practices, including indoor allergen concentrations, moisture and mold problems, pets, and tobacco smoking. The reported links between these risk factors and symptoms were often quite strong. For example, parental smoking was typically associated with 20% to 40% increases in asthma symptoms. In numerous studies, mold or moisture problems in residences were associated with 100% increases in lower respiratory symptoms indicative of asthma. These moisture and mold problems are common; for example, about 20% of U.S. houses have water leaks. Based on these data, the estimated potential reduction in allergy and asthma symptoms from improved IEQ was 8% to 25%, among a large population -- 53 million with allergies and 16 million asthmatics. Given the $15 billion annual cost of allergies and asthma, the potential economic gains are $1 billion to $4 billion.

Sick Building Syndrome (SBS) Symptoms

SBS symptoms are acute symptoms, such as eye and nose irritation and headache, associated with occupancy in a specific building, but not indicating a specific disease. Risk factors for SBS symptoms identified in many studies include lower ventilation rates, presence of air conditioning, and higher indoor air temperatures. Increased chemical and microbiological pollutants in the air or on indoor surfaces, debris or moisture problems in HVAC systems, more carpets and fabrics, and less frequent vacuuming were risk factors in a smaller number of studies. One large study suggests that a 10 cfm per person increase in ventilation rates would decrease prevalences of the most common SBS symptoms on average by one third. Practical measures could diminish all these risk factors. Based on these data, the estimated potential reduction in SBS symptoms was 20% to 50%. The affected population is very large – in a survey of 100 U.S. offices, 23% of office workers (64 million workers) frequently experienced two or more SBS symptoms at work. The estimated productivity decrement caused by SBS symptoms in the office worker population was 2%, with an annual cost of $60 billion. A 20-50% reduction in these symptoms, considered feasible and practical, would bring annual economic benefits of $10 billion to $30 billion.

[367] Excerpted directly from: Satish Kumar and William J. Fisk, "The Role of Emerging Energy Efficient Technology in Promoting Workplace Productivity and Health: Final Report," LBNL, February 13, 2002, pp. 20-21. Available at: http://www-library.lbl.gov/docs/LBNL/497/06/PDF/LBNL-49706.pdf.

Direct Productivity Gains

Published literature documents direct linkages of worker performance with air temperatures and lighting conditions, without apparent effects on worker health. Many but not all studies indicate that small (few ^{o}C) differences in temperatures can influence workers' speed or accuracy by 2% to 20% in tasks such as typewriting, learning performance, reading speed, multiplication speed, and word memory. Surveys have documented that indoor air temperature is often poorly controlled, implying an opportunity to increase productivity.[368] It is estimated that providing ± 3^{o}C of individual temperature control would increase work performance by 3% to 7%. A smaller number of studies have documented improvements in work performance with better lighting, with benefits most apparent for visually demanding work. Increased daylighting was also linked in one study to improved student learning. Based on these studies and recognizing that performance of only some work tasks is likely to be sensitive to temperature and lighting, the estimated potential direct productivity gain is 0.5% to 5%, with the factor of ten range reflecting the large uncertainty. Considering only U.S. office workers, the corresponding annual productivity gain is $20 billion to $200 billion.

[368] Wyon. 1996. Op. Cit.

Appendix K: Insurance and Risk Management Benefits of Green Building Attributes

From: Evan Mills, "Green Buildings as a Risk-Management Strategy," *Energy Associates*, Prepared for Capital-E, December 2002.

Category of Green Buildings Insurance/Risk-Management Benefits										
			Property Loss	General Liability	Business Interruption	Vehicle (Prop or Liab)	Health & Workers Comp.	Life	Environmental Liability	Notes
Design Area 1	Sustainable Sites (14 Points possible)		1			4	3	2	3	
	Prereq 1	**Erosion & Sedimentation Control** (Required)	+						+	Reduced likelihood of property damage due to mudslides and soil subsidence.
	Credit 1	**Site Selection** (1 point)								
	Credit 2	**Urban Redevelopment** (1 point)								
	Credit 3	**Brownfield Redevelopment** (1 point)		-	-		-		-	
	Credit 4.1	**Alternative Transportation**, Public Transportation Access (1 point)				+				Reduced number of personnel using insured transportation infrastructure.
	Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms (1 point)				+				Reduced number of personnel using insured transportation infrastructure.
	Credit 4.3	**Alternative Transportation**, Alternative Fuel Refueling Stations (1 point)				+/-				Reduced number of personnel using insured transportation infrastructure. Potential new risks associated with alternate fuels and vehicles.
	Credit 4.4	**Alternative Transportation**, Parking Capacity (1 point)				+				Reduced number of personnel using insured transportation infrastructure.
	Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space (1 point)								
	Credit 5.2	**Reduced Site Disturbance**, Development Footprint (1 point)								
	Credit 6.1	**Stormwater Management**, Rate or Quantity (1 point)							+	Reduced likelihood of environmental risks associated with runoff.
	Credit 6.2	**Stormwater Management**, Treatment (1 point)							+	Reduced likelihood of environmental risks associated with runoff.
	Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof (1 point)	-				+	+		Reduced stormwater runoff due to water retention by vegetation. Reduced risk of heat-catastrophe mortality. Elevated fire risk due to added vegetation near building.
	Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof (1 point)					+	+		Reduced interior temperatures; increased roof lifetime. Reduced risk of heat-catastrophe mortality.
	Credit 8	**Light Pollution Reduction** (1 point)					+			Reduced labor for lamp replacements and maintenance (workers compensation exposure).
Design Area 2	ater Efficiency (5 Points possible)								1	
	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50% (1 point)								
	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation (1 point)								
	Credit 2	**Innovative Wastewater Technologies** (1 point)							+/-	Potential beneficial or adverse

			Property Loss	General Liability	Business Interruption	Vehicle (Prop or Liab)	Health & Workers Comp.	Life	Environmental Liability	Notes
Category of Green Buildings Insurance/Risk-Management Benefits										
										consequences of alternative technologies.
	Credit 3.1	**Water Use Reduction**, 20% Reduction (1 point)								
	Credit 3.2	**Water Use Reduction**, 30% Reduction (1 point)								
Design Area 3	**nergy & Atmosphere (17 Points ossible)**		**6**	**6**	**9**		**6**	**3**	**6**	
	Prereq 1	**Fundamental Building Systems Commissioning** (Required)	+	+	+		+			Facilitates detection of property and/or health risks associated with project that could lead to service interruptions or physical damages. Reduces liability of architects and engineers.
	Prereq 2	**Minimum Energy Performance** (Required)	+/-	+	+		+/-	+		Diverse set of benefits ranging from reduced fire risk due to multi-pane windows or non-halogen light sources, or reduced business interruption. Isolated potential adverse consequences.
	Prereq 3	**CFC Reduction in HVAC&R Equipment** (Required)							+	
	Credit 1.1	**Optimize Energy Performance**, 20% New / 10% Existing (2 points)	+/-	+	+		+/-	+	+	(See above).
	Credit 1.2	**Optimize Energy Performance**, 30% New / 20% Existing (2 points)	+/-	+	+		+/-	+	+	(See above).
	Credit 1.3	**Optimize Energy Performance**, 40% New / 30% Existing (2 points)	+/-	+	+		+/-	+	+	(See above).
	Credit 1.4	**Optimize Energy Performance**, 50% New / 40% Existing (2 points)	+/-	+	+		+/-	+	+	(See above).
	Credit 1.5	**Optimize Energy Performance**, 60% New / 50% Existing (2 points)	+/-	+	+		+/-	+	+	(See above).
	Credit 2.1	**Renewable Energy**, 5% (1 point)	-		+				+	Increased reliability for on-site generation. Possible reduced environmental liability associated with on-site fossil-fuel (e.g., diesel) systems. New insurance costs and risks associated with added on-site technologies.
	Credit 2.2	**Renewable Energy**, 10% (1 point)	-		+				+	(See above).
	Credit 2.3	**Renewable Energy**, 20% (1 point)	-		+				+	(See above).
	Credit 3	**Additional Commissioning** (1 point)	+	+	+		+			(See notes on commissioning under Prereq 1).
	Credit 4	**Ozone Depletion** (1 point)								
	Credit 5	**Measurement & Verification** (1 point)	+	+/-	+		+		+	Reduced risk of underattainment of savings (see notes on commissioning - possible adverse effects on liability of service providers, ESCOs, etc.).
	Credit 6	**Green Power** (1 point)								
Design Area 4	**aterials & Resources (13 Points ossible)**					**2**	**3**		**8**	
	Prereq 1	**Storage & Collection of Recyclables** (Required)	-						+/-	Fire risks from stored flammables. Pollution risks or benefits.
	Credit 1.1	**Building Reuse**, Maintain 75% of	-				+		+	Reduced exposure to environmental risks

Category of Green Buildings Insurance/Risk-Management Benefits										
			Property Loss	General Liability	Business Interruption	Vehicle (Prop or Liab)	Health & Workers Comp.	Life	Environmental Liability	Notes
		Existing Shell (1 point)								associated with waste handling and disposal, as well as occupational risks to construction workers (assuming reduced new construction). Buildings may not meet current codes for earthquake, etc.
	Credit 1.2	**Building Reuse**, Maintain 100% of Shell (1 point)	-				+		+	Reduced exposure to environmental risks associated with waste handling and disposal, as well as occupational risks to construction workers (assuming reduced new construction). Buildings may not meet current codes for earthquake, etc.
	Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell (1 point)	-				+		+	Reduced exposure to environmental risks associated with waste handling and disposal, as well as occupational risks to construction workers (assuming reduced new construction). Buildings may not meet current codes for earthquake, etc.
	Credit 2.1	**Construction Waste Management**, Divert 50% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 2.2	**Construction Waste Management**, Divert 75% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 3.1	**Resource Reuse**, Specify 5% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 3.2	**Resource Reuse**, Specify 10% (1 point)							+	Reduced exposure to environmental liability issues from waste disposal.
	Credit 4.1	**Recycled Content**, Specify 25% (1 point)								
	Credit 4.2	**Recycled Content**, Specify 50% (1 point)								
	Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally (1 point)				+				Reduced freight-mileage. Of benefit if state-owned vehicles used.
	Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally (1 point)				+				Reduced freight-mileage. Of benefit if state-owned vehicles used.
	Credit 6	**Rapidly Renewable Materials** (1 point)								
	Credit 7	**Certified Wood** (1 point)								
Design Area 5	**door Environmental Quality (15 oints possible)**		**6**	**11**	**10**		**17**	**2**	**13**	
	Prereq 1	**Minimum IAQ Performance** (Required)	+	+	+		+	+	+	Diverse health benefits, formerly excluded by many insurance policies but increasingly being successfully litigated. Reduced risk of moisture damage (e.g., toxic mold). Reduced risk of liability to designer/builder/operator. Can avert absenteeism, shutdowns, or forced relocation due to IAQ problems.
	Prereq 2	**Environmental Tobacco Smoke** (ETS)		+			+	+	+	(See above).

Category of Green Buildings Insurance/Risk-Management Benefits										
			Property Loss	**General Liability**	**Business Interruption**	**Vehicle (Prop or Liab)**	**Health & Workers Comp.**	**Life**	**Environmental Liability**	**Notes**
		Control (Required)								
	Credit 1	**Carbon Dioxide** (CO_2) **Monitoring** (1 point)		+			+		+	(See above).
	Credit 2	**Increase Ventilation Effectiveness** (1 point)	+	+			+		+	(See above).
	Credit 3.1	**Construction IAQ Management Plan**, During Construction (1 point)	+	+	+		+		+	(See above).
	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy (1 point)	+	+	+		+		+	(See above).
	Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants (1 point)		+	+		+		+	(See above).
	Credit 4.2	**Low-Emitting Materials**, Paints (1 point)		+	+		+		+	(See above).
	Credit 4.3	**Low-Emitting Materials**, Carpet (1 point)		+	+		+		+	(See above).
	Credit 4.4	**Low-Emitting Materials**, Composite Wood		+	+		+		+	(See above).
	Credit 5	**Indoor Chemical & Pollutant Source Control** (1 point)		+	+		+		+	(See above).
	Credit 6.1	**Controllability of Systems**, Perimeter (1 point)	+				+		+	(See above).
	Credit 6.2	**Controllability of Systems**, Non-Perimeter (1 point)	+						+	(See above).
	Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992 (1 point)					+			(See above).
	Credit 7.2	**Thermal Comfort**, Permanent Monitoring System (1 point)					+			(See above).
	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces (1 point)					+			(See above).
	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces (1 point)			+		+			(See above).
Design Area 6	**novation & Design Process (5 Poi ossible)**									
	Credit 1.1	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 1.2	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 1.3	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 1.4	**Innovation in Design**: Specific Title (1 point)								Amplifies benefits noted above.
	Credit 2	**LEED™ Accredited Professional** (1 point)								Amplifies benefits noted above.

Appendix L: Annotated Bibliography

The following is a guide to primary sources in areas for which there are no comprehensive internet resources: Water Conservation and Waste Reduction.

Water Conservation

Water Use in Buildings

Pike, Charles. *Study of Potential Water Efficiency Improvement in Commercial Business*. US EPA/DWR, April 1997.
Sweeten, Jon and Ben Chaput. *Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector*. Paper delivered to the AWWA, 1997.

These studies conclude that there is considerable opportunity for cost effective water conservation technology adoption in most commercial building types.

Sustainable Use of Water: California Success Stories. Publication of the Pacific Institute, January 1999. Available online at: http://www.pacinst.org/water.html

This document identifies, describes, and analyzes examples of sustainable water policies and practices throughout the state. Many of the 28 "stories" highlighted offer specific examples of water utilities that have adopted innovative water conservation policies. Others present an overview of a particular water conservation issue area. The most useful "story" for our purposes is Chapter 6: *An Overview of Water – Efficiency Potential in the CII Sector*. It finds that significant cost-effective water conservation potential currently exists in the CII building sector.

Externalities of Water Use and Public Policy

Renzetti, Steven. "Municipal Water Supply and Sewage Treatment: Costs, Prices, and Distortions." *Canadian Journal of Economics*, May 1999. Available online at: http://economics.ca/cje/

This empirical study in Canada estimated that the price charged for fresh water was only one-third to one-half the long-run marginal supply cost, and the prices charged for sewage were approximately one-fifth the long run cost of sewage treatment

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CUWCC. *Guidelines for Preparing Cost-Effectiveness of Urban Water Conservation Best Management Practices*. September 1996. Available online, with many other resources related to urban water conservation, at: http://www.cuwcc.org/home.html.

This document contains the Total Society Cost Model of water conservation. It is designed to capture all avoided future economic, environmental, and social costs of urban water conservation in order to determine its true avoided cost. The CUWCC is currently conducting workshops to assist water utilities in using this model.

Economic Evaluation of Water Management Alternatives. Prepared for the CALFED Bay-Delta Program, October 1999. See: http://calwater.ca.gov/Archives/WaterManagement/WaterManagementArchive.shtml.

Available online at: http://calfed.ca.gov/Programs/WaterManagement/adobe_pdf/Calfed.pdf.

This document evaluates the cost-effectiveness of different water management options that would meet the state's anticipated water needs in 2020. The perspective taken is that of the end user of water in each region where SWP or CVP water is expected to be needed in 2020. The study analyses seven scenarios, each one assuming different policy decisions leading up to year 2020.

Fiske, Gary and Associates. *California Urban Water Agencies Urban Water Conservation Potential - Final Report,* August 2001. Available online at: http://www.cuwa.org/publications.html.

This study determines marginal cost numbers for new water supplies for every region of the state for each year from 2000 – 2040, from the perspective of the regional utility. It includes wastewater facility expansion and O&M expenses in these estimates. Many water experts in the state believe that the marginal cost numbers presented in this study are too low.

Bulletin 160-98: California Water Plan. California Department of Water Resources, 1998.
Available online at: http://rubicon.water.ca.gov/b160index.html.

This document, which is updated every five years, evaluates water supplies and assesses agricultural, urban, and environmental water uses to quantify the gap between water supplies and uses. It also evaluates options for meeting the state's future water needs. The next update will be released in 2003.

The Clean Water and Drinking Water Infrastructure Gap Analysis. Published by the EPA, August 2002.
Available online at: http://www.epa.gov/safewater/gapreport.pdf.

This document evaluates our country's current water delivery and treatment systems, and the financial health of the agencies that operate them. It concludes that the expected gap between future revenues (based on historical price increases) and infrastructure needs for potable water and wastewater treatment will be approximately $148 billion over the next twenty years.

Field, Christopher. *Confronting Climate Change in California: Ecological Impacts on the Golden State.* Publication of the Union of Concerned Scientists, 1999. Available online at http://www.ucsusa.org/.

This document summarizes the likely impacts of climate change in California. It indicates that changes in precipitation patterns will have a dramatic affect on the state's ecology and economy. Specifically, more precipitation will fall as rain, rather than snow, causing massive flooding in the spring and droughts by late summer. Reduced summer runoff of fresh water would also increase summer salinity in San Francisco Bay.

Gleick, Peter. *Water: The Potential Consequences of Climate Variability and Change for the Water Resources of the United States*. Publication of the Pacific Institute, September 2000.
Available online at: http://www.pacinst.org/.

This document summarizes the results of nearly 1,000 peer-reviewed studies on climate change. Consensus conclusions are similar to those presented in the UCS study above.

Bulletin 132: Management of the California State Water Project. Publication of DWR, 1999.
Available online at: http://wwwdwr.water.ca.gov/.

This is part of a series of annual reports that describe the status of State Water Project (SWP) operations. Each annual report updates information regarding project costs and financing, water supply planning, power operations, and significant events that affect the management of the State Water Project. The publication aggregates SWP energy costs associated with pumping water throughout the state.

Preparing for California's Next Drought. Publication of DWR, July 2000.
Available online at: http://wwwdwr.water.ca.gov/.

Between 1987-1992, California experienced its longest drought in more than a century. Over 85% of the counties in the state declared local emergencies. This document presents the lessons learned from this experience and offers policy recommendations to better prepare for future drought years.

Notably, the document states the following:
Article X, Section 2 of the California Constitution prohibits waste or unreasonable use or unreasonable method of use of water. ... Water Code Section 275 directs the Department [of Water Resources] and the SWRCB to take appropriate actions before courts, administrative agencies, and legislative bodies to prevent waste or misuse of water.

Multi-Agency Benchmarking Project. Published by the King County Department of Natural Resources, publication 1282, September 1999.

This document presents the findings from a collaborative effort among seven large West Coast wastewater utilities to collect, compare and analyze cost and operational data. The investigation examines all aspects of sewage treatment facility operation. For example, in 1997, the average direct operating cost among these utilities was $729 per million gallons of treated water. Operations and Maintenance (O&M) accounted for roughly half of this amount. O&M includes direct operational labor, as well as energy and chemicals. Notably, power purchases were the second largest cost factor within O&M.

Waste Reduction

Skumatz, Lisa, SERA Inc, and Jeff Morris, SRMG. *Massachusetts Recycle 2000: Baseline Report* (Excerpts). Prepared for the Executive Office of Environmental Affairs, State of Massachusetts, December 1998.

This document compares the economic and environmental costs of waste disposal and curbside recycling in Massachusetts. This is the only analysis that we have seen that attempts to quantify the "hard to quantify" environmental costs from a state's perspective. It concludes that the total benefits of recycling, net of disposal benefits, are worth $270 - $379 per ton to the state.

Goldman, George and Aya Ogishi. *The Economic Impact of Waste Disposal and Diversion in California.* Department of Agricultural and Resource Economic, UC Berkeley, April 2001.
Available online at: http://are.berkeley.edu/coopext/EconImpWaste.pdf.

This study quantifies and compares the economic impacts of disposal and diversion in six regions within the state. The results show both that on average, diversion has twice the economic impact of disposal and that the benefits of diversion vary greatly among regions in the state. In general, recycling has a greater impact in regions with well-developed recycling infrastructure and mature recycling industries.

California Recycling Economic Information Study (REI), prepared for CIWMB by the National Recycling Coalition in association with R.W. Beck, Inc, July 2001.
Available online at: http://www.ciwmb.ca.gov/agendas/mtgdocs/2002/01/00007124.pdf.

This study uses a broader definition of diversion than the UCB study to quantify the size and makeup of the diversion industry in California and its economic impacts. It also compares diversion to other sectors of the economy and shows how the economic impacts from diversion in California fit within the nationwide economy. It reaches similar conclusions about the economic impact of diversion as the UCB study.

Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste, Final Report. Prepared by the US EPA, September 1998.

This document summarizes and assesses air emission data from different forms of waste management including incineration, landfilling and recycling.

Disposal Cost Fee Study, Final Report. Prepared by the Tellus Institute for the California Integrated Waste Management Board, February 1991.

Before the UCB and REI studies were released, this study provided the most comprehensive data on California's waste disposal system. It categorizes and analyzes the types of waste found in California's waste stream, and identifies environmental threats associated with waste diversion and disposal of various products/types of waste.

Construction Waste Management Section of the California Sustainable Design Training Manual, 2001.

This document provides an overview of waste management and all of the relevant green issues associated with it. It also provides an extensive list of internet sites with additional resources on the topic.

Glossary of Acronyms

A number of acronyms are referred to or used in this report. They are spelled out below, and when they first appear in the text.

ACEEE – American Council for an Energy Efficient Economy
ADL – Arthur D. Little Consultants
af – acre-foot (of water)
ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ARB – Air Resources Board (CA)
ASTM – American Society for Testing and Materials
BEPAC – Building Environmental Performance Criteria (Canada)
BEES – Building for Environmental and Economic Sustainability
BIDS – Building Investment Decision Support
BOMA – Building Owners & Managers Association
BREEAM – British Research Establishment Environment Assessment Method
C&D – construction & demolition
CalTrans – Department of Transportation (CA)
CBA – cost benefit analysis
CEC – California Energy Commission
CIWMB – California Integrated Waste Management Board
CO2 – carbon dioxide
CUWA – California Urban Water Agencies
CUWCC – California Urban Water Conservation Council
DGS – Department of General Services (CA)
DOE – Department of Energy (US)
DOF – Department of Finance (CA)
DSA – Division of the State Architect (CA)
DWR – Department of Water Resources (CA)
EIA – Energy Information Administration (US)
EPA – Environmental Protection Agency
FEMP – Federal Energy Management Program
GHG – greenhouse gases
GW(h) – gigawatt (hour) = 1 billion watts
HVAC – heating, ventilation and air conditioning
IAQ – indoor air quality
IEQ – indoor environmental quality
IFMA – International Facilities Management Association
IPCC – Intergovernmental Panel on Climate Change
IPMVP – International Performance Measurement & Verification Protocol
IRR – internal rate of return
ISO – International Organization for Standardization
kW(h) – kilowatt (hour) = 1000 watts
LADWP – Los Angeles Department of Water and Power
LBNL – Lawrence Berkeley National Labs
LCA – life cycle assessment
LEED – Leadership in Energy & Environmental Design (USGBC)
MW(h) – megawatt (hour) = 1 million watts
MWD – Metropolitan Water District
NIST – National Institute of Standards and Technology
NOx – oxides of nitrogen
NPV – net present value
NREL – National Renewable Energy Labs
O&M – operations & maintenance
PG&E – Pacific Gas & Electric Company
PIER – Public Interest Energy Research (CA)
PM10 – particulate matter
PUC – Public Utilities Commission
PV – solar photovoltaics
PV – present value
SBTF – Sustainable Building Task Force (CA)
SCE – Southern California Edison
SDG&E – San Diego Gas & Electric Co.
SMUD – Sacramento Municipal Utility District
SOx – oxides of sulfur
T&D – transmission & distribution
USGBC – US Green Building Council
VOC – volatile organic compound

King County Department of Development and Environmental Services
SEPA GHG Emissions Worksheet
Version 1.7 12/26/07

Introduction

The Washington State Environmental Policy Act (SEPA) requires environmental review of development proposals that may have a significant adverse impact on the environment. If a proposed development is subject to SEPA, the project proponent is required to complete the SEPA Checklist. The Checklist includes questions relating to the development's air emissions. The emissions that have traditionally been considered cover smoke, dust, and industrial and automobile emissions. With our understanding of the climate change impacts of GHG emissions, King County requires the applicant to also estimate these emissions.

Emissions created by Development

GHG emissions associated with development come from multiple sources:

- The extraction, processing, transportation, construction and disposal of materials and landscape disturbance (Embodied Emissions)
- Energy demands created by the development after it is completed (Energy Emissions)
- Transportation demands created by the development after it is completed (Transportation Emissions)

GHG Emissions Worksheet

King County has developed a GHG Emissions Worksheet that can assist applicants in answering the SEPA Checklist question relating to GHG emissions.

The SEPA GHG Emissions worksheet estimates all GHG emissions that will be created over the life span of a project. This includes emissions associated with obtaining construction materials, fuel used during construction, energy consumed during a buildings operation, and transportation by building occupants.

Using the Worksheet

1. Descriptions of the different residential and commercial building types can be found on the second tabbed worksheet ("Definition of Building Types"). If a development proposal consists of multiple projects, e.g. both single family and multi-family residential structures or a commercial development that consists of more than on type of commercial activity, the appropriate information should be estimated for each type of building or activity.

HOMEWOOD MOUNTAIN RESORT

WATER SUPPLY ASSESSMENT

Prepared For:

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HOMEWOOD
Mountain Resort

Draft Final
September 2010

Table 3. Projected Annual Demand for the McKinney/Quail Sub-district

	Annual Demand (AF/Y)		
Service Area	**2009**	**2010**	**2011**
McKinney/Quail Sub-district	381	385	385
Proposed Project (residential)	n/a	n/a	46
Proposed Project (commercial)	n/a	n/a	5
Proposed Project (irrigation)	n/a	n/a	11
Proposed Project Subtotal	n/a	n/a	62
Total Annual Demand (AF/Y)			**447**

Based on the information presented in Table 3, the proposed project will require 62 AF/Y. When added to the future projected annual demand for the McKinney/Quail Sub-district (385 AF/Y), the total projected annual water demand for the McKinney/Quail Sub-district, including the proposed project and associated irrigation operations, is 447 AF/Y.

<u>Alternative 2</u>

North Base - MCWC Service Area.

Based on the annual water demand in this region calculated by TCPUD in their Water Master (0.84 AF/Y)(TCPUD 2002), the projected water demand for the MCWC Service Area is 134 AF/Y. The projected values for the proposed project, shown in Table 4, were calculated using the demand rates described above (Residential – 0.14 AF/Y per unit and Commercial – 0.07 AF/Y per 1,000 sf CFA). In addition to residential and commercial water demand for the proposed project, water will be used for irrigation operations. Based on schematic design (as discussed in Section 2.2), 8.3 AF/Y of water will be required for irrigation. This value is included in the projected water demand shown in Table 4.

Table 4. Projected Annual Demand for MCWC Service Area

	Annual Demand (AF/Y)		
Service Area	**2009**	**2010**	**2011**
MCWC	134	134	134
Proposed Project - North Base (residential)	n/a	n/a	30
Proposed Project - North Base (commercial)	n/a	n/a	4
Proposed Project - North Base (irrigation)	n/a	n/a	8
Proposed Project - North Base Subtotal	n/a	n/a	42
Total Annual Demand (AF/Y)			**176**

Based on information presented in Table 4, the proposed project (North Base Area) will require 42 AF/Y. When added to the future projected annual demand for the MCWC Service Area (134 AF/Y), the total projected annual water demand for the MCWC Service Area is 176 AF/Y.

National Oceanic and Atmospheric Administration

Greenhouse Gases

Frequently Asked Questions

Introduction

What are greenhouse gases?

Many chemical compounds present in Earth's atmosphere behave as 'greenhouse gases'. These are gases which allow direct sunlight (relative shortwave energy) to reach the Earth's surface unimpeded. As the shortwave energy (that in the visible and ultraviolet portion of the spectra) heats the surface, longer-wave (infrared) energy (heat) is reradiated to the atmosphere. Greenhouse gases absorb this energy, thereby allowing less heat to escape back to space, and 'trapping' it in the lower atmosphere. Many greenhouse gases occur naturally in the atmosphere, such as carbon dioxide, methane, water vapor, and nitrous oxide, while others are synthetic. Those that are man-made include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs), as well as sulfur hexafluoride (SF_6). Atmospheric concentrations of both the natural and man-made gases have been rising over the last few centuries due to the industrial revolution. As the global population has increased and our reliance on fossil fuels (such as coal, oil and natural gas) has been firmly solidified, so emissions of these gases have risen. While gases such as carbon dioxide occur naturally in the atmosphere, through our interference with the carbon cycle (through burning forest lands, or mining and burning occurs in the NH spring and summer as plants convert CO_2 to plant material through photosynthesis. It is then released again in the fall and winter as the plants decompose.

Methane

Methane is an extrememly effective absorber of radiation, though its atmospheric concentration is less than CO_2 and its lifetime in the atmosphere is brief (10-12 years), compared to some other greenhouse gases (such as CO_2, N_2O, CFCs). Methane(CH_4) has both natural and anthropogenic sources. It is released as part of the biological processes in low oxygen environments, such as in swamplands or in rice production (at the roots of the plants). Over the last 50 years, human activities such as growing rice, raising cattle, using natural gas and mining coal have added to the atmospheric concentration of methane. Direct atmospheric measurement of atmospheric methane has been possible since the late 1970s and its conentration rose from 1.52 ppmv in 1978 by around 1%/year to 1990, since when there has been little sustained increase. The current atmospheric concentration is ~1.77 ppmv, and there is no scientific consensus on why methane has not risen much since around 1990.

Tropospheric Ozone

Ultraviolet radiation and oxygen interact to form ozone in the stratosphere. Existing in a broad band, commonly called the 'ozone layer', a small fraction of this ozone naturally descends to the surface of the Earth. However, during the 20th century, this tropospheric ozone has been supplemented by ozone created by human processes. The exhaust emissions from automobiles and pollution from factories (as well as burning vegetation) leads to greater concentrations of carbon and nitrogen molecules in the lower atmosphere which, when it they are acted on by sunlight, produce ozone. Consequently, ozone has higher concentrations in and around cities than in sparsely populated areas, though there is some transport of ozone downwind of major urban areas. Ozone is an important contributor to photochemical smog. Though the lifetime of ozone is short, and is therefore not well-mixed through the atmosphere, there is a general band of higher ozone concentration during NH spring and summer between 30 N and 50 N resulting from the higher urbanization and industrial activity in this band. Concentrations of ozone have risen by around 30% since the pre-industrial era, and is now considered by the IPCC to be the third most important greenhouse gas after carbon dioxide and methane. An additional complication of ozone is that it also interacts with and is modulated by concentrations of methane.

Nitrous Oxide

Concentrations of nitrous oxide also began to rise at the beginning of the industrial revolution and is understood to be produced by microbial processes in soil and water, including those reactions which occur in fertilizer containing nitrogen. Increasing use of

High Global Warming Potential (GWP) Gases

Science

Many of the links on this page are to sites outside of EPA. See EXIT Disclaimer to learn more.

High GWP Gases and Climate Change

There are three major groups or types of high GWP gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These compounds are the most potent greenhouse gases. In addition to having high global warming potentials, SF_6 and PFCs have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere once emitted (see below).

Global Warming Potential (GWP)

The concept of a global warming potential (GWP) was developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. The definition of a GWP for a particular greenhouse gas is the ratio of heat trapped by one unit mass of the greenhouse gas to that of one unit mass of CO_2 over a specified time period.

As part of its scientific assessments of climate change, the Intergovernmental Panel of Climate Change (IPCC) has published reference values for GWPs of several greenhouse gases. While the most current estimates for GWPs are listed in the IPCC's Fourth Assessment Report (AR4), EPA analyses use the 100-year GWPs listed in the IPCC's Second Assessment Report (SAR) to be consistent with the international standards under the United Nations Framework Convention on Climate Change (UNFCCC) (IPCC, 1996). (See the following table titled 2.14 (Errata) (PDF) (5 pp, 360K, About PDF) for a listing of GWPs and atmospheric lifetimes of methane and the other major species of greenhouse gases for comparison. The table is taken from Climate Change 2007: A Physical Science Basis: The Working Group I Contribution to the IPCC Fourth Assessment Report as the SAR is not available on-line.)

High GWP gases are emitted from a broad range of industrial sources and for more of these gases there are few (if any) natural sources of emissions.

The following sections describe some fundamental characteristics of high GWP gases and their presence in the atmosphere:

- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur Hexafluoride (SF_6)

Hydrofluorocarbons (HFCs)

HFCs are man-made chemicals, many of which have been developed as alternatives to ozone-depleting substances (ODS) for industrial, commercial, and consumer products. The global warming potentials of HFCs range from 140 (HFC-152a) to 11,700 (HFC-23). The atmospheric lifetime for HFCs varies from just over a year for HFC-152a to 260 years for HFC-23. Most of the commercially used HFCs have atmospheric lifetimes less than 15 years; e.g., HFC-134a, which is used in automobile air conditioning and refrigeration, has an atmospheric life of 14 years.

The HFCs with the largest measured atmospheric abundances are (in order), HFC-23 (CHF_3), HFC-134a (CF_3CH_2F), and HFC-152a (CH_3CHF_2). The only significant emissions of HFCs before 1990 were of the chemical HFC-23, which is generated as a byproduct of the production of HCFC-22. HFCs are primarily used as a substitute for ozone-depleting chemicals. Between 1978 and 1995, HFC-23 concentrations have increased from 3 to 10 parts per trillion (ppt), and continue to rise. Since 1990, when it was almost undetectable, global average concentrations of HFC-134a have risen significantly to almost 10 ppt (parts per trillion). HFC-134a has an atmospheric lifetime of about 14 years and its abundance is expected to continue to rise in line with its increasing use as a refrigerant around the world. HFC-152a has increased steadily to about 0.3 ppt in 2000, however its relatively short life time (1.4 years) has kept its atmospheric concentration below 1 ppt (IPCC, 2001).

Perfluorocarbons (PFCs)

Primary aluminum production and semiconductor manufacture are the largest known man-made sources of two perfluorocarbons – CF_4 (tetrafluoromethane) and C_2F_6 (hexafluoroethane). The GWP of CF_4 and C_2F_6 emissions is equivalent to approximately 6,500 and 9,200 tonnes, respectively. PFCs are also relatively minor substitutes for ozone-depleting substances (ODSs).

PFCs have extremely stable molecular structures and are largely immune to the chemical processes in the lower atmosphere that break down most atmospheric pollutants. Not until the PFCs reach the mesosphere, about 60 kilometers above Earth, do very high-energy ultraviolet rays from the sun destroy them. This removal mechanism is extremely slow and as a result PFCs accumulate in the atmosphere and remain there for several thousand years. The estimated atmospheric lifetimes for CF_4 and C_2F_6 are 50,000 and 10,000 years respectively. Measurements in 2000 estimate CF_4 global concentrations in the stratosphere at over 70 parts per trillion (ppt). Recent relative rates of increase in concentrations for two of the most important PFCs are 1.3% per year for CF_4 and 3.2% per year for C_2F_6 (IPCC, 2001).

Sulfur Hexafluoride (SF_6)

The global warming potential of SF_6 is 23,900, making it the most potent greenhouse gas the IPCC has evaluated. SF_6 is a colorless, odorless, nontoxic, nonflammable gas with excellent dielectric properties. SF_6 is used for insulation and current interruption in electric power transmission and distribution equipment, in the magnesium industry to protext molten magnesium from oxidation and potentially violent burning, in semiconductor manufacturing to create circuitry patterns on silicon wafers, and as a tracer gas for leak detection.

Like the other high GWP gases, there are very few sinks for SF_6, so all man-made sources contribute directly to its accumulation in the atmosphere. Measurements of SF_6 show that its global average concentration has increased by about 7% per year during the 1980s and 1990s, from less 1 ppt in 1980 to almost 4 ppt in the late 1990′s (IPCC, 2001).

Print As-Is

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

FINAL DRAFT STAFF REPORT

ADDRESSING GREENHOUSE GAS EMISSIONS IMPACTS UNDER THE CALIFORNIA ENVIRONMENTAL QUALITY ACT

SEPTEMBER 17, 2009

TABLE OF CONTENTS

CONTRIBUTORS

Staff of the San Joaquin Valley Unified Air Pollution Control District (SJVAPCD) contributed to various aspects of developing this document. Names of contributing staff are listed alphabetically.

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EXECUTIVE SUMMARY

Global Climate Change (GCC), which is now generally accepted by the scientific community to be occurring and caused by Greenhouse Gases (GHGs), is a widely discussed scientific, economic, and political issue in the United States. Briefly stated, GCC is the cumulative change in the average weather of the earth that may be measured by changes in temperature, precipitation, storms, and wind. GHGs are gases that trap heat in the atmosphere. The scientific and policy communities in the State of California have collectively concluded that a significant and growing scientific body of evidence supports the need for regulating GHG emissions. Worldwide, California is estimated to be the 15^{th} largest emitter of carbon dioxide (CARB 2008), and this fact has added to the impetus behind California's leadership in this area.

California is exercising climate change leadership in two significant efforts: one, the passage and implementation of Assembly Bill 32 (AB32), the "California Global Warming Solutions Act of 2006", which was designed to significantly reduce existing and future GHG emissions in the State of California; and two, in the analysis of environmental impacts of new GHG emissions related to discretionary project approvals under the California Environmental Quality Act (CEQA). This latter effort has been particularly difficult to implement as no state or local agency has provided definitive guidance on how to address GHG emissions impacts under CEQA.

Recognizing the dearth of regulatory guidance, the San Joaquin Valley Air Pollution Control District's Governing Board adopted the Climate Change Action Plan (CCAP) in August 2008. The CCAP directed the District's Air Pollution Control Officer to develop guidance to assist District staff, valley businesses, land–use agencies, and other permitting agencies in addressing GHG emissions as part of the CEQA process. The CCAP also directs District staff to investigate and develop a greenhouse gas banking program, enhance the existing emissions inventory process to include greenhouse gas emissions reporting consistent with new state requirements, and administer voluntary greenhouse gas emission reduction agreements. These items would then be brought before the Governing

Board for their consideration. Regarding CEQA GHG guidance, the goals of the CCAP are to establish District processes for assessing the significance of project specific GHG impacts for projects permitted by the District; assist local land use agencies, developers, and the public by identifying and quantifying GHG emission reduction measures for development projects and by providing tools to streamline evaluation of project specific GHG effects; ensure that collateral emissions from GHG emission reduction projects do not adversely impact public health or environmental justice communities in the Valley; and assist Valley businesses in complying with state law related to GHG emission reduction.

CEQA requires lead agencies to establish specific procedures for administering its responsibilities under CEQA, including orderly evaluation of projects and preparation of environmental documents. Therefore, the District is developing guidance for its own internal use when serving as the lead agency, and is also proposing guidance to assist other agencies in establishing their own processes for determining significance of project related impacts on global climate change. Nothing in this guidance shall be construed as limiting a lead agency's authority to adopt a statement of overriding consideration for projects with significant GHG impact.

This staff report provides a summary of background information on Global Climate Change, the current regulatory environment surrounding GHG emissions, and the various concepts in addressing the potential impacts of Global Climate Change. It evaluates different approaches for estimating impacts, and summarizes potential mitigation measures. As presented in this Staff Report, District staff concludes that existing science is inadequate to support quantification of impacts that project specific GHG emissions have on global climatic change. This is readily understood when one considers that global climatic change is the result of the sum total of GHG emissions, both man made and natural that occurred in the past; that is occurring now; and will occur in the future. The effects of project specific GHG emissions are cumulative, and without mitigation, their incremental contribution to global climatic change could be considered significant. District staff concludes that this cumulative impact is best addressed by requiring all projects subject to CEQA to reduce their GHG emissions through project design elements.

District staff has proposed an approach intended to streamline the process of determining if project specific GHG emissions would have a significant effect. The proposed approach relies on the use of performance based standards and their associated pre-quantified GHG emission reduction effectiveness (Best Performance Standards). Establishing Best Performance Standards (BPS) would help project proponents, lead agencies, and the public by proactively identifying effective, feasible mitigation measures. Emission reductions achieved through implementation of BPS would be pre-quantified thus, negating the need for project specific quantification of GHG emissions.

As defined, BPS is the most effective, achieved-in-practice, means of reducing or limiting GHG emissions from a GHG emissions source. For traditional stationary source projects, BPS includes equipment type, equipment design, and operational and maintenance practices for the identified service, operation, or emissions unit class and category. For development projects, BPS includes project design elements, land use decisions, and technologies that reduce GHG emissions.

BPS would be established through a process approved by the District's Governing Board. The proposed process would provide ample opportunity for stakeholders and other interested parties to participate and provide valuable input into the establishment of baseline GHG emissions and BPS.

Once BPS has been established, projects implementing Best Performance Standards would be determined to have a less than significant individual and cumulative impact on global climate change and would not require project specific quantification of GHG emissions. Projects exempt from the requirements of CEQA, and projects complying with an approved GHG emission reduction plan or mitigation program would also be determined to have a less than significant individual and cumulative impact. Such plans or programs must be specified in law or adopted by the public agency with jurisdiction over the affected resources and have a certified Final CEQA document.

Projects not implementing BPS would require quantification of project specific GHG emissions. To be determined to have a less than significant individual and cumulative impact on global climate changes, such projects must be determined to have reduced or mitigated GHG emissions by 29%, consistent with GHG emission reduction targets established in ARB's AB 32 Scoping Plan[1]. Furthermore, quantification of GHG emissions would be required for all projects for which the lead agency has determined that an Environmental Impact Report is required, whether or not the project incorporates Best Performance Standards.

In evaluating GHG emissions from a specific project the District recommends that a lead agency characterize both direct and indirect GHG emissions. Direct GHG emissions would include emissions resulting from a specific operation or process, e.g. fuel combustion emissions from a boiler. Indirect GHG emissions would include emissions resulting from project related energy consumption, e.g. electricity consumed by the production and electricity required to produce and transport water used by the project. For projects resulting in increased vehicle miles traveled (VMT), indirect GHG emissions associated with transportation related activities would also be included in the GHG emissions quantification.

The proposed methodology the District will use when establishing BPS and assessing GHG significance requires approval by the District Governing Board. However, approval of this methodology would not constitute adoption of a rule or regulation. Other agencies may choose to use this proposed process as guidance when establishing their own procedures for assessing the significance of project specific impacts on global climate change.

[1] *Climate Change Proposed Scoping Plan;* P. 12 and 21. California Air Resources Board, October 2008

CHAPTER 1

CLIMATE CHANGE ACTION PLAN (CCAP) INTRODUCTION

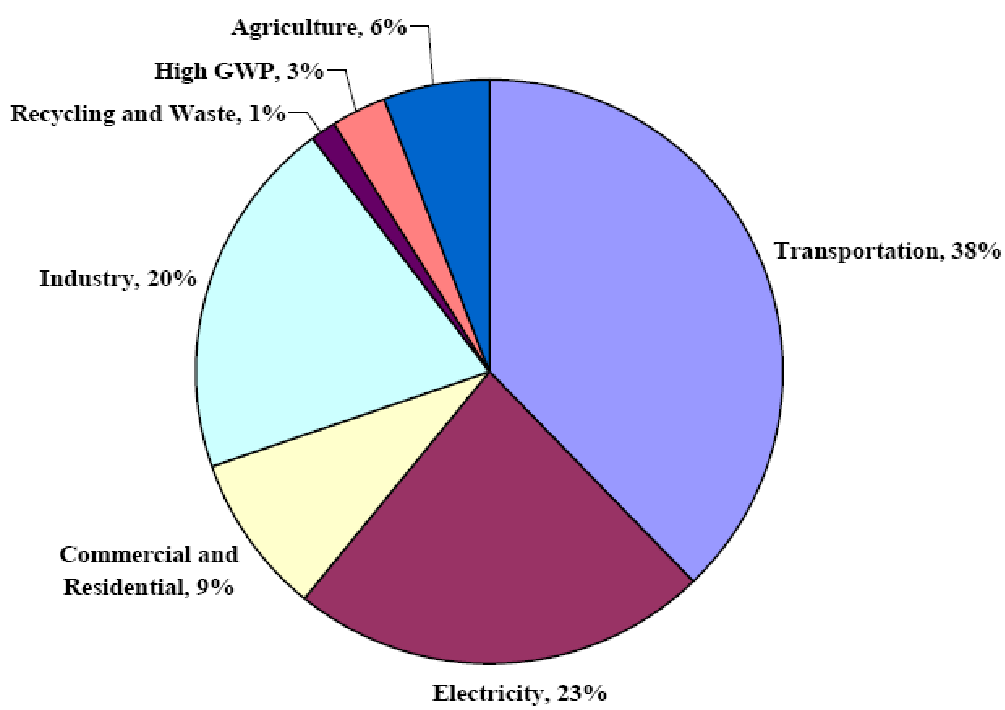
1.1 General Climate Change Issues and Background

The scientific and political communities in the State of California have collectively concluded that a significant and growing scientific body of evidence supports the need for regulating GHG emissions. Compilations of data and analyses, such as the 2007 report from the Intergovernmental Panel on Climate Change (IPCC), have provided a generally accepted scientific basis for implementing climate change policy.

In the last few years information and data have been compiled that demonstrate increases in average global air and ocean temperatures are occurring (AEP 2007). According to the IPCC Report, global temperatures are expected to rise approximately 0.2 degree Celsius per decade for the next couple of decades under a variety of scenarios (IPPC 2007). Further, global temperatures are expected to continue to increase for centuries as a result of human activities due to the time scales associated with climate processes and feedbacks, even if GHG concentrations are stabilized. As a result, based on the current understanding of climate-carbon feedback, model studies show that substantial GHG emission reductions are necessary to avoid substantial increases in global air and ocean temperatures.

As a result of human activities, such as electricity production, vehicle use, etc., GHGs have been accumulating in the earth's atmosphere at a faster rate than has occurred historically, i.e., prior to the Industrial Age starting approximately 150 years ago (AEP 2007). Figure 1 shows that the largest source of GHG in California is transportation, contributing 38 percent of the State's total GHG emissions for the 2002-2004 average emissions, expressed in million metric tons Carbon Dioxide Equivalent ($MMTCO_2E$), up from 35% in 1990. Electricity generation and importation is the second largest source, contributing over 25 percent of the State's GHG emissions (ARB 2008). Additional information is available from the Air Resources Board (www.arb.ca.gov).

Figure 1: California's Greenhouse Gas Emissions by Sector (Gross Emissions: 469 MMT CO_2E)



Source: ARB, 2008

Some greenhouse gases such as water vapor occur naturally and are emitted to the atmosphere through natural processes as well as through human activities. The most common GHG that results from human activity is carbon dioxide, followed by methane and nitrous oxide. GHGs can include:

Water Vapor: Although not considered a pollutant, water vapor is the most important, abundant, and variable GHG. In the atmosphere, it maintains a climate necessary for life. The main source of water vapor is evaporation from the ocean (approximately 85 percent). Other sources include sublimation (change from solid to gas) from ice and snow, evaporation from other water bodies, and transpiration from plant leaves.

Ozone: Unlike other GHG, ozone is relatively short- lived and, therefore, is not global in nature. It is difficult to make an accurate determination of the contribution of ozone precursors (nitrogen oxides and volatile organic compounds) to global climate change (AEP 2007).

Aerosols: Aerosols are suspensions of particulate matter in a gas emitted into the air through burning biomass (plant material) and fossil fuels. Aerosols can warm the atmosphere by absorbing and emitting heat and can cool the atmosphere by reflecting light. Cloud formation can also be affected by aerosols. Sulfate aerosols are emitted when fuel-containing sulfur is burned. Black carbon (or soot) is emitted during bio mass burning or incomplete combustion of fossil fuels. Particulate matter regulation has been lowering aerosol concentrations in the United States; however, global concentrations are likely increasing.

Chlorofluorocarbons: Chlorofluorocarbons (CFCs) are gases formed synthetically by replacing all hydrogen atoms in CH_4 or ethane with chlorine and/or fluorine atoms. CFCs are nonflammable, nontoxic, insoluble, and chemically uncreative in the troposphere (the level of air at the earth's surface). CFCs were first synthesized in 1928 for use as cleaning solvents, refrigerants, and aerosol propellants. They destroy stratospheric ozone; therefore, their production was stopped as required by the Montreal Protocol in 1987 (AEP 2007).

Carbon dioxide: Carbon dioxide (CO_2) is an odorless, colorless gas, which has both natural and anthropogenic sources. Natural sources include the following: respiration of bacteria, plants, animals, and fungus, evaporation from oceans, volcanic outgassing, and decomposition of dead organic matter. Anthropogenic sources of carbon dioxide are from burning coal, oil, natural gas, and wood. Concentrations of CO_2 were 379 parts per million (ppm) in 2005, which is an increase of 1.4 ppm per year since 1960 (AEP 2007).

Methane: Methane (CH_4) is a flammable gas and is the main component of natural gas. When one molecule of CH_4 is burned in the presence of oxygen, one molecule of carbon dioxide and two molecules of water are released. There are no direct ill health effects from CH_4. A natural source of CH_4 is from the anaerobic decay of organic matter. Geological deposits, known as natural gas fields, also contain CH_4, which is extracted for fuel. Other sources are from cattle, fermentation of manure, and landfills.

Nitrous oxide: Nitrous oxide (N_2O), also known as laughing gas, is a colorless greenhouse gas. Higher concentrations of N_2O can cause euphoria, dizziness, and slight hallucinations. N_2O is produced by microbial processes in soil and water, including those reactions that occur in fertilizer containing nitrogen. In addition to agricultural sources, some industrial processes (nitric acid production, nylon production, fossil fuel-fired power plants, and vehicle emissions) also contribute to its atmospheric load. It is used in racecars, rocket engines, and as an aerosol spray propellant.

Fluorinated Gases: Gases that are synthetic, powerful GHG that are emitted from a variety of industrial processes.

- Hydrofluorocarbons: Hydrofluorocarbons (HFCs) are synthetic man-made chemicals that are used as a substitute for CFCs for automobile air conditioners and refrigerants.
- Perfluorocarbons: Perfluorocarbons (PFCs) have stable molecular structures and do not break down though the chemical processes in the lower atmosphere. High-energy ultraviolet rays, roughly 60 lulometers above the earth's surface are able to destroy the compounds. PFCs have long lifetimes, ranging between 10,000 and 50,000 years. Two common PFCs are tetrafluoromethane and hexafluoroethane. Concentrations of tetrafluoromethane in the atmosphere are over 70 parts per trillion (ppt) (AEP 2007). The two main sources of PFCs are primary aluminum production and semiconductor manufacture.
- Sulfur hexafluoride: Sulfur hexafluoride (SF_6) is an inorganic, colorless, odorless, nontoxic, nonflammable gas. Concentrations in the 1990s were roughly 4 ppt (AEP 2007). SF_6 is used for insulation in electric power transmission and distribution equipment, in semiconductor manufacturing, the magnesium industry, and as a tracer gas for leak detection.

Under Assembly Bill 32 (AB32) GHGs are defined as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

The global warming potential (GWP) of the various GHGs is assigned as a measure of their relative average global radiative forcing effect, the potential of a gas or aerosol to trap heat in the atmosphere. Individual GHG species have varying GWP and atmospheric lifetimes. The carbon dioxide equivalent is a consistent methodology for comparing GHG emissions since it normalizes various GHG emissions to a single metric. The reference gas for GWP is carbon dioxide with a GWP of one and GWP weighted emissions are measured in terms of CO_2 equivalents (CO_2E) (EPA 2008). For example, methane has a GWP of 21; methane has a 21 times greater global warming effect than carbon dioxide on a weight basis (EPA 2008). Several GWPs of other GHGs are shown in Table 1 below:

Table 1: Global Warming Potential of GHGs

Gas	Atmospheric Lifetime	GWP
Carbon dioxide (CO2)	50 – 200	1
Methane (CH4)	12 ± 3	21
Nitrous oxide (N2O)	120	310
HFC-23 (Hydrofluorocarbons)	264	11,700
HFC-32	5.6	650
HFC-125	32.6	2,800
HFC-134a	14.6	1,300
HFC-143a	48.3	3,800
HFC-152a	1.5	140
HFC-227ea	36.5	2,900
HFC-236fa	209	6,300
HFC-4310mee	17.1	1,300
CF4 (Perfluorocarbons)	50,000	6,500
C2F6	10,000	9,200
C4F10	2,600	7,000
C6F14	3,200	7,400
Sulfer hexafluoride (SF6)	3,200	23,900

Source: U.S. EPA (http://www.epa.gov/)

1.2 Legislation Relative to Addressing GHG Impacts

Executive Order S-3-05

In response to the increasing body of evidence that GHGs will continue to affect global climate, Governor Schwarzenegger issued executive order (EO S-3-05) in June 2005, which established several greenhouse gas emission reduction targets for California. GHG emissions are to be reduced to 2000 emission levels by 2010; to 1990 emission levels by 2020 (a 29% reduction from business as usual emissions levels projected for 2020) (CARB 2008)); and to 80% below 1990 levels by 2050.

Assembly Bill 32 (AB32)

Subsequent to the Governor's issuance of EO S-3-05, the California State Legislature adopted Assembly Bill (AB) 32 – The California Global Warming Solutions Act of 2006. AB 32 establishes a cap on statewide greenhouse gas emissions and sets forth the regulatory framework to achieve the corresponding reduction in statewide emissions levels. Specifically, AB 32 recognizes a serious threat to the "economic wellbeing, public health, natural resources, and the environment of California" that results from global warming. Consequently, AB 32 mandates a significant reduction in GHGs in order to contribute to efforts to stabilize atmospheric concentrations of GHGs. Specifically, AB 32 requires the California Air Resources Board (ARB) to do the following:

- By July 1, 2007, adopt a list of early action measures that can be implemented by regulation before January 2010.
- By January 1, 2008, adopt mandatory reporting requirements for significant sources.
- By January 1, 2008, establish a statewide GHG emission cap for 2020 based upon 1990 emissions levels.
- By January 1, 2009, adopt a plan (Scoping Plan) indicating how emission reductions will be achieved for significant GHG sources via regulations, market mechanisms, or other measures, to reach the 2020 emissions goal.
- By January 1, 2011, adopt regulations to achieve the maximum technologically feasible and cost effective reductions in GHG.

In addition, ARB is to:

- Convene an Environmental Justice Advisory Committee and an Economic and Technology Advancement Advisory Committee to advise ARB.
- Ensure public notice and opportunity for comments for all actions.
- Prior to imposing any mandates or authorizing market mechanisms, to evaluate several factors, including but not limited to: impacts on California's economy, the environment, and public health; equity between regulated entities; electricity reliability, conformance with other environmental laws, and to ensure that the rules do not disproportionately impact low-income communities.

For further information, see www.climatechange.ca.gov/ab32/index.html

Other key legislation:

- California Environmental Quality Act (CEQA): CEQA requires public agencies in California to analyze potential adverse impacts for proposed projects undertaken by a public agency, funded by a public agency, and requiring discretionary approval by a public agency. The fundamental purposes of CEQA are to inform governmental decision-makers and the public about the significant environmental effects of proposed activities, identify ways to avoid or significantly reduce environmental damage, use feasible alternatives or mitigation measures to avoid significant damage, and disclose to the public why a governmental agency approved a project if significant effects are involved (CEQA Guidelines §15002[a]). To disclose potential adverse impacts from a proposed project, pursuant to CEQA lead agencies typically prepare multidisciplinary environmental impact analysis and make decisions based on the analysis regarding the environmental effects of the proposed project (CEQA Guidelines §15002[a]). The guidelines are available at: http://ceres.ca.gov/ceqa/guidelines/

- Senate Bill (SB) 97 – CEQA: Greenhouse Gas Emissions: In August 2007, Governor Schwarzenegger signed into law Senate Bill (SB) 97 – CEQA: Greenhouse Gas Emissions. SB 97 requires the Office of Planning and Research, by July 1, 2009, to prepare, develop, and transmit to the Resources Agency guidelines for the feasible mitigation of greenhouse gas emissions or the effects of greenhouse gas emissions, as required by CEQA, including, but not limited to, effects associated with transportation or energy consumption. The Resources Agency would be required to certify and adopt those guidelines by January 1, 2010. The Office of Planning and Research would be required to periodically update the guidelines to incorporate new information or criteria established by ARB pursuant to the California Global Warming Solutions Act of 2006. SB 97 also identifies a limited number of types of projects that would be exempt under CEQA from analyzing GHG emissions. Finally, the legislation will be repealed on January 1, 2010. For further information, see http://opr.ca.gov/index.php?a=ceqa/index.html

- Office of Planning and Research (OPR) Technical Advisory: Consistent with SB 97, on June 19, 2008, OPR released its *Technical Advisory on CEQA and Climate Change*, which was developed in cooperation with the Resources Agency, the California Environmental Protection Agency (Cal/EPA), and the ARB. The *Technical Advisory* offers the informal interim guidance regarding the steps lead agencies should take to address climate change in their CEQA documents, until CEQA guidelines are developed pursuant to SB 97 on how state and local agencies should analyze, and when necessary, mitigate greenhouse gas emissions (OPR).

  According to OPR, lead agencies should determine whether greenhouse gases may be generated by a proposed project, and if so, quantify or estimate the GHG emissions by type and source. Second, the lead agency must assess whether those emissions are individually or cumulatively significant. When assessing whether a project's effects on climate change are "cumulatively significant" even though project specific GHG contribution may be individually limited, the lead agency must consider the impact of the project when viewed in connection with the effects of past, current, and probable future projects. Finally, if the lead agency determines that the GHG emissions from the project as proposed are potentially significant, it must investigate and implement ways to avoid, reduce, or otherwise mitigate the impacts of those emissions.

On April 13, 2009, the Governor's Office of Planning and Research sent proposed amendments of the CEQA Guidelines to the Secretary of the Resources Agency for promulgation. The proposed amendments contain Model Policies for GHGs in General Plan. OPR recommended changes to fourteen sections of the existing guidelines, including: the determination of significance as well as thresholds; statements of overriding consideration; mitigation; cumulative impacts; and specific streamlining approaches. The proposed Guidelines also include an explicit requirement that environmental impact reports (EIRs) analyze GHG emissions resulting from a project when the incremental contribution of those emissions may be significant. A copy of the full proposal, as well as the letter of transmittal, may be found at: www.opr.ca.gov.

- SB 375 (Steinberg) Transportation, Land Use, and the California Environmental Quality Act (CEQA): On September 30, 2008, Governor Schwarzenegger signed into law SB 375 (Steinberg). SB 375 focuses on housing and transportation planning decisions to reduce fossil fuel consumption and conserve farmlands and habitat. This legislation is important to achieving AB 32 goals because greenhouse gas emissions associated with land use, which includes transportation, are the single largest sector of emissions in California. Further, SB 375 provides a path for better planning by providing incentives to locate housing developments closer to where people work and go to school, allowing them to reduce vehicle miles traveled every year. Finally, SB 375 provides certain exemptions under CEQA law for projects that are proposed consistent with local plans developed under SB 375. The bill is available here: http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080930_chaptered.html

1.3 California Environmental Quality Act (CEQA)

The California Legislature enacted CEQA in 1970. CEQA is intended to address a broad range of environmental issues, including water quality, noise, land use, natural resources, transportation, energy, human health, biological species, and air quality. CEQA requires that public agencies (i.e., local, county, regional, and state government) consider and disclose the environmental effects of their decisions to the public and governmental decision makers. Furthermore, CEQA mandates that agencies implement feasible mitigation measures or alternatives that would mitigate significant adverse effects on the environment. A significant effect on the environment is defined as a substantial adverse change in the physical conditions which exist in the area affected by the proposed project. This determination of significance must be based on the substantial evidence in light of all the information before the agency.

1.4 The District's Role in the CEQA Review Process

The District has jurisdiction over most air quality matters in the San Joaquin Valley Air Basin and is tasked with implementing certain programs and regulations required by the Federal Clean Air Act and the California Clean Air Act. As parts of the effort to accomplish its mandates, the District has prepared plans to attain national and state ambient air quality standards, conducts a CEQA review program, and maintains a staff of technical personnel versed in air pollution analysis and control. In addition, CEQA Guidelines §15004(b)(2) require a lead agency to consult with *"Any other state, federal, and local agencies which have jurisdiction by law with respect to the project or which exercise authority over resources which may be affected by the project…."*

Nearly all development projects in the San Joaquin Valley Air Pollution Control District, from general plans to individual development applications, have the potential to generate pollutants that will worsen air quality or make it more difficult for national and state air quality attainment standards to be attained. Therefore, for most projects, it is necessary to evaluate air quality impacts to comply with CEQA.

As a public agency, the District takes an active part in the intergovernmental review process under CEQA. The District is available to assist governmental agencies and project proponents in understanding how to characterize project related impacts on air quality and how to mitigate those impacts. The District provides technical guidance on applicable air quality analysis methodologies, identifies applicable rules, proposes mitigation measures, and helps address any other air quality related issues.

In carrying out its duties under CEQA, performs several agency roles: the District may act as a Lead Agency, a Responsible Agency, or a "Commenting" Agency. As discussed below, the role the District serves under CEQA is dependent upon the extent of the District's discretionary approval power over the project.

Lead Agency – A Lead Agency is the public agency with the principal responsibility for carrying out or approving a project subject to CEQA. Lead Agencies are responsible for complying with CEQA by ensuring that the potential environmental impacts of projects are adequately assessed. This may include determining that a project is exempt from CEQA, or preparing a Negative Declaration, or an Environmental Impact Report (EIR) for nonexempt, potentially significant projects. Lead Agencies must also consult with and solicit comments from responsible and commenting agencies during the preparation of a Negative Declaration or EIR.

In general, the local government agency with jurisdiction over land use, such as a city or county, is the preferred Lead Agency for land development projects. The District will undertake the Lead Agency role when no other agency has broader responsibility for approving the project; the project requires a discretionary District permit; and no other agency has prepared (or is preparing) a CEQA document for the project. In addition, the District routinely serves as Lead Agency for its own projects, such as the development of rules and regulations.

Responsible Agency – A Responsible Agency is a public agency, other than the Lead Agency, that has responsibility for carrying out or approving a project. The role of a Responsible Agency is different from that of a Lead Agency. While a Lead Agency must consider all of the potential impacts of a project, a Responsible Agency may only consider those aspects that are within the agency's area of expertise or which are required to be carried out or approved by the agency. A Responsible agency complies with CEQA by considering the Negative Declaration or EIR prepared by the Lead Agency and by reaching its own conclusion on whether or how to approve the project involved.

The District is typically a Responsible Agency for projects or portions of a project that require a District permit, or that require any other approval by the District. When considering the lead agency's environmental analysis, the District will review the air quality section of the analysis and other sections relevant to assessing potential impacts on air quality, i.e. sections assessing traffic and public health impacts. At the conclusion of its review, the District may submit comments to the lead agency that identify any deficiencies in the air quality analysis and suggest approaches to correct the deficiencies. Where appropriate, the District may recommend additional feasible mitigation measures.

Commenting Agency – Under CEQA, an agency that has "jurisdiction by law" over a particular natural resource, but does not have discretionary approval over the project is a "Trustee Agency", otherwise known as a "Commenting Agency". The District serves as a Commenting Agency when reviewing projects which typically do not require air permits, e.g. residential and commercial development projects. In addition to the air quality section, the District may review and comment on other sections of the environmental document that relate to air quality impacts, e.g. traffic, health risks, etc. When serving as a Commenting Agency, the District may provide the Lead Agency comments on the adequacy of the air quality analysis; identify District rules which apply to the project, and may recommend potential mitigation measures for the Lead Agency's consideration.

Identifying significant air quality impacts and mitigation early in the development of a project will allow fundamental design changes for the benefit of air quality at the lowest possible cost. The District is available for consultation at any time during the project review process, but there are certain times when consultation is required. For example, when the District has discretionary approval authority over a project for which another public agency is serving as Lead Agency, the District is to be consulted as a Responsible Agency. When the District does not have any discretionary approval authority over a project, but the project may impact air quality, the District is to be consulted as a Commenting Agency.

1.5 CEQA and GHG Emissions

General scientific consensus and increasing public awareness regarding global warming and climatic change have placed new focus on the CEQA review process as a means to address the effects of GHG emissions from proposed projects on climatic change. Senate Bill 97, as discussed above, amends the CEQA statute to clearly establish that GHG emissions and the effects of GHG emissions are appropriate subjects for CEQA analysis. It directs the Governor's Office of Planning and Research to develop draft CEQA Guidelines "for the mitigation of greenhouse gas emissions or the effects of green house gas emissions" by July 1, 2009 and directs the Resource Agency to certify and adopt CEQA Guidelines by January 1, 2010. However, at this time there are no generally accepted thresholds of significance for determining the impact of GHG emissions from an individual project on global climatic change.

Although AB 32 gives wide responsibility to ARB to regulate GHG emissions from all sources, including non-vehicular sources, it does not preempt or excuse permitting agencies from addressing GHGs under CEQA. Under state law, it is the purview of each lead agency to determine what, if any, significance thresholds will be established to guide its review of projects under CEQA. Traditionally, the District has provided local lead agencies technical guidance for assessing a project's potential impact on air quality, including establishment of significance thresholds for criteria pollutants. The District's Climate Change Action Plan is being developed consistent with the District's traditional role of providing local lead agencies technical guidance for assessing a project's potential impact on air quality, including establishment of significance thresholds for criteria pollutants.

CHAPTER 2

CLIMATE CHANGE ACTION PLAN MISSION

2.1 Purpose of the Climate Change Action Plan

California's Global Warming Solutions Act of 2006 (AB 32) includes a large number of initiatives to reduce GHG emissions state wide. These initiatives are discussed in ARB's AB 32 Scoping Plan, which was approved for adoption by ARB in December 2008.

AB 32 and the AB 32 Scoping Plan do not yet impose direct mandates on local Air Districts. However, the draft AB 32 Scoping Plan includes mandates on land use agencies and businesses which often look to the District for technical assistance. As such, the District can play a supportive role and be a leader in facilitating compliance with AB 32 for Valley land use agencies and businesses.

The goals of the CCAP are to establish District processes for assessing the significance of project specific GHG impacts for projects permitted by the District; assist local land use agencies, developers, and the public by identifying and quantifying GHG emission reduction measures for development projects and by providing tools to streamline evaluation of project specific GHG effects; ensure that collateral emissions from GHG emission reduction projects do not adversely impact public health or environmental justice communities in the Valley; and assist Valley businesses in complying with state law related to GHG emission reduction. For other agencies, including lead agencies, the proposed process for assessing project specific significance is offered as guidance and is not to be interpreted as a mandate.

The District believes that thoughtful and well documented guidance by the District designed to help local land-use agencies to properly address climate change issues in the CEQA documents, and assistance by the District in identifying and implementing GHG mitigation measures, can be beneficial by bringing structure and relative certainty to the CEQA process.

The District can also assist Valley businesses in complying with AB 32 requirements in other ways. The District's long-standing relationship with Valley businesses has yielded a comprehensive regulatory infrastructure that we hope to use to facilitate efficient and streamlined compliance with many of the upcoming AB 32 requirements.

2.2 District Governing Board CCAP Mandates

In August 2008 the District's Governing Board adopted the Climate Change Action Plan (CCAP). The CCAP authorized the Air Pollution Control officer (APCO) to develop guidance documents to assist land use agencies and other permitting agencies in addressing GHG emissions as part of the CEQA process, investigate the development of a greenhouse gas banking program, enhance the existing emissions inventory process to include greenhouse gas emissions reporting consistent with new state requirements, and administer voluntary greenhouse gas emission reduction agreements. Except for the latter two, which can be implemented immediately, the APCO's recommendations for accomplishing these initiatives would then be brought before the Governing Board for their additional consideration.

The balance of this staff report focuses solely on various issues concerning the development of District guidance for addressing project related greenhouse emissions during the CEQA process. This paper does not address the other items called for in the CCAP.

2.2.1 Greenhouse Gas Guidance for CEQA

CEQA requires lead agencies to identify potentially significant effects on the environment of projects they intend to carry out or approve and to mitigate significant effects whenever it is feasible to do so.

For projects with GHG emissions, determining if the GHG emissions are significant involves three steps:

- Identify and quantify GHG emissions.
- Assess the significance of the GHG emissions on the environment.

- If the GHG emissions are found to be significant, identify alternatives and/or mitigation measures that will reduce the impact of the GHG emissions below significance.

The CCAP authorizes the APCO to develop guidance and procedures for assessing the significance of project-related GHG emissions. By establishing a GHG significance level, or developing some alternative method to address GHG impacts, the uncertainty of characterizing the impacts on GCC during the CEQA process will be reduced for both lead agencies and project proponents. Also, for projects that are determined to have significant GHG emissions, or otherwise require GHG mitigation to reduce or offset the GHG emissions, sources of potential and approvable GHG mitigation must be clearly identified.

2.2.2 Carbon Exchange Program

The CCAP authorized the APCO to develop regulations and procedures for a greenhouse gas emission reduction banking system. This voluntary banking system, the San Joaquin Valley Carbon Exchange (SJVCE), would provide a mechanism for the voluntary banking of GHG emission in the San Joaquin Valley.

The outcome of stakeholder meetings will be considered when determining if the SJVCE should be developed. At the conclusion of such meetings, the District may determine that a rule to establish a SJVCE should be developed or that a SJVCE is not warranted.

A District administered GHG banking system may be beneficial to stakeholders in the District for the following reasons:

- Banked GHG emission reductions could be used to provide mitigation for CEQA,
  - GHG emission reductions could possibly be used for compliance with AB32,
  - Promote the early reductions of GHGs and their associated criteria and toxic pollutants in the District (especially in environmental justice areas),
  - Provide a mechanism for the trading of GHG emission reductions,
  - Provide a measure of certainty of banked GHG emission reductions due to the District's extensive experience in banking criteria pollutant emissions, and
  - Provide a mechanism for persons to purchase and retire banked GHG emission reductions for societal benefit.

The goals would be to provide a mechanism to preserve high quality greenhouse gas (GHG) emission reductions and encourage such reductions that have no or minimal collateral criteria or toxic pollutant emission increases, or in fact that create co-beneficial reductions in such emissions.

A SJVCE technical workgroup consisting of District staff, land use agency representatives, industry representatives, agricultural representatives, environmental group representatives, and other interested parties was formed to study the feasibility and need for the SJVCE. This group met three times in late 2008 and early 2009. In parallel to this effort, this workgroup developed a "Report to the APCO Regarding Development of the San Joaquin Valley Carbon Exchange". Currently, the development of a GHG emission reduction registry is being addressed via amendments to Rule 2301 *Emission Reduction Credit Banking*. The latest version of the report and related information to the progress of Rule 2301 are available at http://www.valleyair.org/Programs/CCAP/CCAP_idx.htm.

2.2.3 Voluntary Greenhouse Gas Mitigation Agreements

The CCAP authorizes the APCO to develop guidance and procedures for implementing a program by which project proponents can voluntarily enter into contractual arrangements with the District to fund projects, mitigating their projects cumulative impact on GCC. CEQA Guidelines clearly recognize the use of fee payments as mitigation for a project's otherwise cumulatively significant impacts. A project's contribution is less than cumulatively significant if the project is required to implement or fund its fair share of a mitigation measure or measures designed to alleviate the cumulative impact (CEQA Guidelines § 15130, subd. (a)(3)).

The District has considerable experience with the use of voluntary emission reduction agreements to mitigate impacts of criteria pollutants. In the past, the District has used its grant program (Emissions Reduction Incentive Program), to successfully mitigate impacts of criteria pollutants resulting from growth and development projects occurring within the San Joaquin Valley. To date, the program has resulted in permanent emission reductions totaling 1,074.57 tons NOx, 42.51 tons PM and 125.76 tons of VOC. The District's current mitigation program could readily be expanded to include mitigation of GHG emissions.

Conceptually, project proponents required to mitigate their GHG emissions as part of the CEQA process would enter into voluntary mitigation agreements with the District. Each mitigation agreement would be subject to Governing Board approval. Under such a voluntary agreement, the project proponent would provide funding to the District in amounts necessary to obtain the needed reduction in GHG emissions. The District would accept funds from project proponents and through its grant program fund projects that would achieve the required GHG emission reductions.

The cost of bringing about GHG emission reductions can vary widely. In determining which projects to fund, priority would likely be given to those projects that are the most cost effective. Project's that also result in reductions of criteria and toxic air pollutants, and are located in environmental justice areas would be given priority in the funding process. Funds from individual mitigation agreements could be pooled together to provide sufficient funding for large GHG emission reduction projects. When the emission reduction projects are implemented by the grant recipients, the emissions reductions monitored, verified, and enforced by the District, thus guaranteeing that the mitigation does indeed occur.

Separately, the California Attorney General (AG) has required some projects to mitigate their GHG emissions through the payment of mitigation funds. In fact, for several projects in the District, the District may enter into memorandums of understanding (MOUs) with the AG to accept these funds and obtain GHG emission reductions on behalf of the project proponent.

District staff is currently preparing an analysis of potential GHG reduction projects that might be funded through grants administered by the District. This analysis will include individual project-types, their potential for generating GHG reductions, the cost effectiveness of the reductions, and an assessment of various criteria for considering collateral criteria emission reduction benefits (i.e., how to recognize the benefits of projects that reduce both GHG and criteria pollutants).

2.3 Proposed Timeline and Method to Achieve the CCAP Goals

The District held its first CCAP scoping meeting on November 18, 2008. During this meeting, the District presented the objectives of the proposed CCAP and solicited volunteers to participate in the GHG CEQA Guidance technical workgroup. To receive the broadest input possible, the District sought participation from industry representatives, local Land Use Agency members, other Public Agency members, environmental group representatives and any other interested party.

Three ad hoc committees were formed to evaluate the project scope and quantify GHG emissions resulting from one industrial and one non-industrial project, and to provide guidance/recommendation to be applied when determining the significance and mitigation of project specific GHG emissions during the CEQA environmental review process. Numerous discussions were coordinated on these key issues over 16 conference calls and meetings that were held between December 2008 and March 2009.

District staff conducted a public workshop on May 5 and June 30, 2009 to present, discuss, and receive comments on District's draft guidance for addressing GHG under CEQA. The public hearing is tentatively scheduled to take place in the last quarter of 2009. This staff report for the proposed CCAP containing District's recommendation to the APCO will be revised, published and mailed to affected sources and interested parties prior to a public hearing to consider the adoption of proposed guidance by the District Governing Board.

CHAPTER 3

CURRENT STATUS: ADDRESSING PROJECT GHG IMPACTS

3.1 Introduction

Public agencies, including the California Air Resources Board, and other air districts, are striving to determine the appropriate means by which to evaluate the impact of GHG emissions at the project level. The following discussion summarizes various approaches and methodologies for addressing GHG emissions, as well as possible mitigation measures that are being considered.

The following sections summarize the activities of various agencies and groups concerning the role of GHGs in the CEQA process.

3.2 Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) has made available a large volume of information on greenhouse gases including their nature, impact, emissions inventory, and emissions trend and projections. However, none of the available information addresses or evaluates specific approaches on how to comply with the CEQA requirements, as CEQA is a California-specific law.

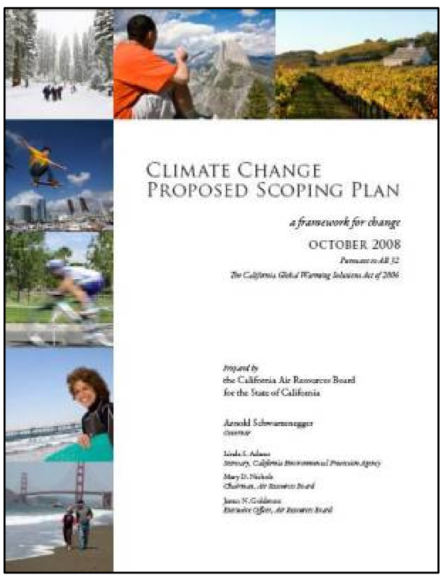
It is important to note that EPA has published an Advanced Notice of Proposed Rulemaking: Regulating Greenhouse Gas Emissions under the Clean Air Act (http://www.epa.gov/climatechange/anpr.html). This notice asks for public input on the appropriateness of regulating GHGs under the Federal Clean Air Act, and if appropriate, the form that regulation would take. The comment deadline for this notice was November 28, 2008. EPA is not expected to act further on this notice anytime soon, but because activities on the federal level have the potential to circumvent or replace local actions, all interested parties should watch and participate in this federal process.

In addition, after a thorough scientific review ordered in 2007 by the U.S. Supreme Court EPA issued in April 17, 2009 a proposed finding that greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride) contribute to air pollution that may endanger public health or welfare. This proposed finding is now under a public comment period.

3.3 California Air Resources Board (ARB)

3.3.1 ARB Scoping Plan

ARB developed a scoping plan addressing AB 32 requirements according to specific deadlines. The AB 32 Scoping Plan[2] contains the main strategies California will use to reduce greenhouse gases (GHG) that cause climate change. The Scoping Plan has a range of GHG reduction actions which include direct regulations, alternative compliance mechanisms, monetary and non-monetary incentives, voluntary actions, and market-based mechanisms such as a cap-and-trade system. The Proposed Scoping Plan was released on October 15, 2008 and approved at ARB's Board hearing on December 12, 2008. The Scoping Plan now requires ARB and other state agencies to adopt regulations and other initiatives reducing GHGs. The majority of the work must be completed by December 31, 2010 with most regulations and other initiatives going into effect by January 1, 2012.



The scoping plan contains the main strategies California will use to reduce greenhouse gases (GHG) from business-as-usual emissions projected from 2020 levels back down to 1990 levels. Business-as-usual (BAU) is the projected emissions in 2020, including increases in emissions caused by growth, without any greenhouse gas reduction measures. The Scoping Plan has a range of GHG reduction actions which include direct regulations, alternative compliance mechanisms, monetary and non-monetary incentives, voluntary actions, and market-based mechanisms such as a cap-and-trade system.

[2] *Climate Change Proposed Scoping Plan*. California Air Resources Board, October 2008

3.3.2 GHG Baseline and Business-as-Usual Emissions

Senate Bill 1771 directed the California Energy Commission (CEC) to determine the statewide GHG emissions inventory by January 2002 and to update it every five years thereafter. As of January 1, 2007, the responsibility for updating the GHG inventory was transferred to ARB per Assembly Bill 1803.

Baseline
The California Air Resources Board (CARB) used its emission inventory to establish the Baseline upon which changes in GHG emissions would be evaluated. The Baseline consists of a three-year average for GHG emissions occurring by sector during the baseline period of 2002-2004. The Baseline Period GHG emissions include emissions from all sources in ARB's emissions inventory, including both, old and new, large and small GHG emission sources.

Business-as-Usual
Business-as-usual (BAU), as established by CARB, is a projected emissions inventory and does not represent actual business or operational practices generating GHG emissions. To establish BAU, ARB projected the Baseline Period emissions to the year 2020, using assumptions about potential growth, assuming no change in the existing business practices, and without considering implementation of any GHG emission reduction measures.

ARB 29%GHG Emission Reduction Target
As presented in the Scoping Plan[3], ARB estimated the 2020 BAU greenhouse gas emissions to be 596 $MMTCO_2E$. The State's GHG emissions level in 1990 was approved by ARB in December 2007 to be 427 $MMTCO_2E$. This sets the 2020 GHG emissions target. The resulting BAU estimate of 596 MMT is compared to the 2020 target of 427 MMT to determine the total statewide GHG reductions needed. The 2020 target of 427 $MMTCO_2E$ requires the reduction of 169 $MMTCO_2E$, or approximately 29%, from the state's projected 2020 BAU emissions and the reduction of 42 $MMTCO_2E$, or almost 10 percent, from 2002-2004 average emissions.

$$29\%\,\text{Total Reduction} = \frac{596\,\text{MMTCO2e}(2020\,\text{BAU Emissions}) - 427\,\text{MMTCO2e}(2020\,\text{Target Emissions})}{596\,\text{MMTCO2e}(2020\,\text{BAU Emissions})}$$

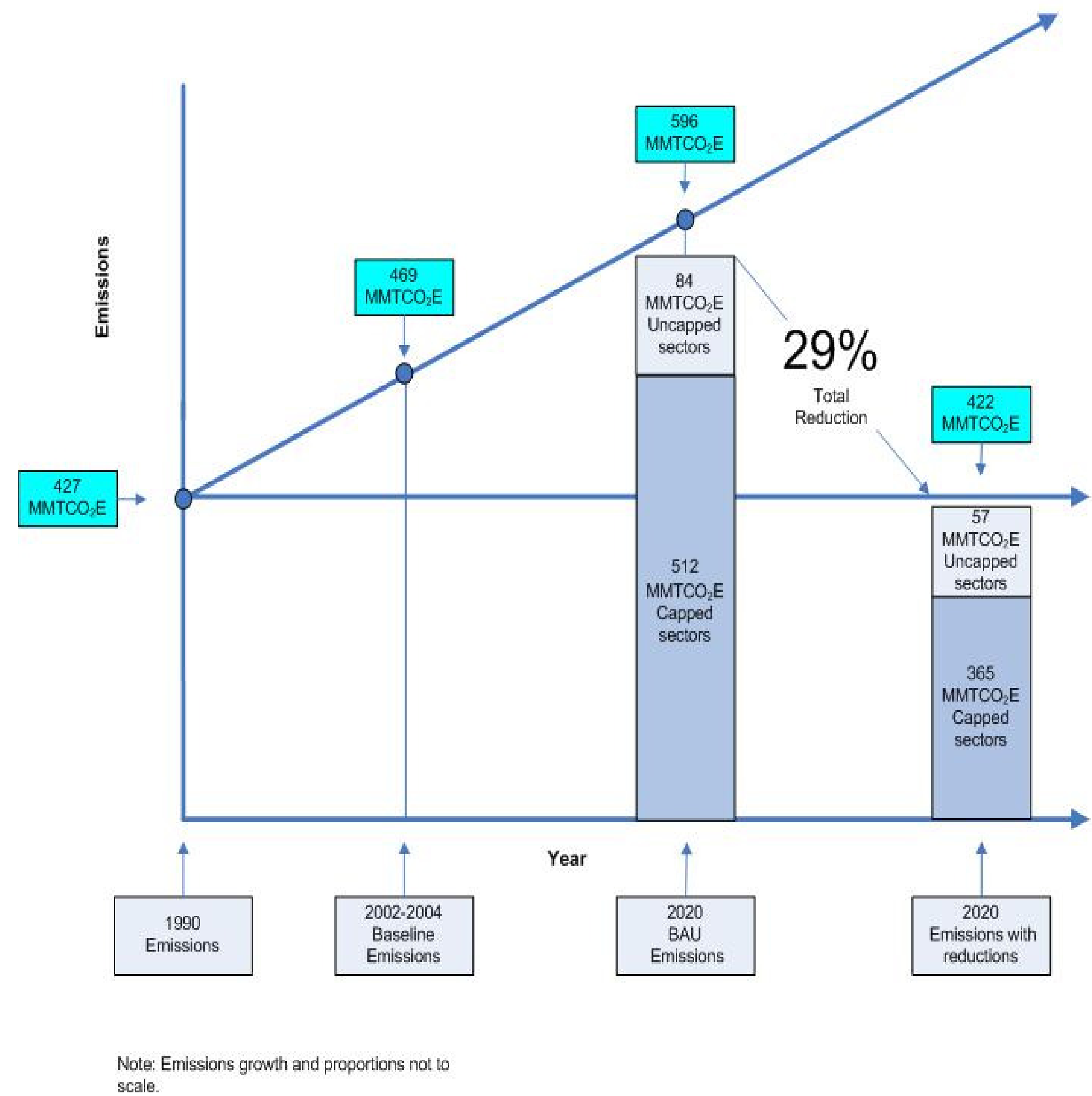
ARB has identified reduction measures totaling 174 $MMTCO_2E$ in the Scoping Plan that would achieve reductions from sources within the cap-and-trade sectors (capped) by 146.7 $MMTCO_2E$ and from sources not covered by cap-and-trade (uncapped) by 27.3 $MMTCO_2E$. With a total projected BAU emission by 2020 of 596 $MMTCO_2E$, the projected total

[3] *Climate Change Proposed Scoping Plan;* P. 12 and 21. California Air Resources Board, October 2008

emission after reductions would be 422 $MMTCO_2E$ of which 365 $MMTCO_2E$ from capped sectors and 57 $MMTCO_2E$ from uncapped sectors.

Figure 2 below illustrates the 1990 state's GHG emissions and 2020 reductions as proposed in the Scoping Plan[4].

Figure 2: California Greenhouse Gas Emissions in 2020



[4] *Climate Change Proposed Scoping Plan;* P. 12 and 21. California Air Resources Board, October 2008

3.3.3 GHG Emission Reduction Measures and Cap-and-Trade Principles

The AB 32 Scoping Plan evaluated a comprehensive array of approaches and tools identifying GHG emission reduction measures to achieve the 1990 GHG emission level target. ARB concluded that reducing GHG emissions from a wide variety of sources can best be achieved through establishment of a cap-and-trade program. A cap-and-trade program establishes an enforceable limit (or cap) on the aggregate total emissions for those entities covered by the program.[5] As proposed by ARB, the State would establish a cap for each compliance period of the program, and emission reductions would increase as the cap declines over time. A key component of a cap-and-trade program is a permit to emit one unit of GHG emissions, typically called an allowance. Allowances are issued in the program in an amount equal to the total emissions limit for a compliance period. At the end of the compliance period, all entities in a cap-and-trade program must surrender allowances equal to their total emissions during the compliance period.

The limited number of allowances issued creates a binding cap on emissions. The State would issue fewer allowances over time, thus ensuring declining emissions. Failure to surrender allowances equal to emissions results in significant penalties. New facilities that begin operation in sectors subject to cap-and-trade would be required to obtain allowances through an auction, from a reserve, or from other allowance holders. This process provides a mechanism for new facilities to operate, while guaranteeing that there is no increase in overall GHG emissions when new facilities are built.

The proposed cap-and-trade would include up to 85 percent of the State's emission sources by 2020, covering electricity, transportation fuels, natural gas, and industrial sectors. ARB estimates that, the cap-and-trade would reduce overall state-wide GHG emissions by 147 $MMTCO_2E$[6] from projected BAU in 2020.

Cap-and-trade programs are market-driven, and do not specify how emission reductions will be achieved. Emissions reductions will be achieved at the facility level using the most cost-effective methods available. Emission reductions achieved through compliance with other emission reduction measures count towards achieving the facility's cap, thus reducing the need to obtain allowances. Furthermore reductions achieved on site have a potential collateral benefit of reducing criteria pollutant emissions.

[5] For further discussion of cap-and-trade see: *Climate Change Proposed Scoping Plan Appendix C, Cap and Trade*, pp. 11 – 24. California Air Resources Board, October 2008

[6] *Climate Change Proposed Scoping Plan,* pp. 16 and 21. California Air Resources Board, October 2008

3.3.4 ARB's Preliminary Recommendations for Significance Thresholds

On October 24, 2008, ARB released its Preliminary Draft Staff Proposal, *Recommended Approaches for Setting Interim Significance Thresholds for Greenhouse Gases under the California Environmental Quality Act.* ARB staff believes that zero thresholds are not warranted in light of the fact that (1) some level of emissions in the near term and at mid-century is still consistent with climate stabilization and (2) current and anticipated regulations and programs apart from CEQA will proliferate and increasingly will reduce the GHG contributions of past, present, and future projects. But any non-zero threshold must be sufficiently stringent to make substantial contributions to reducing the State's GHG emissions peak, causing that peak to occur sooner, and putting California on track to meet its interim (2020) and long-term (2050) emissions reduction targets.

The Proposed Scoping Plan was released on October 15, 2008 and approved at ARB's Board hearing on December 12, 2008. The Scoping Plan now requires ARB and other state agencies to adopt regulations and other initiatives reducing GHGs. The majority of the work must be completed by December 31, 2010 with most regulations and other initiatives going into effect by January 1, 2012.

A key aspect of ARB's approach is to recognize that different GHG thresholds of significance may apply to projects in different sectors. Two primary reasons that sector-specific thresholds are appropriate are: (1) some sectors contribute more substantially to the problem, and therefore should have a greater obligation for emissions reductions, and, (2) looking forward, there are differing levels of emissions reductions expected from different sectors in order to meet California's climate objectives. ARB also believes that different types of thresholds – quantitative, qualitative, and performance-based – can apply to different sectors under the premise that the sectors can and must be treated separately given the state of the science and data. A sector-specific approach is consistent with ARB's proposed Scoping Plan.

<u>Stationary Sources</u>
ARB staff's objective is to develop a threshold of significance that will result in the vast majority (~90% statewide) of the greenhouse gas (GHG) emissions from new stationary source projects being subject to CEQA's requirement to impose feasible mitigation. ARB staff believes this can be accomplished with a threshold that allows small projects to be considered insignificant. ARB staff used existing data for the industrial sector to derive a proposed hybrid threshold. The threshold consists of a quantitative threshold of 7,000 metric tons of CO_2 equivalent per year ($MTCO_2E$/year) for operational emissions (excluding transportation), and performance standards for construction and transportation emissions (CARB). The goal

of this effort is to provide for the mitigation of GHG emissions from industrial projects on a statewide level. Over time, implementation of AB 32 will reduce or mitigate GHG emissions from stationary sources. Once such requirements are in place, they could become the performance standard for stationary projects for CEQA purposes. ARB staff intends to pursue this approach in conjunction with development of the regulatory requirements for stationary sources in the Proposed AB 32 Scoping Plan. Staff is proposing the use of a quantitative significance threshold at least until such time that performance standards, such AB 32 regulatory requirements, are in place to ensure mitigation of significant impacts of GHG emissions from projects in the industrial sector.

ARB determined that GHG emissions from stationary sources are dominated by combustion emissions. To ensure that significant stationary emissions would be captured by the proposed threshold, ARB staff evaluated industrial boilers because they are a very common piece of equipment, are essential in many energy-intensive industries, and are a top contributor to stationary combustion emissions. A recent comprehensive survey of industrial boilers found that boilers with an input capacity of 10 MMBtu/hr or greater correspond to 93 percent of total industrial boiler input capacity. Based on this data, ARB staff used a natural gas boiler input capacity benchmark of 10 MMBtu/hr which equates to emissions of 4,660 $MTCO_2E$/yr. This capacity benchmark defines a significant combustion source. Per ARB's analysis, combustion processes account for 63 percent of the statewide GHG emissions from industrial facilities. Process losses, purchased electricity, and water use and water treatment account for the remaining 27 percent of emissions.

Based on the available data, ARB concludes in its draft proposal that the 7,000 $MTCO_2E$/year benchmark can be used to effectively mitigate industrial projects with significant GHG emissions.

<u>Residential and Commercial Developments</u>

ARB's preliminary draft proposal for residential and commercial projects recognizes the potential for using a performance standard based approach. Projects complying with a previously approved plan that addresses GHG emissions, satisfies CEQA section 15064(h)(3), and that has all of the following attributes could be presumed to have a less than significant impact:

- Project meets a community level GHG target consistent with statewide AB 32 emission limits; and
- Is consistent with a transportation related GHG reduction target adopted by ARB pursuant to SB 375; and
- Includes a GHG inventory and mechanisms to regularly monitor and evaluate emissions; and
- Includes specific enforceable GHG requirements; and

- Incorporates mechanisms that all the plan to be revised to meet targets; and
- Has a certified final CEQA document.

Projects failing to meet the above criteria would go through a second tier analysis. As proposed, Tier II would contain both performance standards and a numerical (X) significance threshold. Projects could be presumed to have a less than significant impact if they met the following minimum performance standards and were below the X threshold of significance:

- Meets an interim ARB performance standard for construction related emissions; and
- Meets an energy use performance standard defined as CEC's Tier II energy efficiency goal; and
- Meets an interim ARB performance standard for water use; and
- Meets an interim ARB performance standard for waste; and
- Meets an interim ARB performance standard for transportation; and
- The project, with performance standards or equivalent mitigation would emit no more than X metric tons CO_2E/year.

It should be noted that ARB has solicited comments regarding whether to include an X factor. As of today, ARB has not finalized its recommendation, and has not scheduled any additional workshops or hearings on the draft proposals.

3.4 Office of Planning and Research (OPR)

OPR Recommendations

On or before January 1, 2010, The Governor's Office of Planning and Research (OPR) will develop, and the California Resources will certify and adopt amendments to the Guidelines providing regulatory guidance on the analysis and mitigation of GHG emissions in CEQA documents. On April 13, 2009, OPR submitted to the Secretary for Natural Resources its proposed amendments to the state CEQA Guidelines for greenhouse gas emissions, as required by Senate Bill 97 (Chapter 185, 2007). These proposed CEQA Guideline amendments would provide guidance to public agencies regarding the analysis and mitigation of the effects of greenhouse gas emissions in draft CEQA documents. The Natural Resources Agency will conduct formal rulemaking in 2009, prior to certifying and adopting the amendments, as required by Senate Bill 97.

In the interim, OPR has drafted and released in January 2009 draft amendments to the CEQA Guidelines for GHG emissions as required by SB97. OPR does not identify a threshold of significance for greenhouse gas emissions, nor have they prescribed assessment methodologies or specific mitigation measures. The proposed language was added for clarification and stayed within CEQA's framework. The preliminary draft amendments encourage lead agencies to consider many factors in performing a CEQA analysis, but preserve the discretion granted by CEQA to lead agencies in making their own determinations based on substantial evidence.

General Guidance
Per the OPR, "*until such time as further state guidance is available on thresholds of significance, public agencies should consider the following general factors when analyzing whether a proposed project has the potential to cause a significant climate change impact on the environment*".

Identify GHG Emissions
Lead agencies should make a good-faith effort, based on available information, to calculate, model, or estimate the amount of CO_2 and other GHG emissions from a project, including the emissions associated with vehicular traffic, energy consumption, water usage and construction activities.

Determine Significance
As with any environmental impact, lead agencies must determine what constitutes a significant impact. In the absence of regulatory standards for GHG emissions or other scientific data to clearly define what constitutes a "significant impact", individual lead agencies may undertake a project-by-project analysis, consistent with available guidance and current CEQA practice. The potential effects of a project may be individually limited but cumulatively significant. Lead agencies should not dismiss a proposed project's direct and/or indirect climate change impacts without careful consideration, supported by substantial evidence. Although climate change is ultimately a cumulative impact, not every individual project that emits GHGs must necessarily be found to contribute to a significant cumulative impact on the environment. CEQA authorizes reliance on previously approved plans and mitigation programs that have adequately analyzed and mitigated GHG emissions to a less than significant level as a means to avoid or substantially reduce the cumulative impact of a project, encourages reliance on other Environmental Impact Reports that discuss greenhouse gases, and tiering from them. The preliminary draft amendments OPR issued included an introduction letter in which OPR indicated that OPR intends to rely on ARB to recommend a method for setting significance thresholds. The draft guidelines add a new section 15064.4 titled "Determining the Significance of GHG Emissions", and it includes a suggestion of situations that might be considered significant.

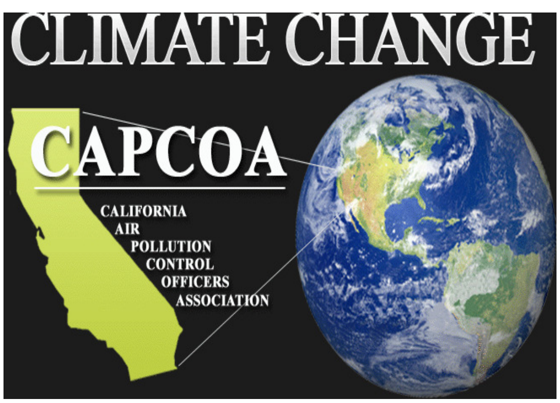
Mitigate Impacts
Mitigation measures will vary with the type of project being contemplated, but may include alternative project designs or locations that conserve energy and water, measures that reduce vehicle miles traveled (VMT) by fossil-fueled vehicles, measures that contribute to established regional or programmatic mitigation strategies, and measures that sequester carbon to offset the emissions from the project. The lead agency must impose all mitigation measures that are necessary to reduce GHG emissions to a less than significant level. However, CEQA does

not require mitigation measures that are infeasible for specific legal, economic, technological, or other reasons, and a lead agency is not responsible for wholly eliminating all GHG emissions from a project; the CEQA standard is to mitigate to a level that is “less than significant”. If there are not sufficient mitigation measures that the lead agency determines are feasible to achieve the less than significant level, the lead agency should adopt those measures that are feasible, and adopt a Statement of Overriding Considerations that explains why further mitigation is not feasible or when an agency makes a statement of overriding considerations, the agency may consider local adverse environmental effects in the context of region-wide or statewide benefits. Agencies are encouraged to develop standard GHG emission reduction or mitigation measures that can be applied on a project-by-project basis.

Land Use Considerations
Local governments with land use authority are beginning to establish policies that result in land use patterns and practices that will result in less energy use and reduce GHG emissions. For example, some cities and counties have adopted general plans and policies that encourage the development of compact, mixed use, transit-oriented development that reduces VMT; encourage alternative fuel vehicle use; conserve energy and water usage; and promote carbon sequestration. Models of such developments exist throughout the state. For local government lead agencies, adoption of general plan policies and certification of general plan EIRs that analyze broad jurisdiction-wide impacts of GHG emissions can be part of an effective strategy for addressing impacts and for streamlining later project-specific CEQA reviews.

3.5 California Air Pollution Control Officers Association (CAPCOA)

CAPCOA – White Paper: CEQA and Climate Change



The intent of CAPCOA’s White Paper is to serve as a resource for public agencies as they establish procedures for reviewing GHG emissions from projects under CEQA. It considers the application of thresholds and offers three alternative programmatic approaches toward determining whether GHG emissions are significant. Although the White Paper considers an option of not establishing a GHG significance threshold, as already noted this option is not considered to be a viable approach and will not be considered further. Ultimately, the White Paper is intended to provide consistent approaches for public agencies to ensure that GHG emissions are appropriately considered and addressed under CEQA (CAPCOA).

The CAPCOA White Paper identifies three programmatic approaches to establishing GHG significance thresholds and also discusses the benefits and problems associated with each approach. Each approach has inherent advantages and disadvantages. The basic approaches are:

- GHG emissions threshold set at zero; or
- GHG threshold set at a non-zero level (AB32 Goals)
- GHG threshold set at a non-zero level (Tiered Approach)

Zero Threshold

An air district or lead agency may determine that any degree of project-related increase in GHG emissions would contribute considerably to climate change which, therefore, would be considered a significant impact. As a result, the air district or lead agency could adopt a zero-emission GHG threshold. If the zero threshold option is chosen, the lead agency would be required to quantify and mitigate GHG emissions for all projects subject to CEQA, regardless of the size of the project or the availability of GHG reduction measures available to reduce the project's emissions. Projects that could not meet the zero-emission threshold would be required to undergo an environmental impact report CEQA process to disclose the unmitigable significant impact, and develop the justification for a statement of overriding consideration to be adopted by the lead agency.

Non-Zero Threshold – Statute and Executive

The first non-zero GHG significance threshold approach is based on achieving the objectives of AB 32 or Executive Order S-3-05 and explores four possible options under this scenario. A project would be required to meet the target objectives, or reduce GHG emissions to the target objectives, to be considered less than significant. The options under this approach are variations of ways to achieve the 2020 goals of AB 32 from new development, which is estimated to be about a 30 percent reduction from business-as-usual. The practical advantages of considering non-zero thresholds for GHG significance determinations can fit into the concept regarding whether the project's GHG emissions represent a "considerable contribution to the cumulative impact" and therefore warrant analysis.

Non-Zero Threshold – Tiered Threshold Options

The second non-zero GHG significance threshold approach is comprised of a number of tiered GHG significance threshold options. Within this option, the CAPCOA White Paper discusses several variations. The tiered threshold options offer both quantitative and qualitative approaches to setting a threshold, as well as different metrics for establishing the various tiers. Variations range from setting the first tier at zero to second tiers set at defined emission levels or based on the size of a project. This approach would then prescribe a set of GHG mitigation strategies that would have to be incorporated into the project in order for the project to be considered less than significant. CAPCOA notes that some applications of the tiered threshold approach may require inclusion in a General Plan or adoption of enabling regulations or ordinances to render them fully effective and enforceable.

CAPCOA offered to ARB on a letter dated January 9, 2009 two possible approaches regarding the issues associated with determining appropriate CEQA significance thresholds for GHG from new residential, commercial and industrial development. One suggested approach is to require all new stationary sources of GHG emissions to meet specific GHG performance standards established for each equipment type of source category of emissions. In addition, any new stationary source exceeding 25,000 tons of CO_2E per year after meeting the specified performance standards would be deemed to have a potentially significant adverse impact on the environment and would be analyzed and mitigated as required under CEQA.

The other suggested approach is that a jurisdiction could establish a CEQA significance threshold for stationary sources designed to capture and mitigate 90% of stationary source emissions. More details on the approaches can be found at: http://www.valleyair.org/Programs/CCAP/1-9-09%20CAPCOA%20Letter%20on%20CEQA%20to%20Lynn%20Terry.pdf.

3.6 Association of Environmental Professionals (AEP)

AEP – White Paper on Global Climate Change

AEP's White Paper was one of the first attempts to discuss GHGs in the context of CEQA. The intent of the White Paper was to provide practical, interim information to CEQA practitioners and to help Lead Agencies determine how to address GHGs and global climate change in CEQA documents prior to the development and adoption of guidance by appropriate government agencies. Further, AEP's White Paper provided a summary of the current regulatory environment surrounding GHG emissions, and the various approaches that a Lead Agency may select in a CEQA document to address the potential impacts of global climate change and a project's specific and cumulative contribution to GHG. The White Paper described several approaches for addressing GHGs and global Climate Change in CEQA documents, but did not recommend a single approach or methodology, leaving that decision to local Lead Agencies. The proposed approaches are summarized in the following bullet points.

Approach 1 – No Analysis: under this approach the Lead Agency would not mention or discuss GHGs or global climate change.

Approach 2 – Screening Analysis: under this approach the Lead Agency would establish a process to screen projects and determine that they would not make significant contributions to GHG emissions or GCC and, therefore, would not need to mitigate accordingly.

Approach 3 – Qualitative Analysis without Significance Determination: this approach involves a qualitative discussion of GHGs and global climate change and potential ways the project will contribute to the generation of GHG emissions, but does not provide any significance conclusions.

Approach 4 – Qualitative Analysis with Significance Determination: under this approach the Lead Agency would qualitatively discuss GHGs and climate change impacts and conclude whether the project impacts are significant.

Approach 5 – Quantitative Analysis without Significance Determination: under this approach the Lead Agency would quantify GHG emissions from the proposed project, but the results are not compared to a quantitative significance threshold.

Approach 6 – Quantitative Analysis with Net Zero Threshold: this approach involves quantifying GHG emissions and using zero net carbon dioxide equivalent increase as the threshold.

Approach 7 – Quantitative Analysis Relative to California GHG Emission Reduction Strategies: this approach employs both quantitative and qualitative components. The quantitative analysis contains an inventory of project GHG emissions. The qualitative component involves project compliance with the emission reduction strategies contained in the California Climate Action Team's (CAT) Report to the Governor, which contains recommendations and strategies to help ensure the targets in Executive Order S-3-05 are met.

Approach 8 – Use of Partial Exemption, "Within the Scope" of a Program EIR, or Tiering: this option relies on the preparation of a broad EIR on a plan, program, or zoning action that is certified and contains a cumulative GHG and global climate change impact analysis and mitigation. A later project that is consistent with the actions, goals, and/or policies in that plan, program, or zoning action need not again evaluate the cumulative impact regarding the project's GHG contribution to global climate change. In this situation, the later project may use the "partial exemption" provision of Public Resources Code §21083.3 and CEQA Guidelines §15183

While some of the approaches discussed above are dated and obsolete (such as those suggesting no analysis, or no determination of significance), the paper remains, in significant part, a valid and useful resource.

3.7 South Coast Air Quality Management District (SCAQMD)

SCAQMD has generally recommended a tiered decision tree approach to establishing a GHG significance threshold (SCAQMD) (See Figure 3). A tiered GHG significance threshold approach is an appealing approach because it provides flexibility in determining whether or not GHG emissions from a project are significant, typically using a single methodology to establish various tiers that can be based on the physical size of the project, land use type, or other characteristics. The tiered approach envisioned by SCAQMD would require quantification of GHG emissions for all projects that are subject to CEQA and quantification of the GHG reduction effectiveness of design parameters incorporated into the project and any mitigation measures imposed by the lead agency.

On December 5, 2008, the SCAQMD Governing Board adopted the staff proposal for an interim GHG significance threshold for projects where the SCAQMD is lead agency. SCAQMD recommended the interim GHG significance threshold proposal uses a tiered approach to determining significance. Tier 3, which is expected to be the primary tier by which the AQMD will determine significance for projects where it is the lead agency, uses the Executive Order S-3-05 goal as the basis for deriving the screening level. The Tier 3 screening level for stationary sources is based on an emission capture rate of 90 percent for all new or modified projects. A 90 percent emission capture rate means that 90 percent of total emissions from all new or modified stationary source projects would be subject to a CEQA analysis, including a negative declaration, a mitigated negative declaration, or an environmental impact report, which includes analyzing feasible alternatives and imposing feasible mitigation measures. Once ARB adopts the statewide significance thresholds, SCAQMD staff will report back to their Governing Board regarding any recommended changes or additions to the SCAQMD's interim threshold.

Tier 1 – consists of evaluating whether or not the project qualifies for any applicable exemption under CEQA. For example, SB 97 specifically exempts a limited number of projects until it expires in 2010. If the project qualifies for an exemption, no further action is required. If the project does not qualify for an exemption, then it would move to the next tier.

Tier 2 – consists of determining whether or not the project is consistent with a GHG reduction plan that may be part of a local general plan, for example. The concept embodied in this tier is equivalent to the existing concept of consistency in CEQA Guidelines §§15064(h)(3), 15125(d), or 15152(a). The GHG reduction plan must, at a minimum, comply with AB 32 GHG reduction goals; include emissions estimates agreed upon by either ARB or the SCAQMD, have been analyzed under CEQA, and have a certified Final CEQA document. Further, the GHG reduction plan must include a GHG emissions inventory tracking mechanism; process to monitor progress in achieving GHG emission reduction targets, and a commitment to remedy the excess emissions if AB 32 goals are not met (enforcement).

If the proposed project is consistent with the local GHG reduction plan, it is not significant for GHG emissions. If the project is not consistent with a local GHG reduction plan or there is no approved plan, the GHG reduction does not include all of the components described above, or there is no adopted GHG reduction plan, the project would move to tier 3.

Tier 3 – Establishes a screening significance threshold level to determine significance using a 90 percent emission capture rate approach as described above. The 90 percent capture rate GHG significance screening level in Tier 3 for stationary sources was derived using the following methodology. Using SCAQMD's Annual Emission Reporting (AER) Program staff compiled reported annual natural gas consumption for 1,297 permitted facilities for 2006 through 2007 and rank-ordered the facilities to estimate the 90th percentile of the cumulative natural gas usage for all permitted facilities. Approximately 10 percent of facilities evaluated comprise more than 90 percent of the total natural gas consumption, which corresponds to 10,000 metric tons of CO_2 equivalent emissions per year ($MTCOCO_2E$/yr) (the majority of combustions emissions is comprised of CO_2). This value represents a boiler with a rating of approximately 27 million British thermal units per hour (mmBtu/hour) of heat input, operating at a 80 percent capacity factor. It should be noted that this analysis did not include other possible GHG pollutants such as methane, N2O; a life-cycle analysis; mobile sources; or indirect electricity consumption. Therefore, when implemented, SCAQMD staff recommended interim proposal is expected to capture more than 90 percent of GHG emissions from stationary source projects. If the project exceeds the GHG screening significance threshold level and GHG emissions cannot be mitigated to less than the screening level, the project would move to Tier 4.

Tier 4 – Decision Tree Options: consists of three decision tree options to demonstrate that a project is not significant for GHG emissions. The compliance options are as follows:

Compliance Option 1 – the lead agency would calculate GHG emissions for a project using a Business As Usual (BAU) methodology. Once GHG emissions are calculated, the project proponent would need to incorporate design features into the project and/or implement GHG mitigation measures to demonstrate a 30 percent reduction from BAU.

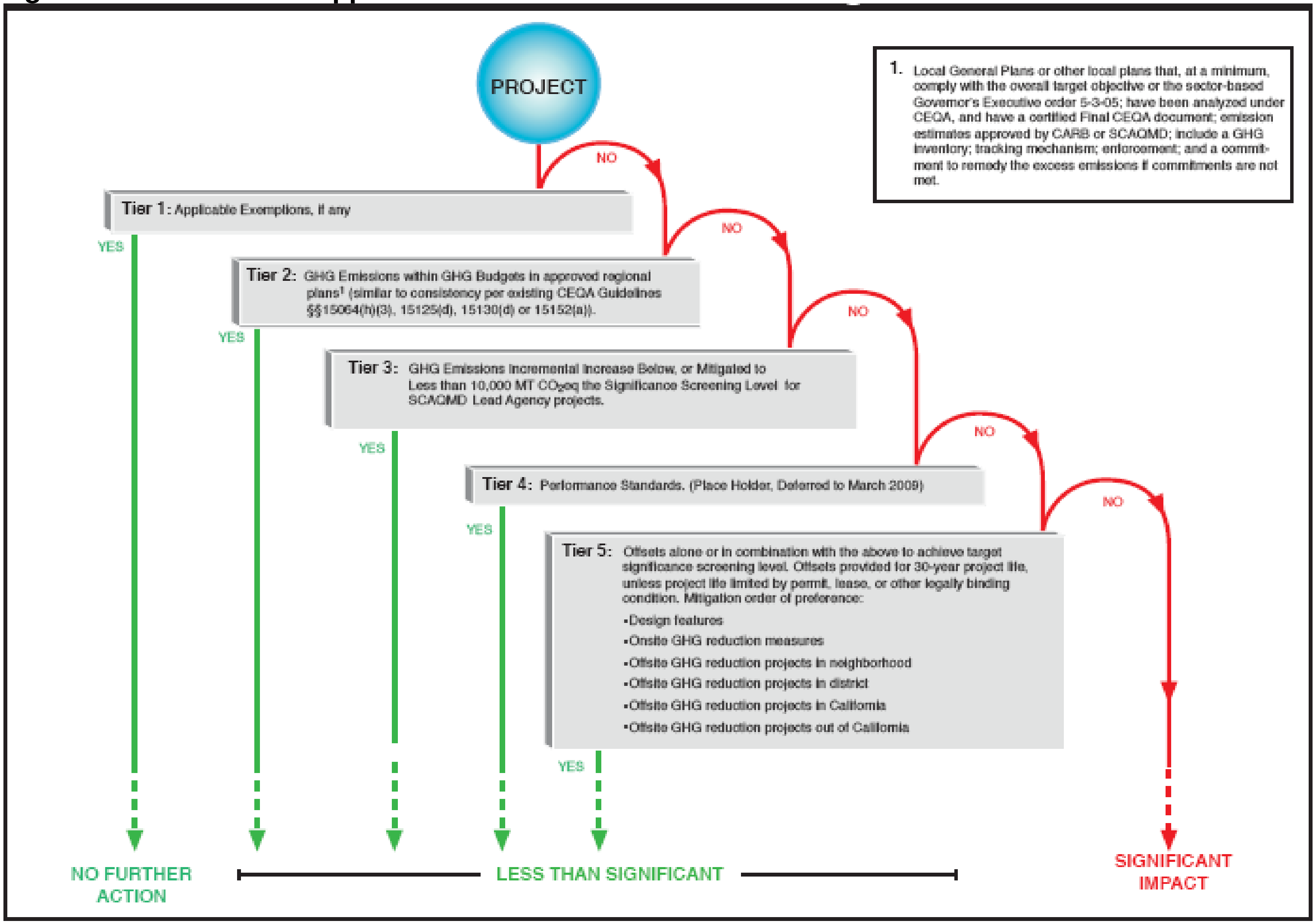
Compliance Option 2 – this option consists of early compliance with AB 32 through early implementation of ARB's Scoping Plan Measures. The intent of this compliance option is to accelerate GHG emission reductions from the various sectors subject to ARB's Scoping Plan to eliminate GHG emission.

Compliance Option 3 – this compliance option consists of establishing sector-based performance standards. For example, it may be possible to use the 1990 inventory required under AB 32 to establish an efficiency standard such as pounds per person, pounds per worker, pounds per square feet, pounds per item manufactured, etc. When calculating GHG emissions from a project, if they are less than the established efficiency standard the project would not be significant relative to GHG emissions, while projects exceeding the efficiency standard would be significant.

If the project proponent cannot achieve the performance standards on any of the compliance options in Tier 4, GHG emissions would be evaluated under Tier 5.

Tier 5 – under this tier, the lead agency would quantify GHG emissions from the project and the project proponent would implement offsite mitigation (GHG reduction projects) or purchase offsets to reduce GHG emission impacts to less than the proposed screening level. In addition, the project proponent would be required to provide offsets for the life of the project, which is defined as 30 years. If the project proponent is unable to obtain sufficient offsets, incorporate design features, or implement GHG reduction mitigation measures to reduce GHG emission impacts to less than the screening level, then GHG emissions from the project would be considered significant.

Figure 3: SCAQMD Tier Approach



Source: SCAQMD, 2008

3.8 Bay Area Air Quality Management District (BAAQMD)

On June 1, 2005 the Bay Area Air District Board of Directors adopted a resolution establishing a Climate Protection Program and acknowledging the link between climate protection and programs to reduce air pollution in the Bay Area. The Board of Directors also formed a standing Committee on climate protection to provide direction on District climate protection activities (BAAQMD). In April 2009, Bay Area AQMD prepared a draft report that evaluates options for California Environmental Quality Act (CEQA) thresholds of significance for use within BAAQMD's jurisdiction.

3.9 Sacramento Metropolitan Air Quality Management District (SMAQMD)

The Sacramento Metropolitan AQMD recommends that CEQA environmental documents include a discussion of anticipated GHG emissions during both the construction and operation phases of the project (SMAQMD). This recommendation is consistent with comments made by the previous and current California Attorney Generals on Land Use projects undergoing CEQA review. The Sacramento Metropolitan AQMD indicates that models are available to quantify GHG emissions from projects. In addition, the Sacramento Metropolitan AQMD offers several examples of type of mitigations that local agencies may consider under CEQA to offset or reduce global warming impacts, and is currently developing a pilot project in which a development project proponent will be contributing fees to the District which will then use those funds in GHG mitigation projects.

3.10 San Joaquin Valley Air Pollution Control District CCAP Committees

As mentioned earlier, three ad hoc committees were created to assist in the guidance development for addressing GHG emissions during the CEQA process. They are (1) the Project Scope Committee, (2) the Level of Significance Committee, and the (3) Mitigation Measure Committee. The committee members included people with industrial, government, consulting, and environmental backgrounds and perspectives. Member lists are found in Appendixes A, B, and C. The committees developed a Guidance Issue Paper first and three progress reports subsequently, each focusing on a specific topic. The Guidance Issue Paper was used primarily to provide a starting point. The expanded discussion by the committees was conveyed in the progress reports and is incorporated here in the Appendixes D-G.

These issue papers do not necessarily represent the position or intention of the San Joaquin Valley Air District Pollution Control District, but are presented with this staff report to represent the input of the committee members themselves. Their assistance in the early stages of scoping and proposing various methods of addressing GHG emissions in CEQA was essential and appreciated.

CHAPTER 4

DISTRICT GHG SIGNIFICANCE DETERMINATION PROPOSAL

4.1 Background

The obligation for public agencies to address the potential environmental effects of greenhouse gas (GHG) emissions arises from the California Environmental Quality Act (CEQA), which requires agencies to identify a project's potentially significant effects on the environment, and to mitigate significant effects whenever feasible. CEQA encourages public agencies to adopt "thresholds of significance" to use in determining the significance of environmental effects. A threshold of significance is an identifiable quantitative, qualitative or performance level of a particular environmental effect. Non-compliance with a threshold of significance would normally result in a determination that the project would have a significant environmental impact. Compliance with a significance threshold would normally result in a determination that project would not have a significant environmental impact.

Including evaluation of project related GHG emissions in CEQA evaluations is part of a rapid evolution of California State Climate policy, formalized, in part, with passage of Assembly Bill 32 (California Global Warming Solutions Act of 2006) (AB 32), Senate Bill 97 (CEQA: greenhouse gas emissions) (SB 97), and Senate Bill 375 (SB 375), commonly referred to in the popular press as the "climate change smart growth bill". Development of significance threshold for GHG emissions must be done in the context of these key legislative mandates.

AB 32 establishes the GHG emission reduction targets to be achieved by the State of California, and provides the framework for achieving those required reductions. AB 32 includes a number of specific requirements to be implemented by the California Air Resources Board (ARB), including preparation of a scoping plan for achieving the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions from sources or categories of sources of greenhouse gases by 2020.

SB 375 enhances ARB's ability to reach AB 32 goals by directing ARB to develop regional greenhouse gas emission reduction targets to be achieved from the automobile and light truck sectors for 2020 and 2035. SB 375 also directs ARB to work with California's 18 metropolitan planning organizations to align their regional transportation, housing and land-use plans and prepare a "sustainable communities strategy" to reduce the amount of vehicle miles traveled in their respective regions and demonstrate the region's ability to attain its greenhouse gas reduction targets. A key component of SB 375 is that ARB is required to establish GHG emission reduction targets for each region, as opposed to individual cities or households.

SB 97 requires the Governor's Office of Planning and Research (OPR) to develop CEQA guidelines for addressing GHG emissions. On April 13, 2009, OPR submitted to the Secretary for Natural Resources its proposed amendments to the state CEQA Guidelines for greenhouse gas emissions, as required by Senate Bill 97. These proposed CEQA Guideline amendments would provide guidance to public agencies regarding the analysis and mitigation of the effects of greenhouse gas emissions in draft CEQA documents.

A key aspect of the proposed OPR guidance is that a lead agency shall have the discretion to determine, in the context of a particular project, whether to:

- Use a model of methodology to quantify GHG emissions, or
- Rely on a qualitative analysis or performance based standards

Furthermore, when assessing the significance of impacts from GHG emissions the lead agency may consider the following:

- The extent to which a project may increase or reduce GHG emissions as compared to the existing environmental setting;
- Whether project emissions exceeds a threshold of significance;
- The extent to which the project complies with regulations or requirements adopted to implement a statewide, regional, or local plan for reduction or mitigation of GHG emissions.

4.2 The Challenge of Assessing Significance

The challenge in assessing the significance of individual project GHG emissions is to determine whether project specific GHG emissions, which are at a micro-scale relative to global emissions, would result in a cumulatively considerable incremental contribution to global climatic change, which is macro-scale impact. "Cumulatively considerable" means that the incremental effects of an individual project are significant when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects. Furthermore, the mere existence of significant cumulative impacts caused by other projects does not constitute substantial evidence that a proposed project's incremental effects are cumulatively significant.

As presented in this staff report, the District has actively sought the input, advice, and assistance of numerous interested parties and stakeholder groups. Through the Climate Change Action Plan scoping meetings, the District explored numerous approaches for establishing significance thresholds for project specific GHG emissions. Furthermore, the District has closely monitored actions taken by ARB and OPR to comply with their legislative mandates and the District continues to actively participate in CAPCOA's GHG Threshold and Mitigation subcommittee. The following discusses the various options considered by the District in establishing its proposed guidance for determining the significance of project specific GHG emissions.

Zero Threshold
The District has given due consideration to the complexity of evaluating the significance of project specific GHG emissions and. Some members of the District's Climate Change Action Plan committee recommended that if project specific impacts can not be quantified, then to be most protective of the environment, the District should apply a zero threshold of significance. In applying a zero threshold of significance, all projects subject to CEQA, with new GHG emissions would have to be found to have a significant impact on global climatic change. Such a determination would require all feasible mitigation, with the goal of mitigating to a net zero emissions level.

Although a zero threshold is appealing in its simplicity; execution of a zero threshold would be difficult or impossible. Projects that could not be mitigated to zero would require preparation of an EIR and in approving such projects, lead agencies would be required to adopt a statement of overriding consideration. This would result in an enormous regulatory burden on new projects and lead agencies across the District, with potentially very little positive gain in terms of GHG emissions mitigation. Furthermore, cost increases associated with compliance would likely result in projects being relocated to areas not subject to similar emission reduction requirements. Such "leakage" would not result in reduced GHG emissions and would serve to create a competitive disadvantage for businesses located within the District. ARB has concluded that zero thresholds are not mandated because some level of emissions in the near term and at mid-century is still consistent with climate stabilization and current and anticipated regulations and programs apart from CEQA will proliferate and increasingly will reduce GHG contributions[7]. ARB does not support a zero threshold, nor does the District.

Quantitative Thresholds

ARB, as well as other air districts within the state, has been considering quantitative thresholds. Several options exist for establishing quantitative thresholds, including mass of GHG emissions generated per unit of activity, GHG emissions per capita per unit basis, and percent reduction compared to business as usual. In evaluating this concept for stationary source projects (industrial and agricultural equipment and operations requiring air quality permits), the District used its database of permitted sources and its emissions inventory data to establish baseline GHG emissions data for key sources of GHG emissions. For development projects, the District used its Indirect Source Review database of development projects to baseline GHG emissions for both residential and non-residential development projects.

Using the data discussed above, the District explored a four tiered significance determination concept for use with both stationary source projects and development projects. Projects exempt from CEQA would be in tier one, and not be subject to further analysis, or GHG mitigation requirements. Tier two would contain projects considered too small to warrant further consideration (arbitrarily 10 percent of projects subject to CEQA). Such projects would not require quantification of GHG emissions, and would not require GHG mitigation. Tier three would contain projects with emissions greater than the minimum threshold, but below a maximum threshold. The maximum threshold would be set low enough to capture enough projects to offset the emissions not captured in tier two. Tier three projects would not require quantification of GHG emissions, would be required to reduce GHG emissions consistent with AB 32 targets, and would be considered less than significant. Tier four would contain projects above the maximum threshold. Tier four projects would require quantification of GHG emissions, and would be required to reduce their GHG emissions in excess to AB 32 emission reduction targets.

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[7] California Air Resources Board, Preliminary Draft Staff Proposal, Recommended Approaches for Setting Interim Significance Thresholds for Greenhouse Gases Under the California Environmental Quality Act. October 24, 2008.

Using existing databases, the District was able to establish baseline emissions for stationary source projects and development projects, and was able to establish mass GHG emissions per unit of activity. However, without supporting scientific information, establishment of tier trigger levels could be argued to be arbitrary. Furthermore, it is unclear that CEQA provides a legal basis for requiring proponents of large projects to mitigate their project impacts to the extent necessary to compensate for emissions not reduced by smaller projects.

Best Performance Standards

The existing science is inadequate to support quantification of the impacts that project specific GHG emissions have on global climatic change. No one has been able to scientifically demonstrate that a project of any size is significant, or insignificant. This is readily understood when one considers that global climatic change is the result of the sum total of GHG emissions, both man made and natural that occurred in the past; that is occurring now; and will occur in the future. Thus, there is growing scientific consensus that impacts of a specific project's emissions on global climatic change are cumulative in nature, and the significance thereof can only be examined in that context.

The State legislature, in enacting AB 32 and SB 375, and the Governor's Office of Planning and Research (OPR) in their CEQA guidelines for addressing GHG emissions (see page 46), provided the foundation for establishing performance based determinations of significance of GHG emissions. In enacting this landmark legislation the State considered the cumulative significance of GHG emissions and established aggressive GHG emission reduction targets for key sources of GHG emissions in the state of California. ARB in carrying out its AB 32 mandates has determined that the emission reductions targets established per AB 32 can be accomplished by achieving a 29% reduction in GHG emissions from business as usual (BAU), from key GHG emission source categories (see Figure 2). Thus establishing what could be considered a de facto standard for GHG emission reductions to be achieved at the project level for GHG emission source categories.

4.3 Determining Significance Using Best Performance Standards

4.3.1 Legislative Basis for use of Best Performance Standards


The Standard

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PESC Winter 2008 Summit - REGISTER NOW!

PESC is pleased to announce that the Winter 2008 Summit will be held Thursday January 17 - Friday January 18, 2008 at the Hyatt Regency Washington on Capitol Hill. Online registration for the PESC Winter 2008 Summit is available online at www.PESC.org. Hotel reservations can be made by contacting the hotel directly at (202) 737-1234 or 1-800-233-1234. Please use the group name "PESC" to ensure you receive the discounted hotel rate of $199.00. The hotel cut-off date is Friday January 4, 2008. Thanks to our generous sponsor, Regent Education, PESC offers workgroup summits FREE of charge to all parties interested in participating. While there is no fee, space is limited and registration is required for this event. Workgroup summits, held during the fall and winter of each year, are the perfect opportunity to gather face-to-face with fellow workgroup members to collaborate on PESC initiatives, to cultivate relationships with other members, and to be updated on all PESC activities. Please keep in mind that summits are working meetings, so many of the workgroups currently active will congregate to discuss and progress on their respective standards development efforts.

Our tentative meeting schedule which includes meetings of various workgroups and boards of the Standards Forum for Education, meetings of the Steering Committee, Board of Directors and includes AACRAO's SPEEDE Committee, is on page 6.

Note that continental breakfast and registration open at 7:30am in the conference foyer on Thursday January 17, 2008. The Winter 2008 Summit kicks off from 8:30am - 5:00pm with concurrent meetings being held all day. Lunch on both days is on your own. A general session takes place from 3:30pm - 5:00pm and includes updates from PESC, the Board of Directors the Steering Committee, and all of the Workgroups and boards that met on the previous day.

See Summit, Page 2

Special Member Meeting - Thursday January 17, 2008

Please be advised that a special meeting of the PESC Membership is being called for Thursday January 17, 2008 at 5:15pm. The meeting will be held at the Hyatt Regency on Capitol Hill during the PESC Winter 2008 Summit. The purpose of the meeting is for the Board to present a revised dues schedule to the members of PESC and hold a vote as changes in dues must be approved by a majority vote of the members. The proposed changes for the next 5 years are included on page 7.

The basis for the use of performance based standards is well founded both legislatively and in implementation of legislative mandates. As presented before, SB 97 and SB 375 clearly provide for establishing either quantitative or qualitative based determinations of significance. ARB, in implementing their legislative mandate to develop guidance for assessing significance of project related GHG emissions, prepared a preliminary draft proposal that defines threshold of significance as "an identifiable quantitative, qualitative or performance level that marks the division between an impact that is significant and one that is not". In April 2009, the Governor's Office of Planning and Research (OPR) proposed several amendments to the CEQA Guidelines to address analysis and mitigation of potential effects of greenhouse gas emissions. Among the proposed amendments are provisions recognizing lead agency discretion to adopt quantitative or qualitative thresholds of significance. Specific amendments are presented below.

OPR proposed a new subdivision that emphasizes that the effects of greenhouse gas emissions are cumulative, and should be analyzed in the context of CEQA's requirements for cumulative impacts analysis. (See section 15130(f)). OPR further proposed a new subdivision to assist lead agencies in determining the significance of project related greenhouse gas emissions. (See section 15064.4.). In addition to quantification of GHG emissions, this section provides for the consideration of several other qualitative factors that may be used in the determination of significance. Per the proposed amendments, a lead agency has discretion to determine whether to:

- Use a model or methodology to quantify greenhouse gas emissions resulting from a project, or
- To rely on a qualitative analysis, or
- To apply performance based standards.

Under OPR's proposed guidance a lead agency may consider the following when assessing the significance of impacts from greenhouse gas emissions on the environment:

- The extent to which the project may increase or reduce greenhouse gas emissions as compared to the existing environmental setting; or
- Whether the project emissions exceed a threshold of significance that the lead agency determines applies to the project, or
- The extent to which the project complies with regulations or requirements adopted to implement a statewide, regional, or local plan for the reduction or mitigation of greenhouse gas emissions.

A new subdivision was added to assist lead agencies in determining methods to mitigate the effects of greenhouse gas emissions. (See section 15126.4(c)). To emphasize the advantages of programmatic planning this new subdivision emphasizes compliance with a plan among the list of potential mitigation measures. However, to qualify as mitigation, specific measures from an existing plan must be identified and incorporated into the project; general compliance with a plan, by itself, is not mitigation. Finally, this subdivision reiterates that mitigation for planning level decisions may include the development of specific measures to be implemented on a project-by-project basis.

The District favors use of performance based standards, but recognizes that performance standards have not been developed for all sources of GHG emissions. Thus, for sources not covered by ARB's scoping plan or SB 375, the District will need to invest resources and work with stakeholders, ARB, planning agencies, and other interested parties to establish source specific performance standards. This process is expected to be ongoing, as mitigation measures and techniques will evolve and improve over time, as will our understanding of those measures.

4.3.2 Determining Significance

4.3.2.1 Introduction

CEQA requires lead agencies to establish specific procedures for administering its responsibilities under CEQA, including orderly evaluation of projects and preparation of environmental documents. Each lead agency is encouraged to develop and publish thresholds of significance for use in determining the significance of environmental effects.

Determining the significance of project specific impacts of GHG emissions on global climate change is a relatively new concept, and, in the absence of uniform guidance from the state, lead agencies throughout California are facing difficulties to develop their own policies and procedures for implementing GHG CEQA requirements. The District is viewed by many in the San Joaquin Valley as the leading authority on air pollution concerns, including GHG issues, and so several lead agencies have asked the District to provide such guidance. Therefore, the District is developing guidance for its own internal use when serving as the lead agency, and is also proposing guidance to assist other agencies in establishing their own processes for determining significance of project related impacts on global climate change. The methodology being proposed relies on the use of performance based standards to assess the significance of project specific GHG emissions, and would be applicable to projects that result in increased GHG emissions. Nothing in this guidance shall be construed as limiting a lead agency's authority to adopt a statement of overriding consideration for projects with significant GHG impact.

The effects of project specific GHG emissions are cumulative, and without mitigation their incremental contribution to global climatic change could be considered cumulatively significant. The District believes that this is best addressed by requiring all projects (not just those with GHG emissions above some arbitrary "significance threshold") to reduce their GHG emissions, whether through project design elements, or mitigation. Projects achieving performance based standards that have been demonstrated to be "Best Performance Standards" would be considered to have a less than cumulative significant impact on global climate change.

Use of BPS would streamline the significance determination process by pre-quantifying the emission reductions that would be achieved by a specific GHG emission reduction measure and pre-approving the use of such a measure to mitigate project-related GHG emissions. Establishing BPS would also streamline the CEQA review process by providing project proponents, lead agencies and the public with clear guidance on how to mitigate GHG emission impacts. Thus, project proponents would be able to incorporate project specific GHG reduction measures during the initial project design phase, which could reduce or mitigate project specific GHG impacts to less than significant levels.

As presented in Chapter 5, to support a determination of significance, the efficiency of GHG emission reduction measures would be quantified at the time Best Performance Standards are established for a specific project type or source category. As shown in Appendix L, implementing BPS for stationary sources is expected to achieve an overall 34.0% reduction in GHG emissions, exceeding the overall 29% GHG emission reduction targeted by ARB in the scoping plan.

4.3.2.2 Definitions

The following definitions are provided to assist the reader in understanding the vernacular associated with the proposed approach of determining significance of project specific impacts on global climate change.

Achieved-in-Practice
Achieved-in-Practice is – Any equipment, technology, practice or operation available in the United States that has been installed and operated or used at a commercial or stationary source site for a reasonable period of time sufficient to demonstrate that the equipment, technology, practice or operation is reliable when operated in a manner that is typical for the process. In determining whether equipment, technology, practice or operation is Achieved-in-Practice, the District will consider the extent to which grants, incentives or other financial subsidies influence the economic feasibility of its use.

Approved Alternate Technology
Approved Alternate Technology is – Any District approved, Non-Achieved-in-Practice GHG emissions reduction measure equal to or exceeding the GHG emission reduction percentage for a specific BPS

Baseline
For Stationary Source projects, Baseline is – the three year average (2002-2004) of GHG emissions for a type of equipment or operation within an identified class and category, expressed as annual GHG emissions per unit.

For Residential Development projects, Baseline is – the three year average of GHG emissions from all dwelling units in the San Joaquin Valley Air District, during the 2002 through 2004 baseline period, expressed as annual GHG emissions per unit.

For Commercial and Industrial Development projects, Baseline is – the three year average of GHG emissions from all commercial or industrial units in the San Joaquin Valley Air District, during the 2002 through 2004 baseline period, expressed as annual GHG emissions per commercial or industrial unit.

Best Performance Standard
For Stationary Source Projects for which the District must issue permits, Best Performance Standard is – For a specific Class and Category, the most effective, District approved, Achieved-In-Practice means of

reducing or limiting GHG emissions from a GHG emissions source, that is also economically feasible per the definition of achieved-in-practice. BPS includes equipment type, equipment design, and operational and maintenance practices for the identified service, operation, or emissions unit class and category.

For Development Projects (Residential, Commercial or Industrial), Best Performance Standard is – Any combination of District approved, Achieved-In-Practice emission reduction measures reducing or limiting GHG emissions by in at least a 29% compared to BAU. GHG emission reduction measures include building standards, appliance standards, project design elements, and land use decisions.

Business-as-Usual
For Stationary Source Projects, Business-as-Usual is - the emissions for a type of equipment or operation within an identified class and category projected for the year 2020, assuming no change in GHG emissions per unit of activity as established for the baseline period.

For Development Projects (Residential, Commercial or Industrial), Business-as-Usual is – total baseline emissions for all emissions sources within the development type, projected for the year 2020, assuming no change in GHG emissions per unit of activity as established for the baseline period.

Category
For stationary source permitting projects, Category is – A District approved subdivision within a “class” as identified by unique operational or technical aspects.

Class
For stationary source permitting projects, Class is - The broadest District approved division of stationary GHG sources based on fundamental type of equipment or industrial classification of the source operation.

4.3.2.3 Establishing Business-as-Usual and Baseline

In executing its legislative mandate to establish emission reduction targets which would achieve the 1990 GHG emission levels by the year 2020, the California Air Resources Board (CARB) used its emission inventory to establish a three-year average for GHG emissions occurring by sector during the baseline period of 2002-2004. As presented in Figure 4, Baseline Period GHG emissions exceed 1990 emission levels by almost 10 percent. Baseline Period GHG emissions include emissions from all sources in ARB's emissions inventory, including both, old and new, large and small GHG emission sources.

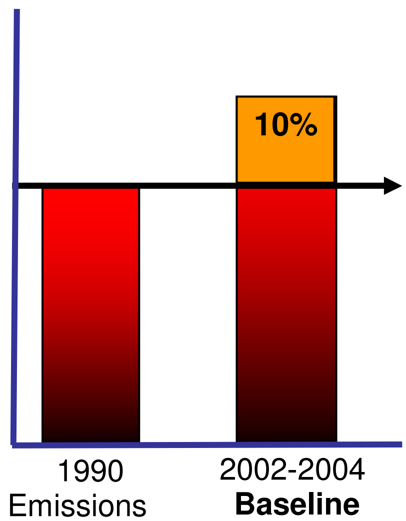
The Baseline Period emissions were then projected to the year 2020, using assumptions about potential growth, assuming no change in the existing business practices, and without considering implementation of any GHG emission reduction measures. CARB designated the baseline emissions inventory projected to the year 2020 as business-as-usual (BAU). As presented in Figure 5, CARB determined that a 29% GHG emissions reduction from BAU is necessary to achieve the 1990 GHG emissions level.

BAU, as established by CARB, is a projected emissions inventory and does not represent actual business or operational practices generating GHG emissions. Therefore, to relate BAU to an emissions generating activity, the District proposes to establish emission factors per unit of activity, for each class and category, using the 2002-2004 baseline period as the reference. For example, for a combustion process, an emissions factor could be expressed as pounds of GHG emissions generated per cubic feet of gas consumed, or pounds of GHG emissions generated per unit of production. For a residential development project an emissions factor could be expressed as annual pounds of GHG emissions generated per dwelling unit.

Thus, by comparing emissions per unit of activity, one can determine the extent to which GHG emissions from a specific source have changed compared to BAU. GHG emission reductions would be determined by establishing a GHG emissions factor per unit of activity for the proposed project and comparing it to the emissions factor established for the 2002-2004 baseline period. Projects implementing BPS, or otherwise demonstrating that GHG emissions have been reduced by 29% will be determined to have a less than significant individual and cumulative impact on global climate change. The percent reduction in GHG emissions would be calculated using the following methodology:

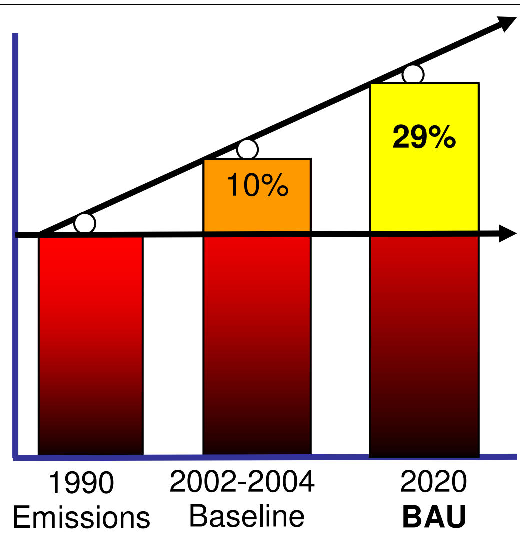
$$\%\ \text{Reduction in GHG emissions} = \frac{(\text{2002 - 2004 baseline GHG emission factor}) - (\text{Proposed project GHG emissions factor})}{\text{2002} - \text{2004 baseline GHG emission factor}}\ x100\%$$

Figure 4: 2002-2004 Baseline Period



- Baseline is a 3-year average GHG emission inventory for the 2002-2004 period
- Baseline includes emissions from all sources in existence at that time; old & new, small & large
- With no growth, the 1990 GHG target could be achieved by a 10% reduction

Figure 5: 2020 Business-as-Usual (BAU)



- BAU is a projection of the baseline emissions inventory reflecting anticipated growth to the year 2020
- ARB's 29% GHG emission reduction target is from BAU
- Projects occurring after the Baseline period may already have achieved GHG emission reductions

4.3.2.4 Determining Project Significance

The District will establish Best Performance Standards (BPS) for stationary sources permitted by the District and will propose GHG emission reduction measures to achieve BPS for development projects. BPS is intended to achieve the maximum GHG emission reductions from a stationary source project and achieve a cumulative total of at least 29% reduction in GHG emissions from development projects, compared to BAU.

In evaluating GHG emissions from a specific project the District recommends that a lead agency characterize both direct and indirect GHG emissions. Direct GHG emissions would include emissions resulting from a specific operation or process, e.g. fuel combustion emissions from a boiler. Indirect GHG emissions would include emissions resulting from project related energy consumption, e.g. electricity consumed by the production and electricity required to produce and transport water used by the project. For projects resulting in increased vehicle miles traveled (VMT), indirect GHG emissions associated with transportation related activities would also be included in the GHG emissions quantification.

Projects exempt from the requirements of CEQA would not require further analysis, including analysis of project specific GHG emissions. Projects complying with an approved GHG emission reduction plan or GHG mitigation program, which avoids or substantially reduces GHG emissions within the geographic area in which the project is located would be determined to have a less than significant individual and cumulative impact for GHG emissions. Such plans or programs must be specified in law or approved by the lead agency with jurisdiction over the affected resource and supported by a CEQA compliant environmental review document adopted by the lead agency.

Projects requiring project specific environmental review would be evaluated according to a Best Performance Standards (BPS) approach. Projects complying with the GHG emission reduction requirements established as Best Performance Standards would not require project specific quantification of GHG emissions and would be determined to have a less than significant individual and cumulative impact for GHG emissions.

Projects not complying with GHG emission reduction requirements established as Best Performance Standards would require quantification of project specific GHG emissions. To be determined to have a less than significant individual and cumulative impact on global climate change, project specific GHG emissions have to be reduced or mitigated by 29% from Business-as-Usual GHG emissions.

Projects requiring preparation of an Environmental Impact Report would require quantification of project specific GHG emissions. Projects implementing BPS or achieving at least a 29% GHG emission reduction compared to BAU would be determined to have a less than significant individual and cumulative impact for GHG.

4.3.2.5 Determining Significance for Stationary Source Projects

Introduction

CEQA requires lead agencies to establish specific procedures for administering its responsibilities under CEQA, including orderly evaluation of projects and preparation of environmental documents. Each lead agency is encouraged to develop and publish thresholds of significance for use in determining the significance of environmental effects. The San Joaquin Valley Air Pollution Control District proposes the following process for determining the individual and cumulative significance of project specific GHG emissions on global climate change when issuing permits for stationary source projects: However, nothing in this guidance shall be construed as limiting a lead agency's authority to adopt a statement of overriding consideration for projects with significant GHG impact.

District Process for Evaluating GHG Significance

- Projects determined to be exempt from the requirements of CEQA would be determined to have a less than significant individual and cumulative impact for GHG emissions and would not require further environmental review, including analysis of project specific GHG emissions. Projects exempt under CEQA would be evaluated consistent with established rules and regulations governing project approval and would not be required to implement BPS.

- Projects complying with an approved GHG emission reduction plan or GHG mitigation program which avoids or substantially reduces GHG emissions within the geographic area in which the project is located would be determined to have a less than significant individual and cumulative impact for GHG emissions. Such plans or programs must be specified in law or approved by the lead agency with jurisdiction over the affected resource and supported by a CEQA compliant environmental review document adopted by the lead agency. Projects complying with an approved GHG emission reduction plan or GHG mitigation program would not be required to implement BPS.

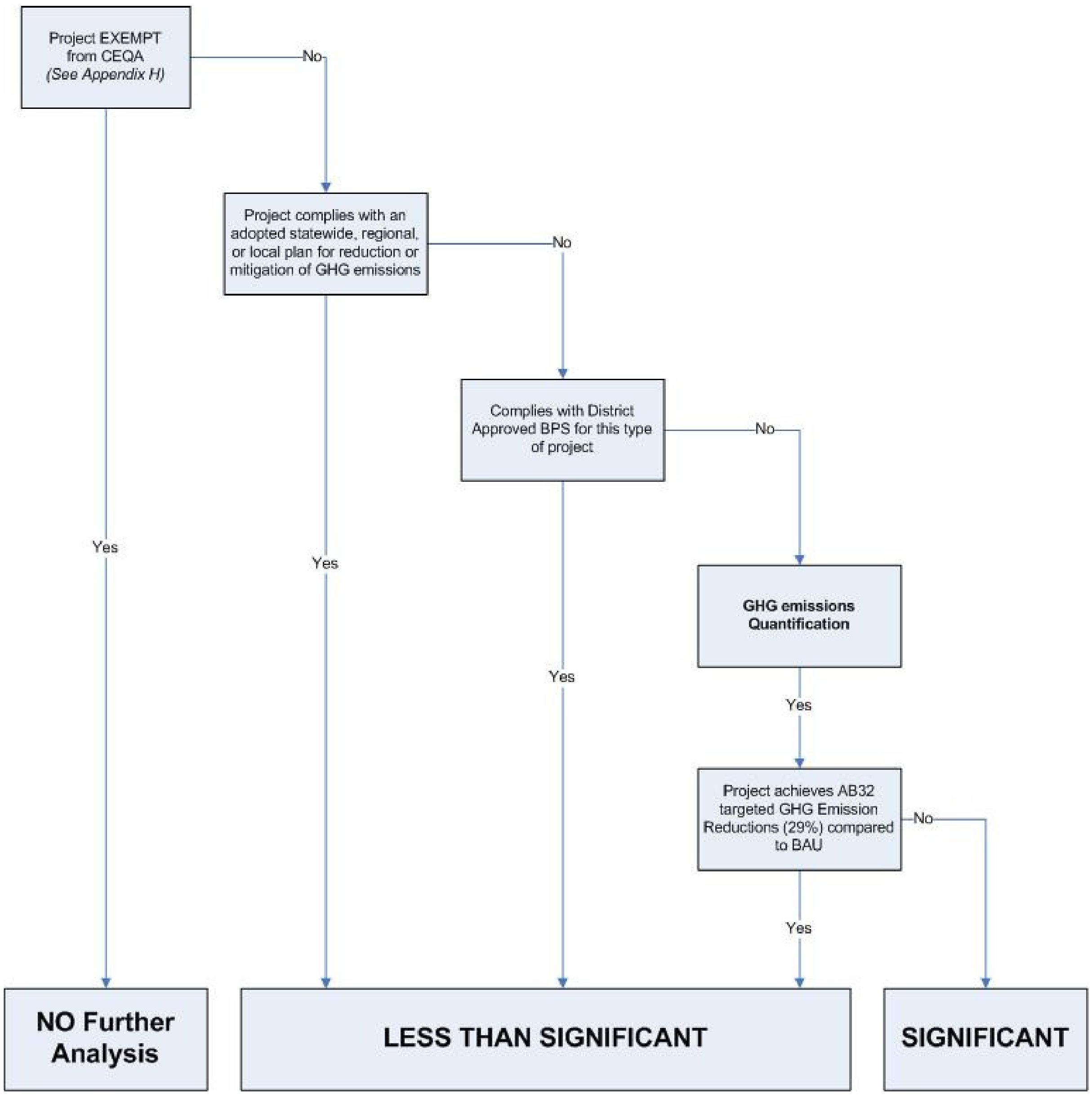
- Projects implementing Best Performance Standards would not require quantification of project specific GHG emissions. Consistent with CEQA Guideline, such projects would be determined to have a less than significant individual and cumulative impact for GHG emissions.

- Projects not implementing Best Performance Standards would require quantification of project specific GHG emissions and demonstration that project specific GHG emissions would be reduced or mitigated by at least 29%, compared to BAU, including GHG emission reductions achieved since the 2002-2004 baseline period. Projects achieving at least a 29% GHG emission reduction compared to BAU would be determined to have a less than significant individual and cumulative impact for GHG.

- Projects requiring preparation of an Environmental Impact Report would require quantification of project specific GHG emissions. Projects implementing BPS or achieving at least a 29% GHG emission reduction compared to BAU would be determined to have a less than significant individual and cumulative impact for GHG.

Figure 6 illustrates implementation of this guidance for permitted sources.

Figure 6: Stationary Source Projects with GHG Emissions



4.3.2.6 Determining Significance for Development Projects

Introduction

Determining the significance of project specific impacts of GHG emissions on global climate change is relatively new and lead agencies are finding themselves challenged to develop their own guidance. Many land use agencies have expressed serious concerns about the lack of guidance, and some have asked the District for their assistance in finding an adequate approach to address these new CEQA requirements. Therefore, the District is proposing the following guidance to assist lead agencies in establishing their own processes for determining significance of project related impacts on global climate change. Nothing in this guidance shall be construed as limiting a lead agency's authority to adopt a statement of overriding consideration for projects with significant GHG impact.

Proposed Land Use Agency Process for Evaluating GHG Significance

- Projects determined to be exempt from the requirements of CEQA would be determined to have a less than significant individual and cumulative impact for GHG emissions and would not require further environmental review, including analysis of project specific GHG emissions. Projects exempt under CEQA would be evaluated consistent with lead agency rules and regulations governing project approval and would not be required to implement BPS.

- Projects complying with an approved GHG emission reduction plan or GHG mitigation program, which avoids or substantially reduces GHG emissions within the geographic area in which the project is located would be determined to have a less than significant individual and cumulative impact for GHG emissions. Such plans or programs must be specified in law or approved by the lead agency with jurisdiction over the affected resource and supported by a CEQA compliant environmental review document adopted by the lead agency. Projects complying with an approved GHG emission reduction plan or GHG mitigation program would not be required to implement BPS.

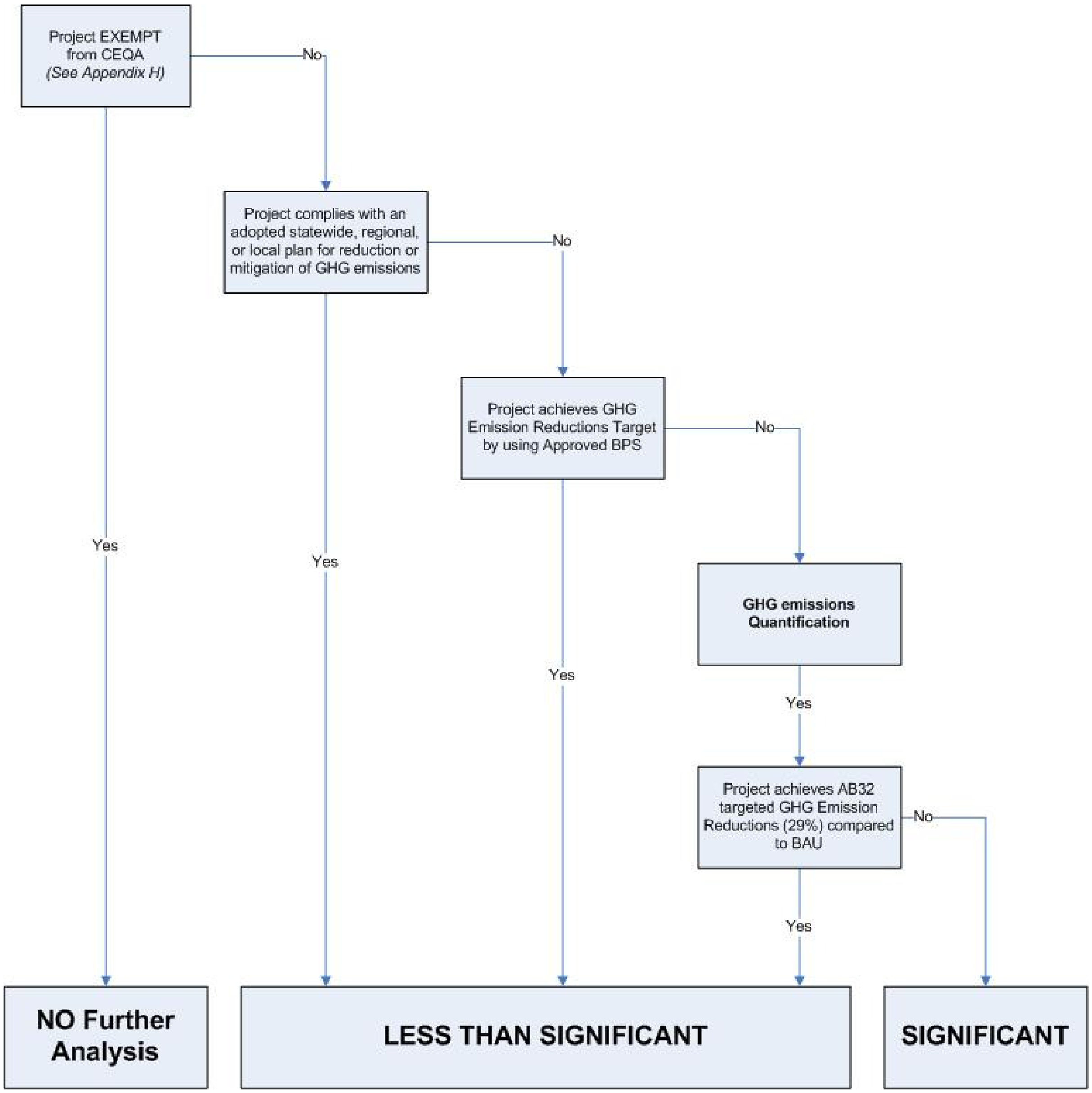
- Projects implementing BPS, reducing project specific GHG emissions by at least 29% compared to BAU, would be determined to have a less than significant individual and cumulative impact on global climate change. Reductions in project specific GHG emissions would include GHG emission reductions achieved since the 2002-2004 baseline period. Projects determined to have a less than significant individual and cumulative impact for GHG emissions would not require quantification of project specific GHG emissions.

- Projects not implementing BPS, to achieve at least a 29% reduction in GHG emissions as compared to BAU, would require quantification of project specific GHG emissions. Projects demonstrated to have reduced or mitigated project specific GHG emissions by at least 29% compared to BAU would be determined to have a less than significant individual and cumulative impact on global climate change.

- Projects requiring preparation of an Environmental Impact Report would require quantification of project specific GHG emissions. Projects implementing BPS or achieving at least a 29% GHG emission reduction compared to BAU would be determined to have a less than significant individual and cumulative impact for GHG.

Figure 7 illustrates implementation for development projects.

Figure 7: Development Projects with GHG Emissions



CHAPTER 5

DISTRICT BEST PERFORMANCE STANDARDS

5.1 Best Performance Standards - Principles

The District will establish Best Performance Standards (BPS) for stationary sources permitted by the District and will propose GHG emission reduction measures to achieve BPS for development projects for use by land use agencies in the San Joaquin Valley. BPS is intended to achieve feasible GHG emission reductions from the stationary source project and achieve a combined total of 29% reduction in GHG emissions from development projects.

Use of BPS would streamline the significance determination process by pre-quantifying the emission reductions that would be achieved by a specific GHG emission reduction measure and pre-approving the use of such a measure to mitigate project-related GHG emissions. Establishing BPS would also streamline the CEQA review process by providing project proponents, lead agencies and the public with clear guidance on how to mitigate GHG emission impacts. Thus, project proponents would be able to incorporate project specific GHG reduction measures during the initial planning phase, which could reduce or mitigate project specific GHG impacts to less than significant levels.

BPS would be established through a process approved by the District's Governing Board. As defined, BPS is the most effective, achieved-in-practice, means of reducing or limiting GHG emissions from a GHG emissions source. For traditional stationary source projects, BPS includes equipment type, equipment design, and operational and maintenance practices for the identified service, operation, or emissions unit class and category. For development projects, BPS includes project design elements, land use decisions, and technologies that reduce GHG emissions.

Establishing BPS would help project proponents, lead agencies, and the public by proactively identifying effective, feasible mitigation measures. Emission reductions achieved through implementation of BPS would be pre-quantified thus, negating the need for project specific quantification of GHG emissions. The use of BPS provides opportunity to streamline the process of determining the individual and cumulative significance of project specific GHG impacts on global climate change, conserving resources and reducing regulatory burdens.

5.2 Establishing Best Performance Standards

5.2.1 Introduction

Through implementing stationary source permitting processes and District Rule 9510 (Indirect Source Review), District staff has considerable experience in evaluating emissions control technologies and evaluating project specific emissions from stationary sources and development projects. The proposed process for establishing BPS builds upon this experience. In developing BPS District staff will solicit input from industry, manufacturers, academia, environmentalists, environmental justice groups, regulatory agencies, and other members of the public, as well as utilize the technical expertise and experience of the District's staff.

In establishing BPS for a specific equipment or operation the District's initial focus will be to establish BPS for equipment and operations that are commonly permitted or representing larger sources of GHG emissions. It is anticipated that initial Classes and Categories will be general in nature, covering a broad range of GHG emission sources. These broad categories will be refined and narrowed in scope as projects pass through the BPS development process and through associated permitting processes.

5.2.2 Public Process

BPS will be established through a public process that provides ample opportunity for stakeholders and other interested parties to participate and provide valuable input into the establishment of baseline GHG emissions and BPS.

The public process will begin with an initial outreach via the District's CCAP list server. Individuals registered with the CCAP list server will be notified when the District initiates the process of establishing BPS for a specific equipment or operation within an identified Class and Category. Individuals interested in participating in the public process would register themselves with a list server dedicated to the BPS under development. Using the dedicated BPS list server, stakeholders and other interested parities will have opportunity to provide the District with information to be considered when drafting documents establishing baseline GHG emissions and BPS. When draft documents are available on the District's website for review and comment, a notice of availability will be send via the BPS list server. Workgroups would be convened as necessary to obtain additional technical information for use in establishing baseline emissions or BPS. After receiving public input, the BPS will be finalized and posted on the District's website. Availability of final BPS will be noticed via the District's general CCAP list server.

5.2.3 Process for Establishing BPS - Stationary Source Projects

5.2.3.1 Introduction

To be approved by the District, BPS must be demonstrated to achieve real GHG emission reductions. Such reductions must be quantifiable to support a determination that project specific GHG emissions would have a less than significant individual and cumulative impact.

In evaluating GHG emissions from a specific project the District will characterize both direct and indirect emissions. Direct GHG emissions would include emissions resulting from the specific operation or process, e.g. exhaust emissions from a boiler. Indirect GHG emissions would include GHG emissions resulting from project related energy consumption, and electricity consumed by the production and transport of water used by the project. For projects resulting in increased vehicle miles traveled (VMT), indirect GHG emissions associated with transportation related activities would also be included in the GHG emissions quantification.

To ensure that the criteria discussed above are satisfied, the District proposes the following process to establish BPS:

5.2.3.2 Process for Establishing BPS for Stationary Source Projects

1. Establish Baseline GHG emissions factor per unit of activity for the proposed equipment or operation identified within a specific class and category

2. For the specific equipment or operation being proposed within a specific class and category, list all technologically feasible GHG emissions reduction measures, including equipment selection, design elements and best management practices, that do not result in an increase in criteria pollutant emissions compared to the proposed equipment or operation

3. For all technologically feasible GHG emission reduction measures identified in steps 2, identify all GHG reduction measures determined to be Achieved-in-Practice. In determining Achieved-in-Practice, consider the extent to which grants or other financial subsidies influence economic feasibility.

4. For each Achieved-in-Practice GHG emission reduction measure identified in steps 3:
   a. Quantify the potential GHG emission reduction, as compared to the Baseline GHG emissions factor per unit of activity
   b. Express the potential GHG emission reduction as a percent of Baseline GHG emissions factor per unit of activity

5. Rank all Achieved-in-Practice GHG emission reduction measures by order of percent GHG emissions reduction,

6. Deem the Achieved-in-Practice GHG emissions reduction measure(s) with the highest percent reduction in GHG emissions as the District approved Best Performance Standard (BPS) for the respective class and category of equipment or operation being proposed, and

7. Eliminate all other Achieved-In-Practice options from consideration as BPS

5.2.4 Process for Establishing BPS - Development Projects

5.2.4.1 Introduction

GHG emission from development projects primarily occur indirectly through energy consumption and vehicle miles traveled (VMT). Developers can reduce GHG emissions from energy consumption through building designs that increase energy efficiency, water conservation, and the use of energy efficient appliances. Developers can further reduce GHG emissions through project designs that reduce VMT through features that promote pedestrian access and use of public transportation. Land use planning decisions, such as creating mixed-use development, discouraging leap-frog development, and creating favorable jobs to housing ratios can significantly reduce VMT and the associated GHG emissions. For the purpose of this guidance a development project is any project, or portion thereof, that is subject to a discretionary approval by a public agency, and will ultimately result in the construction of a new building, facility, or structure, or reconstruction of a building, facility, or structure.

In should be noted that ARB considered only GHG emissions from energy consumption when establishing baseline and BAU emissions for development projects. ARB addresses VMT emission reduction strategies as part of transportation related impacts. However, District staff considers reducing VMT emissions attributable to development projects to be an integral component of the District's attainment strategy, and inclusion of proposed BPS to be a logical extension of that effort.

Given the diversity of development projects occurring in the Valley, it is not feasible to develop a single set of standards that would be applicable to all development projects. Instead, the District will establish a list of GHG emission reductions measures with pre-quantified GHG emission reduction effectiveness. Projects implementing BPS and reducing GHG emissions by 29% through any combination of GHG emission reduction measures, including GHG emission reductions achieved as a result of changes in building and appliance standards occurring since the 2002-2004 baseline period, would be considered to have a less than significant individual and cumulative impact on global climate change.

5.2.4.2 Process for Establishing BPS for Development Projects

To be approved by the District, GHG emissions reduction measures used to meet BPS must be demonstrated to achieve real GHG emission reductions. Such reductions must be quantifiable to support a determination that project specific GHG emissions would have a less than significant individual and cumulative impact. To ensure that these criteria are satisfied, the District proposes the following process to establish BPS.

1. Establish Baseline GHG emissions factor per unit of activity for residential, commercial and industrial development projects

2. For the specific development type (Residential, Commercial or Industrial), list all achieved-in-practice GHG emissions reduction measures, including building design elements, building and appliance standards, project design elements; and land use decisions

3. For each achieved-in-practice GHG emission reduction measure identified in step 2:

   a. Quantify the potential GHG emission reduction, as compared to the Baseline GHG emissions factor per unit of activity, and
   b. Express the potential GHG emission reduction as a percent of the Baseline GHG emissions factor per unit of activity

4. Any combination of approved GHG emissions reduction measures achieving a combined 29% of GHG emissions compared to the established Baseline GHG emissions factor per unit of activity is considered **Best Performance Standard** (BPS) for the respective type of development project.

5.3 Process for Reviewing Established Best Performance Standards

Implementation of strategies to achieve AB 32 emission reduction targets is anticipated to drive technology development, potentially obsolescing or improving established standards over time. Therefore, the District is proposing a process that will result in periodic review of adopted Best Performance Standards and emerging technologies. To ensure that Best Performance Standards reflect the most current available technology, the District will conduct annual reviews and revise established Best Performance Standards, if necessary, to include new and improved technologies. Revisions to BPS will only be applicable to future projects and would not be applied retroactively to projects already permitted or approved.

<u>Project-by-Project Basis</u>

Project proponents or other members of the public may propose other technologies, equipment designs, or operational/maintenance practices. When proposed by a project proponent in lieu of an adopted Best Performance Standard, the District will evaluate the proposed GHG emission reduction measure. If demonstrated to be equivalent to or better than District approved BPS, the proposed GHG emission reduction measure will be added to the list of approved BPS. If demonstrated to be superior to District approved BPS and achieved-in-practice, the proposed GHG emission reduction measure will replace the existing District approved BPS for future projects.

<u>Annual Evaluation</u>

The District will evaluate BPS on an annual basis. District approved BPS will be compared to newly identified GHG emission reduction measures, if available. If demonstrated to be equivalent to District approved BPS, new GHG emission reduction measures will be added to the list of approved BPS. If demonstrated to be superior to District approved BPS and achieved-in-practice, new GHG emission reduction measures will replace existing District approved BPS for future projects.

5.4 Best Performance Standards

During the public participation process for developing this guidance, the District received comments that the discussion of BPS should be supported by specific examples of BPS for major sources of GHG emissions. In response, the District has prepared the following illustrative examples of potential BPS. It should be noted that these examples of BPS are for illustrative purposes only, and should not be used by any lead agency as District-approved or sanctioned standards. As discussed further in this staff report, the proposed process of establishing BPS provides opportunity for public input into the development of BPS, and final BPS can only be established after such a process.

5.4.1 Best Performance Standards for Stationary Source Projects

Introduction

The District's existing CEQA Implementation District Procedure establishes a methodology to consistently evaluate potential environmental impacts from stationary source projects. This internal procedure document will be amended to incorporate requirements associated with the GHG emissions significance determinations. A particular effort will be made to streamline the process of GHG emissions impact evaluation, consistent with the best performance standard-based determination of significance discussed in this staff report.

5.4.2 Illustrative Examples of Best Performance Standards for Stationary Source Projects

The following discussion illustrates possible BPS, as presented in Appendix I, for stationary source projects and provides the bases and/or rationale for each, as well as an assessment of potential GHG emissions reduction impact relative to a 2002-2004 emissions inventory baseline.

It should be noted that these examples of BPS are for illustrative purposes only, and should not be used by any lead agency as District-approved or sanctioned standards. As discussed further in this staff report, the proposed process of establishing BPS provides opportunity for public input into the development of BPS, and final BPS can only be established after such a process.

1. Fossil Fuel-fired Boilers, Steam Generators and Process Heaters with Firing Capacity > 5 MMBtu/hour (HHV)

Illustrative BPS:

All units shall utilize gaseous fuel only and be appropriately sized and/or have adequate load following capability to avoid the venting of steam to the atmosphere except during emergency situations or during specifically identified and limited maintenance or startup/shutdown operations essential to the unit operation. In addition, each unit shall meet at least one of the two following criteria:

(1) The unit shall be designed for a minimum thermal efficiency of 95 % and shall utilize a variable frequency drive electric motor on combustion air/FGR fans or,
(2) The unit shall be designed for maximum thermal efficiency by incorporating all of the following design features: a) install adequate heat transfer surface to provide a maximum design approach of 20 °F between the stack gas temperature and the process inlet temperature, b) limit the use of flue gas recirculation (FGR) for NOx control to no more than 10 % , c) minimize excess air in combustion by

maintaining a maximum O_2 concentration of 3 volume percent in the stack gas and d) use a variable frequency drive electric motor on combustion air/FGR fans

BPS Determination

The proposed BPS for this category represents the best Achieved-in-Practice technology identified, and consists of a collection of current state-of the-art, achieved-in-practice design and operational practices for achieving maximum practical thermal efficiency and limiting GHG production. These consist of the following three elements:

1. Use of gaseous fuel which has a lower carbon content per Btu than liquid or solid fuels and thus provides lowest GHG emissions per Btu fired.

2. Appropriate boiler sizing with load following capability to minimize potential steam venting (and the associated excess GHG emissions). This requirement results in a boiler installation having sufficient turndown capability and operating flexibility to match the thermal demand without venting any steam. This may require installation of multiple smaller units rather than a single large unit and may require specific design features in the burner and controls to provide adequate load-following capability.

3. Maximum practical thermal efficiency achieved by either of the two following options:

   BPS Option 1:

   A fully condensing boiler with a minimum efficiency of 95%. For units without air preheaters, this efficiency level can only be achieved in cases where the process side inlet temperature is below 100 ^oF. Typically a boiler with 100% cold makeup would lie in this category (a tomato processing facility typically operates in this fashion).

   and,

   Utilize a variable speed electric motor on all flue gas fans to provide energy savings whenever the unit is not operating at maximum capacity.

   BPS Option 2:

   Maximize the thermal efficiency by implementing a heat recovery design based on a maximum approach of 20 ^oF between the stack gas temperature and the process inlet temperature. This represents a maximum practical achieved-in-practice heat recovery

   and,

Limit FGR to 10 % to save power on fan operation, allow lower excess air levels in the stack and improve turndown and load following response for the unit. This specification may, in effect, require use of Selective Catalytic Reduction (SCR) for NO_x emissions control in some applications. Operation with a high FGR rate requires a significantly increased horsepower for the combustion air fan operation due both to increased volumetric flow and to increased pressure drop in the unit. Additionally, operation with high FGR rates for NO_x control reduces burner stability and response and results in stack O_2 concentrations as high as 4-5% versus a more efficient 3% O_2 achievable with limited FGR rates

and,

Limit the concentration of O_2 in the stack gas to 3%. This value for O_2 concentration allows minimizing energy loss to the stack while still maintaining adequate safety margin in the operation. As mentioned above, limiting FGR rate to 10% makes this low concentration operation feasible

and,

Utilize a variable frequency drive (VFD) electric motor on all flue gas fans to provide energy savings whenever the unit is not operating at maximum capacity.

To assess the potential impact of the proposed BPS, specific equipment configurations have been established which are assumed to represent the typical (average) equipment in this category in existence at the time of the 2002-2004 emissions inventory:

Boiler: 150 psig steam boiler not equipped with an economizer, producing saturated steam at 150 psig (367 ^oF), feed water at 200 ^oF, stack temperature 407 ^oF (40 ^oF approach) and stack O_2 concentration of 4.5 %. Fan driver is a standard efficiency (85%) electric motor. Flue gas recirculation for NO_x control is 40% of total flue gas.

Steam Generator: 1250 psig steam generator producing 1250 psig steam at 65 % quality, feed water at 140 ^oF, operating at 80% of maximum rate. Stack temperature is 280 ^oF (140 ^oF approach) with 4.5 % O_2. Fan driver is a standard efficiency (85%) electric motor. Flue gas recirculation for NO_x control is 40% of total flue gas.

Process Heater: Refinery heater with 350 ^oF process inlet temperature, operating at 80 % of maximum rate with a stack temperature of 430 ^oF (80 ^oF approach) and stack O_2 concentration of 4.5%. Fan driver is a standard efficiency (85%) electric motor. Flue gas recirculation for NO_x control is 20% of total flue gas.

The following table compares the expected thermal efficiencies and GHG emissions from each equipment category during the baseline years with that which would be attained from implementation of BPS:

Summary of BPS and achieved GHG emission reductions:

BPS for: Boilers, Steam Generators and Process Heaters					
Equipment Category	**Baseline**		**Best Performance Standard**		**GHG Emission Reduction (%)**
	Thermal Efficiency (%)	GHG Emissions (lb-CO_2/MMBtu)	Thermal Efficiency	GHG Emissions (lb-CO_2/MMBtu)	
Boiler	80.6	148	**85.9**	137	**7.4%**
Steam Generator	84.0	142	**87.4**	135	**4.9%**
Process Heater	80.0	148	**82.3**	143	**3.4%**

The emission calculations for BPS in the preceding table assume that a Selective Catalytic Reduction (SCR) system has been installed for NO_x emission control and include the emissions associated with the production of ammonia required for the SCR operation. The calculations also include the impact of reduced electric power requirement for fans associated with BPS.

<u>Compliance Assurance</u>

The BPS for this category shall be enforced through design standards, equipment description, and permit conditions.

The following permit conditions will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

- *The flue gas recirculation (FGR) rate shall not exceed 10%. [California Environmental Quality Act]*

- *Oxygen concentration in the flue gas shall not exceed 3 percent by volume. [California Environmental Quality Act]*

<u>Alternate Approved Technology</u>

Other approved technologically feasible GHG emission reduction measures which are not achieved-in-practice, but offer GHG emissions reductions equal to or greater than the identified BPS are:

- Install equipment utilizing a solar energy source in lieu of fossil fuel.
- Obtain equivalent GHG emission performance by recovery and permanent sequestration of CO_2 from the exhaust of the unit.
- Fire unit with biogenic fuel derived from renewable natural or waste sources (fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)

2. Non-Emergency Flares With Rated Heat Release > 5 MMBtu/hour (HHV)

Illustrative BPS:

Combustion shall be performed in an alternate device in lieu of a flare which produces useful energy which would have otherwise been required (utilized as fuel in an engine, boiler, turbine or delivered to a natural gas pipeline, etc.) where the proposed operation is non-emergency. Emergency flares shall utilize a flow-sensing ignition device rather than a continuous pilot and non-GHG purge gas.

<u>BPS Determination</u>

The proposed BPS for this category represents the most stringent Achieved-in-Practice technology currently recognized consisting of a requirement to utilize the heating value of the material to be combusted in a device (other than a flare) which produces useful energy rather than simply exhausting the energy to the atmosphere as does a flare. Production of useful energy implies that GHG emission reductions are achieved by offsetting other energy consumption which would have been required in any event. For emergency-only flares, which are not considered to be a major source and may be a requirement for protection of public health and safety, the use of a flare may be allowed but the flare is required to operate with a flow sensing ignition system and use only non-GHG gas for purge gas to minimize GHG emissions.

To demonstrate the impact of the proposed BPS, the equipment being operated during the 2002-2004 emission inventory baseline is assumed to be a flare rated at 50 MMBtu/hr, operating at an average utilization of 50% combusting a hydrocarbon stream and utilizing a continuous natural gas-fired pilot consuming 3 scfm of natural gas for pilot and purge operations. Such a flare has estimated GHG emissions of 12,900 tons CO_2E per year. Combusting the fuel in a typical natural gas-fired engine/generator operating with a heat rate of 12,160 Btu per kWh (HHV) produces 18,140 megawatt-hours of electric power per year. This offsets approximately 7,970 tons per year of GHG emissions from utility power plants based on a California electric utility emission rate of 879 lb-CO_2/MWh (EPA eGrid data for 2004). Net GHG emissions are then determined to be 12,900 – 7,970 = 4,930 tons per year or a reduction of 62 percent.

For an emergency-only flare, the requirement to use a flow sensing ignition system would eliminate the fuel consumption by the continuous pilot and eliminate 100% of all routine GHG emissions.

Summary of BPS and achieved GHG emission reductions:

BPS for: Non-Emergency Flares			
Baseline	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Flare With Continuous Pilot	Utilize Alternate Device Producing Useful Energy (Gas-Fired Engine/Generator)	CO_2	**62%**

Compliance Assurance

The BPS for this category shall be enforced through design standards, equipment description, and permit conditions.

The following permit conditions will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

Approved Alternate Technology

An approved technologically feasible GHG emission reduction measure which is not achieved-in-practice, but offers GHG emissions reductions equal to or greater than the identified BPS is:

- Obtain GHG emission performance equivalent to BPS by recovery and permanent sequestration of CO_2 from the exhaust of the unit.

3. Non-Emergency Onsite Electric Power Generation with Fossil Fuel Combustion > 5 MMBtu/hour or With Fossil Fuel-Fired Mechanical Driver > 50 bhp.

Illustrative BPS:

Electric power supply shall be provided solely by a PUC-licensed electric utility in lieu of a fossil fuel-fired unit except for facilities meeting any of the following criteria:

1. *Emergency standby power generation, or*
2. *Power generation from a cogeneration unit*

BPS Determination

The proposed BPS for this category represents the most stringent Achieved-in-Practice technology currently recognized consisting of a requirement to utilize electric power obtained from the public utility electric power grid rather than produce power for private use except for cases where standby emergency power is required. Generation of emergency standby power is not considered to be significant source and thus no specific BPS is required for this case. Cogeneration units

are covered by a separate BPS and are required by the BPS for that class of operation to generate electric power with an incremental GHG emissions rate which is lower than the emissions rate for electric utility generation in California.
To assess the potential impact of the proposed BPS, the equipment operated during the 2002-2004 baseline emission inventory is assumed to be a natural gas-fired IC engine powering a generator and operating at a typical heat rate of 13,000 Btu/kWh (HHV). Expected GHG emissions are 1.52 lb-CO_2/kWh. Converting this operation to utility-supplied electric power per the BPS would yield an alternative emission factor of 0.879 lb-CO_2/ kWh (per EPA eGrid emission data for California (2004)). Net emission reduction from the base case would therefore be 1.52 – 0.879 = 0.64 lb-CO_2/ kWh or 42 %.

Summary of BPS and achieved GHG emission reductions:

BPS for: Non-Emergency Onsite Electric Power Generation			
Baseline	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Natural Gas Engine/Generator	Utility-Supplied Power	CO_2	**42%**

<u>Compliance Assurance</u>

Since compliance with the BPS is achieved by meeting the design standard (installation of an electric motor which does not require a District permit), no enforcement provisions are applicable or necessary.

<u>Approved Alternate Technology</u>

Three other approved technologically feasible GHG emission reduction measures which are not achieved-in-practice, but offer GHG emissions reductions equal to or greater than the identified BPS are:

- Utilize solar energy source in lieu of firing fossil fuels.
- Obtain GHG emission performance equivalent to BPS by recovery and permanent sequestration of CO_2 from the exhaust of the unit.
- Utilize biogenic fuel derived from renewable natural or waste sources in lieu of fossil fuel (biogenic fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)

4. Non-Emergency Mechanical Equipment Driver (requirement in lieu of reciprocating IC engines > 50 hp and combustion turbines > 3 MMBtu/hour excluding combustion turbines in cogeneration service)

Illustrative BPS:

A non-emergency mechanical equipment driver shall consist of an electric motor, in lieu of a fossil fuel-fired unit, with energy efficiency meeting the efficiency criteria for Premium Efficiency Electric Motors as specified in the National Electical Manufacturer's Association (NEMA) Standard MG-1 or, upon District approval of submitted documentation which corroborates a claim by the applicant that such electric motor is not feasible, applicant may install a motor with efficiency equal to the maximum available for the proposed class of motor.

<u>BPS Determination</u>

The proposed BPS for this category, applicable to both proposed stationary and transportable operations, represents the most stringent Achieved-in-Practice technology currently recognized consisting of a requirement to utilize a premium efficiency electric motor in lieu of a fossil fuel-fired device (IC engines, gas turbines, etc.) to power mechanical equipment such as pumps and compressors. This BPS achieves GHG emission reductions due to the average emission rate for power production at utility power plants being lower than that which can be achieved by a fossil fuel-fired equipment driver. The specification of premium efficiency for the electric motor per the stated NEMA standard may not be universally applicable for certain specialized motors which is recognized in the BPS by allowing a lower efficiency based on approved documentation attesting to the infeasibility of the premium efficiency standard.

An electric motor offers lower GHG emissions than any available fossil fuel-fired equipment driver. Assuming a premium 95 % efficient motor, energy use per brake horsepower is 0.7457 kWh/bhp-hr ÷ 95% = 0.785 kWh/bhp-hr. For California, GHG emissions for electricity use are 0.879 lb/kWh (per EPA eGrid emission data for California (2004)) which results in an electric motor GHG emission factor of 0.69 lb-CO_2/bhp-hr. For comparison, a standard efficiency motor at 85% has an emissions factor of 0.77 lb-CO_2/bhp-hr. As a base case to represent equipment operated during the 2002-2004 emission inventory baseline, a natural gas-fired IC engine with a heat rate of 9500 Btu/hp-hr (HHV) is assumed which has a CO_2 emission rate of 1.11 lb-CO_2/hp-hr (approximately 10% higher than currently available engines). Comparing the natural gas engine as a base case with a premium efficiency electric motor (BPS) based on the above values, a potential GHG emission reduction of 47% is indicated.

Summary of BPS and achieved GHG emission reductions:

BPS for: Non-Emergency Mechanical Equipment Driver			
Baseline	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Natural Gas Engine	Premium Efficiency Electric Motor	CO_2	**47%**

<u>Compliance Assurance</u>

Since compliance with the BPS is achieved by meeting the design standard (installation of an electric motor which does not require a District permit), no enforcement provisions are applicable or necessary.

<u>Approved Alternate Technology</u>

Two other approved technologically feasible GHG emission reduction measures which are not achieved-in-practice, but offer GHG emissions reductions equal to or greater than the identified BPS are:

1. Power equipment using a renewable energy source such as solar or wind in lieu of fossil fuel.
2. Utilize biogenic fuel derived from renewable natural or waste sources in lieu of fossil fuel (fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria).

5. Fossil Fuel-Fired Cogeneration (combustion turbines > 3 MMBtu/hr or other combustion devices > 5 MMBtu/hour)

Illustrative BPS:

Fossil fuel- fired cogeneration systems shall be designed to achieve an incremental GHG emission rate not exceeding 700 lb-CO_2 per MWh at the system's design operating point based on power output at the generator terminals, assuming the process thermal demand could alternatively be met by direct fuel firing with 90% thermal efficiency. Heat recovery design shall maximize thermal efficiency by installing adequate heat transfer surface to provide a maximum 20 ^oF approach between stack gas temperature and the process inlet temperature

<u>BPS Determination</u>

Well-designed gas turbine cogeneration systems are generally capable of achieving incremental GHG emission rates below 700 CO_2/MWh depending upon the specific system design and the extent to which the gas turbine operating profile matches the required process thermal load. This standard provides significantly lower emissions when compared to the capacity-rated average emission factor of 915 lb-CO_2/MWh for existing base-loaded combined cycle gas turbine power plants (CCGT) in California based on 2004/2005 CEMS data as stated in the Public Utilities Commission (PUC) Decision 07-01-039 (1/25/07), <u>Greenhouse Gas Emissions Performance Standard</u>. A cogeneration system operating per the BPS would thus supplant base loaded CCGT electricity in California, providing an emission reduction of 915 – 700 = 215 lb-CO_2/MWh or a reduction of 24 %. The BPS also significantly exceeds the performance standard of 1,100 lb- CO_2/MWh for new base load CCGT power generation as adopted by the PUC in the above-referenced Decision 07-01-039. Recognizing that a well designed cogeneration project can inherently produce power at a lower incremental GHG emission rate than the electric utility, selection of a BPS of 700 lb CO_2/MWh seeks to effectively promote efficient cogeneration projects by establishing a standard which generally be achieved by most commercially available gas turbines when applied to a well-designed project while establishing a significant margin below the current GHG emission rate of base loaded utility CCGTs. The heat recovery specification of this BPS requires a 20 ^{o}F approach between process inlet temperature and the stack gas temperature which ensures both a state-of-the-art efficiency in the heat recovery design and an efficient overall cogeneration system design.

Since this category of equipment generates electric power for the utility grid and would most likely supplant baseload CCGT power, equipment operated during the 2002-2004 emission inventory baseline is assumed to be the measured average for baseload CCGT power generation stated above:

Summary of BPS and achieved GHG emission reductions:

BPS For: Fossil Fuel-Fired Cogeneration			
Baseline	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Baseload Electric Utility CCGT Power Plant	Fossil-Fueled Cogeneration System with GHG Emission Rate Not Exceeding 700 lb CO_2/MWh	CO_2	24%

<u>Compliance Assurance</u>

The BPS for this category shall be enforced through design standards, equipment description, and permit conditions.

The following permit conditions will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

Approved Alternate Technology

An approved technologically feasible GHG emission reduction measure which is not achieved-in-practice, but offers GHG emissions reductions equal to or greater than the identified BPS is:

- Utilize biogenic fuel derived from renewable natural or waste sources in lieu of fossil fuel (biogenic fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)

6. Landfill Operations

Illustrative BPS:

Landfills shall comply with CARB Regulation to Reduce Methane Emissions From Municipal Solid Waste Landfills[8].

BPS Determination

The proposed BPS for this category represents the most stringent Achieved-in-Practice GHG emission control method and consists of the following element:

Landfills are a major source of methane emissions. Landfills shall comply with CARB Regulation *to Reduce Methane Emissions From Municipal Solid Waste Landfills.* As organic matter inside the landfill decomposes in the oxygen deficient subterranean environment, methane is released as a byproduct of the anaerobic decomposition. The methane migrates upwards to the surface of the landfill where it is emitted into the atmosphere through pores, cracks and fissures on the landfill surface. Methane may also migrate through underground channels and waterways and be emitted at other locations far from the landfill.

Currently, many landfills are required to install and operate a methane capture and control system. Such a system typically consists of wells sunk into the

[8] www.arb.ca.gov/regact/2009/landfills09/isor.pdf

landfill and connected to a vacuum pump to draw the Methane to a central location instead of allowing it to escape as fugitives from the landfill surface. Once collected, the gas may be flared of or combusted in an energy recovery device such as an IC engine. The methane is converted to CO_2, which is a much less potent GHG, during the combustion. Energy recovered may also displace the use of non-renewable fossil fuels such as diesel, thereby providing an added GHG reduction benefit.

The proposed *CARB Regulation to Reduce Methane Emissions From Municipal Solid Waste Landfills*, which is due to be adopted in early 2010, will enhance capture and control of CH4 from municipal waste landfills. The regulation is expected to reduce CH4 emissions by about 0.07 million metric tons[9], which represents a reduction of approximately 23.8% from current standards.

The regulations includes CH4 reduction strategies such as installation of collection and control systems for landfills that would otherwise be exempt by current regulations, design of collection and control systems to capture maximum amounts of CH4 produced, continuous operation of CH4 control equipment, Improved leak standards (200 ppmv) for CH4 collection and control system components as well as landfill surface emissions, 99% CH4 destruction efficiency for flares and methane-fire energy recovery devices, and other enhanced source testing, inspection, monitoring and operating standards.

This BPS is considered achieved in practice because it represents a strengthening and tightening of existing CH4 control methods, rather than an introduction of new or previously untested methods. As previously stated, many landfills are currently required to install CH4 capture and control systems, typically consisting of collection wells connected to a vacuum pump and a flare for combustion of the captured gas. Fugitive landfill surface CH4 emissions must also be monitored. Although not currently required, some landfills use the collected CH4 for electricity generation or heating.

This BPS would require that additional landfills that are currently exempt or not required to install capture and control systems be required to do so. In addition, the BPS will require that the capture systems be designed for maximum extraction of CH4 in order to minimize fugitive emissions that are often due to poor capture efficiency. The BPS will also require maximum efficiency, 99%, in the control of the captured CH4.

Thus, all of the elements that constitute the BPS are methods currently in use in one form or another. When such control methods are applied in a more rigorous

[9] www.arb.ca.gov/regact/2009/landfills09/isor.pdf, Page ES-2

and effective manner, over a larger number of sources, significant CH4 reductions can be realized.

Summary of BPS and achieved GHG emission reductions:

BPS for: Landfill Operations				
Category	**Baseline**	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Landfills	The baseline scenario is that some landfills are currently required to have Methane capture and control systems, but the standards are not as stringent as proposed in the BPS	Landfills shall comply with CARB Regulation to Reduce Methane Emissions From Municipal Solid Waste Landfills	CH4	**23.8%**

Compliance Assurance

The BPS for this category shall be enforced by a combination of design standards, equipment description and permit conditions.

The following permit conditions will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

- *Landfills shall comply with all emission limits, operation, inspection, source testing and monitoring requirements as approved under the CARB Regulation to Reduce Methane Emissions From Municipal Solid Waste Landfills. [California Environmental Quality Act]*

7. Wastewater Treatment Operations

Illustrative BPS:

Wastewater treatment facilities shall incorporate both of the following two control measures:

(1) Sludge: Sludge shall be treated anaerobically in digesters, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment; and

(2) Liquid Waste: At least 33% of electricity used for liquid waste aeration shall be derived from renewable energy sources, based on grid power the Renewables Portfolio Standard (RPS), and/or supplementation of grid with onsite generation using renewable energy sources such as, but not limited to, biogas, biomass, solar, and wind.

BPS Determination

The proposed BPS for this category represents only Achieved-in-Practice emission control methods, and consists of the following elements:

1. Sludge shall be treated anaerobically in digesters, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment: Anaerobic treatment of sludge is achieved in practice because it is commonly used by municipal wastewater plants. Some smaller plants, however, may use some form of aeration or aerobic treatment for sludge.

   The sludge is typically treated in a covered tank digester. The captured methane may be flared or, again depending on the size of the treatment plant, used to generate supplemental electricity onsite. Many treatment plants currently use IC engines for generation of electricity from methane, although some use fuel cells. This BPS will require anaerobic treatment of sludge, maximum capture of Methane, and the use of captured methane for energy recovery in a method that displaces current or required use of fossil fuels.

Such methods may include generation of onsite electricity using equipment, such as a fuel cell, that emits less GHG and criteria pollutants than grid power generation, the injection of purified biogas into natural gas pipeline, or compressing the gas and using it to power mobile equipment such as trucks.

2. Electricity generation using fossil fuels such as natural gas, oil and coal is a major contributor to global warming emissions, increased use of non-fossil fuels or renewable energy sources such as biogas, biomass, wind and solar will result in the reduction of GHG emissions.

   Water and wastewater services account for up to 4% of all electricity consumption nationally, and 6.9% of all electricity consumption in California10. A significant proportion of this energy consumption goes toward the treatment of wastewater. Further, approximately 50% of the electricity consumed by a typical wastewater treatment plant is used for the aeration of the wastewater11.

   The aeration process involves the bubbling of air into the water to provide oxygen for aerobic microbes that digest organic matter in the water. Electric pumps are used to force air into the water.

   Since 2002, power suppliers in California have been required to procure a certain percentage, known as the Renewables Portfolio Standard (RPS), of electricity from renewable sources. In 2002, Senate Bill 1078 set the RPS at 20% by 2017, meaning that by 2017 power suppliers were to procure at least 20% of their electricity from renewable sources. In 2003 the RPS was accelerated to 20% by 2010, and in 2008 the Governor issued an Executive Order setting a higher RPS standard at 33% by 2020.

   Thus, the use of an RPS is an achieved-in-practice method for the control of emissions associated with electricity consumption. The District therefore considers the application of the current RPS to be a BPS for wastewater aeration. The proposed BPS will require wastewater facilities to implement the 33% RPS, for electricity used in wastewater aeration, as a condition of approval. Since grid power is not expected to attain a 33% RPS until 2020, facilities seeking approval prior to 2020 will have to supplement grid power with onsite generation using renewable energy sources such as, but not limited to, biogas, biomass, wind and solar.

[10] http://www.energy.ca.gov/2004publications/CEC-500-2004-901/CEC-500-2004-901.PDF, page 2
[11] http://www.energy.ca.gov/process/pubs/encina.pdf, page 2, Aeration.

The baseline RPS, based on the AB32 scoping plan, is 12%[12]. Thus, the application of a 33% RPS will result in a reduction of 21% of GHG emissions from electricity used in wastewater aeration.

Approved Alternate Technology

An approved technologically feasible GHG emission reduction measure which is not achieved-in-practice, but offers GHG emissions reductions equal to or greater than the identified BPS is:

- Wastewater shall be treated anaerobically in digesters or covered ponds, with captured Methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment.

Currently, wastewater plants separate sewage into two main streams: biosolids/sludge and liquid sewage. The biosolids are generally treated anaerobically in digesters and the produced Methane gas is captured and used for onsite electricity or heat generation. The liquid sewage is treated aerobically in large aeration ponds or ditches in which air if forcefully bubbled. Aerating the liquid sewage is a very energy intensive process, considering that oxygen is not soluble in water. If treatment of liquid sewage were to be done anaerobically there would be large reductions in the energy required for wastewater treatment, and a corresponding reduction in GHG emissions associated with power generation. In addition, anaerobic treatment of liquid sewage would large quantities of Methane, which can be used as a renewable energy source to replace fossil fuel use.

Since liquid waste aeration is responsible for approximately 50% of electricity consumption at a typical wastewater treatment plant, the use of anaerobic treatment of the liquid waste can cut electricity use by 50%, which represents a corresponding 50% reduction in CO_2 emissions associated with liquid waste aeration.

Anaerobic treatment is the process in which anaerobic microbes (those that do not require oxygen for respiration) digest organic matter and produce Methane and water as byproducts. Anaerobic treatment is a passive process that does not require the use of much energy, except in some cases sometimes heat is required to accelerate the process, especially in very cold climates.

Anaerobic treatment is widely used in California for onsite wastewater treatment by facilities such as dairies, wineries, cheese plants, slaughterhouses and other industrial sources use anaerobic treatment. In many cases anaerobic treatment of the wastewater is coupled with a methane capture system and the use of the

[12] http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf, Page 46.

captured methane for onsite electricity generation or heating. Several dairies have also demonstrated other renewable energy recovery methods such as injection of purified biogas into the natural gas pipeline, and use of compressed biogas as mobile equipment fuel. Such onsite treatment facilities generally handle a small quantity of wastewater with a high oxygen demand. The District also was able to identify one municipal wastewater treatment plant that uses anaerobic treatment for the liquid portion of the waste[13]. The treatment plant, located in the United Kingdom, is a small facility handling wastewater from a population of 5,000.

Based on this information, the District concluded that, although technologically feasible, anaerobic treatment of municipal wastewater, at a scale required to serve a typical city or municipality, is not achieve-in-practice.

The main difficulty with the use anaerobic treatment is the large quantity of wastewater handled at typical municipal treatments plants. Since anaerobic treatment is a much slower process requiring sequestration in ponds or tanks for at least several days, the volume and space that would be required for treatment at typical municipal plants would be prohibitive.

However, anaerobic treatment of wastewater is a field that is being actively researched. One of the main objectives of the on-going research is the reduction of the hydraulic retention time required for proper treatment time. For instance, in a recent study published in the International Journal of Environmental Science and Technology, researchers were able to demonstrate using a laboratory scale that anaerobic treatment of wastewater using a method known as Hybrid Upflow Anaerobic Sludge Blanket (HUASB) Reactor reduced the required hydraulic retention time to 3.3 hours[14].

It is therefore possible that in the near future this treatment method will become more and more practical for application to large municipal wastewater treatment facilities.

[13] http://www.ecovation.com/installations/domestic-sewage-treatment.html

[14] Banu, J.R.; Kaliappan, S.; Yeom, I.T., (2007). Treatment of domestic wastewater using upflow anaerobic sludge blanket reactor. Int. J. Environ. Sci. Tech., 4 (3), 363-370.

Summary of BPS and achieved GHG emission reductions:

BPS for: Wastewater Treatment Operations				
Operation	**Baseline**	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Sludge Treatment	Baseline period standard practice is the treatment of sludge anaerobic digesters, with energy recovery for some facilities and flaring for others	(1)Sludge shall be treated anaerobically in digesters, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment; and	CH4	**0% (not quantifiable due to variability in current use of captured CH4)**
Wastewater Treatment	Baseline renewables portfolio, per AB32 Scoping Plan, is 12%	(2) At least 33% of electricity used for wastewater aeration shall be derived from renewable energy sources, based on grid power Renewables Portfolio Standard (RPS), and/or supplementation of grid with onsite generation using renewable energy sources such as, but not limited to, biogas, biomass, solar, and wind	CO_2	**21%**
Wastewater Treatment Alternate	Aerobic treatment, requiring energy-intensive aeration	**ALTERNATE for (2):** Wastewater shall be treated anaerobically in digesters or covered ponds, with captured Methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment	CO_2	**50%**

Compliance Assurance

The BPS for this category shall be enforced through design standards and equipment description.

The following permit condition will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

8. Oil and Gas Extraction, Storage, Transportation and Refining Operations

Illustrative BPS:

Fugitive Methane emissions shall be minimized by applying VOC Leak Standards, as contained in District Rules 4409 and 4455 to components handling methane.

BPS Determination

The proposed BPS for this category represents the most stringent Achieved-in-Practice emission control method and consists of the following element:

Fugitive Methane emissions shall be minimized by applying VOC Leak Standards, as contained in District Rules 4409 and 4455 to components handling methane: These District rules are intended to minimize fugitive VOC emissions from components used in oil and gas extraction, storage, transportation, and refining.

District Rule 4409 applies to components containing or contacting VOC streams at light crude oil production facilities, natural gas production facilities, and natural gas processing facilities. District Rule 4455 applies to components containing or contacting VOC at petroleum refineries, gas liquids processing facilities, and chemical plants.

The components affected include valves, fittings, threaded connections, pumps, compressors, pressure relief devices, pipes, polished rod stuffing boxes, flanges, process drains, sealing mechanisms, hatches, sight-glasses, meters or seal fluid systems in VOC service.

The rules set leak standards ranging from 200 ppmv to 10,000 ppmv, depending on the type of component, as well as inspection and monitoring standards for all components.

Since the primary purpose of these rules is to control VOC emissions, they do not apply to components at oil production facilities and gas production facilities exclusively handling gas/vapor or liquid with a VOC content of 10% by weight or less; or components at natural gas processing facilities exclusively handing gas/vapor or liquid with a VOC content less than one 1% by weight. The rules also do not apply to components handling commercial grade natural gas.

Thus, the application of these rules to components handling Methane, or those currently exempt because they handle a larger proportion of Methane than VOC, will result in a significant reduction in fugitive Methane emissions. Such an approach therefore can be considered BPS for this category. The method is achieved in practice because the rules are currently being applied to the majority of components, including those with a certain proportion of Methane in their streams.

The District's staff report for rules 4409 and 4455 found that the implementation of these rules with stricter leak standards and increased inspection and monitoring requirements will results in a 60.2% reduction in fugitive VOC emissions. The proposed BPS assumes that a similar reduction in fugitive Methane emissions will be realized by application of the same strict leak, inspection and monitoring standards.

The California Air Resources Board (ARB) is due to promulgate a regulation in 2010 for the control of fugitive Methane emissions from the oil and gas industry. ARB has indicated that their rule is very likely to follow a similar approach as District Rules 4409 and 4455, by establishing leak standards for various components and setting strict inspection and monitoring requirements.

Summary of BPS and achieved GHG emission reductions:

BPS for: Oil and Gas Extraction, Storage, Transportation and Refining Operations				
Category	**Baseline**	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Oil and gas extraction, storage, transportation and refining	No leak standards or inspection and monitoring requirements for CH4 currently or during baseline period of 2002 - 2004	Fugitive Methane emissions shall be minimized by applying VOC Leak Standards, as contained in District Rules 4409 and 4455 to components handling methane	CH4	**60.2%**

Compliance Assurance

The BPS for this category shall be enforced by a combination of design standards, equipment description and permit conditions.

The following permit conditions will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

- *Oil and Gas Extraction, Storage, Transportation and Refining operations shall apply the leak standards and the inspection and monitoring plans as approved under Rules 4409 and/or 4455 to Methane emissions. [California Environmental Quality Act]*

9. Farming Operations – Livestock Rearing

Illustrative BPS:

All operations shall utilize all three following control measures:

(1) All ruminant animal feed shall include at least 6% cottonseed, or, upon District approval, based on sufficient demonstration that use of cottonseed is not feasible, an equivalent substitute; and,

(2) Manure from animal housing areas for mature cows shall be removed and transferred into appropriate treatment facilities at least four times a day and at least once a day for all other animals; and

(3) Collected manure shall be treated anaerobically in digesters or covered lagoons, designed and operated per NRCS standards, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment.

<u>BPS Determination</u>

The proposed BPS for this category represents the most stringent Achieved-in-Practice emission control methods and consists of the following three elements:

1. All ruminant animal feed shall include at least 6% cottonseed, or, upon District approval, based on sufficient demonstration that use of cottonseed is not feasible, an equivalent substitute: Ruminant animals such as cows and goats produce Methane from the first stomach, known as the rumen, where fermentation of animal matter is carried out by microbes. The methane is emitted through the mouth when the animal burps.

   Diet management is one of the achieved-in-practice methods that can be used to reduce Methane emissions from the rumen. Since Methane is a byproduct of the fermentation of crude plant matter, a diet that incorporates nutrient concentrates and simple sugars and limits crude plant matter will result in less Methane emissions. However, there is no reliable scientific research or data quantifying the reductions of Methane from such diets or providing specific formulas in a manner that could facilitate enforcement or monitoring.

The District was however been able to find credible scientific studies that demonstrated that a significant amount of Methane reductions, ranging from 12% to 36%, can be achieved by incorporating dietary oils such as cottonseed into ruminant animals' diets. Beauchmin et al. (2007)15 reported Methane reductions of up to 36% by feeding 6% cottonseed, while Grainger et al. (2007)16 reported a 12% Methane reduction. The District will use the more conservative 12% reduction reported by Grainger at this time.

2. Manure from animal housing areas (mature cows) shall be removed and transferred into appropriate treatment facilities at least four times a day and at least once a day for all other animals: The primary purpose of frequent removal of manure from the animal housing areas is to reduce VOC emissions from the decomposition of fresh manure. However, based on a news alert issued by Science for Environment Policy, frequent removal of manure from the housing areas has also been found to reduce GHG emissions by up to 7.1%[17]**.** Due to other requirements such as BACT and BARCT, livestock operations that are subject to District permit requirements are usually required to clean animal housing areas at least two to four times a day. It is therefore likely that GHG emission reductions will be higher for such facilities, but in order to be conservative, the District will assume only a 7.1% reduction for all facilities.

3. Collected manure shall be treated anaerobically in digesters or covered lagoons, designed and operated per NRCS standards, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment: Anaerobic treatment is the process in which Methanogenic microbes decompose or digest organic compounds in manure, in the absence of Oxygen, and produce Methane, Carbon Dioxide and water as by products. Anaerobic decomposition of manure

[15] Beauchemin, K.A., Kreuzer, M., O'Mara, F., and McAllister, T.A. (2008). "Nutritional management for enteric methane abatement: a review.", Australian Journal of Experimental Agriculture, 48(1-2), pp. 21-27. DOI: 10.1071/EA07199.

[16] Grainger, C., Clarke, T., Beauchemin, K.A., McGinn, S.M., and Eckard, R.J. (2008). "Supplementation with whole cottonseed reduces methane emissions and can profitably increase milk production of dairy cows offered a forage and cereal grain diet.", Australian Journal of Experimental Agriculture, 48(1-2), pp. 73-76. DOI: 10.1071/EA07224.

[17] http://ec.europa.eu/environment/integration/research/newsalert/pdf/49na1.pdf

occurs naturally in many parts of livestock operations such as open corrals. When manure decomposes naturally, Methane is released into the atmosphere as fugitive emissions.

A critical strategy for the reduction of such fugitive Methane emissions is to collect as much of the manure as possible and subject it to anaerobic decomposition in a controlled device such as a digester or covered lagoon. The Methane emitted from such a treatment device is easily captured and used for energy recovery to displace the use of fossil fuels and to convert it to Carbon Dioxide, which has a much lower global warming potential.

In most typical livestock operations such as dairies, it is feasible to collect, on average, approximately 71% of the manure by designing the animal housing and feeding areas so that most of the manure is deposited on paved lanes that can be flushed or vacuumed. Methane produced from the collected manure can be captured with an estimated effectiveness of 95%.

The captured methane will be used for energy recovery in a manner that will displace the use of non-renewable fossil fuels and will also not significantly increase criteria pollutants such as NOx. The capture methane can be utilized, but not limited to, injection into the natural gas pipeline, or powering mobile equipment such as farm trucks. It is estimated that combustion of biomethane for energy recovery will convert up to 99% of the Methane into Carbon Dioxide. Taking the effect of the CO_2 produced from the combustion of CH4 into account, an overall reduction of 63.5% of fugitive CH4 emissions can be achieved by the use of properly designed and controlled anaerobic treatment as a BPS.

The expected reduction is calculated as follows:

Percentage of Methane reduced = [Percentage of manure collected into digester x percentage of methane captured from digester x percentage of methane converted to CO_2] – [methane equivalent of CO_2 produced, as a percentage of methane combusted]
= [71% x 95% x 99%] – [71% x 95% x 99%]/21
= 66.7% - 3.2%
= 63.5%.

The use of bio-methane to displace gasoline results in a 25.2% reduction in CO_2 emissions, as discussed below, assuming compressed bio-methane to be in all respects similar to compressed natural gas:

According to the California Climate Action Registry General Reporting Protocol (Carbon Dioxide Emission Factors for Transport Fuels, Page 94**),** gasoline emits 8.81 kg CO_2 per gallon, while compressed natural gas emits 5.31 Kg CO_2 per Therm.

1 Therm = 100,000 Btu
Energy content of 1 gallon of gasoline = 124,000 Btu

Adjusting the gasoline CO_2 emission factor to 100,000 Btu, (8.81/1.24) = 7.10 Kg CO_2 per Therm.

Reduction in CO_2 = 7.10 – 5.31 = 1.79
% reduction = 1.79/7.10 x 100 = 25.2%

The use of captured methane to displace diesel results in a 27.3% reduction in CO_2 emissions, as discussed below, assuming compressed bio-methane to be in all respects similar to compressed natural gas:

According to the California Climate Action Registry General Reporting Protocol (Carbon Dioxide Emission Factors for Transport Fuels, Page 94**),** diesel emits 10.15 kg CO_2 per gallon, while compressed natural gas emits 5.31 Kg CO_2 per Therm.

1 Therm = 100,000 Btu
Energy content of 1 gallon of diesel = 139,000 Btu

Adjusting the diesel CO_2 emission factor to 100,000 Btu, (10.15/1.39) = 7.30 Kg CO_2 per Therm.

Reduction in CO_2 = 7.30 – 5.31 = 1.99
% reduction = 1.99/7.30 x 100 = 27.3%

The baseline emissions for the livestock operations can be assumed to be the same as the 2002 – 2004 used by the AB32 Scoping Plan, since livestock operations have not changed much since that period. Although permit requirements for many livestock farms took effect in 2004, the particular BPS proposed, with the exception of frequent manure removal from livestock housing areas, have never been implemented as mandatory permit requirements. Instead, many other control measures aimed at reducing VOC and PM10 emissions have been applied with greater emphasis.

Summary of BPS and achieved GHG emission reductions:

BPS for: Farming Operations - Livestock Rearing				
Category	**Baseline**	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Farming Operations - Livestock rearing	Farming operations were not subject to permit regulations until January 1, 2004, hence no enforceable emission reduction requirements were in place during 2 of the 3 baseline years of 2002 to 2004. There is currently no ruminant feed content requirement	(1)All ruminant animal feed shall include at least 6% cottonseed, or, upon District approval, based on sufficient demonstration that use of cottonseed is not feasible, an equivalent substitute; and	CH_4	**12.0%**
		(2) Manure from animal housing areas for mature cows shall be removed and transferred into appropriate treatment facilities at least four times a day and at least once a day for all other animals; and	CH_4	**7.1%**
	Even though removal of manure 4 times a day for mature cows is currently required as BACT, there is no corresponding anaerobic treatment requirement, hence no effect on CH_4	(3) Collected manure shall be treated anaerobically in digesters or covered lagoons, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment	CH_4	**63.5%**

Compliance Assurance

The BPS for this category shall be enforced by a combination of design standards, equipment description, and permit conditions.

The following conditions will apply:

- *In order to minimize Green House Gas emissions and optimize equipment efficiency, all equipment shall be operated in accordance with manufacturer specifications and approved design specifications. [California Environmental Quality Act]*

- *All ruminant animal feed shall include at least 6% cottonseed. [California Environmental Quality Act]*

- *Manure from animal housing areas shall be removed and transferred into appropriate treatment facilities at least four times a day for mature cows and at least once a day for all other animals. [California Environmental Quality Act]*

10. Farming Operations – Application of Manure to Cropland at Livestock Rearing Operations

Illustrative BPS:

Manure shall be incorporated into soil within 24 hours after application.

BPS Determination
The proposed BPS for this category represents the most stringent Achieved-in-Practice emission control method and consists of the following element:

Manure shall be incorporated into soil within 24 hours after application: The most significant GHG emitted from the application of manure to cropland is Nitrous Oxide (N2O), which has a Global Warming Potential of 310. This gas is emitted as a byproduct when microbes in the soil convert Nitrogen in manure into Nitrates (Nitrification) and also when the reverse process of denitrification, in which Nitrates are converted into Nitrogen, occurs.

One of the most important methods for the reduction of N2O emissions is the reduction of manure and fertilizer applied to cropland. This is because quantity of Nitrogen compounds in the soil, in the form of excess manure or fertilizer that is not taken up by crops, is a major driving factor in the production of N2O. However, there are no scientific studies or data that can be used to determine the proper manure or fertilizer application rates that will minimize excess Nitrogen in the soil. Moreover, due to complications associated with regulating farming operations, it is unlikely that any BPS mandating limits on the use of manure or fertilizer for crop fertilization will be feasible.

Another GHG emitted from the application of manure to cropland is Methane. Methane is naturally present in manure that is decomposing under anoxic conditions, such as manure stored in poorly aerated piles.

In a report entitled *"Recommendations to the San Joaquin valley Air Pollution Control Officer Regarding Best Available Control Technology for Dairies in the San Joaquin Valley*", the Dairy Permitting Advisory Group (DPAG) concluded that VOC emissions could be reduced by 29-58% by the prompt incorporation of manure into soil after application to land. Based on this information, this BPS assumes a similar benefit as far as the reduction of CH4 emissions is concerned. However due to the lack of data, the lower control efficiency of 29% will be used. The BPS assumes that incorporating into soil will allow at least a small percentage of CH4 to be assimilated into other complex organic compounds in the soil instead of being emitted directly into the atmosphere. In addition, certain soil microbes are also able to metabolize CH4 into CO_2, hence reducing total CH4 emissions when incorporation into soil is used.
Manure also produces Carbon Dioxide when it decomposes aerobically upon exposure to air as is the case during land application. Also, as previously discussed, soil incorporated CH4 may be further metabolized into CO_2 by soil microbes. However, there is no BPS that can effectively reduce CO_2 emissions from the application of manure to cropland.

The emissions for land application of manure can be assumed to be the same as emissions occurring during the 2002 – 2004 baseline years used by the AB32 Scoping Plan. Manure application operations have not changed much since that period. Although permit requirements for many farming operations took effect in 2004, the particular BPS proposed has generally not been implemented as mandatory permit requirement. Instead, many other control measures aimed at reducing PM10 emissions have been applied with greater emphasis.

Summary of BPS and achieved GHG emission reductions:

BPS for: Farming Operations – Application of Manure to Cropland				
Category	**Baseline**	**BPS**	**GHG**	**GHG Emission Reduction (%)**
Farming Operations - Land application of manure	Farming operations were not subject to permit regulations until January 1, 2004, hence no enforceable emission reduction requirements were in place during 2 of the 3 baseline years of 2002 to 2004. Incorporation of land applied manure is currently required as BACT, but there is no specific time period within which manure must be incorporated	Manure shall be incorporated into soil within 24 hours after application	CH_4	**29%**

<u>Compliance Assurance</u>

The BPS for this category shall be enforced by permit condition.

The following condition will apply:

- *Manure shall be incorporated into soil within 24 hours after application. [California Environmental Quality Act]*

5.4.3 Best Performance Standards for Development Projects

Introduction

As presented previously in Chapter 1, Figure 1: *California's Greenhouse Gas Emissions by Sector,* the Commercial and Residential sectors represents nine (9) percent of the State's greenhouse gas (GHG) emissions inventory. Greenhouse gas (GHG) emissions from development projects result from operational and transportation related activities. GHG emissions from operational activities are dominated by energy consumed for space and water heating, lighting, and operation of electrical appliances. GHG emissions from transportation activities are dominated by consumption of gasoline and diesel for movement of goods and people.

In characterizing GHG emissions from the Commercial and Residential sectors, the 1990 emissions set by the California Air Resources Board (ARB) are based on fuel use activities which comprise more than 80 percent of the overall 1990 statewide greenhouse gas emissions. The forecasted 2020 business-as-usual emissions developed by ARB considered GHG emissions contributions resulting from energy consumption only (e.g.: natural gas, distillate, wood, and diesel)[18]. Thus, reducing GHG emissions from these sectors has significant overlap with energy efficiency and conservation measures (E-1 and CR-1) addressed in ARB's *Climate Change Proposed Scoping Plan*-Electricity Generation sector that was adopted by ARB's Board in December 2008.

5.4.3.1 GHG Emissions and Reduction Measures

5.4.3.1.1 Energy Efficiency and Conservation

The Electricity Generation sector overlaps and intercepts many of the GHG sectors identified by ARB. Generating electricity consumes about half of all natural gas in the state, making electricity production the single largest consumer of natural gas. The Residential sector consumes another 22 percent of the state's total natural gas consumption; 88 percent of which is used for space and water heating[19]. Comprising 23 percent of the state's total GHG emissions, the Electricity Generation sector is

[18] *Staff report – California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit.* California Air Resources Board, November 16, 2007
[19] *Integrated Energy Policy Report, 2007 Summary,* P.18. California Energy Commission.

California's second largest source of GHG emissions. The Transportation sector is number one, responsible for 38 percent of the State's GHG emissions.

Strategies for reducing GHG emissions from the Electricity Generation sector include reducing the amount of energy consumed and reducing GHG emissions resulting from electricity production. Of these two strategies, the California Energy Commissions (CEC) has determined that reducing GHG emissions depends largely on the success of California's energy efficiency and renewable energy programs[20]. The importance of increasing energy efficiency is mirrored by ARB's determination that increasing energy efficiency will be California's most effective tool for achieving GHG reductions in the Electricity Generation sector[21].

Existing progressive green building standards provide a starting point for performance standards. Existing green building rating systems like LEED (Leadership in Energy and Environmental Design), the California Green Building Code, and others, contain examples of measures that are likely to result in substantial GHG emission reductions from residential and commercial projects.

As presented below in Table 2, ARB has proposed 12 strategies for maximizing energy efficiency, four of which are based on further development of the State's building and appliance energy efficiency codes and standards.

[20] *Integrated Energy Policy Report, 2007 Summary,* P.6. California Energy Commission.
[21] *Climate Change Proposed Scoping Plan Appendices; Vol. I, Electricity and Natural Gas.* P.C-87. California Air Resources Board, October 2008

Table 2- Twelve Strategies for Maximizing Energy Efficiency[22]

• **Cross-cutting Strategy for Buildings**
o "Zero Net Energy" Buildings
• **Codes and Standards Strategies**
o More stringent building codes and appliance standards
o Broader standards for new types of appliances and for water efficiency
o Improved compliance and enforcement for existing standards
o Voluntary efficiency and green building targets beyond mandatory codes
• **Strategies for Existing Buildings**
o Voluntary and mandatory whole-building retrofits for existing buildings
o Innovated financing to overcome first-cost and split incentives for energy efficiency, on-site renewables, and high efficiency distributed generation
• **Existing and Improved Utility Program Strategies**
o More aggressive utility programs to achieve long-term savings
• **Other Needed Strategies**
o Water system and water use efficiency and conservation measures
o Local government programs that lead by example and tap local authority over planning, development, and code compliance
o Additional industrial and agricultural efficiency efforts
o Providing real time energy information to help customers conserve
o and optimize energy performance

5.4.3.1.2 Building and Appliance Standards

Under California Public Resources Code, the CEC is authorized to adopt and update Building Efficiency Standards and Appliance Efficiency Regulation. Building standards include both prescriptive and performance standards for new construction, and for alterations and additions to existing buildings. The standards include pre-defined performance levels for various building components and energy consumption. Examples of such standards are new Cool Roof requirements, mechanical ventilation requirements, compliance option

[22] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Electricity and Natural Gas. P.C-100. California Air Resources Board, October 2008

credits for distributed energy storage, and calculation of Time Dependent Valuation energy.

Because most of California's older buildings were built to lesser or non-existent building efficiency standards, improving the energy efficiency of existing residential and commercial buildings in California could produce substantial GHG benefits. In fact, improving the efficiency of California's existing building stocks is the single most important activity to reduced GHG emissions within the electricity and natural gas sectors[23]. New standards will become in effect in August 2009.

California's Appliance Efficiency Regulations include standards for both federally and non-federally regulated appliances. The standards apply to appliances sold or offered for sale in California, with a few exceptions. Appliance standards improve the operation and efficiency of refrigerators, freezers, air conditioners and other appliances. Normally, the CEC updates building standards on a three-year cycle. The most recent update occurred in 2008, and several updates are expected to occur between now and 2020[24]. As with building standards, the CEC establishes appliance standards at its discretion. The most recent update occurred in 2007, and several updates are expected to occur between now and 2020[25].

As presented in ARB's Scoping Plan, the California Public Utilities Commission working with the CEC, California's Invester owned utilities (IOUs) and numerous stakeholders, prepared the Long Term Energy Efficiency Strategic Plan. This long-term plan recommends strategies that can enable the utilities and other factors to achieve energy efficiency goals for the 2009-2020 period and beyond, contributing ignorantly to the State's AB 32 goals. Two targets adopted by the CPUC, and supported by the CEC, are as follows:

1. By 2020, all new residential buildings will be zero net energy; and
2. By 2030, all new commercial buildings will be zero net energy[26].

Zero net energy building, which is yet to be defined by energy agencies, would be those that are very energy efficient and generate

[23] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Electricity and Natural Gas. P.C-108. California Air Resources Board, October 2008

[24] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Electricity and Natural Gas. P.C-104. California Air Resources Board, October 2008

[25] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Electricity and Natural Gas. P.C-104. California Air Resources Board, October 2008

[26] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Electricity and Natural Gas. P.C-112. California Air Resources Board, October 2008

enough energy on-site to completely offset the energy consumed within the building over the course of a year.

5.4.3.1.3 Green Building Strategy

"Green buildings" are designed, built, operated, renovated, and maintained using an integrated approach that creates and ensures a healthy and comfortable environment while maximizing energy and resource efficiencies[27]. As concluded by ARB, the design, construction, demolition, renovation, maintenance and operation of buildings together account for considerable electricity, and natural gas demand. Water usage and waste generation further contributes to GHG emissions. Mining, harvesting, processing, and transportation of building materials used in construction, and products used in the operation of buildings, accounts for further GHG emissions. The choice of where buildings are sited and how they are integrated within communities also affects transportation patterns and infrastructure needs resulting in potentially significant GHG impacts. The *Climate Change Proposed Scoping Plan* (adopted by ARB Board in December 2008) includes a Green Building Strategy that when implemented will further reduce GHG emissions from both existing and new buildings.

5.4.3.1.4 Vehicle Use

GHG emission from vehicle use is the other factor contributing to GHG emissions from development projects and overlap with emission reductions targeted by ARB under the Transportation sector of the *Climate Change Proposed Scoping Plan*. As determined by ARB, the Transportation sector is responsible for 38 percent of the State's GHG emissions. ARB has established three overarching strategies for reducing GHG emissions from vehicle use: more efficient vehicles, lower-carbon fuels, and reduction in vehicle miles traveled (VMT)[28]. ARB has stated that these strategies will be achieved through regulations, market mechanisms, and land use policy. ARB's recommended actions to reduce GHG emissions from the Transportation sector are listed below in Table 3.

[27] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Electricity and Natural Gas. P.C-138. California Air Resources Board, October 2008

[28] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Transportation. P.C-55. California Air Resources Board, October 2008

Table 3: Actions for Reducing Transportation GHG Emissions[29]

• California Cap-and-Trade Program linked to the Western Climate Initiative
• Pavley I and Pavley II – Light-Duty Vehicle Standards
• Vehicle Efficiency Measures
• Low-Carbon Fuel Standard
• Ship Electrification at Ports
• Goods Movement Efficiency Measures
• Heavy-Duty Vehicle GHG Emission Reduction – Aerodynamic Efficiency
• Medium- and Heavy-Duty Vehicle Hybridization
• Regional Transportation-Related Greenhouse Gas Targets
• High Speed Rail

5.4.3.1.5 Regional Transportation-Related Greenhouse Gas Targets[30]

Transportation planning is done on a regional level in major urban areas, reflecting local land use patterns and decisions. Through regional planning efforts, such as the "Blueprint" planning model, regions can select future growth scenarios that lead to more environmentally and economically sustainable and energy efficient communities. Senate Bill 375 (SB 375) (Steinberg, Chapter 728, Statues of 2008) establishes mechanisms for the development of regional GHG reduction targets for passenger vehicle. Under SB 375, ARB is required to develop, in consultation with metropolitan planning organizations (MPOs) passenger vehicle GHG reduction targets for 2020 and 2035. The bill creates incentives for local governments and developers by providing relief from certain CEQA requirements for development projects that are consistent with regional plans that achieve the GHG reduction targets.

5.4.3.1.6 GHG Baseline & Business as Usual Emissions

ARB estimated the statewide 1990 greenhouse gas emissions level of 427 MMT CO_2E based on data from State and federal agencies, international organizations, and California industries. Upon approval by

[29] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Transportation. P.C-55. California Air Resources Board, October 2008
[30] *Climate Change Proposed Scoping Plan Appendices*; Vol. I, Transportation. P.C-75. California Air Resources Board, October 2008

ARB's Board in December 2007, the 1990 emissions level became the 2020 emissions limit, which represents an aggregated emissions limit for California. The gross statewide emissions in 1990 were 433 MMT CO_2E with forestry sinks offsetting approximately 7 MMT CO_2E, resulting in net emissions to the atmosphere of approximately 427 MMT CO_2E. The 1990 emissions level is a compilation or inventory of the amount and type of greenhouse gases emitted by different sources on an annual basis[31]. The resulting 2020 BAU estimates of 596 MMT CO_2E are compared to the 1990 level target for 2020 of 427 MMT CO_2E in yr 1990 to determine the total statewide GHG reductions needed which is 169 MMT CO_2E or approximately 30% reduction.

The California Air Resources Board (ARB) forecasting approach for BAU greenhouse gas emissions in 2020 uses emissions estimates from 2002 through 2004 to develop baseline GHG emissions from which to grow emissions into the future[32]. The 3-year average baseline emissions estimate of 2002-2004 includes emissions from older, less energy efficient structures and emissions from structures built to comply with building and appliance standards in effect during the baseline years. Based on the GHG emissions ARB determined, in order to achieve the GHG reduction targets established in AB 32 development projects after 2004 would need to reduce GHG emissions by about 10% from the 1990 emissions and for all sectors altogether by about 30% from BAU emissions as projected for 2020.

5.4.3.1.7 Achieved GHG Emission Reductions

Building and appliance standards are critical tools in reducing energy demand. During the baseline years of 2002-2004, all new construction was required to comply with building standards adopted in 2001. Building and Appliance standards have been revised since 2004. Each successive version of the building and appliance standards requires new technologies and tighter performance standards, thus, reducing GHG emissions from new development projects, as well as reducing emissions from renovation of older structures[33]. The building standards were updated in 2005 and new 2008 standards have been published that take effect in 2009. The 2009 standards contain numerous

[31] *Business-as-Usual Forecasting Method Summary,* P. 1. California Air Resources Board, July 30, 2008

[32] *California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit;* P. 2. California Air Resources Board, November 16, 2007

[33] *Climate Change Proposed Scoping Plan Appendices; Vol. I, Electricity and Natural Gas.* P.C-104. California Air Resources Board, October 2008

requirements for improving energy efficiency in both residential and non-residential structures. The appliance standards were updated in 2003, 2005 and again in 2006, with further updates planned. Thus, it is reasonable to conclude that new development projects occurring after 2004 are already implementing measures that reduce GHG emissions below the 2002-2004 emissions.

As presented below in Tables 4 and 5, preliminary estimates by the District show that 2007 residential use of natural gas is about 20% less than the 2002-2004 baseline period. Reducing natural gas consumption should result in a concomitant reduction in GHG emissions. Thus, these data suggest that new residential developments may already be emitting less GHG emissions than the 2002-2004 baseline period. CEC also has data demonstrating that although the number of residential customers have increased, the average household use has been reduced as a result of the appliance and building energy efficiency standards[34].

Emission reduction targets established by ARB are based on average fuel consumption for the baseline year. Therefore, emission reductions occurring after the baseline year should be credited towards the achieving the required percent reduction. The District recognizes that this apparent reduction may be influenced by other factors other than building and appliance standards and that commercial development may not have experienced equivalent reductions. Before finalizing its determination, the District will conduct a more detailed analysis of development project energy consumption and associated emission reductions.

Table 4: 2002-2004 Per capita GHG Emissions from natural gas - Residential

	CA MTCO2[1]	SJV MTCO2	SJV average household[2]	MTCO2 per Dwelling Unit
Residential	26.87	2.821	1,161,751.00	0.0000024

Notes:
-[1] Excel with embedded PDF document, Air Resources Board, http://www.arb.ca.gov/cc/inventory/data/forecast.htm
- [2] From E-5 Population and Housing Estimates for Cities, Counties and the State, 2001-2009, with 2000 Benchmark, California Energy Commission, http://www.dof.ca.gov/research/demographic/reports/estimates/e-5/2009/
- It is assumed that natural gas consumption for San Joaquin Valley (SJV) is about 10.5% of California's.

Table 5: 2007 Per capita GHG Emissions from natural gas - Residential

[34] California Residential Natural Gas Consumption, http://energyalmanac.ca.gov/naturalgas/residential_natural_gas_consumption.html

	SJV MTCO2[1]	SJV average household[2]	MTCO2 per Dwelling Unit
Residential	3	1,304,301.00	0.0000019

Notes:
-[1] Calculated value based on data from California Energy Consumption Database, http://www.ecdms.energy.ca.gov/ and methodologies by Air Resource Board, http://www.arb.ca.gov/cc/inventory/1990level/1990level.htm
- [2] From E-5 Population and Housing Estimates for Cities, Counties and the State, 2001-2009, with 2000 Benchmark, California Energy Commission, http://www.dof.ca.gov/research/demographic/reports/estimates/e-5/2009/

5.4.4 Energy Efficiency and Land Use Planning

As previously discussed, GHG emissions from commercial and residential develop are dominated by building and appliance energy efficiencies and GHG emissions resulting from movement of goods and people. Thus, there is considerable overlap between Commercial and Residential sectors and the Electricity Generation and Transportation Sectors.

In developing its recommendations for approved GHG emission reduction measures for development projects, the District considered the extent to which development projects will be subject to GHG emission reduction requirements imposed by ARB and other state agencies with statutory authority for reducing GHG emissions from development projects. Additionally, the District considered GHG emission reductions that have already been achieved as a result of changes to the building and appliance standards adopted by the CEC after the 2002-2004 baseline period.

5.4.4.1 Energy Efficiency and Conservation GHG Emission Reduction Measures

As previously discussed, the CEC has statutory authority for establishing performance standards for building and appliance efficiencies. California's per capita electricity use has stayed flat for the past 30 years because of efficiency standards and utility efficiency programs[35].

The California Public Utilities Commission and the California Energy Commission provided their recommendations to ARB on strategies for reducing GHG emissions in the electricity and natural gas sectors[36]. Included in their evaluations for potential areas of GHG emissions

[35] *Integrated Energy Policy Report 2007 Summary*. California Energy Commission. 2007
[36] *Final Opinion and Recommendations on Greenhouse Gas regulatory Strategies.* CA Energy Commission & CA public Utilities Commissions, October 2008

reductions is the energy efficiency through codes and standards. The CEC has set the 2008 standards for building energy efficiency standards which are to be in effect as of January 1, 2010.

The CEC and the Climate Action Team Energy Subgroup have the necessary expertise and statutory authority for establishing performance standard for building and appliance standards. The CEC and Climate Change Action Team Energy Subgroup have already done outstanding research and brought forth recommendations to ARB. The measures or areas identified for the energy sector are already those that would bring the majority of the reductions and already reflect the best practices in energy efficiency.

The District concludes that for commercial and residential developments, compliance with building and appliance standards established by CEC reduces project specific GHG emissions and thus, constitutes a valid GHG emission reduction measure for energy efficiency and conservation.

5.4.4.2 Land Use Planning GHG Emission Reduction Measures

Reducing vehicular emissions from commercial and residential developments overlap emission reductions targeted by ARB under the Transportation sector of the *Climate Change Proposed Scoping Plan*. ARB has established three overarching strategies for reducing GHG emissions from vehicle use: more efficient vehicles, lower-carbon fuels, and reduction in vehicle miles traveled (VMT). Local governments have the ability to directly influence both siting and design of new residential and commercial developments in a way that reduces vehicle miles traveled (VMT). Reductions in VMT can be achieved through diversified land use patterns that provide people greater access to alternative forms of transportation, including transit, biking and walking. Reductions in VMT can be achieved through diversified land use patterns where people can live, work, and play without having to drive great distances. Land use planning that reduces VMT can also reduce the GHG emissions by reducing land consumption, energy use, water use, and waste.

Potential reductions in GHG emissions from land use planning are established through Senate Bill 375 (SB375). The bill focuses on housing and transportation planning decisions to reduce fossil fuel consumption and conserve farmlands and habitat. It allows an opportunity to provide incentives to locate housing developments closer to where people work and go to school, allowing them to reduce vehicle miles traveled every year. SB375 integrates AB 32's goal to reduce GHG emissions into transportation planning by requiring that a sustainable communities strategy be added to the regional transportation Plan. SB 375 also directs ARB to work with California's Metropolitan Planning Organizations to align their regional transportation, housing and land-use plans and prepare a "sustainable communities strategy" to reduce the amount of vehicle miles traveled in their respective regions and demonstrate the region's ability to attain its greenhouse gas reduction targets to be achieved from the automobile and light truck sectors for 2020 and 2035. When it is determined that the SCS cannot achieve the targets, the Metropolitan Planning Organization The must develop an Alternative Planning Strategy.

Per guidance provided by OPR, CEQA authorizes reliance on previously approved plans and mitigation programs that have adequately analyzed and mitigated GHG emissions to a less than significant level.

5.4.5 Illustrative GHG Emission Reduction Measures for Development Projects

Both GHG and criteria pollutant emissions from development projects are direct results of energy consumption and vehicle miles traveled. Land use decisions that would impact GHG emissions are the same land use decisions that would impact criteria pollutant emissions from development projects. The District, through implementation of District Rule 9510 (Indirect Source Review) has considerable experience with evaluating criteria pollutant emissions from development projects, and evaluating the mitigating effects of project design elements.

Any combination of approved GHG emissions reduction measures achieving a combined 29% of GHG emissions compared to the established Baseline GHG emissions factor per unit of activity is considered **Best Performance Standard** (BPS) for the respective type of development project. Projects achieving a 29% reduction in GHG emissions would be determined to have a less than significant individual and cumulative impact for GHG emissions. To be considered to have a less than significant individual and cumulative impact for GHG emissions, projects not achieving a 29% reduction would require quantification of GHG emissions and demonstration that GHG emissions have been reduced or mitigated by 29%, including GHG emission reductions achieved since the 2002-2004 baseline.

The following discussion illustrates possible GHG emission reduction measure, as presented in Appendix J, for development projects (residential, commercial and industrial) and provides the basis and/or rationale for each, as well as an assessment of potential GHG emissions reduction impact relative to a 2002-2004 emissions inventory baseline. It should be noted that these examples of BPS are for illustrative purposes only, and should not be used by any lead agency as District-approved or sanctioned standards. As discussed further in this staff report, the proposed process of establishing BPS provides opportunity for public input into the development of BPS.

To simplify the evaluation process, the District will develop a point system and tools for use by lead agencies to score the effectiveness of the achieved BPS. An important effort that will contribute to the establishment of GHG Emission Reduction Measures for development projects is the ongoing work by the California Air Pollution Control Officers Association (CAPCOA) to identify and quantify control efficiencies for development mitigation measures reducing GHG and criteria pollutant emissions. The District is an active participant in the CAPCOA effort.

The illustrative GHG Emission Reduction Measures table lists the mitigation measures that relate to bicycle/pedestrian use, transit, parking, commercial and residential development design, building design, and commuting (See Appendix J). Each measure has been assigned a land use type for which a point value in reduction may be claimed. The point values are used to quantify the approximate emission reduction factor associated with a particular mitigation measure. The land use types include residential (R), commercial (C), and mixed-used (M). Each point associated with a particular measure is equivalent to an equal percentage of emission reductions. For example, implementing mitigation measures in a project that adds up to 15 mitigation points means that the measures are anticipated to achieve a 15% reduction in project related GHG operational emissions. The demonstrated GHG emission reductions would be added to the GHG emission reductions achieved since the 2002-2004 baseline.

BICYCLE/PEDESTRIAN/TRANSIT MEASURES

1. Bike Parking Measure *- Commercial, Mixed-Use*

Measure Description
Non-residential projects provide plentiful short-term and long-term bicycle parking facilities to meet peak season maximum demand. Short term facilities are provided at a minimum ratio of one bike rack space per 20 vehicle spaces. Long-term facilities provide a minimum ratio of one long-term bicycle storage space per 20 employee parking spaces.

Reduction Methodology & Source[37]
As a rule of thumb, the Center for Clean Air Policy (CCAP) guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 0.625%.

[37] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

2. End of Trip Facilities Measure - *Commercial, Mixed-Use*

Measure Description

Non-residential projects provide "end-of-trip" facilities including showers, lockers, and changing space. Facilities shall be provided in the following ratio: four clothes lockers and one shower provided for every 80 employee parking spaces. For projects with 160 or more employee parking spaces, separate facilities are required for each gender.

Reduction Methodology & Source[38]

The Transportation Demand Management (TDM) Encyclopedia allows a 2-5% reduction for worksite showers ad lockers. The CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: TDM Encyclopedia May 11, 2006; CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 0.625%.

3. Bike Parking at Multi-Unit Residential Measure - *Residential*

Measure Description

Long-term bicycle parking is provided at apartment complexes or condominiums without garages. Project provides one long-term bicycle parking space for each unit without a garage. Long-term facilities shall consist of one of the following: a bicycle locker, a locked room with standard racks and access limited to bicyclists only, or a standard rack in a location that is staffed and/or monitored by video surveillance 24 hours per day.

Reduction Methodology & Source[39]

As a rule of thumb, the CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 25% of that for this measure

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[38] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[39] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 0.625%.

4. Proximity to Bike Path/Bike Lanes Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Entire project is located within 1/2 mile of an existing Class I or Class II bike lane and project design includes a comparable network that connects the project uses to the existing offsite facility. Existing facilities are defined as those facilities that are physically constructed and ready for use prior to the first 20% of the projects occupancy permits being granted. Project design includes a designated bicycle route connecting all units, on-site bicycle parking facilities, offsite bicycle facilities, site entrances, and primary building entrances to existing Class I or Class II bike lane(s) within 1/2 mile. Bicycle route connects to all streets contiguous with project site. Bicycle route has minimum conflicts with automobile parking and circulation facilities. All streets internal to the project wider than 75 feet have class II bicycle lanes on both sides.

Reduction Methodology & Source[40]

As a rule of thumb, the CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 0.625%.

[40] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

5. Pedestrian Network Measure - *Commercial, Mixed-Use, Residential*

Measure Description

The project provides a pedestrian access network that internally links all uses and connects to existing external streets and pedestrian facilities. Existing facilities are defined as those facilities that are physically constructed and ready for use prior to the first 20% of the projects occupancy permits being granted. The project provides a pedestrian access network that internally links all uses for connecting to planned external streets and pedestrian facilities (facilities must be included pedestrian master plan or equivalent).

Reduction Methodology & Source[41]

Because this measure also eliminates physical barriers between residential and non-residential uses that impede bicycle or pedestrian circulation, this measure is similar in nature to 6. As cited in the TIAX report, the CCAP guidebook attributes a 1% reduction in VMT. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is between 0.5% and 1.0%.

6. Pedestrian Barriers Minimized - *Commercial, Mixed-Use, Residential*

Measure Description

Site design and building placement minimize barriers to pedestrian access and interconnectivity. Physical barriers such as walls, berms, landscaping, and slopes between residential and non-residential uses that impede bicycle or pedestrian circulation are eliminated. Barriers to pedestrian access of neighboring facilities and sites are minimized. This measure is not meant to prevent the limited use of barriers to ensure public safety by prohibiting access to hazardous areas, etc..

Reduction Methodology & Source[42]

The reduction is based on the TIAX report, which indicates a 1% reduction, and the CCAP report, which attributes a 1% to 5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

[41] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[42] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

With this measure the estimated achieved GHG emission reduction is 1.0%.

7. Bus Shelter for "existing" Transit Service Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Bus or Streetcar service provides headways of one hour or less for stops within 1/4 mile; project provides safe and convenient bicycle/pedestrian access to transit stop(s) and provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting).

Reduction Methodology & Source[43]

This reduction is based on the assumption that the measure applies to providing bus stop route information & benches. Emission reductions are based on conclusion obtained from the TIAX report and the CCAP guidebook. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 0.5%.

8. Bus Shelter for "planned" Transit Service - *Commercial, Mixed-Use, Residential*

Measure Description

Project provides transit stops with safe and convenient bicycle/pedestrian access. Project provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting) in anticipation of future transit service. If measure *7 is selected, it excludes this measure.*

Reduction Methodology & Source[44]

This reduction is based on the assumption that the measure applies to providing bus stop route information & benches. Emission reductions are based on conclusion obtained from the TIAX report and the CCAP guidebook. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

Achieved GHG Emission Reductions

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[43] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[44] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

With this measure the estimated achieved GHG emission reduction is 0.25%.

9. Traffic Calming Measure - *Commercial, Mixed-Use, Residential*

Measure Description
Project design includes pedestrian/bicycle safety and traffic calming measures in excess of jurisdiction requirements. Roadways are designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips by featuring traffic calming measures. Traffic calming measures include: bike lanes, center islands, closures (cul-de-sacs), diverters, education, forced turn lanes, roundabouts, speed humps, etc.

Reduction Methodology & Source[45]
SMAQMD appears to have the best information available as reflected in their Guidance for Land Use Emission Reductions, which allocates reductions by the percent of intersections with traffic calming improvements as indicated in the table below. We were unable to locate more specific information. Source: Draft Update to SMAQMD Guidance for Land Use Emission Reductions.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is between 0.25% and 1.0%. *(See Table in Appendix J)*

45 *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

PARKING MEASURES

10. Paid Parking - *Commercial, Mixed-Use, Residential*

10.1 Paid Parking: Urban Site within ¼ mile from transit stop-

Measure Description
Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.

Reduction Methodology & Source[46]
Shoupe, 2005. Parking Cash Out. [$5/day reduces drive-alone share by 21% for commuters to downtown LA, with elasticity of -0.18 (e.g., if price increases 10%, then solo driving goes down by 1.8% more (Wilson 1991)] [Reported 1-10% reduction in trips to central city sites, and 2-4% in suburban sites (Urban Institute)]. The District has used a conservative number for this approach.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 5.0%.

10.2 Paid Parking: Urban Site greater than ¼ mile from transit stop-

Measure Description
Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.

[46] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

Reduction Methodology & Source[47]
Shoupe, 2005. Parking Cash Out. [$5/day reduces drive-alone share by 21% for commuters to downtown LA, with elasticity of -0.18 (e.g., if price increases 10%, then solo driving goes down by 1.8% more (Wilson 1991)] [Reported 1-10% reduction in trips to central city sites, and 2-4% in suburban sites (Urban Institute)]. The District has used a conservative number for this approach.

Achieved GHG Emission Reductions
With this measure the estimated GHG achieved emission reduction is 1.5%.

10.3 Paid Parking: Suburban site within 1/4 mile of transit stop

Measure Description
Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.

Reduction Methodology & Source[48]
Shoupe, 2005. Parking Cash Out. [$5/day reduces drive-alone share by 21% for commuters to downtown LA, with elasticity of -0.18 (e.g., if price increases 10%, then solo driving goes down by 1.8% more (Wilson 1991)] [Reported 1-10% reduction in trips to central city sites, and 2-4% in suburban sites (Urban Institute)]. The District has used a conservative number for this approach.

Achieved GHG Emission Reductions
With this measure the estimated GHG achieved emission reduction is 2.0%.

10.4 Paid Parking: Suburban site greater than 1/4 mile from transit stop

Measure Description
Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.

[47] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.
[48] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

Reduction Methodology & Source[49]
Shoupe, 2005. Parking Cash Out. [$5/day reduces drive-alone share by 21% for commuters to downtown LA, with elasticity of -0.18 (e.g., if price increases 10%, then solo driving goes down by 1.8% more (Wilson 1991)] [Reported 1-10% reduction in trips to central city sites, and 2-4% in suburban sites (Urban Institute)]. The District has used a conservative number for this approach.

Achieved GHG Emission Reductions
With this measure the estimated GHG achieved emission reduction is 1.0%.

11. Parking Cash Out Measure - *Commercial, Mixed-Use*

Measure Description
Employer provides employees with a choice of forgoing subsidized parking for a cash payment equivalent to the cost of the parking space to the employer.

Reduction Methodology & Source[50]
Shoupe, 2005. Parking Cash Out. [2/3 as effective as charging for parking (8 case studies - chapter 4, 13% reduction in solo driver trips, -12% VMT per employee, and -11% in vehicle trips per commuter)]. The District has used a conservative number for this approach.

Achieved GHG Emission Reductions
With this measure the estimated GHG achieved emission reduction is 0.6%.

12. Minimum Parking - *Commercial, Mixed-Use, Residential*

Measure Description
Provide minimum amount of parking required. Special review of parking required. If zoning codes in the San Joaquin Valley area have provisions that allow a project to build less than the typically mandated amount of parking if the development features design elements that reduce the need for automobile use. This measure recognizes the air quality benefit that results when facilities minimize parking needs, and grants mitigation value to project that implement all available parking reductions. Once land uses are determined, the trip reduction

[49] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.
[50] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

factor associated with this measure can be determined by utilizing the Institute of Transportation Engineers (ITE) Parking generation publication[51]. The reduction in trips can be computed as shown below by the ratio of the difference of minimum parking required by code and ITE peak parking demand to ITE peak parking demand for the land uses multiplied by 50%. The maximum achievable trip reduction is 6%. For projects where retail space occupies 50% or more of the total built space, do not use December specific parking generation rates (from ITE). Percent Trip Reduction = 50*[(min parking required by code - ITE peak parking demand) / (ITE peak parking demand)].

Reduction Methodology & Source[52]
Nelson/Nygaard, 2005. pg. 16. (trip reduction = ((actual parking provision - ITE parking generation rate) / ITE parking generation rate) *0.5). (Note: this formula is not verbatim from that cited in the Nelson/Nygaard document, since the formula provided did not make sense for computing trip reductions. This is what EDAW believes was meant, and this method actually works.) The allowed reduction is the range mid-point.

Achieved GHG Emission Reductions
With this measure the estimated GHG achieved emission reduction is 3.0%.

13. Parking Reduction Beyond Code Measure - *Commercial, Mixed-Use, Residential*

Measure Description
Provide parking reduction less than code. Special review of parking required. Recommend a Shared Parking strategy. Trip reductions associated with parking reductions beyond code shall be computed in the same manner as described under measure 11, as the same methodology applies. The maximum achievable trip reduction is 12%. This measure can be readily implemented through a Shared Parking strategy, wherein parking is utilized jointly among different land uses, buildings, and facilities in an area that experience peak parking needs at different times of day and day of the week. For example, residential uses and/or restaurant/retail uses, which experience peak parking demand during the evening/night and on the weekends, arrange to share parking facilities with office and/or educational uses, which experience peak demand during business hours and during the week.

[51] The ITE Parking Generation Manual (3rd Edition) is available at: http://www.ite.org/tripgen/parking.asp . The ISBN number for this publication is 0-935403-79-5.
[52] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

Reduction Methodology & Source[53]

Nelson/Nygaard, 2005. pg. 16. (trip reduction = ((actual parking provision - ITE parking generation rate) / ITE parking generation rate) *0.5). (Note: this formula is not verbatim from that cited in the Nelson/Nygaard document, since the formula provided did not make sense for computing trip reductions. This is what EDAW believes was meant, and this method actually works.) The allowed reduction is the range mid-point. Trip reduction

Achieved GHG Emission Reductions

With this measure the estimated GHG achieved emission reduction is 6.0%.

14. Pedestrian Pathway through Parking Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Provide a parking lot design that includes clearly marked and shaded pedestrian pathways between transit facilities and building entrances. Pathway must connect to all transit facilities internal or adjacent to project site. Site plan should demonstrate how the pathways are clearly marked, shaded, and are placed between transit facilities and building entrances.

Reduction Methodology & Source[54]

The CCAP guidebook attributes between 1% and 4% reduction from all pedestrian measures. There is no specific information related to providing shaded pedestrian pathways between transit facilities and building entrances. It could be said that providing covered carpool/vanpool spaces near the entrance to the buildings has the similar goal of increasing the comfort of the user while walking to the building entrance. The TIAX report assigns a 1% reduction to the covered carpool measure. Transit usage is most affected by the headway times and the proximity to the destination. Therefore, it would seem reasonable to assume .5% Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.

Achieved GHG Emission Reductions

With this measure the estimated GHG achieved emission reduction is 0.5%.

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[53] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[54] Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007. Sacramento Metropolitan Air Quality Management District.

15. Off Street Parking Measure - *Commercial, Mixed-Use, Residential*

Measure Description

For 1.5% reduction, parking facilities shall not be sited adjacent to public roads contiguous with project site. Functioning pedestrian entrances to major site uses are located along street frontage. Parking facilities do not restrict pedestrian, bicycle, or transit access from adjoining uses. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, a description of where parking is located relative to the buildings on the site, site plans, maps, or other graphics, which demonstrate the placement of parking facilities behind on-site buildings relative to streets contiguous with the project site. Surrounding uses should be high density or mixed-use, there shall be other adjoining pedestrian and bicycle connections, such as wide sidewalks and bike lanes, and surrounding uses shall also implement measure 15.

For 1.0% reduction, (parking structures only) proponent must show that parking facilities that face street frontage feature ground floor retail along street frontage. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, a written description of the parking facility and the amount of retail space on the ground floor, site plans, maps, or other graphics demonstrating the placement of retail/commercial space along all street fronts contiguous with parking structure.

For 0.1% reduction, the project is not among high-density or mixed uses, is not connected to pedestrian or bicycle access ways, or is among uses that do not also hide parking. This point value is reflective of the importance that other pedestrian and density measures be in place in order for this measure to be effective.

Reduction Methodology & Source[55]

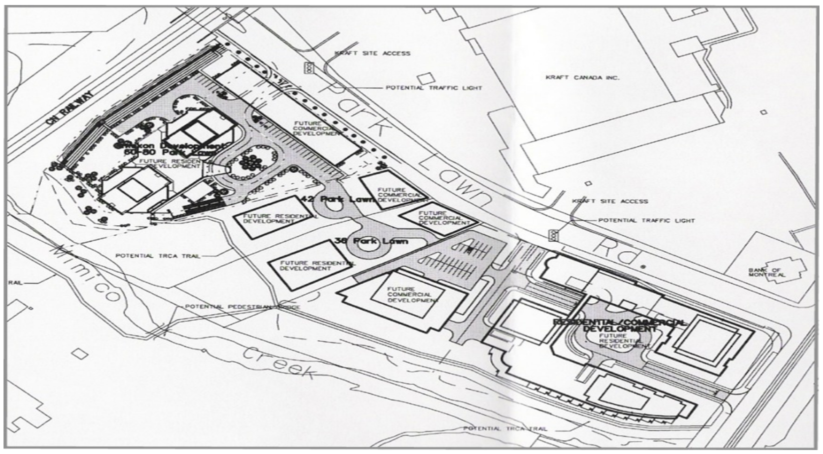
No empirical support for this specific measure; however, range of values is based on other pedestrian-oriented measures. The range recognizes the dependence of this measure on other measures. To be awarded 1.0 points, development must be in an area with density, wide sidewalks, and where other uses are also hiding parking. The efficacy of this measure is reduced to 0.1 if the development does not include other pedestrian and mixed-use measures. Parking structure with ground-floor retail is awarded 0.5.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is between 0.1% and 1.5%.

[55] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

SITE DESIGN MEASURES



16. Office/Mixed-Use Proximate to Transit Measure - *Commercial, Mixed-Use*

Measure Description

Mitigation value is based on project density and proximity to transit. Planned transit must be in MTP or RT Master Plan. To count as "existing transit" service must be fully operational prior to the first 20% of the projects occupancy permits being granted. Project must provide safe and convenient pedestrian and bicycle access to all transit stops within 1/4 mile. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, a written description of how the project complies with the measure, a map or graphic depicting the location of the project in relation to the transit stop. Graphic should demonstrate a 1/4 mile radius, arc, from transit and planned pathways and linkages to the transit stop. Proponent shall also provide graphics depicting the size and layout of the building as well as the calculations demonstrating the FAR (floor to area ratio).

Reduction Methodology & Source[56]
No empirical support for this measure, beyond that provided by SMAQMD in its draft guidance. According to Nelson/Nygaard, 2005, trip generation at the non-residential end is influenced by density to a much lesser degree, so this is fairly consistent with the transit reductions applied in measure 20. Assumes a 30 minute transit schedule.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is between 0.2% and 1.5%.

17. Orientation toward "existing" transit, bikeway, or pedestrian corridor - *Commercial, Mixed- Use, Residential*

Measure Description
Project is oriented towards existing transit, bicycle, or pedestrian corridor. Setback distance is minimized. Setback distance between project and adjacent uses is reduced to the minimum allowed under jurisdiction code. Setback distance between different buildings on project site is reduced to the minimum allowed under jurisdiction code. Setbacks between project buildings and sidewalks is reduced to the minimum allowed under jurisdiction code. Buildings are oriented towards street frontage. Primary entrances to buildings are located along public street frontage. Project provides bicycle access to existing bicycle corridor. Project provides access to existing pedestrian corridor. (Cannot get points for both this measure and measure 17).

Reduction Methodology & Source[57]
The CCAP guidebook attributes a 0.5% reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit rider ship would result in a 0.5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 0.50%.

[56] Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007. Sacramento Metropolitan Air Quality Management District.
[57] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

18. Orientation toward "planned" transit, bikeway, or pedestrian corridor - *Commercial, Mixed-Use*

Measure Description
Project is oriented towards planned transit, bicycle, or pedestrian corridor. Setback distance is minimized. Planned transit, bicycle or pedestrian corridor must be in the MTP, RT Master Plan, General Plan, or Community Plan. Setback distance between project and existing or planned adjacent uses is minimized or non-existent. Setback distance between different buildings on project site is minimized. Setbacks between project buildings and planned or existing sidewalks are minimized. Buildings are oriented towards existing or planned street frontage. Primary entrances to buildings are located along planned or existing public street frontage. Project provides bicycle access to any planned bicycle corridor(s). Project provides pedestrian access to any planned pedestrian corridor(s).

Reduction Methodology & Source[58]
The CCAP guidebook attributes a 0.5 % reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit rider ship would result in a 0.5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 0.25%.

19. Residential Density Measure - *Residential*

Measure Description
Residential Density with "no transit", project provides high-density residential development. Mitigation value is based on project density with no transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.

Residential Density with "planned" light rail transit, project provides high-density residential development. Mitigation value is based on project density and proximity to planned light rail transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project

[58] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.

Residential Density with "planned" bus rapid transit, project provides high-density residential development. Mitigation value is based on project density and proximity to planned bus rapid transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.

Residential Density with "existing" light rail transit, project provides high-density residential development. Mitigation value is based on project density and proximity to existing light rail transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.

Residential Density with "existing' bus rapid transit, project provides high-density residential development. Mitigation value is based on project density and proximity to existing bus rapid transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.

Reduction Methodology & Source[59]
Nelson/Nygaard, 2005. pg 11. (trip reduction = 0.6*(1-(19749*((4.814+households per residential acre)/ (4.814+7.14))^-.639)/25914) (Holtzclaw et al 2002). Asymptote of 60% reduction. **Relative to a 3 du/ac development.** Note that there is no direct empirical support for the added reductions for proximity to transit; the 60% asymptote in this equation is to correct for double-counting from transit services, mix-of-uses, and bicycle and pedestrian connections (which could contribute another 40% reduction).

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is: See Table in Appendix J.

[59] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

20. Street Grid Measure - *Commercial, Mixed-Use, Residential*

Measure Description
Multiple and direct street routing (grid style). The measure applies to projects with an internal connectivity factor (CF)>=0.80, and average of 1/4 mile or less between external connections along perimeter of project. [CF=# of intersections / (# of cul-de-sacs + intersections)].

Reduction Methodology & Source[60]
Reductions are based on CCAP estimates for similar measures. Source: CCAP Transportation Emission Guidebook.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 1.0%.

21. Neighborhood Electric Vehicle Access - *Commercial, Mixed-Use, Residential*

Measure Description
Make physical development consistent with requirements for neighborhood electric vehicles (NEV). Current studies show that for most trips, NEVs do not replace gas, fueled vehicles as the primary vehicle. For the purpose of providing incentives for developers to promote NEV use, assume the percent reductions noted below.

For 1.5% reduction, a neighborhood shall have internal NEV connections and connections to other existing NEV networks serving all other types of uses.

For 1.0% reduction, a neighborhood shall have internal and external connections to surrounding neighborhoods.

For 0.5% reduction, a neighborhood has internal connections only.

Reduction Methodology & Source[61]
No direct empirical support for this measure available. May not be relevant/applicable in the near term, until NEVs become more common/inexpensive. Current studies show that for most trips, NEVs do not

[60] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.
[61] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

replace gas-fueled vehicles as the primary vehicle. For the purposes of providing incentives for developers to promote NEV use, assume that a neighborhood with internal NEV connections only receives 0.5 points, with external connections to other surrounding uses, 1.0 point, with external connections to other NEV networks, 1.5 points.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is between 0.5% and 1.5%.

22. Affordable Housing Component Measure - *Residential*

Measure Description
Residential development projects of 5 or more dwelling units provide a deed-restricted low-income housing component on-site (as defined in Ch 22.35 of Sacramento County Ordinance Code) [Developers who pay into In-Lieu Fee Programs are not considered eligible to receive credit for this measure]. Percent reductions shall be calculated according to the following formula: % reduction=% units deed-restricted below the market rate housing *0.04. The table in Appendix J illustrates sample percent reductions for the percentage of units that are deed restricted below the market housing rate. If the percentage is not listed on the table, the calculation must be done using the equation provided in the methodology.

Reduction Methodology & Source[62]
Nelson/Nygaard, 2005. pg. 15. (trip reduction = % units deed-restricted below market rate housing * 0.04).

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is between 0.6% and 4.0%.

[62] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

MIXED-USE MEASURES

23. Urban Mixed-Use Measure - *Mixed Use*

Measure Description

Development of projects predominantly characterized by properties on which various uses, such as office, commercial, institutional, and residential are combined in a single building or on a single site in an integrated development project with functional inter-relationships and a coherent physical design. Mitigation points for this measure depend on job to housing ratio.

Reduction Methodology & Source[63]

Nelson/Nygaard, 2005. pg. 12. (trip reduction = (1-(ABS(1.5*h-e)/(1.5*h+e))-0.25)/0.25*0.03) where h = study area housing units, e = study area employment (Criteron & Fehr & Peers, 2001). Asymptote of 9% reduction, and an ideal 1.5 jobs per household. Note, these point reductions were taken from Urbemis 2007 9.2.4[64] data according to sample jobs to housing ratio. Cannot get credit for both this measure and the following measures: Suburban Mixed-Use and Other Mixed-Use.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is between 3.0% and 9.0%.

24. Suburban Mixed-Use Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Have at least three of the following on site and/or offsite within ¼ mile: Residential Development, Retail Development, Park, Open Space, or Office.

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[63] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[64] Urbemis 2007 Version 9.2.4. Rimpo and Associates.

Reduction Methodology & Source[65]

By definition, this type of land use implies that housing availability is greater than employment availability. On a project-by-project basis, use formula :Nelson/Nygaard, 2005. pg. 12. (trip reduction = (1-(ABS(1.5*h-e)/(1.5*h+e))-0.25)/0.25*0.03) where h = study area housing units, e = study area employment (Criteron & Fehr & Peers, 2001) to obtain higher than 3% reduction. Otherwise, assume 3% max reduction. Cannot get credit for this measure and the following measures: Other Mixed-Use and Urban Mixed-Use measures.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 3.0%.

25. Other Mixed-Use Measure - *Mixed-Use, Residential*

Measure Description

All residential units are within ¼ mile of parks, schools or other civic uses. Civic uses are government facilities that provide services directly to the public (post office, city hall, courthouse, community center, etc.).

Reduction Methodology & Source[66]

This measure has less to do with employment/housing balance. No empirical support for this measure, but logic from suburban mixed-use measure applies. Can't get credit for both this measure and the following measures: Urban Mixed-Use and Suburban Mixed-Use Measures.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 1.0%.

[65] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[66] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

BUILDING COMPONENT MEASURES

26. Energy Star Roof Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Install Energy Star labeled roof materials. Energy star qualified roof products reflect more of the sun's rays, decreasing the amount of heat transferred into a building.

Reduction Methodology & Source[67]

Reductions are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 0.5 for qualified roof products. Baseline conditions assume indirect emission reduction through more even temperature control of environmental space. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions. The District has used a conservative number for this approach.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 0.5%.

27. Onsite Renewable Energy System Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Projects that install renewable energy systems capable of generating 2.5%-12.5% of project's annual energy need shall receive1.0 mitigation points.

[67] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

Reduction Methodology & Source[68]

Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that at least 12.5% of the buildings total energy use (as expressed as a fraction of annual energy cost) is supplied through the use of on-site renewable energy systems. Alternatively a project may use the Department of Energy (DOE) Commercial Buildings Energy Consumption Survey (CBECS) database to determine the estimated electricity use. Non-polluting and renewable energy potential includes solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, projects may take advantage of net metering with the local utility. The measure is enforceable through LEED Letter certification and building design calculations demonstrating that at least 12.5% of total energy costs are supplied by the renewable energy system(s). The District has used a conservative number of 1.0 for projects that install renewable energy systems capable of generating 2.5%-12.5% of project's annual energy need.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 1.0%.

28. Exceed Title 24 Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Project Exceeds Title 24 requirements by 20%.

Reduction Methodology & Source[69]

Reductions assume at least a 20% over Title 24 requirements, as calculated by the Sacramento Municipal Utility District (SMUD, 2006 Advantage Home Program Overview). The proposed point value for this operational mitigation measure is 1.0, consistent with the rating assigned to this measure by SMAQMD Land Use Mitigation Measures. Total compliance margin is based on energy savings relative to the total energy budget and cooling energy budget of the Title 24 Standard design home. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, specifications and any available manufacturer's documentation on the devices to be used. This measure's successful implementation may be verified by a site review following

[68] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

[69] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

construction to confirm that the project as built contains ozone destruction catalysts as described in the Air Quality Plan.

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 1.0%.

29. Solar Orientation Measure - *Residential*

Measure Description
Orient 75 or more percent of homes and/or buildings to face either north or south (within 30 degrees of North or South). Building design includes roof overhangs that are sufficient to block the high summer sun, but not the lower winter sun, from penetrating south facing windows. Trees, other landscaping features and other buildings are sited in such a way as to maximize shade in the summer and maximize solar access to walls and windows in the winter.

Reduction Methodology & Source[70]
Reduction assumes that proper solar orientation can produce a total energy savings of 11% to 16.5% and reduce heating fuel consumption by up to 25% (Local Government Commission, 1998). Mitigation measure points are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 0.5 for proper orientation. Reduction methodology will be based on quantification of the difference in solar radiance from development with designed orientations (75 or more percent of homes and/or buildings to face within 30 degrees either north or south) compared to evenly distributed orientations. Project compliance will be based on the percentage of orientation buildings designed with proper design features (overhangs, landscaping).

Achieved GHG Emission Reductions
With this measure the estimated achieved GHG emission reduction is 0.5%.

[70] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

30. Non Roof Surfaces Measure - *Commercial, Mixed-Use Residential*

Measure Description

Provide shade (within 5 years) and/or use light-colored/high-albedo materials (reflectance of at least 0.3) and/or open grid pavement for at least 30% of the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc.; OR place a minimum of 50% of parking spaces underground or covered by structured parking; OR use an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area. Unshaded parking lot areas, driveways, fire lanes, and other paved areas have a minimum albedo of .3 or greater.

Reduction Methodology & Source[71]

Reductions are based on the Sustainable Site credits (SS Credit 7.1) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that the project provides any combination of the following strategies for 50% of the site landscape (including roads, sidewalks, courtyards and parking lots): Shade (within 5 years of occupancy); paving materials with a solar Reflectance Index (SRI) of at least 29; open grid pavement system.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 1.0%.

31. Green Roof Measure - *Commercial, Mixed-Use, Residential*

Measure Description

Install a vegetated roof that covers at least 50% of roof area. Project should demonstrate detailed graphics depicting the planned roof, detailed information on maintenance requirements for the roof, and the facilities plan for maintaining the roof post construction.

Reduction Methodology & Source[72]

Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green

[71] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

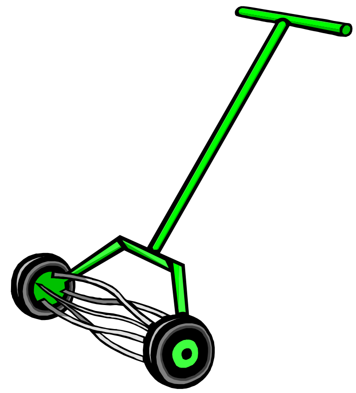
[72] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that a vegetated roof is installed on a least 50% of the roof area or that a combination high albedo and vegetated roof surface is installed that meets the following standard: (Area of SRI Roof/0.75)+(Area of vegetated roof/0.5) >= Total Roof Area.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 0.5%.

TDM & MISC. MEASURES



33. Electric Lawnmower Measure - *Residential*

Measure Description

Provide a complimentary electric lawnmower to each residential buyer.

Reduction Methodology & Source[73]

Reduction is based on a 0.5% reduction in total air shed VOC emissions, as attributable to the Lawn Mower Buy-Back program (Portland, Oregon, ten-year ozone maintenance plan). Mitigation measure points are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 1.0 for electric lawnmowers. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.

Achieved GHG Emission Reductions

With this measure the estimated achieved GHG emission reduction is 1.0%.

[73] *Recommended Guidance for Land Use Emission Reductions, Version 2.4, August 2007*. Sacramento Metropolitan Air Quality Management District.

ADDITIONAL PERFORMANCE STANDARDS REQUIRING FURTHER INVESTIGATION

In addition to those GHG emission reduction measures identified above, the District recognizes there are other potential mitigation measures that can be incorporated into the list but would need further evaluation. In relation, those identifiable measures have been incorporated in the Table in Appendix J.

In parallel, CAPCOA has developed a list of mitigation measures compiled from a number of sources (e.g., CAPCOA White Paper, AG's website, & several air agencies). CAPCOA evaluated the list to eliminate redundancy and rank according to importance or potential GHG control efficiencies. A consultant will be assisting CAPCOA in performing literature search to identify a methodology for quantifying GHG mitigation measure control efficiencies for CO_2, CH_4, and N_2O, and quantifying the control efficiencies. The District participates in this work and will continue to follow it closely as well as other similar types of effort.

SAMPLE ISR PROJECTS

From projects that have complied with Indirect Source Review (ISR), the District has randomly selected three projects to see how they compare to the GHG emission reduction measures proposed by the District to reduce greenhouse gas emissions.

- Sample project 1: Mixed-use development including: 209,650 square feet of commercial space, 278,200 square feet of office space, and 24 dwelling units. The total achieved CO_2 mitigation points achieved for this project was 20.4.

- Sample project 2: Residential development including: 205 single family residential dwelling units. The total achieved CO_2 mitigation points achieved for this project was 11.6.

- Sample project 3: Commercial development including: 59,909 square feet of commercial space. The total achieved CO_2 mitigation points achieved for this project was 14.7.

Based on these samples, the District believes that it will be difficult, but feasible, for development projects to achieve the 29% reduction. However, it would require further mitigation by project proponents than that which is typically being proposed for today's projects.

REFERENCES

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17. SJVAPCD- San Joaquin Valley Greenhouse Gas CEQA Guidance Issue Paper (December 10, 2008)

18. SJVAPCD- CEQA GHG Guidance Project Scope Subcommittee – Characterization of Greenhouse Gas Emissions (February 10, 2009)

19. SJVAPCD- CEQA GHG Guidance Level of Significance Subcommittee (February 18, 2009)

20. SJVAPCD- CEQA GHG Guidance Mitigation Measures Subcommittee (March 04, 2009)

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Appendix A:
Project Scope Committee Members

Project Scope- List of Ad Hoc Committee Members

Name	Affiliation
Daniel Barber	San Joaquin Valley Air Pollution Control District
J.P Cativiela	Dairy CARES
Dennis J. Champion	Occidental of Elk Hills
Casey Creamer	California Cotton Ginners
Tin Cheung	The Planning Center
Dawn S. Chianese	Environ
Kevin Clutter	Conestoga-Rovers & Associates (CRA)
Jerry Frost	Kern Oil
Wendy Garcia	Constellation Wines
Sarah Jackson	EarthJustice
Julia Lester	Environ
Arnaud Marjollet	San Joaquin Valley Air Pollution Control District
Mark Montelongo	San Joaquin Valley Air Pollution Control District
Elena Nuno	Michael Brandman Associates
Dennis Roberts	San Joaquin Valley Air Pollution Control District
Patia Siong	San Joaquin Valley Air Pollution Control District
Dennis Tristao	J.G. Boswell Company
Tom Umenhofer	Western States Petroleum Association
Nicole Vermilion	The Planning Center

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Appendix B:
Level of Significance Committee Members

Level of Significance- Ad hoc Subcommittee Members:

Name	**Affiliation**
Bettina Arrigoni	Global Energy Partners, LLC
Dan Barber	SJVAPCD
John Beckman	Building Industry Assoc. of the Delta
David Campbell	Tricor
Donna Carpenter	Sikand Engineering
Dennis Champion	Occidental of Elk Hills
Dawn S. Chianese	Environ
Tin Cheung	The Planning Center
Casey Creamer	California Cotton Ginners
Caroline Farrell	Center on Race, Poverty & Environment
Jerry Frost	Kern Oil
Wendy Garcia	Constellation Wines
Issac A. George	City of Arvin
Spencer Hammond	Chevron
Erin Burg Hupp	Attorney at Law-Meyers Nave
Sarah Jackson	Earth Justice
Bob Keenan	HBATK
Julia Lester	Environ
John Ludwick	Berry Petroleum Company
Arnaud Marjollet	SJVAPCD
Michael B. McCormick	PMC
Mark Montelongo	SJVAPCD
Gordon Nipp	Kern-Kaweah Chapter of Sierra Club
Elena Nuno	Michael Brandman Assoc.
Tonya Short	HBA of Kern County
Patia Siong	SJVAPCD
David Smith	DMD Associates
Lee Smith	Attorney-Stoel Rives
Dennis Tristao	J.G. Boswell Company
Tom Umenhofer	Western States Petroleum Association
Lisa Van de Water	SJVAPCD
Nicole Vermilion	The Planning Center

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Appendix C:
Mitigation Measures Committee Members

Mitigation Measures- Ad hoc Subcommittee Members:

Name	Affiliation
Bettina Arrigoni	Global Energy Partners, LLC
Dan Barber	SJVAPCD
John Beckman	Building Industry Assoc. of the Delta
David Campbell	Tricor
Donna Carpenter	Sikand Engineering
Dennis Champion	Occidental of Elk Hills
Dawn S. Chianese	Environ
Tin Cheung	The Planning Center
Casey Creamer	California Cotton Ginners
Caroline Farrell	Center on Race, Poverty & Environment
Jerry Frost	Kern Oil
Wendy Garcia	Constellation Wines
Issac A. George	City of Arvin
Spencer Hammond	Chevron
Erin Burg Hupp	Attorney at Law-Meyers Nave
Sarah Jackson	Earth Justice
Bob Keenan	HBATK
Julia Lester	Environ
John Ludwick	Berry Petroleum Company
Arnaud Marjollet	SJVAPCD
Michael B. McCormick	PMC
Mark Montelongo	SJVAPCD
James P. Mosher	CO_2 & Energy
Gordon Nipp	Kern-Kaweah Chapter of Sierra Club
Elena Nuno	Michael Brandman Assoc.
Tonya Short	HBA of Kern County
Patia Siong	SJVAPCD
David Smith	DMD Associates
Lee Smith	Attorney-Stoel Rives
Dennis Tristao	J.G. Boswell Company
Tom Umenhofer	Western States Petroleum Association
Lisa Van de Water	SJVAPCD
Nicole Vermilion	The Planning Center

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Appendix D:
San Joaquin Valley Greenhouse Gas CEQA Guidance Issue Paper (December 10, 2008)

San Joaquin Valley
Air Pollution Control District

SAN JOAQUIN VALLEY GREENHOUSE GAS CEQA GUIDANCE ISSUE PAPER

December 10, 2008

TABLE OF CONTENTS

CHAPTER 1- INTRODUCTION

The California Legislature enacted CEQA in 1970. CEQA is intended to address a broad range of environmental issues, including water quality, noise, land use, natural resources, transportation, energy, human health, biological species, and air quality. CEQA requires that public agencies (i.e., local, county, regional, and state government) consider and disclose the environmental effects of their decisions to the public and governmental decision makers. Further, it mandates that agencies implement feasible mitigation measures or alternatives that would mitigate significant adverse effects on the environment. CEQA requires public agencies to identify potentially significant effects on the environment of projects they intend to carry out or approve, and to mitigate significant effects whenever it is feasible to do so.

Although AB 32 gives wide responsibility to ARB to regulate GHG emissions from all sources, including non-vehicular sources, it does not preempt or excuse permitting agencies from addressing GHGs under CEQA.

In August 2008 the District's Governing Board adopted the Climate Change Action Plan (CCA). The CCAP authorized the Air Pollution Control officer to develop guidance documents to assist land use agencies address greenhouse gas (GHG) emissions as part of the California Environmental Quality Act (CEQA) process, develop a greenhouse gas banking program, enhance the existing emissions inventory process to include greenhouse gas emissions, and administer voluntary greenhouse gas emission reduction agreements. These items would then be brought before the Governing Board for their consideration.

This white paper focuses solely on various issues concerning the development of District guidance for addressing project related greenhouse emissions during the CEQA process. This paper does not address the other items called for in the CCAP. Information on climate change and governmental activities in California to reduce GHG emissions are presented in the District's Climate Change Action Plan Staff Report.

The intent of this white paper is to provide a starting point for developing guidance for addressing GHG emissions during the CEQA process. There are many potentially valid concepts, each with its own benefits and disadvantages that will be evaluated by the GHG CEQA Guidance Technical Workgroup.

The goals of the GHG CEQA guidance are to provide a mechanism:

- to identify the scope of GHG emissions related to specific projects,
- quantify those GHG emissions,
- identify GHG emissions mitigation measures, and
- to assess the significance of project related GHG emissions.

CHAPTER 2 SCOPE OF PROJECT GHG EMSSIONS

Per CEQA Guidelines Section 15378, "Project" means the whole of an action, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and that is any of the following:

(1) An activity directly undertaken by any public agency including but not limited to public works construction and related activities clearing or grading of land, improvements to existing public structures, enactment and amendment of zoning ordinances, and the adoption and amendment of local General Plans or elements thereof pursuant to Government Code Sections 65100-65700.
(2) An activity undertaken by a person which is supported in whole or in part through public agency contracts, grants, subsidies, loans, or other forms of assistance from one or more public agencies.
(3) An activity involving the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies

For the purpose of this GHG CEQA guidance, a key issue to be resolved is what emissions should be attributed to a project?

Project related GHG emissions could consist of:

- Direct project GHG operational emissions:
    - Combustion emissions,
    - Methane generation, etc

- Ancillary project GHG operational emissions:
    - Power consumption to operate project equipment
    - Power consumption to operate peripheral equipment

- Indirect project GHG emissions:
    - Operational mobile sources emissions
        - Delivery vehicles - raw material
        - Shipping vehicles - finished goods
    - Project life cycle emissions
        - Emissions generated during the entire life cycle of the project: ranging from mining of raw materials, processing those materials into steel, manufacturing of equipment, to shipment and installation of equipment at the project site, etc.

CHAPTER 3 QUANTIFICATION OF PROJECT GHG EMSSIONS

Protocols for quantifying GHG emissions:

- Translating project activities into GHG emissions
- Emission factors associated with each activity

For example, determining GHG emission from electricity consumption associated with the operation of the project equipment would require consideration of the following:

- Energy consumption (e.g. kwh used)
- Source of electricity (e.g. fossil fuel combustion, hydroelectric, solar, etc)
- Energy production characterization (fossil fuel: coal, natural gas, oil, etc)
- Energy production source %
- Emission factors
- Etc

For example, determining GHG emission from mobile sources (raw materials delivery trucks) associated with the project would require consideration of the following:

- Size of truck
- Truck engine tier
- Truck engine horse power
- Vehicle Miles Traveled (VMT)
- % of VMT attributed to the specific project operation
- Fuel type
- Emission factors
- Etc

For example, determining GHG emission from mobile sources (worker commute) associated with the project would require consideration of the following:

- Number of workers
- Number of vehicles
- Type of vehicles
- Carpooling parameters
- Vehicle Miles Traveled (VMT)
- % of VMT attributed to the specific operation
- Fuel type
- Emission factors
- Etc

CHAPTER 4 GHG EMISSIONS MITIGATIONS

CEQA Guideline, section 15370, defines mitigations as:

- Avoiding the impact all together by not taking a certain action or parts of an action,
- Minimizing impacts by limiting the degree or magnitude of the actions and its implementation,
- Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment,
- Reducing or eliminating the impact over time by preservation and maintenance operation during he life of the action, or
- Compensating for the impact by replacing or providing substitute resources or environments.

Identifying GHG emission mitigations would require consideration of the following:

- Reference point:
    - Business As Usual (BAU),
    - AB32 mandates,
    - Etc
- Surplus aspect of proposed mitigation compared to any current or future GHG emission reduction requirements:
    - Identify current and future GHG emission reduction requirements
- Longevity of the GHG emission mitigations:
    - Life of the GHG emissions reduction projects (e.g. planting trees versus trees decomposition, etc)
    - GHG emission reduction future requirements
- Quantification GHG emission mitigations:
    - Type and nature of GHG emissions reduction project
    - Scope of GHG emissions reduction project (See identification and quantification of project GHG emission sections)
- Voluntary Emission Reduction Agreement
- GHG emission reduction banking system used to mitigate future GHG emissions increases
- Verification and enforceability of the proposed GHG emission mitigations:
    - Local GHG emissions reduction projects
    - GHG emissions reduction projects occurring somewhere else on Earth

CHAPTER 5 SIGNIFICANCE OF PROJECT RELATED GHG EMISSIONS

CEQA requires public agencies to identify potentially significant effects on the environment of projects they intend to carry out or approve, and to mitigate significant effects whenever it is feasible to do so. Per CEQA Guidance, section 15382, "Significant effect on the environment" means a substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the project, including land, air, water, minerals, flora, fauna, ambient noise, and objects of historic or aesthetic significance.

This determination of significance must be based on the substantial evidence in light of all the information before the agency. At this time there are no generally accepted thresholds of significance for determining the impact of GHG emissions from an individual project on global climatic change.

Under state law, it is the purview of each lead agency to determine what, if any, significance thresholds will be established to guide its review of projects under CEQA. Traditionally, the District has provided local lead agencies technical guidance for assessing a project's potential impact on air quality, including establishment of significance thresholds for criteria pollutants.

Existing and proposed approaches to addressing the significance of GHG emissions during the CEQA process will be discussed and evaluated.

Possible approaches for addressing GHG during the CEQA process:

- Single GHG significance threshold
- Multiple GHG significance thresholds
- Specific project type determination
- Program level CEQA determination
- Facility level CEQA determination
- Performance based threshold
- Tiered classification of projects' impacts
- Combination of any of the above
- Others, to be determined

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Appendix E:
CEQA GHG Guidance Project Scope Subcommittee – Characterization of Greenhouse Gas Emissions
(February 10, 2009)

CEQA GHG Guidance
Project Scope Subcommittee

Characterization of Greenhouse Gas Emissions

February 10, 2009

The District has actively sought input from the ad hoc committee and the following document is still under development. The District is still receiving comments from the committee, which will be considered before finalizing this document.

Ad Hoc Committee Members:

Daniel Barber, J.P Cativiela, Dennis J. Champion, Casey Creamer, Tin Cheung, Dawn S. Chianese, Kevin Clutter, Jerry Frost, Wendy Garcia, Sarah Jackson, Julia Lester, Arnaud Marjollet, Mark Montelongo, Elena Nuno, Dennis Roberts, Patia Siong, Dennis Tristao, Tom Umenhofer, and Nicole Vermilion.

See appendix A

CEQA GHG Guidance Project Scope, February 10, 2009

Introduction

During the Greenhouse Gas (GHG) CEQA Guidance Technical Workgroup meeting an ad hoc committee was formed to evaluate GHG emissions resulting from one industrial and one non-industrial project. Key objectives were to identify and quantify potential direct sources of GHG emissions, to the extend feasible, identify and quantify potential indirect GHG emissions, and to report back to the Technical Workgroup, providing guidance/recommendations regarding the scope of GHG emissions to be considered during the CEQA environmental review process.

Several discussions were coordinated on these key objectives over four conference calls that were held on December 17 and 23, 2008 and on January 6 and 9, 2009. This document summarizes the subcommittee's discussions.

The industrial project selected by the committee consists of adding a 14.6 MMBtu/hr natural gas fired powdered milk spray dryer operation increasing throughput of an existing milk processing facility by 1,200 tons of milk per day. The mixed-use development project consists of 201,000 sq ft commercial, 278,000 sq ft of office space, plus 24 residential units, all situated on 40 acres. Both projects are actual projects submitted to the District. When possible, GHG emissions were calculated using project specific information, otherwise, assumptions were made using best available information.

Emission sources were categorized as either Direct, Indirect, or lifecyle. Direct emissions result from a physical change in the environment which is caused by and which is immediately related to the project. Examples of direct emissions are operational emissions (emissions from activities occurring on-site), mobile source emissions (vehicular emissions resulting from delivery of operational materials to the facility, shipment of finished goods, and vehicular emissions resulting from employee, customer, or residential traffic), and emissions from on-site construction activities. Direct emission sources are traditionally considered during the CEQA review process. Indirect emissions result from a physical change in the environment which is not immediately related to the project, but is caused by the project. Examples of indirect emissions include emissions resulting from the generation of electricity to meet project related energy demands. Lifecycle emissions result from a physical change in the environment which is not immediately related to the project, but is caused by a given product or service caused or necessitated by the existence of a project. Examples of lifecycle emissions include emissions from mining, timber harvesting, processing raw materials into intermediate, i.e. converting iron ore into steel, and fabrication of raw materials into finished goods used by a project. Details of emissions sources are presented in attached Table-1 and Table-2.

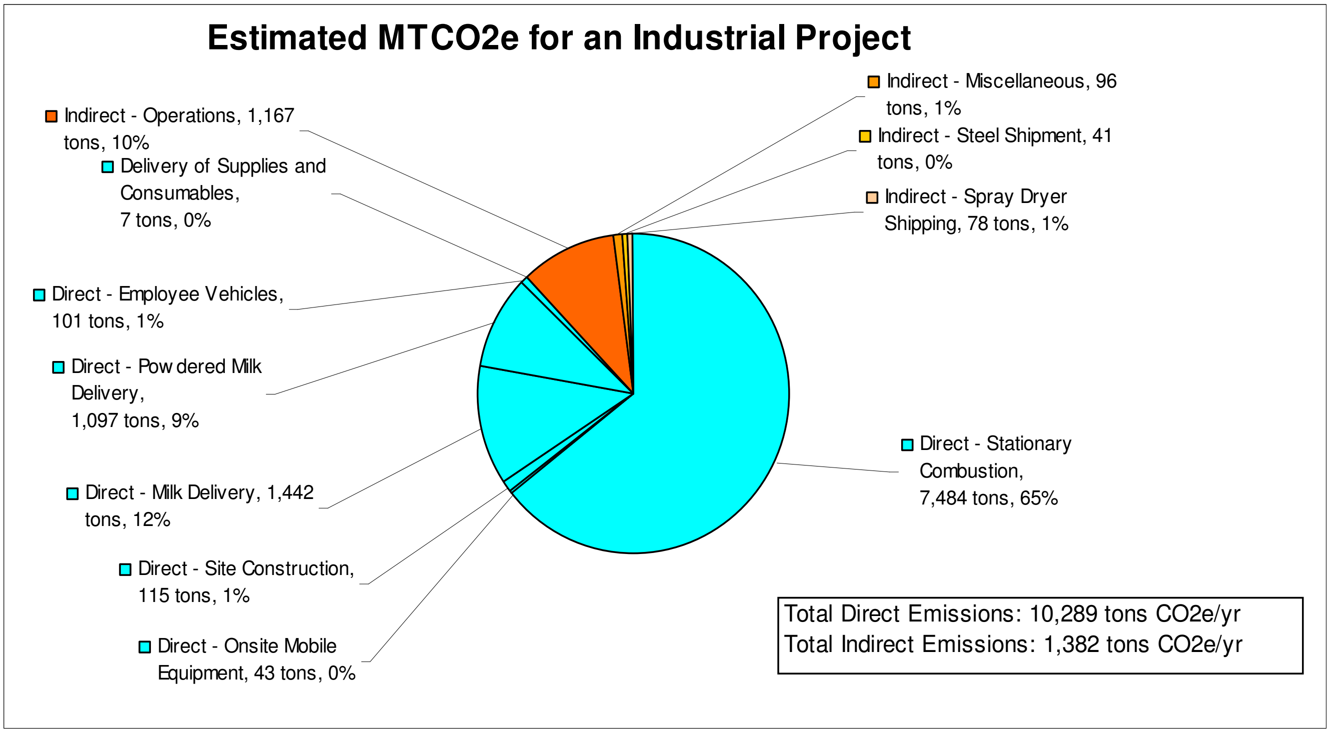
CEQA GHG Guidance Project Scope, February 10, 2009

Industrial Project Emissions – Determinations

The following statistics, also shown in Figure 1, pertain to the industrial project described above:

- Stationary source emissions account for about 70% of direct emissions
- Mobile source emissions account for about 26% of direct emissions
- Construction emissions account for about 1% of direct emissions
- Electrical power consumption account for about 95% of indirect emissions
- Shipment of steel and boiler account for about 5% of indirect emissions
- Total indirect emissions account for about 12% of combined total direct and indirect emissions

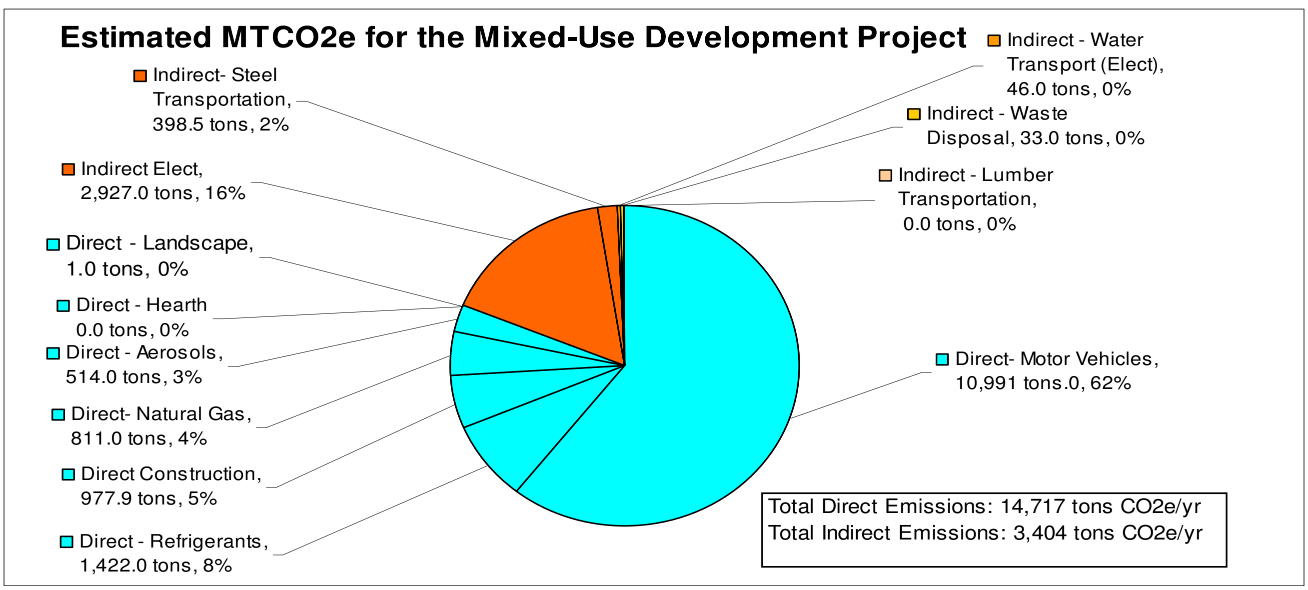
Figure 1: Estimated GHG Emissions for an Industrial Project



Mixed-Use Project Emissions – Determinations
The following statistics, also shown in Figure 2, pertain to the mixed-use project described above:

- Mobile source emissions account for about 75% of direct emissions
- Refrigerant loss account for about 10% of direct emissions
- Construction emissions account for about 7% of direct emissions
- Natural gas consumption account for about 6% of direct emissions
- Aerosol emissions account for about 4% of direct emissions
- Electrical power consumption account for about 97% of quantifiable indirect emissions
- Total indirect emissions account for about 19% of combined total direct and indirect emissions
- It was not feasible to estimate indirect emissions associated with transportation of raw materials and finished goods

Figure 2: Estimated GHG Emissions for an Mixed- Use Development Project



The assumptions used in the analysis of these two projects can be found in Appendix B and Appendix C.

CEQA GHG Guidance Project Scope, February 10, 2009

Indirect Emissions from Electrical Power Consumption - Determinations
The following points represent the committee's majority opinion on this topic:

- For both industrial and non-industrial projects it is feasible to estimate potential electrical consumption and the associated indirect GHG emissions
- Decreasing electrical power consumption would reduce GHG emissions and concomitantly have a positive impact on global climatic change
- Estimating emissions from electrical power consumption is speculative because the actual source of generation (wind, fossil fuel, nuclear, hydroelectric, etc) and location of generation (within or outside California) is unknown
- Traditionally, indirect emissions associated with production of electrical power are not attributed to a development or industrial project
- Emissions resulting from electrical power generation have already been attributed to the power production facility and the power production facility has already been required to mitigate the impacts of its emissions
- Power generating facilities are subject to AB32 emission reduction targets and thus, will be required to mitigate their GHG emissions
- Including indirect emissions associated with electrical power consumption likely double counts GHG emissions associated with electrical power generation. Thus, overstating a project's environmental impacts

Indirect Emissions from Raw Materials and Finished Goods (Lifecycle Emissions) - Determinations
The following points represent the committee's majority opinion on this topic:

- Within limits, it was feasible to estimate potential emissions associated with transportation of raw materials and delivery of finished goods for industrial projects.
- It was not feasible to estimate indirect emissions associated with transportation of raw materials and finished goods for non-industrial projects.
- Estimation of potential emissions associated with transportation of raw materials and delivery of finished goods is highly speculative.
- Knowing emissions resulting from manufacturing and transportation of finished goods could influence decisions on sourcing products and consumer consumption.
- Reducing emissions associated with manufacture and transportation of finished goods would have a positive impact on global climatic change.
- Emissions associated with transportation of raw materials and delivery of finished goods is a minor percentage of direct project emissions.

Greenhouse Gas Reporting Protocols

As a starting point, the committee reviewed two greenhouse gas reporting protocols: (1) the General Reporting Protocol (the Protocol) developed by the California Climate Action Registry, and (2) the Greenhouse Gas Protocol (GHG Protocol) developed by the World Business Council for Sustainable Development and the World Resources Institute.

The Protocol is used primarily by California Registry members in calculating and reporting emissions through the California Action Registry Reporting Online Tool. It provides guidance for businesses, government agencies, and non-profit organizations to participate in the California Climate Action Registry, a voluntary greenhouse gas registry. The Protocol is used to report emissions within California or with the United States.

The GHG Protocol also provides guidance for businesses and other organizations. It consists of two modules: the Corporate Accounting and Reporting Standards and the Project Accounting Protocol Guidelines. The first one contains methodologies for business and others to inventory and report all of the GHG emissions they produce. The latter one is geared toward calculating reductions in GHG emissions from specific GHG-reduction projects. The GHG Protocol states that the GHG assessment boundary is to include all the GHG effect regardless of where they occur and who has control over the sources and sinks associated with them.

The Protocol identifies the operational boundaries through direct emissions and indirect emissions. The GHG Protocol also identifies the emissions as direct or indirect but uses several types of scope of accounting and reporting for indirect emissions.

Methodologies for calculating GHG emission are relevant to calculating project specific GHG emission and were used here. More details on the reporting requirements can be found at http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html for the Protocol, and at http://www.wri.org/project/ghg-protocol for the GHG Protocol.

Discussion:
Pursuant to the California Environmental Quality Act (CEQA) Guidelines Section 15064(d), “in evaluating the significance of the environmental effect of a project, the Lead Agency shall consider direct physical changes in the environment which may be caused by the project and reasonably foreseeable indirect physical changes in the environment which may be caused the by project.” The CEQA Guidelines clearly

states that a physical change that is speculative or unlikely to occur is not reasonably foreseeable (CEQA Guidelines Section 15064[d][3]).

While use of raw materials for construction and operation is an indirect consequence of a project, the emissions and potential environmental impacts associated with the production and transportation of raw materials is unknown and estimation of said emissions is highly speculative. The quantification of emissions associated with raw material usage is likely to be double-counted when developing emission inventories for industrial sources. The source of the raw materials and/or manufacturing processes associated with raw material usage may occur outside the state and is not included in the emissions inventory for the state and therefore should not be included in the emissions inventory for the project for the purposes of CEQA.

Substantial research would be required to minimize the speculative nature of trying to characterize indirect emissions for each project. Project proponents would have to determine the origin of the materials used during the construction and/or operation of the project. Additional research would be necessary to gather emission rates for the international vehicles (ship, aircraft, trains, trucks, etc.), global energy production, global industrial processes, and other GHG emitting processes. Even if this information is compiled, the resulting estimates represent an insignificant percentage, as compared to direct project emission.

While indirect emissions from electrical power consumption can be estimated, the estimate is speculative because actual emissions are determined by the source of power used to generate the electricity (wind, fossil fuel, nuclear, hydroelectric, etc), which is largely unknown for the power being consumed by a specific project. Furthermore, the source of power generation is unknown and may occur outside the boundaries of the air basin or the borders of California. Estimates of indirect emissions from electrical power consumption would be speculative and estimates may not be accurate.

Furthermore, traditionally, indirect emissions associated with production of electrical power are not attributed to a development or industrial project. Emissions of criteria pollutants resulting from electrical power generation have already been attributed to the power production facility and the power production facility has already been required to mitigate the impacts of its criteria pollutants emissions. The same logic applies to GHG emissions. Power generating facilities are subject to AB32 emission reduction targets and thus, will be required to mitigate their GHG emissions. Including indirect emissions associated with electrical power consumption would likely double count GHG emissions associated with electrical power generation and overstate a project's environmental impacts.

Indirect emissions associated with waste disposal can be estimated. However, as with indirect emissions associated with electrical power generation, criteria pollutants emissions resulting from waste disposal have already been attributed to the waste disposal facility. Indeed, the waste disposal facility has already been required to mitigate its operational environmental impacts. As with power generating facilities, waste disposal facilities are subject to AB32 emission reduction targets and thus, will be required to mitigate their GHG emissions. Including indirect emissions associated with waste disposal would likely double count GHG emissions and overstate a project's environmental impacts.

CEQA GHG Guidance Project Scope, February 10, 2009

Appendix A

List of Ad Hoc Committee Members

Name	**Affiliation**
Daniel Barber	San Joaquin Valley Air Pollution Control District
J.P Cativiela	Dairy CARES
Dennis J. Champion	Occidental of Elk Hills
Casey Creamer	California Cotton Ginners
Tin Cheung	The Planning Center
Dawn S. Chianese	Environ
Kevin Clutter	Conestoga-Rovers & Associates (CRA)
Jerry Frost	Kern Oil
Wendy Garcia	Constellation Wines
Sarah Jackson	EarthJustice
Julia Lester	Environ
Arnaud Marjollet	San Joaquin Valley Air Pollution Control District
Mark Montelongo	San Joaquin Valley Air Pollution Control District
Elena Nuno	Michael Brandman Associates
Dennis Roberts	San Joaquin Valley Air Pollution Control District
Patia Siong	San Joaquin Valley Air Pollution Control District
Dennis Tristao	J.G. Boswell Company
Tom Umenhofer	Western States Petroleum Association
Nicole Vermilion	The Planning Center

CEQA GHG Guidance Project Scope, February 10, 2009

Table 1 - Estimated MT CO_2 e for Industrial Project

Greenhouse Gas Emissions for a Powdered Milk Spray Dryer Operation																
CAT		Emission Source	Process Rate units/year	Units	Emission Factors lb-CO2 (eq) /unit			Annual Emissions ton-CO2 (eq) /year				% Emission Category		% Total Emissions (Direct and Indirect)	
					CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	Total	% of Total	Cum. %	% of Total	Cum. %
DIRECT		**Direct Emissions - Stationary Source**													
	1	Stationary Combustion	127,896	MMBtu	116.7	0.27	0.068	7,463	17	4	**7,484**	72.7%	72.7%	64.1%	64.1%
	2	Onsite Mobil Equipment	6,751	Gallons-LPG	12.7	0.00037	0.005467	43	0	0	**43**	0.4%	73.2%	0.4%	64.5%
		Direct Emissions - Construction													
	3	Site Construction						115	0	0	**115**	1.1%	74.3%	1.0%	65.5%
		Direct Emissions - Offsite Vehicle Travel													
	4	Milk Delivery	774,551	Heavy Truck Miles	3.72	0.000236	0.00328	1,441	0	1	**1,442**	14.0%	88.3%	12.4%	77.8%
	5	Powdered Milk Delivery	589,011	Heavy Truck Miles	3.72	0.000236	0.00328	1,096	0	1	**1,097**	10.7%	99.0%	9.4%	87.2%
	6	Employee Vehicles	182,910	Vehicle Miles	1.08	0.0012	0.0219	99	0	2	**101**	1.0%	99.9%	0.9%	88.1%
	7	Delivery of Supplies and Consumables	3,704	Heavy Truck Miles	3.72	0.000236	0.00328	7	0	0	**7**	0.1%	100.0%	0.1%	88.2%
		Total Direct Emissions						**10,264**	**17**	**8**	**10,289**	**100.0%**			
INDIRECT		**Indirect Emissions - Electric Power**													
	8	Operations	2,653	MWh	878.71	0.15	1.1	1,166	0	1	**1,167**	84.4%	84.4%	10.0%	98.2%
	9	Miscellaneous	219	MWh	878.71	0.15	1.1	96	0	0	**96**	6.9%	91.4%	0.8%	99.0%
		Indirect Emissions - Miscellaneous													
	10	Steel Shipment	1,151,100	ton-miles	0.071	7.37E-05	1.50E-05	41	0	0	**41**	3.0%	94.4%	0.4%	99.3%
	11	Spray Dryer Shipping	2,190,000	ton-miles	0.071	7.37E-05	1.50E-05	78	0	0	**78**	5.6%	100.0%	0.7%	100.0%
		Total Indirect Emissions						**1,381**	**0**	**1**	**1,382**	**100.0%**			
		Total Emissions						**11,645**	**17**	**9**	**11,671**			**100.0%**	

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Table 2 - Estimated MT CO_2E for the Mixed-Use Development

CATEGORY	Source	Annual Emissions	% Emission Category		% Total Emissions (Direct and Indirect)	
		Metric tons CO2e	% of Total	Cum. %	% of Total	Cum. %
DIRECT	Motor Vehicles	10,991.0	74.7%	74.7%	60.7%	60.7%
	Refrigerants	1,422.0	9.7%	84.3%	7.8%	68.5%
	Construction	977.9	6.6%	91.0%	5.4%	73.9%
	Natural Gas	811.0	5.5%	96.5%	4.5%	78.4%
	Aerosols	514.0	3.5%	100.0%	2.8%	81.2%
	Landscape	1.0	0.0%	100.0%	0.0%	81.2%
	Hearth	0.0	0.0%	100.0%	0.0%	81.2%
		14,717	**100.0%**			
INDIRECT	Indirect Elect	2,927.0	86.0%	86.0%	16.2%	97.4%
	Steel Transportation	398.5	11.7%	97.7%	2.2%	99.6%
	Water Transport (Elect)	46.0	1.4%	99.0%	0.3%	99.8%
	Waste Disposal	33.0	1.0%	100.0%	0.2%	100.0%
	Lumber Transportation	0.0	0.0%	100.0%	0.0%	100.0%
		3,404	**100.0%**			
	TOTAL	**18,121**			100.0%	

The project consists of:

40 acres	
201,000 sqft	commercial
278,000 sqft	office
24 units	residential

NOTES:

(1) The sources and emissions are based on project specific data already available.

(2) Emissions for waste disposal were obtained using EPA's Waste Reduction Model (WARM).
http://epa.gov/climatechange/wycd/waste/calculators/Warm_home.html

(3) Data for residential and businesse waste disposal rate was obtained from the California Integrated Waste Management Board
http://www.ciwmb.ca.gov/Profiles/

(4) URBEMIS 2007 was used to estimate emissions from construction.

Appendix B

Basis for Greenhouse Gas Estimate for Powdered Milk Spray Dryer Operation

Direct Emissions – Stationary Source

- Maximum Firing Capacity for spray dryer is 14.6 MMBtu/hr natural gas
- Facility will operate 8760 hr/yr
- Burner Utilization is 100%
- Emission factors (with Global Warming Potential) for natural gas combustion are from CCAR, V.3, April, 2008:

	kg/MMBtu	lb/MMBtu	GWP	lb- CO_2E/scf
CO_2:	53.06	116.7	1	116.7
Methane:	0.0059	0.013	21	0.27
N2O	0.0001	0.00022	310	0.068

- Emissions for milk evaporation (from delivered milk to 50% concentrate fed to the dryer) are attributed to the existing milk evaporation system (3 boilers) and not included with the dryer.
- 50 hp forklift used to handle bagged product. Operates 8 hours per day with 50% utilization of horsepower and 30% thermal efficiency.
- Emission factors (with Global Warming Potential) for LPG-powered vehicles are from CCAR, V.3, April, 2008 for California:

	g/mile	lb/mile	GWP	lb- CO_2E/gal
CO_2:	-	-	1	12.7*
Methane:	0.04	$8.81x10^{-5}$	21	0.00037**
N2O	0.04	$8.81x10^{-5}$	310	0.00547**

* CO_2 is based on 5.79 kg/gal for diesel (per CCAR) and an annual fuel consumption of 6,751 gal LPG
** Methane and N2O are based on hypothetical fuel economy of 5 mpg

Direct Emissions - Construction

- Construction emissions include direct emissions from construction sources at the plant site plus emissions associated with shipping of the spray dryer
- Construction site CO_2 emissions were estimated using URBEMIS and assume a 2 acre site with 10,400 square feet of combined industrial building and office space.
- Methane and N2O emissions for construction were approximated by factoring from the CO_2 emissions based on the heavy truck emission factors presented above.

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Direct Emissions - Offsite Vehicle Travel

- Maximum Milk Solids processing is 84.6 tpd dry product
- Powdered milk product trucks carry 25 tons per round trip and travel 478 miles per round trip at 6 mpg.
- Delivered raw milk quantity is estimated based on 7 wt% milk solids in raw milk.
- Milk delivery trucks travel 44 miles round trip at 6 mpg and carry 6000 gal per round trip.
- Emission factors (with Global Warming Potential) for Heavy Trucks are from CCAR, V.3, April, 2008 for California:

	g/mile	lb/mile	GWP	lb- CO_2E/mi
CO_2:	-	3.72*	1	3.72
Methane:	0.0051	1.12×10^{-5}	21	0.00024
N2O	0.0048	1.06×10^{-5}	310	0.00328

* CO_2 is based on 10.15 kg/gal for diesel (per CCAR) and a fuel efficiency of 6 mpg

- Average employee travel is 35 mi round trip with average fuel economy of 18 mpg
- Plant staff:

Administrative Staff:	10 per shift, 5 shifts per week (shared with evaporator)
Operations Supervisor:	1 per shift, 3 shifts per day (shared with evaporator)
Dryer Operators:	2 per shift, 3 shifts per day
Maintenance	5 per shift, 5 shifts per week (shared with evaporator)
Security	1 per shift, 3 shifts per day (shared with evaporator)

- Emission factors (with Global Warming Potential) for Passenger Cars are from CCAR, V.3, April, 2008 for California:

	g/mile	lb/mile	GWP	lb- CO_2E/mi
CO_2:	-	1.08*	1	1.08
Methane:	0.026	5.73×10^{-5}	21	0.0012
N2O	0.032	7.05×10^{-5}	310	0.0219

* CO_2 is based on 8.81 kg/gal for diesel (per CCAR) and a fuel efficiency of 18 mpg

Mobile Source Emissions Associated with Shipment of Plant Operating Supplies and Consumables:

- Total installed cost for the dryer system was $20,000,000 (assumed)

- Annual expense for plant consumables and operating supplies is 2% of TIC = $400,000/year(2 x typical per Peters and Timmerhaus, Plant Design and Economics for Chemical Engineers, 2nd ed, McGraw-Hill, 1958.)
- Shipping cost for plant consumables and operating supplies is 5% of value or 0.05 x 200,000 = $20,000/year (assumed)
- Shipping rate is $5.40/mi (a shipping expenditure of $5.40 generates one vehicle mile for a heavy diesel truck – rough estimate based on published UPS shipping rates)

Indirect Emissions - Electric Power

- Operating electrical loads consist of:
  Main Blower Motor @ 250 hp (per applicant)
  Rotary atomizer for dryer @ 75 kw power input (basis GEA Niro literature)
  Pumps for handling milk are 10 bhp (assumed)
  Product conveying and bagging requires 15 bhp (assumed)
- Electric Motor Efficiency is 90%
- Emission factors (with Global Warming Potential) for electricity usage are from CCAR, V.3, April, 2008 for California:

	lb/MWh	GWP	lb- CO_2E/MWh
CO_2:	878.71	1	878.71
Methane:	0.0067	21	0.15
N2O	0.0037	310	1.1

- Miscellaneous electrical loads:
  Instrumentation and anciliary loads = 2 kw
  Dryer is housed in a 100' x 100' expanded manufacturing area (indoors) which requires 24 hour lighting at 2.2 W/ft2
  400 ft2 incremental office space associated with the milk drying operation requiring 2.5 W/ft2
  Plant outdoor lighting assumed to be existing.

Indirect Emissions - Miscellaneous

- Specific power consumption for ocean shipping (main engine output) is 0.04735 kwh per ton-milebased on data for the “Emma Maersk” (freight capacity of 61,213 tons requiring 80,000 kw to maintain a speed of 24 knots).
- Ship fuel consumption is 203 g/kwh (residual fuel oil) per: Cooper, David, “Representative Emission Factors for use in Quantification of Emissions from Ship Movements Between Port in the European Community”, Swedish Environmental Research Institute, 2002.
- Ship transit CO_2 emission factor is 677 g- CO_2 /kw per ARB's “Emission Inventory for Ship Main Engines and Boilers”

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- Ship methane and N2O emission factors are based on CCAR factors for combustion of residual fuel oil at a stationary source and on the calculated fuel consumption.
- Due to length of shipment, emissions due to anchorage and hoteling were assumed to be negligible.
- The dryer is assumed to be procured and shipped from China (Hong Kong to Los Angeles - one-way shipping distance of 7,300 miles) and only cargo ship emissions are considered.
- Dryer is assumed to weigh 300 tons.
- Steel (300 tons) is assumed to be shipped from India to China (Mumbai to Hong Kong – one way shipping distance of 3,837 miles)

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Appendix C

Basis for Greenhouse Gas Estimate for a Mixed-Use Development Project

Direct Emissions

Motor Vehicles

- The vehicle percentages are based on default values in URBEMIS 2002.
- The build-out for this project is year 2010.
- The vehicle miles traveled is estimated at 61,000 with 12,200 trips.
- The emission factors for the running emissions are based on the U.S. Environmental Protection Agency and Climate Leaders Greenhouse Gas Inventory Protocol – Core Module Guidance, for direct emissions from mobile combustion sources.
- The emission factors for the starting emissions are based on the U.S. Environmental Protection Agency EPA420-P-04-016 (Update of Methane and Nitrous Oxide Emission Factors for On-highway Vehicles).

Refrigerant

- It is assumed that there are 24 domestic refrigeration units, about 490 units of Residential/office/commercial A/C ranging in capacity.
- An annual leak rate in percent of capacity is included.

Construction

- URBEMIS 2007 was used to obtain emissions from construction.
- The analysis evaluates the project consisting of 40 acres, 201,000 square feet of commercial land use, 278,000 square feet of office land use, and 24 multi-dwelling residential units in Fresno County.
- The construction timeline was one year.

Natural Gas

- A natural gas usage factor based on default value in URBEMIS 2002 for methane and nitrous oxide was assigned to the type of land (e.g.: office, retail/shopping, residential, etc.) and its associated square footage or units.

Aerosols

- MOBILE6 and URBEMIS 2007 were used to estimate the carbon emissions for this arena.

Landscape

- URBEMIS 2007 was used to obtain landscape emissions.

Hearth

- No hearth emissions were included as there were no wood-burning fireplaces in the development per City of Fresno code, however if hearths were allowed URBEMIS 2007 would have been used to provide the hearth emissions.

Indirect Emissions

Electricity

- The emission factor was obtained from the General Reporting Protocol – Reporting Entity-wide Greenhouse Gas Emissions, Version 2.2, March 2007 by the California Climate Action Registry.
- The residential electricity usage rate was assumed to be 5626.50 kwh/unit/yr based on South Coast Air Quality Management 1993 CEQA Handbook, Table 9-11-A.
- The electricity use was based on Table E-1 from the California Energy Commission - California Commercial End-Use Survey March 2006.
- The analysis evaluates the project consisting of 201,000 square feet of commercial land use, 278,000 square feet of office land use, and 24 multi-dwelling residential units.
- The total electricity use is about 8,000 MWh/year.

Steel Transportation

- Specific power consumption for ocean shipping (main engine output) is 0.04735 kwh per ton-milebased on data for the “Emma Maersk” (freight capacity of 61,213 tons requiring 80,000 kw to maintain a speed of 24 knots).
- Ship fuel consumption is 203 g/kwh (residual fuel oil) per: Cooper, David, “Representative Emission Factors for use in Quantification of Emissions from Ship Movements Between Port in the European Community”, Swedish Environmental Research Institute, 2002.
- Ship transit CO_2 emission factor is 677 g- CO_2 /kw per ARB’s “Emission Inventory for Ship Main Engines and Boilers”
- Ship methane and N2O emission factors are based on CCAR factors for combustion of residual fuel oil at a stationary source and on the calculated fuel consumption.
- Due to length of shipment, emissions due to anchorage and hoteling were assumed to be negligible.
- The steel is assumed to be shipped from India to Los Angeles – (one-way shipping distance of 10,500 miles) and only cargo ship emissions are considered.
-

Water Transport (Electricity use in typical urban water systems)

- Emission factor was obtained from the General Reporting Protocol – Reporting Entity-wide Greenhouse Gas Emissions, Version 2.2, March 2007 by the California Climate Action Registry.

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- Emission factor was also from the California's Energy-Water Relationship Final Staff Report, November 2005 by the California Energy Commission.
- It is assumed that there's about 80,000 gallons per day of water and about 115,000 kWh in energy usage.

Waste Disposal

- Waste disposal data was obtained from the California Integrated Waste Management Board – 1999 estimated materials disposed by residential sector and 1999 estimated business waste amounts for Fresno County.
- It is estimated that 137 tons of waste would be generated.
- Data was entered into US EPA's Waste Reduction Model to obtain greenhouse gas emissions.

Lumber Transportation

- It is assumed that lumber is shipped to Fresno from Springfield, Oregon. The one-way travel distance is 669 miles.
- It is estimated that 16,000 board feet of lumber is needed for a house of 2,000 square feet.
- The number of train hauling cars is 75 cars in which 24 would be used to transport lumber. The hauling capacity is about 100 tons per cars which would equate to about 12,000 board feet of lumber.
- The conversion emission factor for diesel is 0.0287 kg CO_2 /mile based on the calculation tool provided by the GHG Protocol – Mobile Guide, Version 1.3, March 2005.

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Appendix D

Summary of Written Comments

Written comments pertaining to proposed recommendations for establishing the scope of a project's greenhouse gas impacts are summarized below.

1. Sarah Jackson (Earth Justice)

One of CEQA's main functions is to provide public agencies and the general public "with detailed information about the effects of a proposed project on the environment." *San Franciscans for Reasonable Growth v. City & County of San Francisco*, 151 Cal. App. 3d 61, 72 (1984). Full analysis of all direct and indirect emissions caused by a project, using a lead agency's "best efforts to find out and disclose all that it possibly can," CEQA Guidelines section 15144, will provide maximum opportunities for mitigation and will allow for more environmentally sound decision-making. Furthermore, CEQA requires that indirect or secondary effects "which are caused by the project and are later in time or farther removed in distance, but are still reasonably foreseeable," CEQA Guidelines section 15358(a), be analyzed. Both the ARB and South Coast have determined that lifecycle analyses of GHGs are appropriate and South Coast recently proposed that lifecycle analyses be prepared for all projects undergoing CEQA analysis in order to "produce a more defensible approach." *See* South Coast Interim GHG Significance Threshold Staff Proposal at 3-7, October 2008. Categorical exclusions of emissions from analysis is contrary to CEQA's purpose and would minimize the true environmental impact of the project.

2. Gordon Nipp (Kern-Kaweah Chapter of Sierra)

- Emissions from project electricity consumption can be estimated by following the Climate Action Registry protocol. The basic methodology uses updated US EPA-developed EGRID emission factors for calculating indirect emissions from electricity use. For California, this factor is 878.71 pounds of CO_2 per MWh of usage, a figure that is lower than for many other regions because it includes renewables production. While anyone can call any such figure "speculative", this protocol is in current usage and is well established. Electricity consumption estimations should not be considered speculative.
- Including indirect emissions associated with a project's electricity consumptions as part of the project's environmental impact and requiring mitigation for this impact would not lead to double counting of these emissions. If, for example, a project were required as mitigation to generate a portion of its electricity with solar PV, the electricity generated by the project's PV would not have to be generated by a power plant. The power plant would not be required to mitigate

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impacts of electricity generated by project PV, electricity that the power plant doesn't have to generate.

- Indirect GHG emissions from electrical power generation should be included during CEQA review.

3. Wendy Garcia (Constellation Wines)

1) Regarding power consumption: I believe the project scope recommendations would be stronger by removing statements such as:

"Estimating emissions from electrical power consumption is speculative because the actual source of generation (wind, fossil fuel, nuclear, hydroelectric, etc) and location of generation (within or outside California) is unknown."

These emissions can be estimated. Power providers such as PG&E, SCE and others contract with, and purchase power from, specific electical generators. It is not speculative.

2) The de minimus level for reporting of GHG emissions is 3 to 5 percent, depending upon the reporting program. In the scope recommendation document indirect emissions are greater than 5% of total GHG emissions, so they are significant, but for the other reasons cited, indirect emissions should be left out of the scope for quantifying GHGs for CEQA purposes.

Final Draft Staff Report

Appendix F:
CEQA GHG Guidance Level of Significance Subcommittee (March 5, 2009)

CEQA GHG Guidance
Level of Significance Subcommittee

May 5, 2009

The District has actively sought input from the ad hoc committee and the following document is still under development. The District is still receiving comments from the committee, which will be considered before finalizing this document.

Ad Hoc Committee Members
Bettina Arrigoni, Daniel Barber, John Beckman, David Campbell, Donna Carpenter, Dennis J. Champion, Tin Cheung, Dawn S. Chianese, Casey Creamer, Caroline Farrell, Jerry Frost, Wendy Garcia, Issac A. George, Spencer Hammond, Erin Burg Hupp, Sarah Jackson, Bob Keenan, Julia Lester, John Ludwick, Arnaud Marjollet, Michael B. McCormick, Mark Montelongo, Gordon Nipp, Elena Nuno, Tonya Short, Patia Siong, David Smith, Lee Smith, Dennis Tristao, Tom Umenhofer, Lisa Van De Water, and Nicole Vermilion.

See Appendix A

Climate Change Action Plan
GHG CEQA Technical Workgroup--Level of Significance Subcommittee
May 5, 2009

Introduction

During the Greenhouse Gas (GHG) CEQA Guidance Technical Workgroup meeting an ad hoc committee was formed to provide guidance/recommendations to be applied when determining the significance project specific GHG emissions during the CEQA environmental review process.

Key tasks for the subcommittee include:

- Review of current CEQA requirements/guidelines for determining significance, including lead agency authority and responsibilities for determining significance
- Review actions by the following agencies that are to be developing GHG significance thresholds: Office of Planning and Research (OPR), California Energy Commission (CEC), Caltrans, Air Resources Board (ARB), South Coast Air Quality Management District (SCAQMD), Council of Governments (COG), and California Air Pollution Control Officers Association (CAPCOA)
- Discuss committee views on establishing GHG significance thresholds. In support of the discussion, the subcommittee identified the following key questions to be addressed:

1. Zero Threshold:
   - What are the pros and cons of implementing a zero significance threshold?
   - What are the pros and cons of implementing a zero versus a non-zero significance threshold?
2. If a non-zero threshold would be recommended, should the metric for determining significance consist of a numerical threshold, a qualitative assessment, or are both approaches valid?
3. If there is a dual path (qualitative and quantitative), is it necessary to demonstrate equivalency, if so, how?
4. If a numeric value is established, is the value specific to a project type, or does the same value apply to all project types?
5. What metrics should be considered in establishing a quantitative threshold?
6. What metrics should be considered in establishing a qualitative significance threshold?

Several discussions were coordinated on these key objectives over four conference calls that were held on January 15, 23, 28, February 2, 6, and 10, 2009. Written comments received by the District are presented in Appendix K. The following summarizes the committee's progress.

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Review of Lead Agency Authority and Responsibilities

To establish a common understanding, the subcommittee reviewed current CEQA requirements/guidelines for determining significance, including lead agency authority and responsibilities for determining significance. Subsequently, the subcommittee reviewed OPR's draft amended CEQA Guidelines for addressing GHG impacts during the CEQA process. The committee concludes that most of OPR's draft provisions are logical extensions of the CEQA and the provisions do not functionally change lead agency authority and responsibility under CEQA. The following are the main factors of OPR's proposed amendments to CEQA Guidelines addressing GHG impacts, (See *Appendix B* for more detail):

1) Exceedance of thresholds;
2) Emissions calculated and compared to a threshold, qualitative, or performance-based standards [for editorial additions, see reference 15064.4 (b) (4)];
3) Other agency thresholds can be used to set levels;
4) Increase or decrease in energy use/efficiency (not clear whether local or regional); and
5) Projects impact on attainment to AB 32 goals.

Review of Other Agencies Approaches to Determine GHG Significance

The group reviewed approaches proposed or adopted by the following agencies:

- Office of Planning and Research (OPR), (*Appendix B*)
- California Energy Commission (CEC), (*Appendix C*)
- Caltrans,
- Air Resources Board (ARB), (*Appendix D*)
- South Coast Air Quality Management District (SCAQMD),
- Council of Governments (COG), and
- California Air Pollution Control Officers Association (CAPCOA) (*Appendix E*)

Views on Determining GHG Significance

To provide for stakeholder input the District encouraged subcommittee members to discuss their views on various approaches for determining significance of project related GHG. To facilitate the discussion, the subcommittee is working through the key questions identified above. The following discussion summarized the subcommittee's progress.

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Zero Threshold

1. *Zero Threshold:*
   - *What are the pros and cons of implementing a zero significance threshold?*
   - *What are the pros and cons of implementing a zero versus a non-zero significance threshold?*

There are two fundamental approaches; establish a zero threshold, meaning that any project that emits GHG emissions has a significant impact, or establish a non-zero threshold, meaning that projects below a threshold would be determined to have a less than significant impact. There was considerable discussion and strong opinions on this issue.

The underlying concept of a zero threshold is that there is no level below which project specific GHG emissions would be considered to have a less than significant impact. Those recommending adoption of a zero threshold cite the following reasons:

- Would accelerate attainment of AB32 emission reduction targets
- Mitigating to zero would ensure that a project would not have a significant individual and cumulative impact
- Very easy to understand if a project would be considered significant
- Projects with GHG emissions would require preparation of an environmental impact report (EIR), thus requiring lead agencies to require all feasible mitigation measures
- No scientific basis to conclude that any level, other than zero, would not have a significant impact on global climatic change

The underlying concept of a non-zero threshold is that there is a level below which it is reasonable to conclude that project specific GHG emissions would have a less than significant impact. Those in favor of adopting a non-zero threshold cite the following reasons:

- Adopting a zero threshold would result in all projects with GHG emissions being determined to have a significant impact, thus requiring preparation of an EIR for every project with GHG emissions
- CEQA does not require mitigating project related impacts to less than significant and since it is not technically or economically feasible to mitigate to zero, most likely, projects would be approved by adopting overriding considerations
- To mitigate project related GHG emissions to less than significant would require mitigation of 100 percent of all GHG emissions

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- Not technically feasible to mitigate <u>all</u> projects with GHG emissions to zero, without stopping growth within the District and perhaps, California
- No scientific basis to conclude that a specific project would have a measurable impact on global climatic change

Non-Zero Threshold

2. *If a non-zero threshold would be recommended, should the metric for determining significance consist of a numerical threshold, a qualitative assessment, or are both approaches valid?*

There was considerable discussion surrounding these two questions with little resolution at this time. The major theme is that there is no scientific information available at this time to support a numeric value. The subcommittee acknowledges that ARB and South Coast AQMD both have proposed establishing thresholds based on percentages of the emission inventory for industrial sources. The subcommittee also acknowledges that OPR in drafting amendments to CEQA Guidelines provide for significance determinations based on either quantitative or qualitative assessments. The subcommittee further acknowledges that guidance being developed by ARB and South Coast includes provisions for both qualitative and quantitative determinations. The majority opinion is that if a non-zero approach is adopted, there should be flexibility to use both quantitative and qualitative approaches.

Qualitative Versus Quantitative Significance Determination

3. *If there is a dual path (qualitative and quantitative), is it necessary to demonstrate equivalency, if so, how?*
4. *If a numeric value is established, is the value specific to a project type, or does the same value apply to all project types?*

The District diagrammed four possible approaches illustrating how quantitative and qualitative standards could be used for assessing project related GHG impacts, (*Appendix* F – J). One approach is to evaluate significance based on whether or not a project is consistent with a quantitative standard <u>OR</u> is below some qualitative standard. Another approach presented is to evaluate significance based on whether a project is consistent with a qualitative standard <u>AND</u> is below some quantitative standard. The third and fourth approaches would evaluate significance based on a tiered or “Waterfall” approach, which could be a combination of quantitative and qualitative standards. It was recognized that regardless of the approach used, projects determined to be exempt under CEQA would be considered to have a less than significant impact.

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The pros and cons of each approach were explored and the following common themes emerged:

- Other than if a single numerical value were to be applied across all projects, qualitative and quantitative significance standards should be developed for each type of emission source (sectors). Identified sectors included development projects, transportation projects, energy production, and industrial projects.
- It will take time to develop qualitative standards and there is reasonable probability that the standards will be controversial and subject to litigation. In the interim, lead agencies and project proponents still have to assess project impacts on a case by case basis.
- There is a lack of information to establish numerical thresholds based on scientific information.
- Qualitative assessments should be, based in part, on compliance with established GHG emission reductions targets such as those established in AB32 or SB375, or approved performance standards.
- Because a project is not subject to CEQA does not necessarily means that it is not subject to AB32.
- A qualitative approach could be fashioned similar to the Indirect Source Review (ISR) approach.

Metrics to Consider in Establishing a Quantitative or Qualitative Threshold

5. *What metrics should be considered in establishing a quantitative threshold?*
6. *What metrics should be considered in establishing a qualitative significance threshold?*

In addition to the above concepts, the subcommittee discussed establishing a quantitative threshold for residential developments in which project related GHG emissions would be compared to a per capita threshold, or other unit to be determined, i.e. square foot, etc. This concept could be consistent with implementation of SB375.

The subcommittee gave significant time to discussing the availability of validated scientific information that could be used to establish project specific quantitative thresholds. Certain committee members share the opinion that there is compelling information demonstrating that any increase in GHG emissions has a significant impact on global climatic change. However, other committee members share the opinion that the existing scientific information is insufficient to support establishing project specific significance thresholds.

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GHG CEQA Technical Workgroup--Level of Significance Subcommittee
May 5, 2009

Appendix A

Ad hoc Subcommittee Members:

Name	Affiliation
Bettina Arrigoni	Global Energy Partners, LLC
Dan Barber	SJVAPCD
John Beckman	Building Industry Assoc. of the Delta
David Campbell	Tricor
Donna Carpenter	Sikand Engineering
Dennis Champion	Occidental of Elk Hills
Dawn S. Chianese	Environ
Tin Cheung	The Planning Center
Casey Creamer	California Cotton Ginners
Caroline Farrell	Center on Race, Poverty & Environment
Jerry Frost	Kern Oil
Wendy Garcia	Constellation Wines
Issac A. George	City of Arvin
Spencer Hammond	Chevron
Erin Burg Hupp	Attorney at Law-Meyers Nave
Sarah Jackson	Earth Justice
Bob Keenan	HBATK
Julia Lester	Environ
John Ludwick	Berry Petroleum Company
Arnaud Marjollet	SJVAPCD
Michael B. McCormick	PMC
Mark Montelongo	SJVAPCD
Gordon Nipp	Kern-Kaweah Chapter of Sierra Club
Elena Nuno	Michael Brandman Assoc.
Tonya Short	HBA of Kern County
Patia Siong	SJVAPCD
David Smith	DMD Associates
Lee Smith	Attorney-Stoel Rives
Dennis Tristao	J.G. Boswell Company
Tom Umenhofer	Western States Petroleum Association
Lisa Van de Water	SJVAPCD
Nicole Vermilion	The Planning Center

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Appendix B

Agency Review & Activities:

Office of Planning and Research

This memorandum summarizes the relevant OPR CEQA guideline revisions that may impact the District's quest to define significant GHG impacts. Of most importance is the new Guideline section 15064.4 that describes significant GHG impacts, section 15126.4 concerning mitigating GHG impacts and the minor changes to Appendix G the initial study form.

In summary (these are set out in more detail below), the following are the main factors that the OPR draft uses to measure significance:

1) Exceedance of thresholds;
2) Emissions calculated and compared to a threshold, qualitative, or performance-based standards [for editorial additions, see reference 15064.4 (b) (4)];
3) Other agency thresholds can be used to set levels;
4) Increase or decrease in energy use/efficiency (not clear whether local or regional); and
5) Projects impact on attainment to AB 32 goals.

The OPR document consists of some introductory comments and draft revisions to the guidelines that relate to Greenhouse gases. This Summary just discusses the more significant sections.

1. The document indicates in the introduction that OPR intends to rely on CARB to recommend a method for setting significance thresholds.
2. The draft guidelines add a new section 15064.4 titled "Determining the Significance of GHG Emissions", and it includes a suggestion of situations that might be considered significant. A project may be significant to the extent that it:
    a. Helps or hinders the attainment of GHG emission goals;
    b. The extent to an increase or decrease in consumption of fuels or other energy resources (especially fossil fuels);
    c. May result in increased efficiency with respect to GHG emissions;
    d. Exceeds a threshold of significance;
    e. This section also includes a provision that the Lead agency must make its own "good faith" effort to actually calculate the level of GHG emissions "including emissions associated with energy

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consumption"; using a model or methodology; and relies on qualitative or other performance based standards for estimating the significance of greenhouse gas emissions.

Other relevant sections:

1. 15064.7(c) which offers little guidance in setting thresholds of significance, but notes that lead agencies may consider thresholds set by other agencies;
2. 15093(d) which discusses overriding consideration indicates that local projects can be approved with significant effects if there are region-wide or statewide benefits;
3. 15126.4(c) which adds "Mitigation Measures Related to Greenhouse Gases" including energy consumption mitigation measures;
4. 15150(b)(1)(B) which encourages reliance on other EIRs that discuss greenhouse gases;
5. 15152(i) which encourages tiering from other EIRs;
6. 15130(b)(1)(B) which allows agency to use summary of projections in cumulative impacts discussion based on EIRs for other local and regional plans; and
7. 15130(f) whose cumulative impacts may be significant.
8. Adds to Appendix – which identifies potential significant effects and whether an EIR is required, contains sections regarding GHG impacts on forestry, emphasizes Vehicle Miles Traveled (VMT) and de-emphasizes Level of Service (LOS) in the Transportation/Traffic section, and adds general greenhouse gas impacts that would trigger the potential to be significant as follows:

   GREENHOUSE GAS EMISSIONS
   Would the project:
   1. Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment, based on any applicable threshold of significance?
   2. Conflict with any applicable plan, policy or regulation of an agency adopted for the purpose of reducing the emissions of greenhouse gases?

   CONCLUSION
   Most of these provisions are logical extensions of the CEQA process. The difficulty will be determining emissions and setting numerical thresholds which are not resolved herein.

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Appendix C

Agency Review & Activities:

California Energy Commission

The California Energy Commission (CEC) is the lead agency for power plant siting under California law, and has licensing authority for all thermal power plants with capacity of 50 MW or more that are proposed for construction within the state. The CEC's licensing process, which includes extensive environmental impact review, has been certified as the functional equivalent of the CEQA environmental impact review (EIR) process. Traditionally, the CEC EIR has used a "no cumulative impact" argument in response to GHG emissions. CEC staff feel confident in this assessment in light of the fact that new, cleaner power plants will displace energy needed from marginal, older, "dirtier" power plants, causing a net decrease in the system-wide GHG emissions. So, as long as there are "dirty" plants and plants that run less efficiently than new plants, the displacement argument holds.

However, in response to ARB's Scoping Plan and anticipated implementation of AB 32, CEC staff and the CEC are taking a closer look at how they deal with GHG in their EIR findings. The Siting Committee held two workshops[74] in October and November in and accepted subsequent written comment, to discuss conceptual interim approaches for evaluating GHG emissions from new power plants. Potential threshold approaches were discussed amongst committee members, staff, industry representatives and environmental representatives including:

Zero threshold - mitigation for all projects;
System threshold - mitigation for some projects;
System/local-reliability-areas (LRA) threshold - mitigation based on LRA; and
"Best available control technology" - mitigation by technology.

Most of the discussion bounced between the zero-threshold (environmental representatives) and the system-threshold (industry representatives). Several of the industry representatives stated that they are already mitigating by applying best available control technology whenever possible. By the end of the discussion, the Siting Committee directed staff to conduct (actually, a consultant will conduct) a Generic System Analysis to understand the implications of changes to the energy system upon the addition of a new power plant. This analysis is due back to staff in February or March for internal review. It is

[74] The transcript and other documents from this workshop are available at http://www.energy.ca.gov/ghg_powerplants/documents/

possible that this general analysis may be used programmatically for future EIR analyses for new power plants, but at this point it is unclear.

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Appendix D

Agency Review & Activities:

ARB Preliminary Guidelines Significance Standards

Framework of ARB's Preliminary Proposal for GHG Significance Levels

The Preliminary Proposal proposes guidelines for residential, commercial and industrial projects. A residential or commercial project is categorized as a project that is either: 1) statutorily or categorically exempt; 2) less than significant because it complies with either a previously approved CEQA-compliant programmatic document or a combination of quantitative and performance standards; or 3) significant and requiring preparation of an EIR. An industrial project may also be either 1) categorically or statutorily exempt, or; 2) meet a combination of quantitative and performance standard thresholds to achieve a less than significant CEQA status.

Please see attached flow charts from ARB's preliminary proposal.

For more information (including a power point that expands on performance standards):
http://www.arb.ca.gov/cc/localgov/ceqa/meetings/meetings.htm

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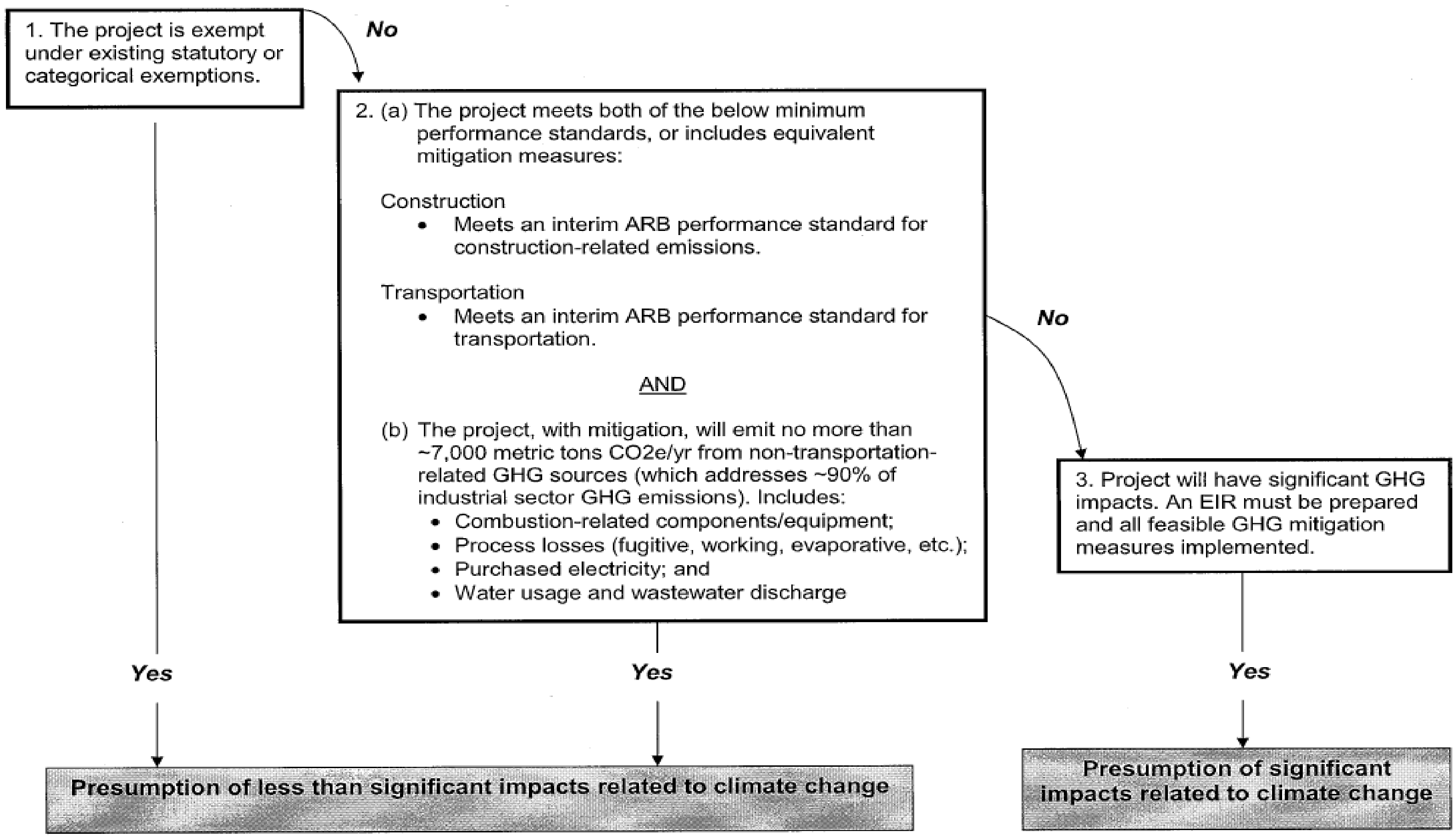
ATTACHMENT A
Preliminary Draft Proposal for Industrial Projects



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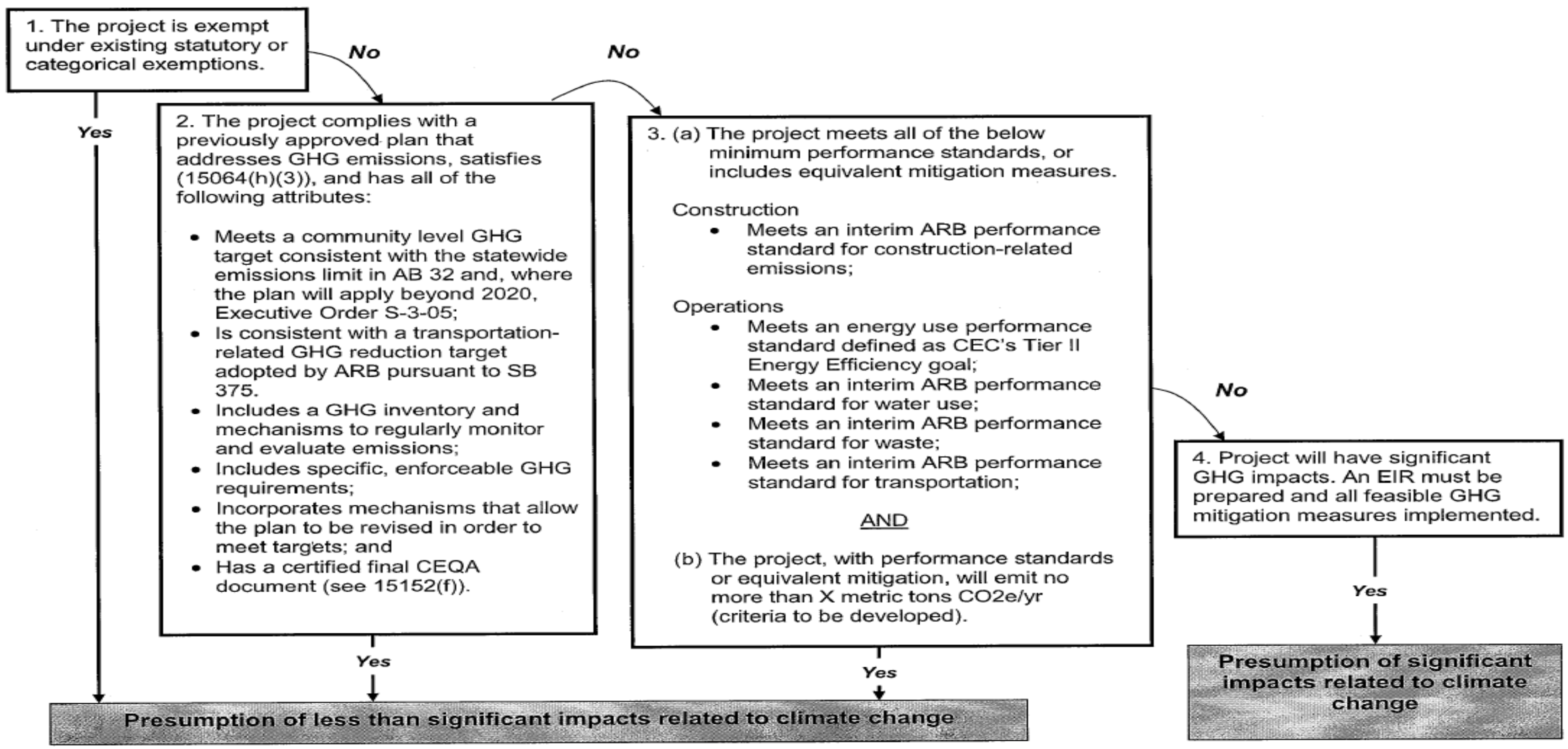
ATTACHMENT B
Preliminary Draft Proposal for Residential and Commercial Projects



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Appendix E

Agency Review & Activities:

CAPCOA Recommendations

Industrial Sources

CAPCOA supports a bifurcated approach to CEQA review and mitigation for industrial emission sources, as follows:

1. Require all new industrial sources of GHG emissions to meet specific GHG performance standards established for each equipment type or source category of emissions. Additionally, any new industrial source exceeding 25,000 tons of CO_2E per year after meeting the specified performance standards would be deemed to have a potentially significant adverse impact on the environment and would be analyzed and mitigated as required under CEQA.

OR

2. A jurisdiction could establish a CEQA significance threshold for industrial sources designed to capture and mitigate 90% of industrial source emissions. All new industrial sources exceeding the established threshold would be considered significant and subject to CEQA review and mitigation. Industrial sources with GHG emissions below the threshold would not be subject to performance standards and would not require mitigation or CEQA review for GHG impacts.

CAPCOA believes each option would be functionally equivalent in the level of GHG emission reductions achieved from new industrial source projects. The bifurcated approach allows lead agencies the flexibility to choose the type of CEQA threshold best suited to their local review process for industrial projects proposed within their jurisdiction.

Residential and Commercial Projects:

CAPCOA has not yet reached consensus on a recommended approach regarding CEQA thresholds for residential and commercial projects.

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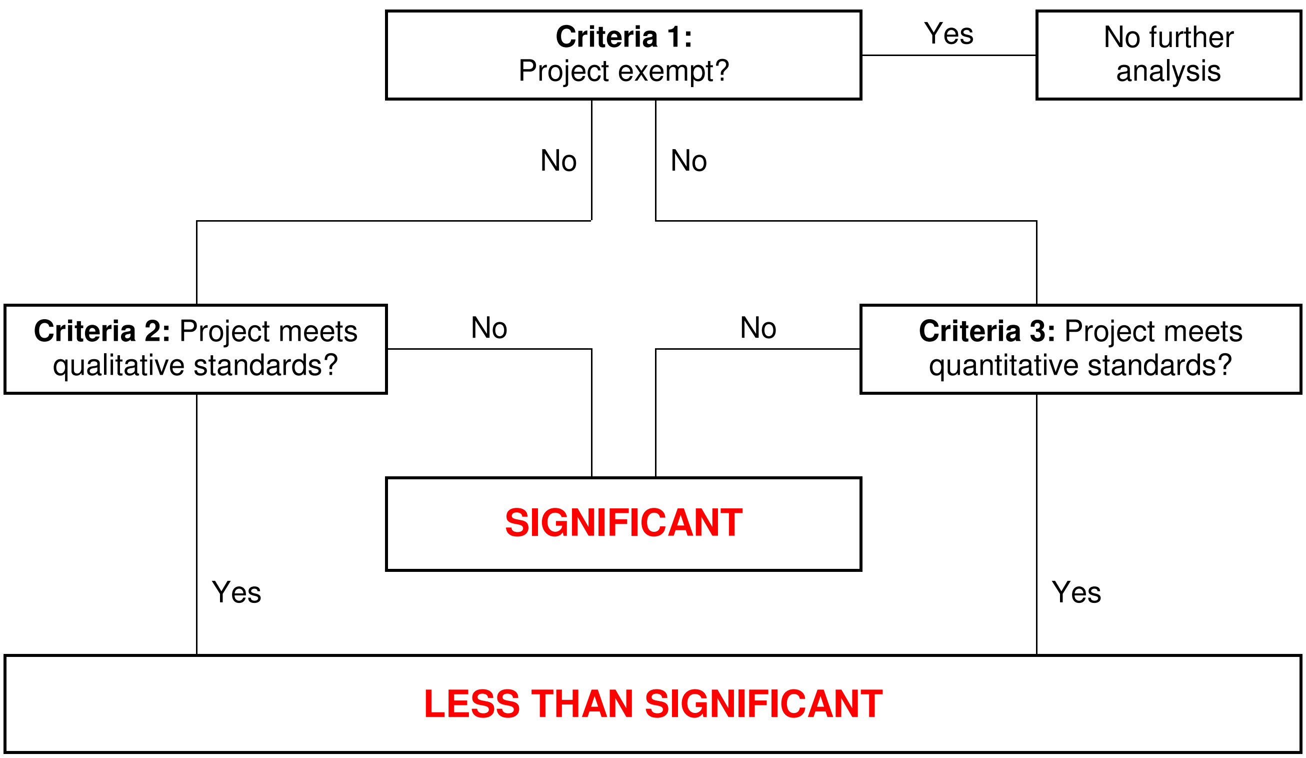
Appendix F

Qualitative OR Quantitative Significance Determination

Qualitative **OR** Quantitative Approach

(Criteria 2 ***OR*** *Criteria 3)*



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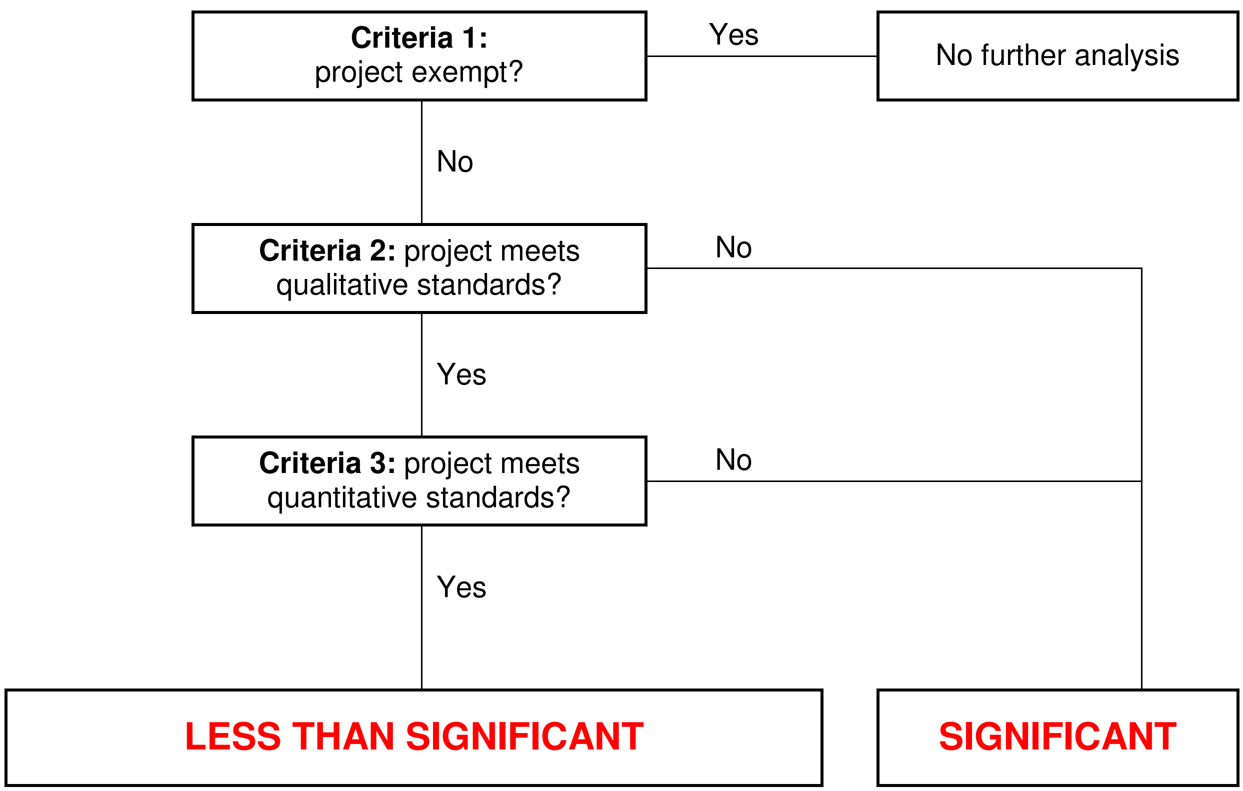
Appendix G

Qualitative AND Quantitative Significance Determination

Qualitative **AND** Quantitative Approach

*(Criteria 2 **AND** Criteria 3)*



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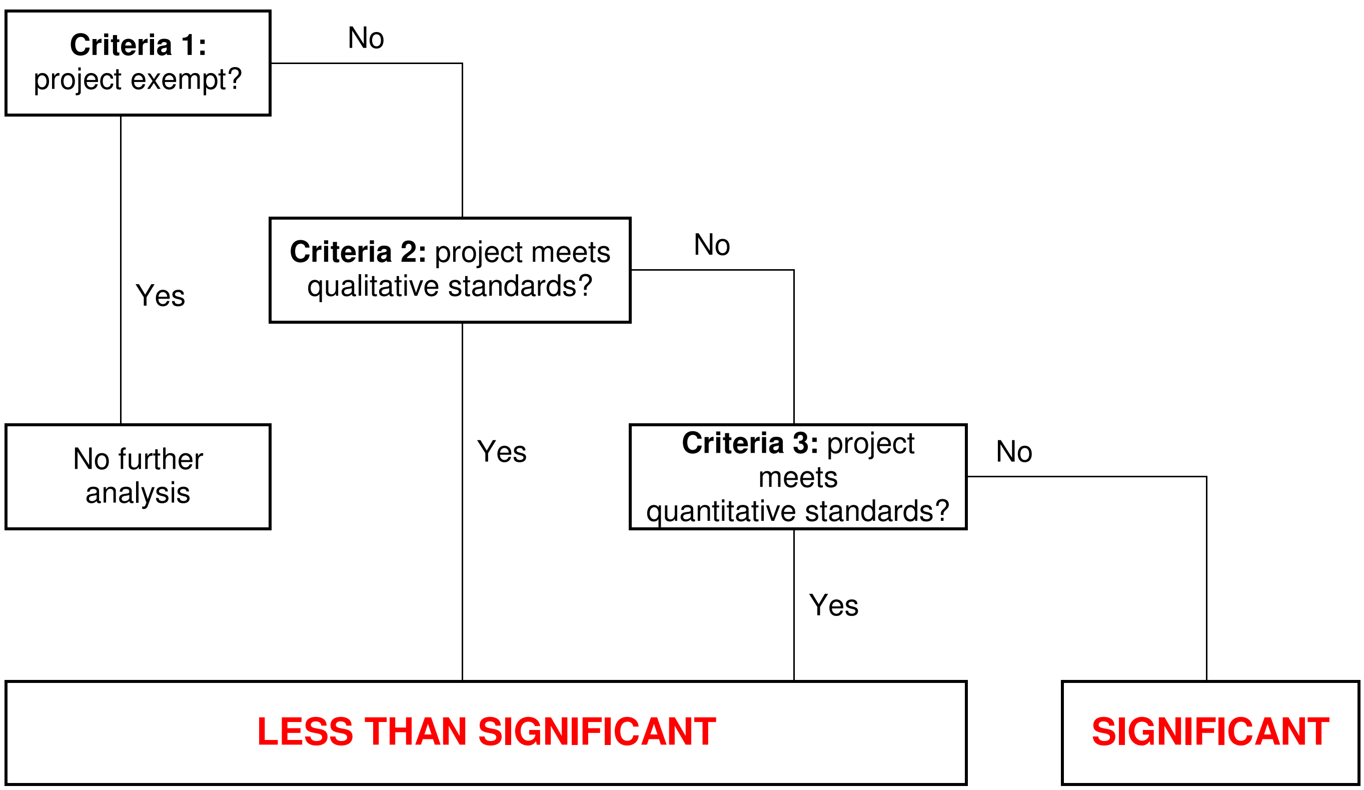
Appendix H

Cascade Significance Determination
Method 1

MIXED 1: Qualitative / Quantitative **CASCADE** Approach (**OR**)



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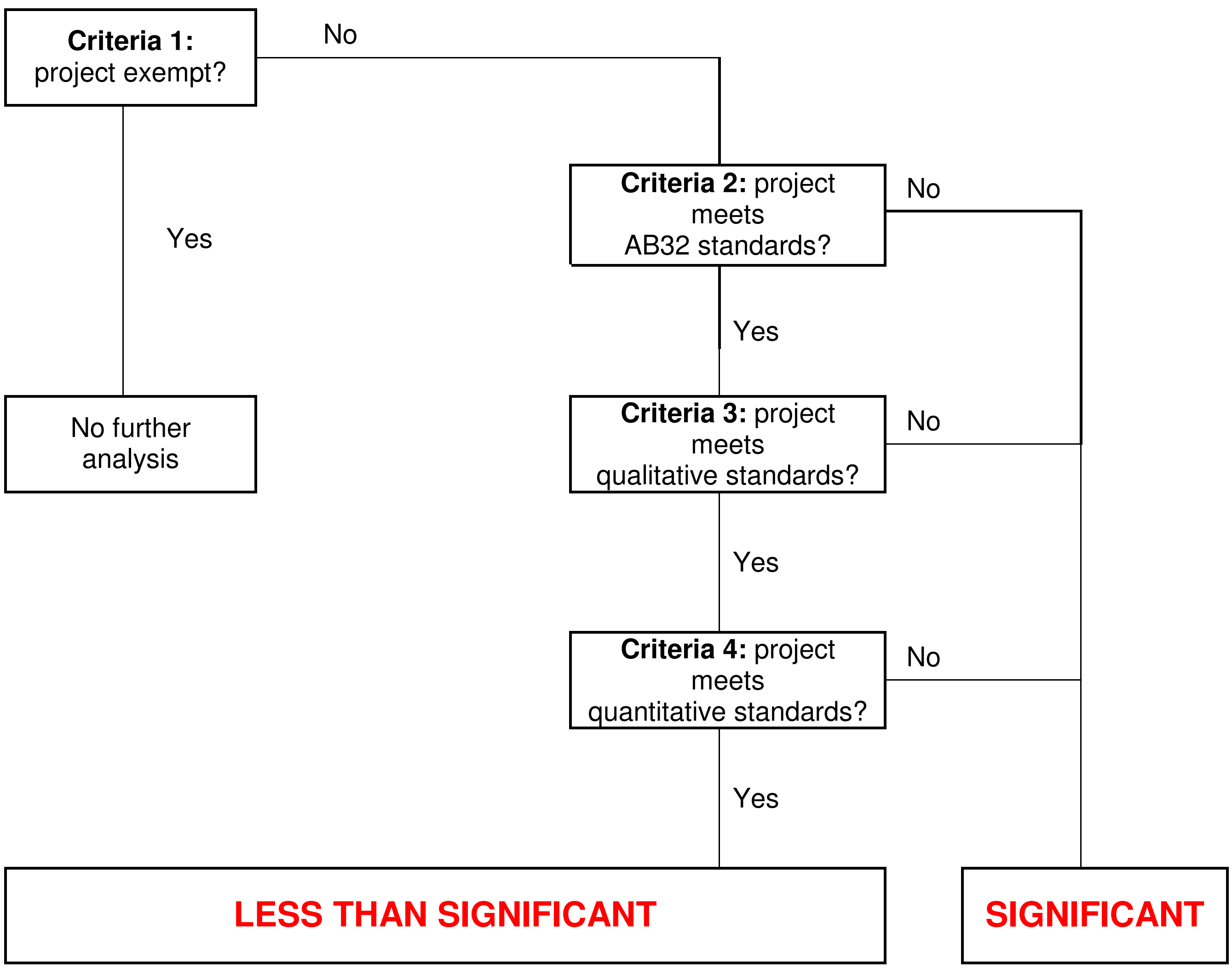
Appendix I

**Cascade Significance Determination
Method 2**

MIXED 2: Qualitative / Quantitative CASCADE Approach (AND)

*(Criteria 2) **AND** (Criterias 3 and 4)*



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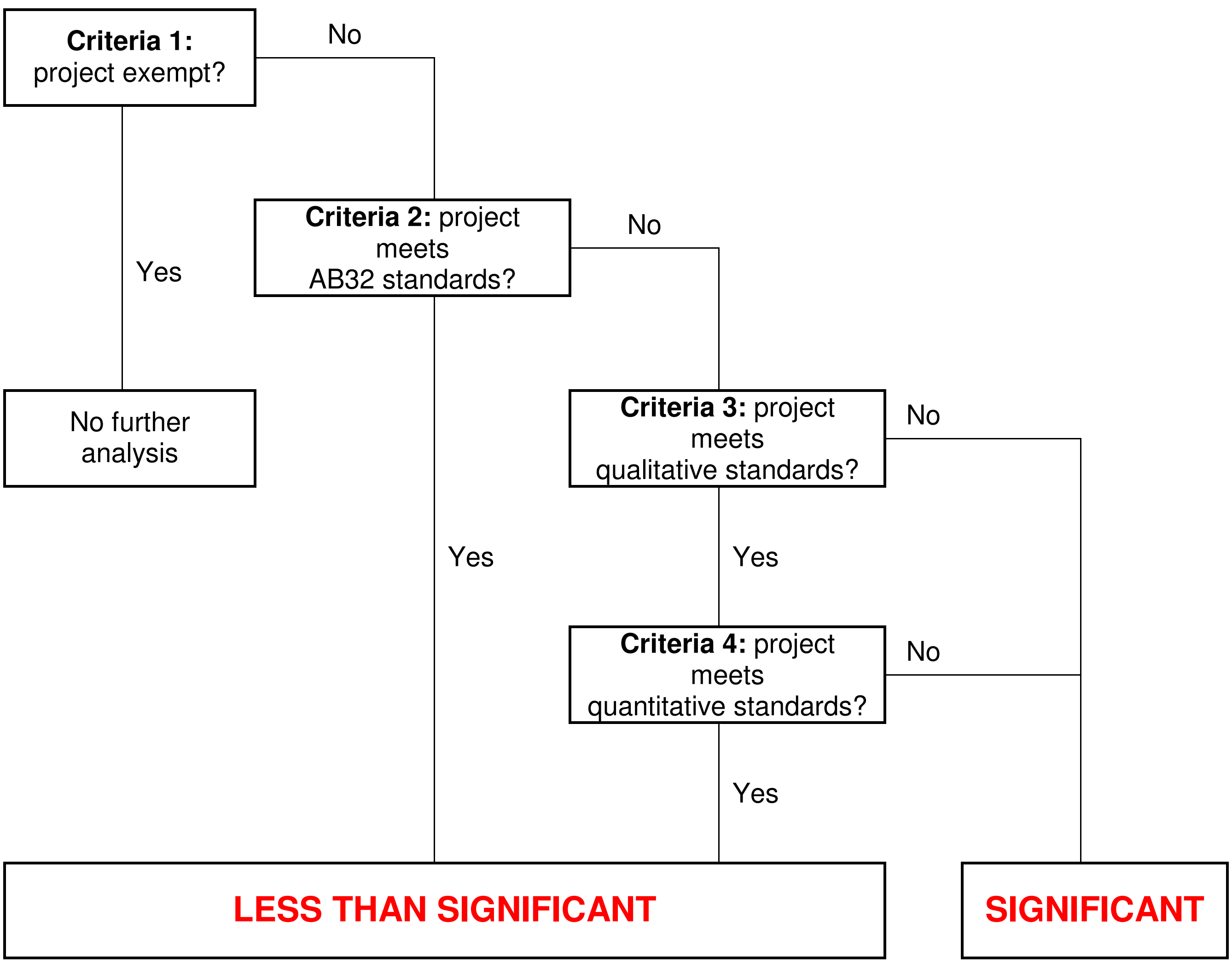
Appendix J

Cascade Significance Determination
Method 3

MIXED 2: Qualitative / Quantitative CASCADE Approach (OR / AND Mixed)

*(Criteria 2) **OR** (Criterias 3 and 4)*



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Appendix K

Summary of Written Comments Received

Written comments pertaining to significance levels are summarized below.

1. Gordon Nipp (Kern-Kaweah Chapter of Sierra)

I attach the papers by James Hansen that I see as authoritative. While they won't give the Air District specific guidance on what number to set as a significance threshold under CEQA, they speak to the seriousness of the problem. Of course, under CEQA, the more serious the problem, the lower the threshold. Global warming is perhaps the most serious problem our species has ever faced - hence the call for a zero threshold.

Attachment 1:

Hansen, J., Mki. Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagani, M. Raymo, D.L. Royer, and J.C. Zachos, 2008: Target atmospheric CO_2: Where should humanity aim? *Open Atmos. Sci. J.*, **2**, 217-231, doi:10.2174/1874282300802010217.

http://arxiv.org/abs/0804.1126

http://arxiv.org/abs/0804.1135

Attachment 2:

Testimony by James Hansen: Global Warming Twenty Years Later: Tipping Points Near

www.columbia.edu/~jeh1/2008/**TwentyYearsLater**_20080623.pdf

(Note: a link to this document is also available on the District website under the section "Documents" at http://www.valleyair.org/Programs/CCAP/CCAP_idx.htm)

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2. Thomas A. Umenhofer (Western States Petroleum Association)

It is critical that any CEQA GHG Threshold of Significance be a reasonable, balanced, and equitable approach which harmonizes the requirements of CEQA, AB 32, and SB 375. SJVAPCD staff has identified a representative range of options. At this time, Western States Petroleum Association (WSPA) encourages a "cascade approach with off-ramps". It is understood that current CEQA GHG Threshold of Significance efforts are considered Phase 1 (Technical Workgroup Stakeholder Input) of a multi-phased Climate Change Action Plan (CCAP) process. As the process proceeds into Phase 2 (Development of CEQA Guidance), WSPA believes that the following key points discussed during Phase 1, be carried forward:

- Quantitative (numeric) thresholds for purpose of defining a significant impact of CEQA GHGs pursuant to climate change (a global concern) currently have no scientific basis. In the absence of a legitimate scientific basis, the establishment of quantitative thresholds of significance is problematic and without justification.

- Compliance by individual projects with the provisions of AB 32 (and SB 375), including participation in a cap and trade program, will result in a reduction in state GHG emissions. Accordingly, the net state GHG reductions by definition would result in a net environmental benefit and, therefore, projects which comply with the provisions of AB 32 (and SB 375) should not require additional analysis under CEQA.

- Performance standards do have basis in practice.

- It is anticipated that significant future research and development (R&D) will be necessary in the area of energy efficiency and GHG reduction opportunities pursuant to AB 32. Thresholds of Significance should incorporate flexibility to allow for credit for applying successful new technologies. Without providing a mechanism for crediting future beneficial programs, there will be no incentive for early initiation of key R&D activities.

3. Robert Boston (Berry Petroleum Company)

Berry encourages the enclosed cascade approach very similar to attachments H and J of the District's Climate Change Action Plan (CCAP) and believes the following ideas should be discussed in the development of CEQA guidance process.

Currently available technology does not meet AB-32 required reductions. To meet AB-32, the state must make significant investment in new energy efficiency and GHG reduction research and development (R&D). Significance thresholds need to

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GHG CEQA Technical Workgroup--Level of Significance Subcommittee
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credit R&D projects for successful new technologies. New technology cannot replace existing operations until R&D proves the technology. Without crediting new technology for the future impacts, approving R&D projects will require greater expense to mitigate temporary increases, even though the projects will eventually lead to significant reductions. Therefore, unless District significance threshold policy removes the disincentives to GHG reductions and energy efficiency R&D projects, the lead agency will not assure projects conform to all public plans and policy, as required by the Governor's Office of Public Research guidance.

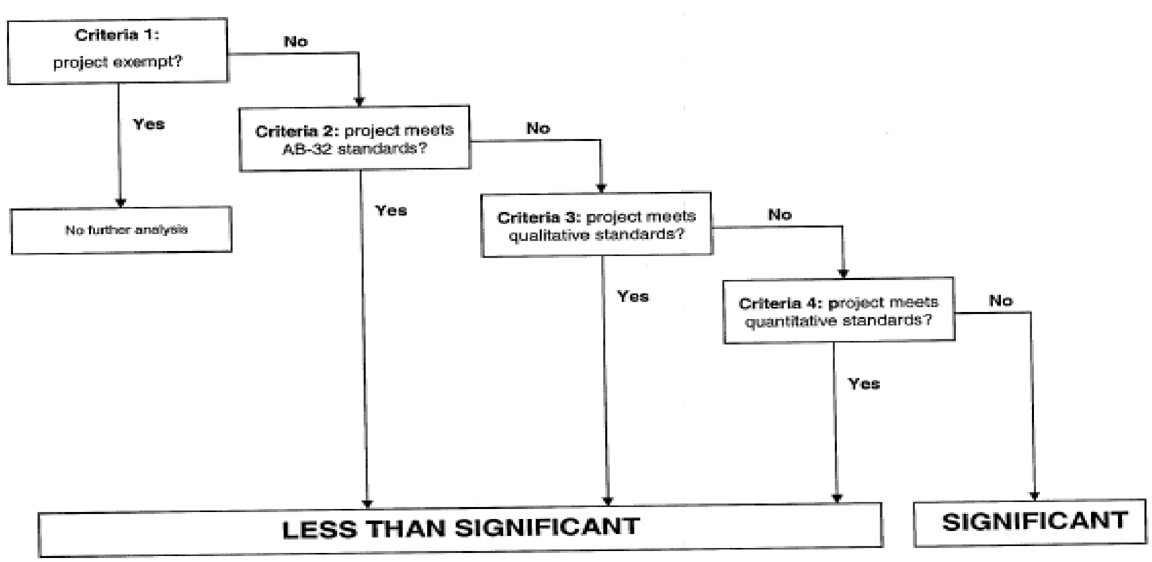
Additionally, individual project that can meet AB-32 required reduction will result in a reduction in sector GHG emissions. Therefore, individual projects in compliance with AB-32 required reduction should not require additional analysis under CEQA.

Qualitative thresholds in the form of performance standards are available in most or all sectors and can be supported from a technical standpoint. Therefore, individual projects in compliance with the qualitative thresholds should not require additional analysis under CEQA.

Currently there is no legitimate scientific basis showing what quantitative thresholds of CEQA GHGs have a significant impact on climate change. Therefore, quantitative thresholds could be used to determine significance when legitimate science is made, but should be considered a minor criterion for determining significance of project.

Berry Petroleum Company

Cascade Significance Determination



Final Draft Staff Report

Appendix G:
CEQA GHG Guidance Mitigation Measures Subcommittee
(March 4, 2009)

Climate Change Action Plan
GHG CEQA Technical Workgroup—Mitigation Measures
March 4, 2009

CEQA GHG Guidance
Mitigation Measures Subcommittee

March 4, 2009

The District has actively sought input from the ad hoc committee and the following document is still under development. The District is still receiving comments from the committee, which will be considered before finalizing this draft document.

Ad Hoc Committee Members
Bettina Arrigoni, Daniel Barber, John Beckman, David Campbell, Donna Carpenter, Dennis J. Champion, Tin Cheung, Dawn S. Chianese, Casey Creamer, Caroline Farrell, Jerry Frost, Wendy Garcia, Issac A. George, Spencer Hammond, Erin Burg Hupp, Sarah Jackson, Bob Keenan, Julia Lester, John Ludwick, Arnaud Marjollet, Michael B. McCormick, Mark Montelongo, James Mosher, Gordon Nipp, Elena Nuno, Tonya Short, Patia Siong, David Smith, Lee Smith, Dennis Tristao, Tom Umenhofer, Lisa Van De Water, and Nicole Vermilion.

See Appendix A

Climate Change Action Plan
GHG CEQA Technical Workgroup—Mitigation Measures
March 4, 2009

Introduction

Per CEQA Guidelines, when project related impacts exceed a significance threshold the lead agency is required to impose all feasible mitigation measures. Environmental impacts from GHG emissions are global in nature and unlike environmental impacts from criteria pollutants may be mitigated through non-traditional measures. During the Greenhouse Gas (GHG) California Environmental Quality Act (CEQA) Guidance Technical Workgroup meeting an ad hoc committee was formed to provide guidance/recommendations regarding mitigation of project specific GHG emissions during the CEQA environmental review process. To facilitate discussion, the District asked subcommittee members to share their views for addressing the following questions:

Key discussion topics considered by the ad hoc committee include:

7. Should GHG mitigation be geographically limited to measures that occur within the District, within the State of California, or the United States?
8. How would a lead agency evaluate mitigation measures consisting of GHG emission reduction credits purchased from a firm selling carbon credits?
9. How would a lead agency evaluate mitigation measures consisting of GHG emission reduction activities achieved by their company outside the project area?
10. How would a lead agency determine that GHG emissions have been mitigated to less than significant if the significance threshold consists solely of a performance standard?
11. How would a lead agency determine that GHG emissions have been mitigated to less than significant if the significance threshold consists of both a performance standard and a numerical value?

Conference calls were held on February 20 and 25, 2009. The following summarizes the committee's progress.

7. *Should GHG mitigation be geographically limited to measures that occur within the District, within the State of California, or the United States?*

The committee recognizes that mitigation measures which reduce GHG emissions can also have collateral benefits on local air quality, i.e. implementation of solar panels can reduce emissions of criteria pollutants, by reducing fossil fuel consumption. The committee suggests that lead agencies preferentially implement local GHG mitigation measures. However, global climatic change results from the individual and cumulative impacts of project related GHG emissions and any reduction in GHG emissions would serve to mitigate project related global climatic change. The committee acknowledges the need for project proponents to have flexibility to seek the most cost effective measures for reducing project related GHG impacts. The committee does not support geographical limitations on GHG mitigation measures.

Climate Change Action Plan
GHG CEQA Technical Workgroup—Mitigation Measures
March 4, 2009

8. *How would a lead agency evaluate mitigation measures consisting of GHG emission reduction credits purchased from a firm selling carbon credits?*

Carbon credits enable individuals and businesses to mitigate GHG emissions by offsetting, reducing or displacing the GHG emissions in another place, typically where it is more economical to do so. Carbon credits typically include renewable energy, energy efficiency and reforestation projects. Carbon credits can currently be purchased from several businesses, and more are likely to develop to match the demand for carbon credits. A key consideration of the use of carbon credits as mitigation is enforceability. Per CEQA Guidelines §15126.4(a)(2) mitigation measures must be fully enforceable through permit conditions, agreements, or other legally binding instrument. The California Climate Action Registry and The Climate Registry have established lists of organizations to serve as verification bodies, providing GHG verification services. The American National Standards Institute (ANSI) is administering a GHG validation/verification body accreditation entity program under ISO 14065. The committee suggests that lead agencies limit use of carbon credits to credits which have been verified by an accredited organization, or to those accredited by the California Resources Board, or otherwise approved by the District.

9. *How would a lead agency evaluate mitigation measures consisting of GHG emission reduction activities achieved by their company outside the project area?*

The committee acknowledges that larger companies may have facilities outside the project area and can implement corporate-wide GHG reduction measures that could be used to offset project specific emissions. However, the committee acknowledges that it would not be feasible for a lead agency to verify emission reductions that occur outside their jurisdiction. The committee acknowledges that the responsibility for demonstrating adequacy of GHG emission reductions resides with the project proponent. The committee suggests that lead agencies limit mitigation to measures which have been verified by an accredited organization, or to those accredited by the California Resources Board, or otherwise approved by the District. The committee is optimistic that local verification will be more cost effective, thus, encouraging project proponents to initiate local GHG emission reductions.

10. *How would a lead agency determine that GHG emissions have been mitigated to less than significant if the significance threshold consists solely of a performance standard?*

The committee acknowledges that performance standards for development projects may not be as precise as performance standards established for stationary sources subject to air district permit requirements. For development projects, the committee suggests quantification of the emission reductions that would be achieved by a specific element within the performance standard and require mitigation that would

Climate Change Action Plan
GHG CEQA Technical Workgroup—Mitigation Measures
March 4, 2009

achieve an equivalent reduction. For example, if the performance standard was to exceed Title 24 energy requirements by 30 percent and the project proponent exceeded Title 24 by 20 percent, they would be accountable for mitigating the amount of GHG emissions attributable to the 10 percent shortfall.

For stationary source projects subject to performance standards established by the District, ARB, or other applicable government agency, the committee considered compliance with a performance standard mandatory. This concept is consistent with current permitting activities that would require compliance with Best Available Control Technology (BACT).

11. *How would a lead agency determine that GHG emissions have been mitigated to less than significant if the significance threshold consists of both a performance standard and a numerical value?*

Resolution of this question is dependent upon whether the project proponent has the option of complying with either standard, or whether the project proponent must comply with both standards. If the project proponent has the option of complying with either standard and does not meet either standard, then it is plausible that the lead agency has the discretionary authority to require mitigation to the standard of their choice. Determining if the project had been mitigated to less than significant would follow the approach discussed above for development and stationary source projects.

If the project proponent has to comply with both standards, then determining if the project had been mitigated to less than significant would require demonstration that mitigation was equivalent to both standards, using approaches discussed above.

Climate Change Action Plan
GHG CEQA Technical Workgroup—Mitigation Measures
March 4, 2009

Appendix A

Ad hoc Subcommittee Members:

Name	**Affiliation**
Bettina Arrigoni	Global Energy Partners, LLC
Dan Barber	SJVAPCD
John Beckman	Building Industry Assoc. of the Delta
David Campbell	Tricor
Donna Carpenter	Sikand Engineering
Dennis Champion	Occidental of Elk Hills
Dawn S. Chianese	Environ
Tin Cheung	The Planning Center
Casey Creamer	California Cotton Ginners
Caroline Farrell	Center on Race, Poverty & Environment
Jerry Frost	Kern Oil
Wendy Garcia	Constellation Wines
Issac A. George	City of Arvin
Spencer Hammond	Chevron
Erin Burg Hupp	Attorney at Law-Meyers Nave
Sarah Jackson	Earth Justice
Bob Keenan	HBATK
Julia Lester	Environ
John Ludwick	Berry Petroleum Company
Arnaud Marjollet	SJVAPCD
Michael B. McCormick	PMC
Mark Montelongo	SJVAPCD
James P. Mosher	CO_2 & Energy
Gordon Nipp	Kern-Kaweah Chapter of Sierra Club
Elena Nuno	Michael Brandman Assoc.
Tonya Short	HBA of Kern County
Patia Siong	SJVAPCD
David Smith	DMD Associates
Lee Smith	Attorney-Stoel Rives
Dennis Tristao	J.G. Boswell Company
Tom Umenhofer	Western States Petroleum Association
Lisa Van de Water	SJVAPCD
Nicole Vermilion	The Planning Center

Staff Report

Appendix H:
Responses to Comments
(May 5, 2009)

SUMMARY OF SIGNIFICANT COMMENTS RECEIVED FROM WORKSHOP HELD MAY 5, 2009

Climate Change Action Plan: Addressing Greenhouse Gas Emissions Under the California Environmental Quality Act

Stakeholders providing comments:

- Center on Race, Poverty & Environment (CRPE)
- Environmental Justice for Catholic Charities of Stockton (EJCCS)
- City of Fresno (COF)
- Earth Justice (EJ)
- Stoel Rives (SR)
- LSA Associates (LSAA)
- Sacramento Metropolitan Air Quality Management District (SMAQMD)
- Sierra Club (SC)
- Southern California Gas Co. (SCGC)
- R.F. Macdonald Co. (RFMC)
- Arthur Unger (private individual; AU)
- Building Association of Central California/ Home Builders Association of Tulare & Kings Counties, Inc./ Building Industry Association of Fresno & Madera Counties, Inc. (altogether BIACC)
- Building Industry Association of the Delta (BIAD)
- California Cotton Ginners & Growers Association (CCGGA)
- Community Alliance for Responsible Environmental Stewardship (CARES)

AB 32

1. **Comment:** Expresses no confidence in the 29% reduction laid out in AB32. Strongly feels the 29% was a political compromise to get the legislation passed. Comments included that there is no scientific basis behind the percentage. (CRPE)

   Response: AB32 does not specify a percentage reduction. It requires ARB to adopt a statewide GHG emissions limit to be achieved by 2020. The 29% number was identified in ARB's Scoping Plan (stated as "approximately 30%"). The 29% GHG emissions reduction is based on the emissions difference from the projected 2020 GHG Business-as-usual emissions to the 1990 GHG emissions level as presented in ARB's Scoping Plan. Data collected by ARB in supporting the establishment of the 1990 and 2020 emissions are provided as appendixes to the Scoping Plan and can also be found on ARB's website at http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm.

2. **Comment:** AB32 states: "Ensure that activities undertaken to comply with regulation not disproportionally impact low income communities. Must consider the potential for direct/indirect and cumulative emission impacts, including localized impacts in communities that are already adversely impacted by air pollution." Strongly advises the District to take a closer look into disadvantaged communities. (EJCCS)

   Response: District's implementation on GHG will be consistent with District's Environmental Justice policy.

<u>Timeline</u>

3. **Comment:** Based on the District's implementation timeline, how will the District comply with OPR's guidance and ARB's guidance as they're made available? (CRPE)

   Response: The District will adjust its guidance, if necessary, to be consistent with rules or regulations that may be adopted.

4. **Comment:** What are other air districts in the state doing? Since the SJVAPCD can't wait for ARB to draft guidance on GHG in CEQA.(EJCCS)

   Response: The staff report presents a summary of what other air districts and agencies are doing to address GHG in regards to CEQA.

<u>Best Performance Standards</u>

5. **Comment:** How will "best performance standards" meet the targets laid out in the Staff Report? (CRPE)

   Response: Chapters 4 and 5 of the current staff report include a discussion about quantification of GHG emission reductions for each Best Performance Standard.

6. **Comment:** What criteria will go into developing best performance standards? Each type of criteria needs to be supported by substantial evidence. (CRPE)

   Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards,

7. **Comment:** If "best performance standards" are adopted, will the District allow local land use agencies to adopt or modify their own lists as well? Because there may be things that a big city can do, and a small city can't. But again, projects need to be given credit. (COF)

Response: CEQA Guidelines clearly give lead agencies the discretion to adopt their own thresholds of significance. The District proposed guidance is offered to assist lead agencies in establishing their own thresholds of significance.

8. **Comment:** Will there be more details on what "best performance standards" are? And how are they developed? (EJ)

   Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards

9. **Comment:** Will there be industry input on developing the best performance standards? (CCG)

   Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including the process for public input.

10. **Comment:** There are concerns over the approach that projects meeting Best Performance Standards don't need to quantify GHG emissions. Nothing has been seen to support "not" having to quantify GHG emissions. (LSAA)

    Response: As presented in Chapter 4, GHG emission reductions have been quantified for each Best Performance Standard. Project specific GHG emissions would require quantification if the project does not meet Best Performance Standards, or if an Environmental Impact Report is required for the project.

11. **Comment:** As the District comes up with best performance standards, will the SJVAPCD analyze their estimated quantitative mitigative effects and seek to achieve 29% mitigation from all projects? (SMAQMD)

    Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including quantification of GHG emission reductions associated with each proposed Best Performance Standards.

12. **Comment:** Projects that will produce GHG beyond 2020 will need stricter mitigations so that they comply with AB 32 goals for future years. I presume that "Best Performance Standards" would lower GHG impacts at least as much as does conforming to AB 32. (AU)

    Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including revision as necessary to be consistent with rules or regulations that may be adopted in the future.

13. **Comment:** BIACC agrees with the District that any CEQA GHG threshold proposal must preserve a lead agency's discretion to consider the context of a particular project when evaluating how best to assess and, if appropriate, mitigate a project's GHG emissions. The staff report also properly recognizes that the baseline for evaluation of a project's GHG impacts is the existing environmental setting. The staff report also properly recognizes that a project's compliance with applicable local, regional or statewide GHG reduction plans is critical to evaluating the project's impacts. As the Office of Planning and Research recognizes in their proposed language for CEQA regulations for GHG, a lead agency's evaluation of a project's impacts on climate change should pay particular attention to a project's contribution towards overall reduction of the state's or region's carbon footprint. (BIACC)

    Response: Support for the District's proposal is noted.

14. **Comment:** We agree that several options exist for establishing qualitative thresholds; however we also note that several of the options listed in the Staff Report are not mutually exclusive. Specifically, evaluating GHG emissions reductions on a per capita per unit basis should be done using a percent reduction compared to business as usual approach. (BIACC)

    Response: Comment noted.

15. **Comment:** We know that the statewide goal of reducing greenhouse gas emissions levels to 1990 levels is "specified in law" through AB32, and constitutes an adopted mitigation plan or program under this Guideline. SB 375 Sustainable Communities Strategies and other applicable local and regional GHG reduction plans will also qualify. (BIACC)

    Response: Comment noted.

16. **Comment:** We generally agree with the approach illustrated in Table 2, under which a project can demonstrate that its' GHG emissions are less than significant if it reduces project emissions 29% below business as usual ("BAU"). (BIACC)

    Response: Support for the District's proposal is noted.

17. **Comment:** We strongly disagree with the conclusion in the narrative staff report, which states that all projects permitted by the District will be required to implement a specific set of best performance standards, regardless of whether a project can separately demonstrate that it complies with an existing GHG reduction plan or that it has reduced GHG emissions reductions goal, which is not supported by existing CEQA statute or case law. Instead, projects that cannot reduce their GHG emissions 29% reduction below BAU should be

given the option to implement best performance standards or demonstrate equivalent reductions. But a single project should not be required to do both for its GHG emissions to be considered less than significant. (BIACC)

Response: The District concurs and has modified the proposed guidance to recognize compliance with an approved GHG emission reduction plan that is supported by a certified CEQA environmental review document. Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including demonstration of equivalency.

18. **Comment:** We strongly question the District's authority to require projects, at this time, to achieve GHG emissions reductions beyond a fair share of those contained in AB 32. (BIACC)

    Response: The proposed guidance is consistent with authority granted to lead agencies under CEQA to reduce project related environmental impacts to less than significant by implementation of all feasible mitigation measures,

19. **Comment:** BIACC supports the development of best performance standards as one option for demonstrating less than significant GHG emissions. Furthermore, we believe the District can serve a critical role by acting as a resource or clearinghouse for feasible mitigation measures that project proponents can consider when developing their projects and possible GHG mitigation strategies. (BIACC)

    Response: Support for the District's proposal is noted.

20. **Comment:** BIAD endorses the concept of Best Performance Standards as one method for determining the significance of a project. We agree with the analysis performed by the District in deciding upon BPS as an acceptable methodology and look forward to continuing our work with the District to establish BPS with flexibility and specificity. We also look forward to the District reducing the regulatory burden of this program by streamlining the process as discussed in the workshop on May 5th. We believe it is critical for this streamlining process to take contemporaneously with the adoption of the threshold for level of significance. (BIAD)

    Response: Support for the District's proposal is noted.

21. **Comment:** We appreciate the District's recognition of SB 375 and the Sustainable Community Strategy Plans (SCPS) to be adopted by local agencies. We strongly believe that compliance with SB 375 and a locally adopted SCSP should also stand alone as a determination of significance for GHG under CEQA. (BIAD)

Response: Comment noted.

22. **Comment:** The District on the matter of quantitative reductions for determining level of significance chose to abstain from embracing the analysis used in the initial adoption of AB32. The California Global Warming Solutions Act of 2006 was established with quantitative goals for the state to achieve in 2020 and 2050. The quantitative goals of AB32 were not chosen randomly or arbitrarily but rather based in part on the Kyoto Protocols and extensive scientific studies on global warming. (BIAD)

    Response: The District believes that the proposed guidance and recommendations are consistent with AB32.

23. **Comment:** BIAD supports the quantitative analysis found in AB32 setting the quantitative reduction of GHG at 29% below Business As Usual (BAU) as the proper target to achieve the goals and objectives of AB32. This numeric threshold should, independently and apart from compliances with BPS established by the District or SCSP established by local agencies satisfy the level of significance threshold for GHG under CEQA. (BIAD)

    Response: As presented in the staff report, the District is unaware of scientific data supporting a numerical significance threshold.

24. **Comment:** By allowing a project applicant to choose between three equally valid methods of determining level of significance: 1) compliance with a local, regional or statewide plan to reduce GHG emissions such as a SCSP; 2) reducing project GHG emissions 29% below BAU; or 3) compliance with District adopted BPS, the District will be maintaining a flexible and workable regulatory system in furtherance of the objectives of AB32. BIAD would support regulations allowing a project to be deemed less than significant upon determination they have complied with any one of these three methods. (BIAD)

    Response: The District has modified the proposed guidance to recognize compliance with an approved GHG emission reduction plan that is supported by a certified CEQA environmental review document.

25. **Comment:** The current draft suggests a Best Performance Standard (BPS) approach, but does not specify what is a best performance standard. (CCGGA)

    Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including a definition of Best Performance Standards.

26. **Comment:** The District needs to take into account that emissions for all new projects have already been accounted for in ARB 2020 "business as usual" inventory and the Scoping Plan is a feasible mitigation approach. (CCGGA)

    Response: District's proposed process does take into account the emission reductions that have been achieved since the 2002-04 emissions baseline.

27. **Comment:** The District needs to be aware that new facilities and new projects will be subject to a considerable amount of double counting due to overlapping regulations. This will put new facilities at a disadvantage compared with an existing facility. A new facility will have to comply with the Best Performance Standard and then also reduce emissions according to the Cap-and-Trade program. Existing facilities will only have to comply with the Cap-and-Trade. This is yet another reason why ARB Scoping Plan needs to be considered feasible mitigation. (CCGGA)

    Response: The District recognizes that there is the potential for overlap, however, OPR in its proposed amendments to CEQA Guidelines has clarified that compliance with AB32 alone is not sufficient to support a determination of significance.

28. **Comment:** New project's need to have the ability to use offsets in lieu of meeting the yet undefined Best Performance Standard is an important economic factor. We appreciate that the District has added this flexibility into the Climate Change Action Plan and strongly believe that it needs to be preserved. Industries need flexibility and the ability to purchase offsets achieves gives new projects that flexibility. (CCGGA)

    Response: Support for the District's proposal is noted.

29. **Comment:** It was said the District would consider local agencies plan to be a best practice standard, would advice "caution" on that. As all general plans in the Valley have been done, none has had a finding that this is "absolute" best arrangement in land uses/transportation for reducing GHG. Maybe as agencies are asked to amend the land use design and circulation element improvements can be better than what's been adopted, a land use plan shouldn't be considered to be sufficient. (COF)

    Response: The proposed guidance to land use agencies is consistent with amendments to CEQA Guidelines proposed by OPR.

30. **Comment:** Performance standards won't reduce GHG emissions. Each performance standard needs to be measureable. (EJCCS)

Response: Chapters 4 and 5 of the current staff report include a discussion about quantification of GHG emission reductions for each Best Performance Standard.

31. **Comment:** It is important that the District's CEQA guidance does not render moot AB 32's market based systems that could overcome the significant economic feasibility issues of certain dairy manure management projects that could not only reduce GHG emissions but could provide an important source of renewable energy. It is crucially important that the "best performance standards" for dairy operations be established so that the ability of a dairy to voluntarily implement additional projects that could further reduce GHG emissions through a market based cap and trade system is not compromised. (CARES)

    Response: The proposed guidance does not require dairy operators to implement Best Performance Standards. It provides a means for streamlining the significance review process. Project proponents not implementing Best Performance Standards are required to quantify project related GHG emissions and demonstrate that they have reduced or mitigated project related GHG emissions by 29%.

32. **Comment:** If the District establishes "best performance standards," that are in effect requirements to apply mitigation measures, the District essentially requiring a project to implement specified mitigation measures or to otherwise mitigate BAU emission by 29% in order to avoid a significance finding. This would be inconsistent with the intent that the District has emphasized during the working group process. It is also inconsistent with CEQA since a project's impacts must first be determined to be significant before feasibly mitigation may be required. (CARES)

    Response: The proposed guidance does not require implementation of Best Performance Standards. It provides a means for streamlining the significance review process. Project proponents demonstrating that they have reduced or mitigated project related GHG emissions by 29% can conclude that project related impacts are not individually or cumulatively significant. As presented in the staff report, the District believes that a significance determination based on use of performance based standards is consistent with amendments to the CEQA Guidelines proposed by OPR.

33. **Comment:** The District is encouraged to specify Best Performance Standards and quantify the percentage GHG reduction associated with each standard. Such quantification should be supported by substantial evidence. (SC)

    Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including quantification of GHG emission reductions for each Best Performance Standard.

Business-As-Usual Emissions

34. **Comment:** The District's plan needs to reveal specific details on "business as usual." (SC)

    Response: Chapter 3 of the current staff report includes a discussion about Business-as-Usual (BAU) that clarifies BAU, as determined by ARB, represents a level of emissions from an emissions category and does not represent operational activities or processes.

35. **Comment:** How does "business as usual" relate to new projects? (EJ)

    Response: Chapter 3 of the current staff report includes a discussion about Business-as-Usual (BAU) that clarifies BAU, as determined by ARB, represents a level of emissions from an emissions category and does not represent operational activities or processes.

36. **Comment:** The District needs to spell out what "business as usual" really is. If not, it will lead to abusive practices among consultants. (SC)

    Response: Chapter 3 of the current staff report includes a discussion about Business-as-Usual (BAU) that clarifies BAU, as determined by ARB, represents a level of emissions from an emissions category and does not represent operational activities or processes.

Greenhouse Gas Reductions

37. **Comment:** Can thoughts be shared on criteria vs. GHG reduction? How to avoid being technology specific? How to avoid double counting? How is the District going to maintain fuel neutrality? (SCGC)

    Response: Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including quantification of GHG emission reductions associated with each proposed Best Performance Standards. The proposed guidance is consistent with the District's traditional role of regulating sources of criteria pollutants to protect public health.

38. **Comment:** How will the District approach a project's total emissions? Then assume a 29% reduction, and in relation be able to show the actual project emission reductions. (EJ)

Response: As presented in Chapter 4, project specific GHG emissions would require quantification if the project does not meet Best Performance Standards, or if an Environmental Impact Report is required for the project. The proposed guidance is consistent with CEQA Guidelines proposed by OPR.

39. **Comment:** Anything the District does for providing guidance with GHG in CEQA, needs to be consistent with existing CEQA law. (CRPE)

    Response: The proposed guidance is consistent with CEQA Guidelines proposed by OPR.

40. **Comment:** It is encouraged that the District evaluates real quantifiable emissions and not life cycle emissions that are not quantifiable. (COF)

    Response: OPR has provided clarification that lifecycle quantification is not required. District's policy is consistent with that recommendation.

41. **Comment:** CEQA provides a tool called "Certified Regulatory Program," it allows people to enter a program and be certified to achieving a certain level of reductions. This takes the burden off lead agencies and applicants. (COF)

    Response: The District has modified the proposed guidance to recognize compliance with an approved GHG emission reduction plan that is supported by a certified CEQA environmental review document.

40. **Comment**: Dairy families throughout the San Joaquin Valley will be undertaking significant voluntary efforts to reduce their greenhouse gas emissions in a market based cap and trade system. It is crucially important that the SJVAPCD's guidance does not inadvertently destroy the "voluntariness" of those efforts, and thus the economic feasibility of implementing those projects. (CARES)

    Response: The proposed guidance does not require implementation of Best Performance Standards. It provides a means for streamlining the significance review process. Project proponents demonstrating that they have reduced or mitigated project related GHG emissions by 29% can conclude that project related impacts are not individually and cumulatively significant. As presented in the staff report, the District believes that a significance determination based on use of performance based standards is consistent with amendments to the CEQA Guidelines proposed by OPR.

41. **Comment:** Draft Staff Report contains no argument that the precise 29% value is the cutoff point between feasibility and infeasibility. The 29% cutoff point seems arbitrary. How does the District justify a 29% cutoff point if mitigation beyond that value is feasible? The final plan should include

substantial evidence supporting a specific cutoff point. The District should require reductions of GHG emissions beyond the 29% below BAU requirement in the Climate Change Action Plan. (SC)

Response: As presented in the staff report, existing science is inadequate to support a significance determination based on a precise evaluation of project related GHG emissions. The 29% emission reduction is not arbitrary, but it consistent with the emission reduction target established by ARB in its AB 32 scoping plan, which is consistent with its legislative mandate pursuit to State adoption of AB32.

Miscellaneous

42. **Comment:** Streamlining needs more specifics. In relation, streamlining measures can lead to projects getting tied into litigation. (SC)

    Response: Chapters 4 and 5 of the staff report have been expanded to include additional implementation details. It is the District's intent to develop guidance and tools to streamline the implementation of the process.

43. **Comment:** More time will be needed to review the information as it's made available before the next workshop. (EJ)

    Response: The request is consistent with the District's intent. The goal is to post all documents two weeks prior to the next workshop scheduled for June 30, 2009.

44. **Comments:** Will meeting minutes and participants be made available? (RFMC)

    Response: Available District documents can be found on the Districts website at http://www.valleyair.org/Programs/CCAP/CCAP_idx.htm.

45. **Comments:** What is the definition of a project- New? Existing? Constructing? (RFMC)

    Response: For the proposed guidance, the term "project" has the same meaning as defined in CEQA Guidelines. .

46. **Comments:** Will any new fee be associated with this new GHG in CEQA implementation? (RFMC)

    Response: The proposed guidance is intended to assist the District, lead agencies, and the public in addressing CEQA requirements and it does not propose new fees.

47. **Comments:** For final draft, is a socio-economic analysis going to be performed that will address potential "leakage." (RFMC)

    Response: By law, District staff is required to perform a socioeconomic impact analysis prior to adoption, amendment, or repeal of a rule that has significant air quality benefits or that will strengthen emission limitations. The proposed guidance serves only as recommendations and is not a District rule. Therefore, a socio-economic analysis is not required.

48. **Comment**: The District should consider a tier for industrial projects consistent with the tier for transportation and development projects that allows a project that is consistent with requirements of an approved state, regional or local regulations or plan that includes a GHG analysis. The District should not rule out the possibility that a project's GHG emissions may have an insignificant impact on the environment in the absence of the use of "best performance standards" or 29% emission reductions below BAU. (CARES)

    Response: The District concurs and has modified the proposed guidance to recognize compliance with an approved GHG emission reduction plan that is supported by a certified CEQA environmental review document. Chapters 4 and 5 of the current staff report include a discussion about methodology for developing Best Performance Standards, including demonstration of equivalency.

49. **Comment:** The Draft Staff Report is deficient in that it does not present scientifically based evidence that a project deemed "Less Than Significant" under the regimen presented in Table 2 or Table 3 would not still have a significant effect on global climate change. (SC)

    Response: As presented in the staff report, the existing science is inadequate to support a determination that project specific GHG emissions, regardless of the amount, would or would not have a significant impact on global climatic change. As presented in the current staff report the District has evaluated the various options for determining the significance of project related impacts.

50. **Comment:** Many facets of the Climate Change Action Plan, including the notions of BPS and BAU, are so vague as to invite litigation. Final CCAP should contain specific and precise details. (SC)

    Response: The staff report has been revised to provide additional information regarding BPS and BAU.

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Appendix I:
Best Performance Standards Stationary Source Projects

Best Performance Standards (BPS) for: GHG Emissions From Stationary Sources		
Emission Unit or Operation	**BPS**	**Approved Alternate Technology**
Fossil Fuel-Fired Boilers, Steam Generators & Process Heaters With Firing Capacity > 5 MMBtu/hour (HHV)	All units shall utilize gaseous fuel only and be appropriately sized and/or have adequate load following capability to avoid the venting of steam to the atmosphere except during emergency situations or during specifically identified and limited maintenance or startup/shutdown operations. In addition, each unit shall meet at least one of the two following criteria: 1. The unit shall be designed for a minimum thermal efficiency of 95 % and shall utilize variable frequency drive electric motor on combustion air/FGR fans or, 2. The unit shall be designed for maximum thermal efficiency by incorporating all of the following design features: a) install adequate heat transfer surface to provide a maximum design approach of 20 oF between the stack gas temperature and the process inlet temperature, b) limit the use of flue gas recirculation (FGR) for NOx control to no more than 10 % , c) minimize excess air in combustion by maintaining a maximum O2 concentration of 3 volume percent in stack gas and d) use variable frequency drive electric motor on combustion air/FGR fans	1. Install equipment utilizing solar energy source in lieu of fossil fuel 2. Obtain GHG emission performance equivalent to BPS by recovery and permanent sequestration of CO_2 from the exhaust of the unit 3. Utilize biogenic fuel derived from natural or waste sources in lieu of fossil fuel (biogenic fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)
Non-Emergency Flares with rated heat release > 5 MMBtu/hour (HHV)	Combustion shall be performed in an alternate device in lieu of a flare which produces useful energy which would have otherwise been required (utilized as fuel in an engine, boiler, turbine or delivered to a natural gas pipeline, etc.) where the proposed operation is non-emergency. Emergency flares shall utilize a flow-sensing ignition device rather than a continuous pilot and non-GHG purge gas	Obtain GHG emission performance equivalent to BPS by recovery and permanent sequestration of CO_2 from the exhaust of the unit

Emission Unit or Operation	BPS	Approved Alternate Technology
Non-Emergency Onsite Electric Power Generation with Fossil Fuel Combustion > 5 MMBtu/hour Or With Fossil Fuel-Fired Mechanical Driver > 50 bhp	Electric power supply shall be provided solely by a PUC-licensed electric utility in lieu of a fossil fuel-fired unit except for facilities meeting any of the following criteria: 1. Emergency standby power generation, or 2. Power generation from a cogeneration unit	1. Utilize solar energy source in lieu of firing fossil fuels 2. Obtain GHG emission performance equivalent to BPS by recovery and permanent sequestration of CO_2 from the exhaust of the unit 3. Utilize biogenic fuel derived from natural or waste sources in lieu of fossil fuel (biogenic fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)
Non-Emergency Mechanical Equipment Driver (requirement in lieu of reciprocating IC engines > 50 hp and combustion turbines > 3 MMBtu/hour excluding combustion turbines in cogeneration service)	A non-emergency mechanical equipment driver shall consist of an electric motor, in lieu of a fossil fuel-fired unit, with energy efficiency meeting the efficiency criteria for Premium Efficiency Electric Motors as specified in the National Electrical Manufacturer's Association (NEMA) Standard MG-1 or, upon District approval of submitted documentation which corroborates a claim by the applicant that such electric motor is not feasible, applicant may install a motor with efficiency equal to the maximum available for the proposed class of motor.	1. Power equipment using a renewable energy source such as solar or wind in lieu of fossil fuel 2. Utilize biogenic fuel derived from natural or waste sources in lieu of fossil fuel (biogenic fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)

Emission Unit or Operation	BPS	Approved Alternate Technology
Fossil Fuel-Fired Cogeneration (combustion turbines > 3 MMBtu/hr or other combustion devices > 5 MMBtu/hour)	Fossil fuel fired cogeneration systems shall be designed to achieve an incremental GHG emission rate not exceeding 700 lb- CO_2 per MWh at the system's design operating point based on power output at the generator terminals, assuming the process thermal demand could alternatively be met by direct fuel firing with 90% thermal efficiency. Heat recovery design shall maximize thermal efficiency by installing adequate heat transfer surface to provide a maximum 20 ^{o}F approach between stack gas temperature and the process inlet temperature	Utilize biogenic fuel derived from renewable natural or waste sources in lieu of fossil fuel (biogenic fuels derived from agricultural operations performed specifically for fuel production do not meet this criteria)
Landfill Operations	Landfills shall comply with CARB Regulation to Reduce Methane Emissions From Municipal Solid Waste Landfills. (www.arb.ca.gov/regact/2009/landfills09/isor.pdf)	None identified
Wastewater Treatment	Wastewater treatment facilities shall incorporate both of the following two control measures: 1. Sludge: Sludge shall be treated anaerobically in digesters, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment; and 2. Liquid Waste: At least 33% of electricity used for liquid waste aeration shall be derived from renewable energy sources, based on grid power Renewables Portfolio Standard (RPS), and/or supplementation of grid with onsite generation using renewable energy sources such as, but not limited to, biogas, biomass, solar, and wind.	1. Sludge: None identified 2. Liquid Waste: Liquid waste shall be treated anaerobically in digesters or covered ponds, with captured Methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment.

Emission Unit or Operation	BPS	Approved Alternate Technology
Oil And Gas Extraction, Storage, Transportation And Refining Operations	Fugitive Methane emissions shall be minimized by applying VOC Leak Standards, as contained in District Rules 4409 and 4455 to components handling methane	None identified
Direct-Fired Combustion Heat Transfer Equipment (Dryers, Kilns, etc)	Best Performance Standards for this category of equipment will be developed by the District in the future	
Farming Operations –Livestock rearing	All operations shall utilize all three following control measures: 1. All ruminant animal feed shall include at least 6% cottonseed, or, upon District approval, based on sufficient demonstration that use of cottonseed is not feasible, an equivalent substitute; and 2. Manure from animal housing areas for mature cows shall be removed and transferred into appropriate treatment facilities at least four times a day and at least once a day for all other animals; and 3. Collected manure shall be treated anaerobically in digesters or covered lagoons, with captured methane used for energy recovery in a method that displaces current or required fossil fuel use, such as, but not limited to, injection into natural gas pipeline, or powering mobile equipment	None identified.
Farming Operations – Land application of manure	Manure shall be incorporated into soil within 24 hours after application	None identified.

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Appendix J:
GHG Emission Reduction Measures - Development Projects

GHG Emission Reduction Measures						
MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
<u>Bicycle/Pedestrian/Transit Measures</u>						
1	**Bike parking**	C	M	~	0.625	Non-residential projects provide plentiful short-term and long-term bicycle parking facilities to meet peak season maximum demand. Short term facilities are provided at a minimum ratio of one bike rack space per 20 vehicle spaces. Long-term facilities provide a minimum ratio of one long-term bicycle storage space per 20 **employee** parking spaces.
2	**End of trip facilities**	C	M	~	0.625	Non-residential projects provide "end-of-trip" facilities including showers, lockers, and changing space. Facilities shall be provided in the following ratio: four clothes lockers and one shower provided for every 80 employee parking spaces. For projects with 160 or more employee parking spaces, separate facilities are required for each gender.
3	**Bike parking at multi-unit residential**	~	~	R	0.625	Long-term bicycle parking is provided at apartment complexes or condominiums without garages. Project provides one long-term bicycle parking space for each unit without a garage. Long-term facilities shall consist of one of the following: a bicycle locker, a locked room with standard racks and access limited to bicyclists only, or a standard rack in a location that is staffed and/or monitored by video surveillance 24 hours per day.
4	**Proximity to bike path/bike lanes**	C	M	R	0.625	Entire project is located within 1/2 mile of an existing Class I or Class II bike lane and project design includes a comparable network that connects the project uses to the existing offsite facility. Existing facilities are defined as those facilities that are physically constructed and ready for use prior to the first 20% of the projects occupancy permits being granted. Project design includes a designated bicycle route connecting all units, on-site bicycle parking facilities, offsite bicycle facilities, site entrances, and primary building entrances to existing Class I or Class II bike lane(s) within 1/2 mile. Bicycle route connects to all streets contiguous with project site. Bicycle route has minimum conflicts with automobile parking and circulation facilities. All streets internal to the project wider than 75 feet have class II bicycle lanes on both sides.
5	**Pedestrian network**	C	M	R	1	The project provides a pedestrian access network that internally links all uses and connects to **existing** external streets and pedestrian facilities. Existing facilities are defined as those facilities that are physically constructed and ready for use prior to the first 20% of the projects occupancy permits being granted.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
5a	**Pedestrian Network**	C	M	R	0.5	The project provides a pedestrian access network that internally links all uses for connecting to **planned** external streets and pedestrian facilities (facilities must be included pedestrian master plan or equivalent).
6	**Pedestrian barriers minimized**	C	M	R	1	Site design and building placement minimize barriers to pedestrian access and interconnectivity. Physical barriers such as walls, berms, landscaping, and slopes between residential and non-residential uses that impede bicycle or pedestrian circulation are eliminated. Barriers to pedestrian access of neighboring facilities and sites are minimized. This measure is not meant to prevent the limited use of barriers to ensure public safety by prohibiting access to hazardous areas, etc…
7	**Bus shelter for existing transit service**	C	M	R	0.5	Bus or Streetcar service provides headways of one hour or less for stops within 1/4 mile; project provides safe and convenient bicycle/pedestrian access to transit stop(s) and provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting).
8	**Bus shelter for planned transit service**	C	M	R	0.25	Project provides transit stops with safe and convenient bicycle/pedestrian access. Project provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting) in anticipation of future transit service. If measure 7 is selected, it excludes this measure.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
9	**Traffic calming**	C	M	R	see table in Measure Description	Project design includes pedestrian/bicycle safety and traffic calming measures in excess of jurisdiction requirements. Roadways are designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips by featuring traffic calming measures. Traffic calming measures include: bike lanes, center islands, closures (cul-de-sacs), diverters, education, forced turn lanes, roundabouts, speed humps, etc… Percent of Streets with Improvements

		Percent of Streets with Improvements			
		25%	50%	75%	100%
Percent of **Intersections** with Improvements	25%	**0.25**	**0.25**	**0.5**	**0.5**
	50%	**0.25**	**0.5**	**0.5**	**0.75**
	75%	**0.5**	**0.5**	**0.75**	**0.75**
	100%	**0.5**	**0.75**	**0.75**	**1.0**

MEASURE #	Measure Name	Commercial	Mixed-Use	Residential	Estimated CO_2 Equivalent Point Reductions	Measure Description
Parking Measures						
10	**Paid parking**	C	M	R	see below	Employee and/or customer paid parking system
10a	**Paid Parking - Urban site within 1/4 mile from transit stop**	C	M	R	5	Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.
10b	**Paid Parking- Urban site greater than 1/4 mile from transit stop**	C	M	R	1.50	Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.
10c	**Paid Parking- Suburban site within 1/4 mile of transit stop**	C	M	R	2	Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.
10d	**Paid Parking- Suburban site greater than 1/4 mile from transit stop**	C	M	R	1	Employee and/or customer paid parking system. Daily charge for parking must be equal to or greater than the cost of a local transit pass + 20%. Monthly charge for parking must be equal to or greater than the cost of a local monthly transit pass, plus 20%.
10e	**Parking cash out**	C	M		0.6	Employer provides employees with a choice of forgoing subsidized parking for a cash payment equivalent to the cost of the parking space to the employer.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
11	**Minimum parking**	C	M	R	3	Provide minimum amount of parking required. Special review of parking required. If zoning codes in the San Joaquin Valley area have provisions that allow a project to build less than the typically mandated amount of parking if the development features design elements that reduce the need for automobile use. This measure recognizes the air quality benefit that results when facilities minimize parking needs, and grants mitigation value to project that implement all available parking reductions. Once land uses are determined, the trip reduction factor associated with this measure can be determined by utilizing the Institute of Transportation Engineers (ITE) Parking generation publication. The reduction in trips can be computed as shown below by the ratio of the difference of minimum parking required by code and ITE peak parking demand to ITE peak parking demand for the land uses multiplied by 50%. The maximum achievable trip reduction is 6%. For projects where retail space occupies 50% or more of the total built space, do not use December specific parking generation rates (from ITE). Percent Trip Reduction = 50*[(min parking required by code - ITE peak parking demand) / (ITE peak parking demand)].
12	**Parking reduction beyond code**	C	M	R	6	Provide parking reduction less than code. Special review of parking required. Recommend a Shared Parking strategy. Trip reductions associated with parking reductions beyond code shall be computed in the same manner as described under measure 11, as the same methodology applies. The maximum achievable trip reduction is 12%. This measure can be readily implemented through a Shared Parking strategy, wherein parking is utilized jointly among different land uses, buildings, and facilities in an area that experience peak parking needs at different times of day and day of the week. For example, residential uses and/or restaurant/retail uses, which experience peak parking demand during the evening/night and on the weekends, arrange to share parking facilities with office and/or educational uses, which experience peak demand during business hours and during the week.
13	**Pedestrian pathway through parking**	C	M	R	0.5	Provide a parking lot design that includes clearly marked and shaded pedestrian pathways between transit facilities and building entrances. Pathway must connect to all transit facilities internal or adjacent to project site. Site plan should demonstrate how the pathways are clearly marked, shaded, and are placed between transit facilities and building entrances.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
14	**Off street parking**	C	M	R	see below	Parking facilities are not adjacent to street frontage
14a	**Off street parking**	C	M	R	1.5	For 1.5% reduction, parking facilities shall not be sited adjacent to public roads contiguous with project site. Functioning pedestrian entrances to major site uses are located along street frontage. Parking facilities do not restrict pedestrian, bicycle, or transit access from adjoining uses. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, a description of where parking is located relative to the buildings on the site, site plans, maps, or other graphics, which demonstrate the placement of parking facilities behind on-site buildings relative to streets contiguous with the project site. Surrounding uses should be high density or mixed-use, there shall be other adjoining pedestrian and bicycle connections, such as wide sidewalks and bike lanes, and surrounding uses shall also implement measure 15.
14b	**Off street parking**	C	M	R	1	For 1.0% reduction, (parking structures only) proponent must show that parking facilities that face street frontage feature ground floor retail along street frontage. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, a written description of the parking facility and the amount of retail space on the ground floor, site plans, maps, or other graphics demonstrating the placement of retail/commercial space along all street fronts contiguous with parking structure.
14c	**Off street parking**	C	M	R	0.1	For 0.1% reduction, the project is not among high-density or mixed uses, is not connected to pedestrian or bicycle access ways, or is among uses that do not also hide parking. This point value is reflective of the importance that other pedestrian and density measures be in place in order for this measure to be effective.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
<u>Site Design Measures</u>						
15	**Office/Mixed-Use proximate to transit**	C	M	~	see below	Mitigation value is based on project density and proximity to transit. Planned transit must be in MTP or RT Master Plan. To count as "existing transit" service must be fully operational prior to the first 20% of the projects occupancy permits being granted. Project must provide safe and convenient pedestrian and bicycle access to all transit stops within 1/4 mile. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, a written description of how the project complies with the measure, a map or graphic depicting the location of the project in relation to the transit stop. Graphic should demonstrate a 1/4 mile radius, arc, from transit and planned pathways and linkages to the transit stop. Proponent shall also provide graphics depicting the size and layout of the building as well as the calculations demonstrating the FAR (floor to area ratio).
15a	**Office/Mixed-Use proximate to <u>Planned Light Rail Transit</u>**	C	M	~	0.4	0.75-1.5 FAR (Floor to Area Ratio)
		C	M	~	0.5	1.5-2.25 FAR (Floor to Area Ratio)
		C	M	~	0.75	2.25 or greater FAR (Floor to Area Ratio)
15b	**Office/Mixed-Use proximate to <u>Planned Bus Rapid Transit</u>**	C	M	~	0.2	0.75-1.5 FAR (Floor to Area Ratio)
		C	M	~	0.25	1.5-2.25 FAR (Floor to Area Ratio)
		C	M	~	0.3	2.25 or greater FAR (Floor to Area Ratio)

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
15c	**Office/Mixed-Use proximate to Existing Light Rail Transit**	C	M	~	0.75	0.75-1.5 FAR (Floor to Area Ratio)
		C	M	~	1	1.5-2.25 FAR (Floor to Area Ratio)
		C	M	~	1.5	2.25 or greater FAR (Floor to Area Ratio)
15d	**Office/Mixed-Use proximate to Existing Bus Rapid Transit**	C	M	~	0.4	0.75-1.5 FAR (Floor to Area Ratio)
		C	M	~	0.5	1.5-2.25 FAR (Floor to Area Ratio)
		C	M	~	0.75	2.25 or greater FAR (Floor to Area Ratio)
16	**Orientation toward existing transit, bikeway, or pedestrian corridor**	C	M	R	0.5	Project is oriented towards existing transit, bicycle, or pedestrian corridor. Setback distance is minimized. Setback distance between project and adjacent uses is reduced to the minimum allowed under jurisdiction code. Setback distance between different buildings on project site is reduced to the minimum allowed under jurisdiction code. Setbacks between project buildings and sidewalks is reduced to the minimum allowed under jurisdiction code. Buildings are oriented towards street frontage. Primary entrances to buildings are located along public street frontage. Project provides bicycle access to existing bicycle corridor. Project provides access to existing pedestrian corridor. (Cannot get points for both this measure and measure 17)

MEASURE #	Measure Name	Commercial	Mixed-Use	Residential	Estimated CO_2 Equivalent Point Reductions	Measure Description
17	**Orientation toward planned transit, bikeway, or pedestrian corridor**	C	M	~	0.25	Project is oriented towards planned transit, bicycle, or pedestrian corridor. Setback distance is minimized. Planned transit, bicycle or pedestrian corridor must be in the MTP, RT Master Plan, General Plan, or Community Plan. Setback distance between project and existing or planned adjacent uses is minimized or non-existent. Setback distance between different buildings on project site is minimized. Setbacks between project buildings and planned or existing sidewalks are minimized. Buildings are oriented towards existing or planned street frontage. Primary entrances to buildings are located along planned or existing public street frontage. Project provides bicycle access to any planned bicycle corridor(s). Project provides pedestrian access to any planned pedestrian corridor(s).
18	**Residential Density With No Transit**	~	~	R	see below	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.
-	**3-6 Du/acre**	~	~	R	0	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.
-	**7-10 Du/acre**	~	~	R	1	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated** CO_2 **Equivalent Point Reductions***	***Measure Description***
-	**11-20 Du/acre**	~	~	R	3	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.
-	**21-30 Du/Acre**	~	~	R	5	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.
-	**31-40 Du/acre**	~	~	R	6	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.
-	**41-50 Du/acre**	~	~	R	8	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.
-	**50+ Du/acre**	~	~	R	10	Project provides high-density residential development. Mitgation value is based on project density with **no transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
18a	**Residential density With <u>Planned Light Rail Transit</u>**	~	~	R	see below	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**3-6 Du/acre**	~	~	R	0	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**7-10 Du/acre**	~	~	R	1.75	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**11-20 Du/acre**	~	~	R	3.75	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.

MEASURE #	Measure Name	Commercial	Mixed-Use	Residential	Estimated CO_2 Equivalent Point Reductions	Measure Description
-	**21-30 Du/Acre**	~	~	R	5.75	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**31-40 Du/acre**	~	~	R	6.75	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**41-50 Du/acre**	~	~	R	8.75	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**50+ Du/acre**	~	~	R	10.75	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated** CO_2 **Equivalent Point Reductions***	***Measure Description***
18b	**Residential Density with <u>Planned Bus Rapid Transit</u>**	~	~	R	see below	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**3-6 Du/acre**	~	~	R	0	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**7-10 Du/acre**	~	~	R	1.25	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**11-20 Du/acre**	~	~	R	3.25	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
-	**21-30 Du/Acre**	~	~	R	5.25	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**31-40 Du/acre**	~	~	R	6.25	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**41-50 Du/acre**	~	~	R	8.25	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.
-	**50+ Du/acre**	~	~	R	10.25	Project provides high-density residential development. Mitgation value is based on project density and proximity to **planned bus rapid transit**. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border. Planned transit must be in a MTP or RT Master Plan.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated*** CO_2 ***Equivalent Point Reductions***	***Measure Description***
18c	**Residential Density with <u>Existing Light Rail Transit</u>**	~	~	R	see below	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**3-6 Du/acre**	~	~	R	0	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**7-10 Du/acre**	~	~	R	2.5	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**11-20 Du/acre**	~	~	R	4.5	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**21-30 Du/Acre**	~	~	R	6.5	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated CO_2 Equivalent Point Reductions***	***Measure Description***
-	**31-40 Du/acre**	~	~	R	7.5	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**41-50 Du/acre**	~	~	R	9.5	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**50+ Du/acre**	~	~	R	11.5	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing light rail** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
18d	**Residential Density with <u>Existing Bus Rapid Transit</u>**	~	~	R	see below	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**3-6 Du/acre**	~	~	R	0	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**7-10 Du/acre**	~	~	R	2	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated CO_2 Equivalent Point Reductions***	***Measure Description***
-	**11-20 Du/acre**	~	~	R	4	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**21-30 Du/Acre**	~	~	R	6	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**31-40 Du/acre**	~	~	R	7	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**41-50 Du/acre**	~	~	R	9	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.
-	**50+ Du/acre**	~	~	R	11	Project provides high-density residential development. Mitgation value is based on project density and proximity to **existing bus rapid** transit. Density is calculated by determining the number of units per acre ("du/acre") within the residential portion of the project's net lot area. Existing transit facilities must be within 1/4 mile of project border. Project provides safe and convenient bicycle/pedestrian access to all transit stop(s) within 1/4 mile of project border.

MEASURE #	Measure Name	Commercial	Mixed-Use	Residential	Estimated CO_2 Equivalent Point Reductions	Measure Description
19	Street grid	C	M	R	1	Multiple and direct street routing (grid style). The measure applies to projects with an internal connectivity factor (CF)>=0.80, and average of 1/4 mile or less between external connections along perimeter of project. [CF=# of intersections / (# of cul-de-sacs + intersections)]
20	Neighborhood Electric Vehicle access	C	M	R	see below	Make physical development consistent with requirements for neighborhood electric vehicles (NEV). Current studies show that for most trips, NEVs do not replace gas,fueled vehicles as the primary vehicle. For the purpose of providing incentives for developers to promote NEV use, assume the percent reductions noted below.
20a	Neighborhood Electric Vehicle access	C	M	R	1.5	For 1.5% reduction, a neighborhood shall have internal NEV connections and connections to other existing NEV networks serving all other types of uses.
20b	Neighborhood Electric Vehicle access	C	M	R	1	For 1.0% reduction, a neighborhood shall have internal and external connections to surrounding neighborhoods.
20c	Neighborhood Electric Vehicle access	C	M	R	0.5	For 0.5% reduction, a neighborhood has internal connections only.
21	Affordable Housing Component	~	~	R	see below	Residential development projects of 5 or more dwelling units provide a deed-restricted low-income housing component on-site (as defined in Ch 22.35 of Sacramento County Ordinance Code) [Developers who pay into In-Lieu Fee Programs are not considered eligible to receive credit for this measure]. Percent reductions shall be calculated according to the following formula: % reduction=% units deed-restricted below the market rate housing *0.04
21a	Affordable Housing Component	~	~	R	0.6	Reductions apply if 15% of units are deed-restricted below the market housing rate.

MEASURE #	*Measure Name*	*Commercial*	*Mixed-Use*	*Residential*	*Estimated CO_2 Equivalent Point Reductions*	*Measure Description*
21b	**Affordable Housing Component**	~	~	R	0.8	Reductions apply if 20% of units are deed-restricted below the market housing rate.
21c	**Affordable Housing Component**	~	~	R	1.2	Reductions apply if 30% of units are deed-restricted below the market housing rate.
21d	**Affordable Housing Component**	~	~	R	1.6	Reductions apply if 40% of units are deed-restricted below the market housing rate.
21e	**Affordable Housing Component**	~	~	R	2	Reductions apply if 50% of units are deed-restricted below the market housing rate.
21f	**Affordable Housing Component**	~	~	R	2.4	Reductions apply if 60% of units are deed-restricted below the market housing rate.
21g	**Affordable Housing Component**	~	~	R	2.8	Reductions apply if 70% of units are deed-restricted below the market housing rate.
21h	**Affordable Housing Component**	~	~	R	3.2	Reductions apply if 80% of units are deed-restricted below the market housing rate.

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated CO_2 Equivalent Point Reductions***	***Measure Description***
21i	**Affordable Housing Component**	~	~	R	3.6	Reductions apply if 90% of units are deed-restricted below the market housing rate.
21j	**Affordable Housing Component**	~	~	R	4	Reductions apply if 100% of units are deed-restricted below the market housing rate.
Mixed-Use Measures						
22	**Urban Mixed-Use Measure**	~	M	~	see below	Development of projects predominantly characterized by properties on which various uses, such as office, commercial, institutional, and residential are combined in a single building or on a single site in an integrated development project with functional inter-relationships and a coherent physical design. Mitigation points for this measure depend on job to housing ratio.
22a	**Urban Mixed-Use Measure**	~	M	~	3	Reductions apply if the ratio (jobs:houses) is ≥ .5 < 1.0
22b	**Urban Mixed-Use Measure**	~	M	~	6.6	Reductions apply if the ratio (jobs:houses) is ≥ 1 < 1.5
22c	**Urban Mixed-Use Measure**	~	M	~	9	Reductions apply if the ratio (jobs:houses) is ≥ 1.5 < 2.0
22d	**Urban Mixed-Use Measure**	~	M	~	7.29	Reductions apply if the ratio (jobs:houses) is ≥ 2.0 < 2.5

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated CO_2 Equivalent Point Reductions***	***Measure Description***
22e	**Urban Mixed-Use Measure**	~	M	~	6	Reductions apply if the ratio (jobs:houses) is ≥ 2.5 < 3.0
22f	**Urban Mixed-Use Measure**	~	M	~	5	Reductions apply if the ratio (jobs:houses) is ≥ 3.0< 3.5
22g	**Urban Mixed-Use Measure**	~	M	~	4.2	Reductions apply if the ratio (jobs:houses) is ≥3.5 ≤ 4.0
23	**Suburban mixed-use**	C	M	R	3	Have at least three of the following on site and/or offsite within ¼ mile: Residential Development, Retail Development, Park, Open Space, or Office.
24	**Other mixed-use**	~	M	R	1	All residential units are within ¼ mile of parks, schools or other civic uses.
Building Component Measures						
25	**Energy Star roof**	C	M	R	0.5	Install Energy Star labeled roof materials. Energy star qualified roof products reflect more of the sun's rays, decreasing the amount of heat transferred into a building.
26	**Onsite renewable energy system**	C	M	R	1	Project provides onsite renewable energy system(s).
27	**Exceed title 24**	C	M	R	1	Project Exceeds title 24 requirements by 20%

MEASURE #	***Measure Name***	***Commercial***	***Mixed-Use***	***Residential***	***Estimated CO_2 Equivalent Point Reductions***	***Measure Description***
28	**Solar orientation**	~	~	R	0.5	Orient 75 or more percent of homes and/or buildings to face either north or south (within 30 degrees of North or South). Building design includes roof overhangs that are sufficient to block the high summer sun, but not the lower winter sun, from penetrating south facing windows. Trees, other landscaping features and other buildings are sited in such a way as to maximize shade in the summer and maximize solar access to walls and windows in the winter.
29	**Non-Roof Surfaces**	C	M	R	1	Provide shade (within 5 years) and/or use light-colored/high-albedo materials (reflectance of at least 0.3) and/or open grid pavement for at least 30% of the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc.; OR place a minimum of 50% of parking spaces underground or covered by structured parking; OR use an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area. Unshaded parking lot areas, driveways, fire lanes, and other paved areas have a minimum albedo of .3 or greater
30	**Green Roof**	C	M	R	0.5	Install a vegetated roof that covers at least 50% of roof area. Project should demonstrate detailed graphics depicting the planned roof, detailed information on maintenance requirements for the roof, and the facilities plan for maintaining the roof post construction.
TDM and Misc. Measures						
31	**Electric lawnmower**	~	~	R	1	Provide a complimentary electric lawnmower to each residential buyer

Additional GHG Emission Reduction Measures Requiring Additional Investigation			
1	**Bike Lane Street Design**		Incorporate bicycle lanes and routes into street systems, new subdivisions, and large developments.
2	**Bike & pedestrian design**		Include pedestrian and bicycle-only streets and plazas within developments. Create travel routes that ensure that destinations may be reached conveniently by public transportation, bicycling or walking.
3	**School siting**		Site schools to increase the potential for students to walk and bike to school.
4	**Transit street design**		The project will provide for on-site road and off-site bus turnouts, passenger benches, and shelters as demand and service routes warrant subject to review and approval by local transportation planning agencies.
5	**Site design measures**		Site design to minimize th need for external trips by including services/facilities for day care, banking/ATM, restaurants, vehicle refueling, and shopping.
6	**Other mixed-use**		All residential units are within 1/4 mile of parks, schools or other civic uses.
7	**Mixed-Use**		Include mixed-use, infill, and higher density in development projects to support the reduction of vehicle trips, promote alternatives to individual vehicle travel, and promote efficient delivery of services and goods.
8	**Open Space**		Preserve and create open space and parks. Preserve existing trees, and plant replacement trees at a set ratio.
9	**Natural Gas Stove**		Project features only natural gas or electric stoves in residences.
10	**Solar Design**		Incorporate appropriate passive solar design and solar heaters.
11	**Vehicle Idling**		Limit idling time for commercial vehicles, including delivery and construction vehicles.
12	**Ride Sharing Programs**		Create car sharing programs. Accommodations for such programs include providing parking spaces for the car share vehicles at convenient locations accessible by public transportation.
13	**Shuttle Service**		Provide shuttle service to public transit.

14	**School Bus Services**		Work with the school district to restore or expand school bus services.
15	**Shuttle Bus Services**		Operation of a shuttle bus to shopping, health care, public services sites and other nearby trip attactors to reduce automobile use.
16	**Energy efficient appliances**		Install energy efficient heating and cooling systems, appliances and equipment, and control systems.
17	**Renewable Energy Use**		Install solar, wind, and geothermal power systems and solar hot water heaters. Educate consumers about existing incentives.
18	**Solar Panels in Parking areas**		Install solar panels on carports and over parking areas.
19	**Photovoltaic Roofing Tiles**		Install Photovoltaic roofing tiles for solar power.
20	**Tree Planting**		Protect existing trees and encourage the planting of new trees. Adopt a tree protection and replacement ordinance, e.g., requiring that trees larger than a specified diameter that are removed to accommodate development must be replaced at a set ratio.
21	**Local Farmer's Market**		Project shall dedicate space in a centralized, accessible location for a weekly farmers' market.
22	**Community Gardens**		Project shall dedicate space for community gardens.
23	**Best management practices**		Require best management practices in agriculture and animal operations to reduce emissions, conserve energy and water, and utilize alternative energy sources, including biogas, wind and solar.
24	**Land Use Density**		The project should provide densities of nine units per acre or greater, where allowed by the General Plan and/or Zone Plan, along bus routes and at bus stops to encourage transit use, where feasible.
25	**Zero Emission Infrastructure**		Provide the necessary facilities and infrastructure to encourage the use of low or zero-emission vehicles (e.g., electric vehicle charging facilities and conveniently located alternative fueling stations).
26	**Low carbon fuel incentive program**		Institute a low-carbon fuel vehicle incentive program.

Final Draft Staff Report

Appendix K:
Comments to Responses
(June 30, 2009)

SUMMARY OF SIGNIFICANT COMMENTS RECEIVED FROM WORKSHOP HELD JUNE 30, 2009

Climate Change Action Plan: Addressing Greenhouse Gas Emissions Under the California Environmental Quality Act

Stakeholders providing comments:

- Arthur Unger (AU)
- California Cotton Ginners and Growers Association (CCGGA)
- Center for Biological Diversity (CBD)
- Center on Race, Poverty & the Environment (CRPE)
- City of Fresno (CF)
- Constellation Wines US (CWUS)
- Dairy CARES (DC)
- Dudek (D)
- EarthJustice (EJ)
- Fresno Public Health Department (FPHD)
- Kern County Planning Department (KCPD)
- Kern Oil & Refining Company (KORC)
- Sierra Club (SC)
- Silgan Containers MFG. Corp. (SCMC)
- Southern CA Gas Company (SCGC)
- Vector Environmental, Inc. (VEI)
- Western Agricultural Processors Association (WAPA)
- Western States Petroleum Association (WSPA)
- Western United Dairymen (WUD)

Best Performance Standards (BPS)

1. **Comment:** Focusing on AB32, the proposed threshold ignores the long term emission reductions necessary to stabilize the climate and the relevant environmental objectives from which to derive a threshold of significance for the greenhouse gases. (CBD, EJ,CRPE)

   Response: The GHG emission reduction targets established pursuant to AB32 are legislative mandates based on the state's understanding of climate change and its causes. Attempting to establish significance thresholds based on yet to be established GHG emission reduction targets, or on executive-directive reduction targets established without public process, is speculative and thus outside the technical consideration required by CEQA.

2. **Comment:** The Draft CCAP Report provides no analysis of the emissions BPS do not capture and whether these emissions constitute a cumulatively

significant impact. The Draft CCAP Report does not connect BPS with the attainment of a defined and scientifically based environmental objective. (CBD, EJ, CRPE)

Response: This comment is not correct. The proposed GHG significance determination, and the reductions expected, directly link BPS with the attainment of GHG emission reduction targets legislatively mandated by the State of California.

3. **Comment:** The proposed BPS capture only a portion of the carbon footprint of a particular source. For example, the BPS for livestock rearing focuses only on methane and ignores emissions from vehicle trips, energy use, and water consumption that are also a direct or indirect effect of livestock rearing operations. To property address a project's emissions it is important for a project that is significant to analyze all of its impacts on the environment, including indirect or lifecycle impacts, to the extent possible. Because the BPS focuses on a subset of a project's emissions, it improperly short circuits the full consideration and mitigation of project impacts. (CBD, EJ, CRPE)

   Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes. The District agrees that both direct and indirect source of GHG emissions should be considered when evaluating project specific impacts and when establishing BPS. The staff report has been revised to more clearly reflect consideration of both direct and indirect sources of GHG emissions. However, consistent with OPR's proposed revisions to the CEQA Guidelines lifecycle impacts are not required to be considered when evaluating impacts from project specific GHG emissions.

4. **Comment:** The Staff Report needs to clarify that the BPS are examples only. (KORC, DC, VEI)

   Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance.

5. **Comment:** The proposed guidance doesn't consider the use of renewable fuels as an approved BPS. It is important to recognize that the EPA's Renewable Fuel Standards (RFS) Program and CARB's Low Carbon Fuel Standard (LCFS) require refiners to invest millions of dollars in capital to begin manufacturing renewable and low carbon fuels predicated by Climate Change Program mandates, such as AB32. Kern recommends the BPS for internal combustion engines (gasoline or diesel) should satisfy CEQA project mitigation by fueling the engine on renewable or bio-fuels that meet the specification of either the Federal RFS or the State LCFS programs. (KORC)

   Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

6. **Comment:** In the development of BPS, there should be an option to install an engine that uses a fuel versus electrification and the District should remain fuel neutral. The engine should be the best performing engine for the corresponding fuel type. The requirement of electric as the standard goes beyond the guidance for achieving AB32 greenhouse gas emission reduction goals. (CCGGA)

   Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

7. **Comment:** The District guidance does not include enough flexible alternatives or pathways for determining that a project is less than significant without application of BPS or a 29% reduction from BAU; the District should include additional alternatives in its guidance. (DC)

   Response: This guidance is an evolving document which will be revised in the future as additional approaches become available. Lead agencies maintain the flexibility in providing alternative pathways in demonstrating a less than significant impact.

8. **Comment:** There is a concern that feed cost measures restrict economic feasibility. (WUD)

   Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

9. **Comment:** None of the BPS options identified in the draft guidance (for dairies) are workable and are likely to cause severe and unintended consequences if included in CEQA guidance documents in their present form. Urge the "illustrative examples" be removed pending discussion with stakeholders on whether the BPS policy should even apply to agriculture sources. Thorough stakeholder input is strongly urged prior to the publication of any additional draft guidance in this area. (DC)

   Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

10. **Comment:** If an agricultural source does not take the BPS or 29% reduction pathway, it is not clear how or whether it could establish that its GHG emissions are less than significant, or if there is any such nonzero level of emissions, no matter how small, that could be determined as "less than significant" for CEQA reasons. (DC)

    Response: As presented in the Draft Staff Report, the District has considered the various options for determining significance of project specific GHG emissions and concludes that use of performance based standards is the best approach. However, the methodology may evolve as the science progresses.

11. **Comment:** It is suggested that the definition for BPS be rewritten to eliminate any confusion with the established definition for BACT (under the Clean Air Act) and industry-based, operationally based BPS. The definition should be amended to ensure proper interpretation of the term "Best Performance Standards." (WSPA)

    Response: The Draft Staff Report has been revised to include key definitions, including a definition of BPS.

12. **Comment:** In Section 5.1.2 of the Draft Staff Report, it is suggested that the wording of the second sentence in the paragraph be replaced with this statement: "the District is presenting BPS that are illustrative in nature and for demonstration purposes only. Specific BPS will be developed subsequent to the Board approval of the BPS development process and in cooperation with interested parties". This statement is reflective of the discussion at the workshop (Slide 17) of presentation. (WSPA)

    Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

13. **Comment:** It is requested that the District reassess how the introduction to Section 5.3.3 is written to avoid future misuse of the Draft CCAP Staff Report.

    Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

14. **Comment:** It is suggested that the section on fossil fuel-fired, steam generators and process heaters needs to be completely rewritten to be more

consistent with subsequent sections (in terms of general guidance) and responsive to technological and operational practicalities. (WSPA)

Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

15. **Comment:** Concerned that the BPS process seems to establish outdated technologies or processes as the "baseline" for determining GHG reductions. How much of those 2002-2004 "baseline" technologies/practices would be allowed to be installed/used now? It seems untenable to allow new projects to calculate reductions from a standard that would not be allowed today. (EJ)

    Response: ARB's Scoping Plan projects the 2002-2004 baseline emissions inventory to establish the 2020 Business-As-Usual (BAU) emissions inventory. The Plan estimates that a 29% reduction in GHG emissions from BAU is required to achieve the targeted 1990 emissions level. GHG Emission reductions achieved since the baseline period contribute to achieving the required 29% reduction target and should be considered when evaluating project related GHG emissions as compared to BAU.

16. **Comment;** In section 5.1.4 Process of Establishing Best Performance Standards: the section is seriously flawed and needs to include consideration of "cost effectiveness." A BPS selection process that is based on a listing of all technologically feasible and achieved in practice control technologies without due consideration of cost effectiveness is unacceptable. It is recommended the District conduct a cost-effectiveness and socio-economic impact analysis for this proposed plan. (KORC, SCGC)

    Response: The District acknowledges the recommendation to consider cost effectiveness when establishing BPS. When determining that a particular GHG reduction measure has been achieved-in-practice, the District will consider the extent to which grants or other financial subsidies influence economic feasibility of a specific technology or GHG reduction measure. The Draft Staff Report discussion on establishing BPS has been amended consistent with this position.

17. **Comment:** CWUS is generally supportive of the use of BPS as a CEQA mitigation measure. However, the proposed process for establishing a BPS should include a step for assessing economic feasibility. (CWUS)

    Response: The District acknowledges the recommendation to consider cost effectiveness when establishing BPS. When determining that a particular GHG reduction measure has been achieved-in-practice, the District will consider the extent to which grants or other financial subsidies influence economic feasibility of a specific technology or GHG reduction measure. The

Draft Staff Report discussion on establishing BPS has been amended consistent with this position.

Business as Usual (BAU)

18. **Comment:** Neither SJVAPCD nor any other entity has established meaningful assumptions for measuring BAU for areas like transportation emissions. Does BAU vary from project to project or is it a static concept? Could a project close to a transit claim it is below BAU in comparison to a hypothetical project away from transit? Could a project simply do nothing but take credit for mandated increases in fuel economy as a means to assert it is below BAU? (CBD, EJ, CRPE)

    Response: ARB's Scoping Plan projects the 2002-2004 baseline emissions inventory to establish the 2020 Business-As-Usual (BAU) emissions inventory. BAU, as established by CARB, is a projected emissions inventory for 2020 and does not represent actual business or operational practices generating GHG emissions. Consequently, BAU is a static value that does not vary from project to project within the same GHG emissions category. To translate BAU into an emissions generating activity, the District proposes to establish emission factors per unit of activity, for each class and category, using the 2002-2004 baseline period. During this process, the District will seek stakeholder input.

    Project specific GHG emission reductions would be determined by establishing a GHG emissions factor for the proposed project and comparing it to the emissions factor established for the 2002-2004 baseline period. Projects implementing BPS, or otherwise demonstrating that GHG emissions have been reduced by 29% will be determined to have a less than significant individual and cumulative impact on global climate change.

19. **Comment:** Examining reductions from BAU involves a series of assumptions that can be difficult for the public to scrutinize and evaluate. The purpose of CEQA is to provide information on environmental impacts to decision makers and the public 'in a manner that will be meaningful and useful." Use of a BAU, rather than a simple numerical metric thwarts this fundamental purpose. (CBD, EJ, CRPE)

    Response: As discussed in Response to Comment 18, project specific GHG emissions would be compared to emission factors per unit of activity established per class and category for the baseline period. Additionally, as the Draft Staff Report indicates, development of BPS will include ample opportunity for public involvement. The process of establishing BPS includes advanced quantification of GHG emission reduction effectiveness, which will facilitate, not hinder, the ability of the public to scrutinize and evaluate project related impacts and mitigation measures.

20. **<u>Comment:</u>** There are concerns on accomplishing an 80% GHG emission reduction below 1990 levels by 2050 when only 29% below business as usual levels are recommended and by suggesting that projects built today are already below BAU due to additional regulation passed since the baseline period. (CBD, EJ, CRPE, AU)

Response: The scope of the guidance is based on AB32's goal of meeting the 1990 GHG emissions level by year 2020. The guidance being proposed establishes a process for determining significance of project specific GHG emissions, consistent with the legislatively mandated GHG emission reduction targets.

As presented in the Draft Staff Report, the District has considered the various options for determining significance of project specific GHG emissions and concludes that use of performance based standards is the best approach. However, the methodology may evolve as the science and/or legislation progresses.

21. **<u>Comment:</u>** When does mitigation start for a project? How does a new boiler achieve 29% in relation to "business as usual" (boiler in 2002-2004)? (CF)

Response: As presented in the Draft Staff Report, BAU is a projected emissions inventory, based on the 2002 through 2004 baseline period and is not based on specific operational parameters. The District is proposing that emission reductions achieved since the 2002-2004 be credited towards achieving the targeted 29% reduction in GHG emissions. For the specific example of a new boiler, the actual percent reduction in GHG emissions to be achieved by BPS will be established by the process presented in the Draft Staff Report.

22. **<u>Comment:</u>** In the Rio Bravo Ranch EIR, BAU means building with no mitigation measures whatsoever (pages 5.7-54 through 5.7-56). In order to prevent abuse, BAU should be clearly defined. For example, what mitigation measures should be included in BAU? Is it permissible to include no mitigation measures at all? Should measures that are required under some adopted program be considered mitigation measures or as a part of BAU? (SC)

Response: The Draft Staff Report has been amended to include a definition of BAU to be used in the context of establishing BPS and assessing GHG emission reduction measures. As presented in the Draft Staff Report, BAU is a projected emissions inventory, based on the 2002 through 2004 baseline period and is not based on specific operational parameters. The use of BAU by ARB for establishing GHG emission reduction targets has a different meaning than expressed in the EIR.

As presented in the Draft Staff Report, the District is proposing that all emission reductions achieved since the 2002-2004, including compliance with an adopted program, be credited towards achieving the targeted 29% reduction in GHG emissions.

As presented in the Draft Staff Report, the District has considered the various options for determining significance of project specific GHG emissions and concludes that use of performance based standards is the best approach. However, the methodology may evolve as the science progresses.

Greenhouse Gas Reductions

23. **Comment:** It is important that the District doesn't create GHG requirements which would discourage the voluntary replacement of old equipment with newer technology, just because the reduction is less than the 29% goal identified in the Staff Report. A net reduction should be a net reduction. If a replacement/reconstruction project can satisfy the basic permitting and prohibitory rule requirements for the source category, we want people to continue to propose these projects. (SCMC)

    Response: Implementation of BPS is not expected to discourage voluntary equipment replacement projects. The requirement to meet BPS would only apply to projects resulting in increases in GHG emissions. Therefore, voluntary replacement of older equipment would not require implementation of BPS, unless the project would result in an increase in GHG emissions, as compared to pre-project GHG emission levels.

24. **Comment:** The proposed 29% below BAU ignores the longer term GHG emission reduction targets necessary to reduce the risk of dangerous climate change. The proposed thresholds should be revised to account for scientific data on emission reductions necessary to minimize the risk of dangerous climate change. (CBD, EJ, CRPE)

    Response: The scope of the guidance is based on AB32's goal of meeting the 1990 GHG emissions level by year 2020. The guidance being proposed establishes a process for determining significance of project specific GHG emissions, consistent with the legislatively mandated GHG emission reduction targets.

    As presented in the Draft Staff Report, the District has considered the various options for determining significance of project specific GHG emissions and concludes that use of performance based standards is the best approach. However, the methodology may evolve as the science progresses.

25. **Comment:** The 29% reduction target in the draft CCAP is excessive and economically unachievable considering the only viable control that reduces combustion GHG emissions is to limit fuel usage (e.g., shut down combustion

sources, manufacture less, purchase costly credits, and/or go out of business. (KORC)

Response: The scope of the guidance is based on AB32's goal of meeting the 1990 GHG emissions level by year 2020, but it's important to recognize that for CEQA purposes, its application is limited to projects with GHG emissions increases. The guidance being proposed establishes a process for determining significance of project specific GHG emissions increases, consistent with the legislatively mandated GHG emission reduction targets.

As presented in the Draft Staff Report, the District has considered the various options for determining significance of project specific GHG emissions increases and concludes that use of performance based standards is the best approach. However, the methodology may evolve as the science progresses.

26. Comment: If small projects are allowed to be considered insignificant, how do we know the sum of these small projects will not be cumulatively significant? Could some of these small projects have GHG sources that are exceptionally easy to mitigate? (AU)

Response: Our proposed BPS approach applies to all projects with increases in GHG emissions, so is does not consider small projects to be insignificant.

27. Comment: Based on lead agency experience with the recent Big West Flying J Refinery Expansion, we would recommend that this policy not apply to larger industrial projects as the technology is specific to the industry. GHG emissions reductions can be achieved through changes in operations that cannot always be established ahead of time as best performance standards. (KCPD)

Response: The principal of the proposed approach of determining significance of project specific GHG emissions would apply to all projects subject to CEQA. As presented in the Draft Staff Report, GHG emissions would be quantified for projects requiring preparation of an EIR. For such projects, the significance determination would be based on whether or not it incorporates BPS, or if project specific GHG emissions have been reduced by 29%. However, lead agencies will continue to have the flexibility currently provided under CEQA to exercise discretionary judgment related to imposing feasible mitigation and determining significance.

28. Comment: District stated that projects that do not result in an increase in greenhouse emissions will not be subject to the Climate Change Action Plan (CCAP). However, there is no such provision in the current draft of the CCAP. (VEI)

Response: While it is inherent in the basic concepts of CEQA, the Draft Staff Report has been amended to clarify that projects not resulting in an increase in GHG emissions will be considered to have a less than significant individual and cumulative impact on global climate change.

29. **<u>Comment:</u>** How will GHG reductions be calculated? (VEI)

    Response: GHG emission reductions will be calculated according to methodologies approved by the District. The Draft Staff Report discusses the general concepts of calculating GHG emission reductions. These principals will be applied to establish specific methodologies for each identified class and category of GHG emission source. Additionally, the District will give consideration to methodologies developed by ARB and other agencies with expertise in evaluating GHG emissions.

30. **<u>Comment:</u>** How will the District account for an increase in the number of sources over time, as BPS is currently being achieved? Will reductions be valid or offset by increase in number of sources? (FPHD)

    Response: As presented in the Draft Staff Report, BAU is a projected emissions inventory, based on the 2002 through 2004 baseline period and is not based on specific operational parameters. ARB established the projected emissions inventory with consideration of anticipated growth in the number of GHG emission sources. As illustrated in the Draft Staff Report, the AB 32 projected 29% reduction in GHG emissions, including growth, will meet the 1990 GHG emissions level target.

31. **<u>Comment:</u>** The staff report should include specific details about these existing emission reductions for which a project could be credited. For example, will a project automatically be given credit towards the 29% reduction for Title 24 upgrades since 2004? (SC)

    Response: The Draft Staff Report has been amended to clarify that emission reductions achieved since the 2002 – 2004 baseline period will be credited towards achieving the required 29% reduction in GHG emissions to meet the 1990 emissions level target.

32. **<u>Comment:</u>** Will credit toward the 29% reduction be applied for statewide measures that CARB is responsible for? For example, a significant reduction in passenger and light truck emissions will be achieved with implementation of the Pavley vehicle standards upon EPA approval of the waiver. Similarly, emission reductions will be achieved through more stringent Renewable Portfolio Standards applicable to electric utilities. (D)

    Response: Achieving the GHG emission reduction targets requires a multifaceted approach. Achieved reductions in GHG emissions, regardless of the mechanism, will be credited towards achieving the required 29% reduction in GHG emissions to meet the 1990 emissions level target.

Miscellaneous

33. **Comment:** If a project would not normally be considered subject to CEQA, requirements should not be created which will add CEQA burdens. (SCMC)

    Response: As stated in the Draft Staff Report, projects determined to be exempt from CEQA would not require analysis of project specific GHG emissions and would not require implementation of BPS.

34. **Comment:** The SJVAPCD needs to explain how the cumulative total of the emissions it's not capturing will not have a significant environmental effect. For example, by using a 29% BAU threshold, SJVAPCD is saying that allowing 71% of emissions from all new development to be released into the atmosphere would not have a significant environmental effect. The conclusion is unsupportable given that emissions must be reduced by more than 80% below 1990 levels to avoid dangerous climate change. (CBD, EJ, CRPE)

    Response: The GHG emission reduction targets established pursuant to AB32 are legislative mandates based on the state's understanding of climate change and its causes. Attempting to establish significance thresholds based on yet to be established GHG emission reduction targets, or on executive-directive reduction targets established without public process, is speculative and thus outside the technical consideration required by CEQA.

35. **Comment:** The Draft CCAP Report misleadingly states that "execution of a zero threshold would be difficult or impossible." The best available science most strongly supports a zero threshold. The further a threshold is from zero, the more tenuous the evidence to support a determination that the threshold is effective at meeting the environmental objective of avoiding dangerous climate change. (CBD, EJ, CRPE)

    Response: The District agrees neither with the assertion that the "Draft Staff Report is misleading", nor with the statement that "the best available science most strongly supports a zero threshold". On the contrary, District staff thinks it is impossible, using today's science, to say that any single project has a significant impact on global climate change. The District's rationale for supporting a BPS approach for determining cumulative significance of project specific GHG emissions is clearly presented in the Draft Staff Report: the District has considered the various options for determining significance of project specific GHG emissions and concludes that use of performance based standards is the best approach. However, the methodology may evolve as the science progresses.

36. **Comment:** The commenter believes the District could justify the further use of the Scoping Plan to establish a level of insignificance. For instance, agricultural pumps are not subject to regulation according to the Scoping Plan and therefore that emissions category should be considered insignificant for

GHG CEQA purposes. BPS may work for streamlining permits for larger sources. The standards currently written place a heavy burden on small sources. (CCGGA, WAPA)

Response: The Scoping Plan itself cannot be used as a threshold. During the process of developing BPS, the District will consider the extent to which CARB has developed guidance specific to a given GHG emissions source category.

37. **Comment:** Since tier two projects would not have to mitigate the GHG they generate, it is critical to limit the number and GHG generation of tier two projects. (AU)

Response: The tier approach presented in the Draft Staff Report was part of a discussion of the various options for establishing a process of assessing significance of project specific GHG emissions. As presented Chapter Four, the District is proposing a performance based approach for all projects with increases in greenhouse gases emissions.

38. **Comment:** Why should the bottom of page 70 (in Staff Report) assume that equipment operated during the 2002-2004 baseline emission inventory is assumed to be natural gas-fired IC engine, rather than utility supplied electric power? Without this assumption the 42% net emission reduction can not be achieved. (AU)

Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

39. **Comment:** Incorporating GHG into soil (Staff Report: Page 93) might improve with consultation with soil scientists. Would no till farming or organic farming, sequester more carbon than methods now used in the Valley? (AU)

Response: The Draft Staff Report has been revised to clarify that BPS are presented for illustrative purposes, and should not be used by a lead agency to determine best performance standards for use with our guidance. During the development process of BPS, District plans to involve stakeholders in identifying BPS for each industry sector.

40. **Comment:** It is not appropriate to equate agricultural sources/sinks for GHG emissions with large fossil-fuel combustion sources. A "one-size-fits-all" policy not only is inappropriate but inconsistent with state and federal policies. (DC)

Response: As presented in the Draft Staff Report, the District has considered the various options for determining significance of project specific GHG emissions and concludes that use of performance based standards is the best approach. As proposed, all projects which would result in increased GHG emissions are required to reduce and or mitigate project specific GHG emissions. Although all projects would be required to reduce GHG emissions, BPS is specific to each Category and Class.

41. **Comment:** The guidance and policy should clearly and explicitly state that a project in conformance with an adopted Climate Change Action Plan is considered less than significant and does not contribute to cumulative impacts. (KCPD)

    Response: As presented in the Draft Staff Report projects complying with an approved GHG emission reduction plan or GHG mitigation program, which avoids or substantially reduces GHG emissions within the geographic area in which the project is located would be determined to have a less than significant cumulative impact for GHG emissions. Such plans or programs must be specified in law or approved by the lead agency with jurisdiction over the affected resource and supported by a CEQA compliant environmental review document adopted by the lead agency.

42. **Comment;** Recommend considerations be given to projects that have undergone environmental review where such review included consideration of GHG emissions and the projects were subsequently issued negative declarations or mitigated negative declarations. (VEI)

    Response: Nothing being proposed by the District would change the principals of CEQA. Projects approved by a lead agency and supported by a CEQA compliant environmental assessment would be reviewed consistent with existing CEQA Guidelines and would not be required to implement GHG reduction measures beyond those imposed by the lead agency.

43. **Comment:** With respect to determinations made for projects that have undergone environmental review without consideration of GHG emissions, we recommend that additional review be conducted pursuant to State CEQA Guidelines Section 15164 (Addendums to EIR or Negative Declarations). (VEI)

    Response: Nothing being proposed by the District would change the principals of CEQA. Projects approved by a lead agency and supported by a CEQA compliant environmental assessment would be reviewed consistent with existing CEQA Guidelines, including CEQA Guidelines Section 15164**.**

44. **Comment:** What are the pros & cons of how SB375 and ARB's efforts to draft geographic targets relate to the District's Guidance? (CF)

    Response: In general, geographic targets have the potential benefit of implementing program level VMT reduction measures that relate to transportation and land use planning. The success of these efforts however depends greatly on collaboration among multiple land use and state agencies. However, it is important to note that the light-duty vehicle emissions resulting from development projects complying with plans resulting from SB 375 implementation will be exempt from further CEQA review, and therefore will not be subject to this District proposed guidance.

45. **Comment:** "Achieved in Practice" needs to be addressed, and further discussed in the Staff Report. (CCGGA)

    Response: The Draft Staff Report has been revised to include key definitions, including a definition of "Achieved in Practice".

46. **Comment:** In GHG Banking Staff Report, the District says it will be revising its CEQA policy to address GHG emissions. Is this the policy the District is referring to? If so, when will this revision be subject to CEQA, as mentioned in the response to comments? (EJ)

    Response: The District staff was not able to find the reference to the District CEQA Implementation Policy in GHG Banking Staff Report. However, the "policy" referenced in the District CEQA GHG Guidance Draft Staff Report is actually an internal District procedure for implementing CEQA during the permitting process. If the District's governing Board adopts the proposed GHG significance determination guidance, the internal procedure will be revised to include consideration of GHG emissions. Revision of internal guidance is not subject to CEQA.

47. **Comment:** Biogenic carbon dioxide emitted from combustion or fermentation of biomass should be considered to have net-zero GHG emissions. This clarification could be added to the Section 1.1, *description of carbon dioxide*, and Section 4.3.2, *Process*. Clarifying that biogenic CO_2 is a recycling of carbon, not added CO_2 to the ecosystem, will streamline evaluation of such projects. (CWUS)

    Response: The District recognizes that certain sources of biogenic carbon can be considered to have net-zero GHG emissions. However, the determination that a specific source of biogenic carbon would have net-zero GHG emissions is a complex analysis, which should take into consideration the entire process, including activities which directly or indirectly contribute to total GHG emissions. The determination of whether a specific activity or source of biogenic carbon would be considered carbon neutral will be considered when developing BPS for a specific Class and Category.

Final Draft Staff Report

Appendix L:
Evaluation of BPS Performance for Stationary Source Permitting Projects

Evaluation of BPS Performance for Stationary Source Permitting Projects

ARB in their AB32 Scoping Plan[75] concluded that an overall 29% reduction from BAU 2020 emissions levels was necessary to achieve the targeted 1990 emissions rate, and the District's BPS-based approach to addressing CEQA significance is designed to achieve that level of reductions from new growth in GHG emissions. This appendix is a demonstration that such reductions are achievable through implementation of BPS. The attached table summarizes the theoretical affect of implementing our illustrative example BPS, using a two-year history of permitting actions in the San Joaquin Valley. We have categorized the expected reductions as follows:

Facilities NOT subject to ARB's cap-and-trade program
For facilities not subject to cap-and-trade, calculations of GHG emission reductions are directly based on implementing the District's illustrative example BPS. We examined each permitting project that took place in the past two years in the San Joaquin Valley Air District. For those projects for which we proposed an illustrative example BPS, we theoretically applied the BPS to the project, and analyzed the resulting GHG emissions reduction. The percent reduction for each type of projects is shown, as is the total emissions and total emissions reduction for the type of source.

Facilities subject to ARB's cap-and-trade program
The AB 32 Scoping Plan evaluated a comprehensive array of approaches and tools to achieve the required GHG emission reductions to achieve the 1990 GHG emission levels. ARB concluded that reducing GHG emissions from a wide variety of the largest sources can best be achieved through establishment of a cap-and-trade program. The program would establish a limit or "cap" on total GHG emissions generated by sectors covered by the system. The AB32 Scoping Plan identifies the following four sectors that would be subject to a cap-and-trade program: transportation, electricity, commercial and residential, and industry. ARB has determined that for the four sectors included within the cap-and-trade program overall, annual GHG emissions would be reduced from 512 $MMTCO_2E$ (projected 2020 BAU) to 365 $MMTCO_2E$[76]. This represents a 28.7% reduction in GHG emissions compared to BAU.

$$28.7\%\,\text{Total Reduction} = \frac{512\,\text{MMTCO2e}(2020\,\text{BAU Capped Emissions}) - 365\,\text{MMTCO2e}(2020\,\text{Target Capped Emissions})}{512\,\text{MMTCO2e}(2020\,\text{BAU Capped Emissions})}$$

[75] *Climate Change Proposed Scoping Plan;* P. 21. California Air Resources Board, October 2008
[76] *Climate Change Proposed Scoping Plan;* P. 21. California Air Resources Board, October 2008

Facilities subject to ARB's cap-and-trade program are expected to contribute to the overall 29% GHG emissions cap-and-trade reduction target. For these facilities, since implementation of BPS is required for all emission sources with increased GHG emissions, reductions achieved by implementing BPS will be additive to GHG emission reductions achieved at the facility level under the cap-and-trade program. However, per the District's proposed guidance, projects complying with a GHG emissions reduction program approved by the lead agency with jurisdiction over the affected resource and supported by a CEQA compliant environmental review document would be considered to have a less than significant individual and cumulative impact on global climate change. Such projects would not be required to implement BPS. To ensure that the District's estimates of total GHG emission reductions that would be achieved through implementation of BPS are conservative, District staff has assumed for the purposes of this analysis only that the approved cap-and-trade program will have been specified in law or otherwise supported by a CEQA compliant environmental review document such that GHG impacts from projects in these cap-and-trade categories will be considered to have a less than significant individual and cumulative impact on global climate change. Therefore, for projects occurring at facilities belonging to sectors subject to the cap-and-trade program, emission reductions achieved through implementing BPS have been calculated as above, but are not added to the overall 28.7% reduction achieved through compliance with cap-and-trade. For these facilities, the District conservatively limits GHG emission reduction estimates to the 28.7% cumulative reduction that will be achieved through compliance with cap-and-trade provisions.

Overall GHG Emission Reductions

As presented in Table 1, implementing BPS will achieve an overall 34.0% reduction in GHG emissions, thus demonstrating that implementing BPS, even excluding the affects of BPS on Cap-and-Trade sources, exceeds the overall 29% GHG emission reduction targeted by ARB in the scoping plan.

Table 1: GHG Emission Reductions

GHG Emission Reductions Due to Combined Implementation of Illustrative Examples of Best Performance Standards (BPS) and Cap-and-Trade Program for District Projects During 2007 and 2008

BPS Category	GHG Emissions Increases Due to New Unts (tons-CO2/yr)	GHG Emission Increases Due to Modifications (tons-CO2/yr)	Total GHG Emissions Increase (tons-CO2/yr)	Evaluated Total GHG Reductions Due to BPS (tons-CO2/yr)	Cap & Trade Emission Reduction (tons-CO2/yr)	Percent GHG Emissions Reductions Due to BPS Only	Percentage Emission Reduction Due to Combined Cap & Trade Plus BPS
Facilities Not Subject to Cap & Trade							
Boilers, Process Heater and Steam Generators > 5MMBtu/hour	244,111	43,836	287,947	19,590	0.0%	6.8%	6.8%
Non-Emergency Flares > 5 MMBtu/hr	15,548	97,487	113,035	50,325	0.0%	44.5%	44.5%
Non-Emergency Onsite Electric Power Generation with Fossil Fuel Combustion > 5 MMBtu/hr of with Fossil Fuel Fired Mechanical Driver > 50 hp	13,472	0	13,472	8,892	0.0%	66.0%	66.0%
Non-Emergency Mechanical Equipment Driver	94,045	2,269	96,314	65,289	0.0%	67.8%	67.8%
Fossil Fuel-Fired Cogeneration (combustion turbines > 3 MMBtu/hr or other combustion devices > 5 MMBtu/hr)	27,606	0	27,606	6,625	0.0%	24.0%	24.0%
Landfill Operations	0	183	183	7,508	0.0%	4102.7%	4102.7%
Wastewater Treatment Operations	0	0	0	0	0.0%	0.0%	0.0%
Oil and Gas Extraction, Storage, Transportation and Refining Operations (fugitive emissions)	9	46,901	46,910	69,359	0.0%	147.9%	147.9%
Farming Operations - Livestock Rearing	654,382	87,820	742,202	336,557	0.0%	45.3%	45.3%
Farming Operations - Application of Manure to Cropland	0	0	0	0	0.0%	0.0%	0.0%
Facilities Subject to Cap & Trade							
Boilers, Process Heater and Steam Generators > 5MMBtu/hour	1,527,074	300,791	1,827,865	117,593	612,149	6.4%	28.7%
Flares	24,387	224,095	248,482	94,240		37.9%	
Non-Emergency Onsite Electric Power Generation with Fossil Fuel Combustion > 5 MMBtu/hr of with Fossil Fuel Fired Mechanical Driver > 50 hp	0	0	0	0		0.0%	
Non-Emergency Mechanical Equipment Driver	1,135	0	1,135	749		66.0%	
Fossil Fuel-Fired Cogeneration (combustion turbines > 3 MMBtu/hr or other combustion devices > 5 MMBtu/hr)	55,440	0	55,440	13,306		24.0%	
Total Impact of BPS and Cap-and-Trade	**2,657,209**	**803,382**	**3,460,591**	**790,033**	**612,149**	**34.0%**	

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
Bicycle/Pedestrian/Transit Measures									
1	**Bike parking**	C,M	0.625	**Non-residential projects provide plentiful short-term and long-term bicycle parking facilities to meet peak season maximum demand**	0.625	0.946	0.5915464	general	As a rule of thumb, the Center for Clean Air Policy (CCAP) guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
2	**End of trip facilities**	C,M	0.625	**Non-residential projects provide "end-of-trip" facilities including showers, lockers, and changing space**	0.625	0.946	0.5915464	general	The Transportation Demand Management (TDM) Encyclopedia allows a 2-5% reduction for worksite showers ad lockers. The CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: TDM Encyclopedia May 11, 2006; CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
3	**Bike parking at multi-unit residential**	R	0.625	**Long-term bicycle parking is provided at apartment complexes or condominiums without garages**	0.625	0.946	0.5915464	general	As a rule of thumb, the CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 25% of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
4	**Proximity to bike path/bike lanes**	R,C,M	0.625	**Entire project is located within 1/2 mile of an existing Class I or Class II bike lane and project design includes a comparable network that connects the project uses to the existing offsite facility**	0.625	0.946	0.5915464	general	As a rule of thumb, the CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
5	**Pedestrian network**	R,C,M	1	**The project provides a pedestrian access network that internally links all uses and connects to all existing or planned external streets and pedestrian facilities contiguous with the project site.**	1.0	0.946	0.9464742	general	Because this measure also eliminates physical barriers between residential and non-residential uses that impede bicycle or pedestrian circulation, this measure is similar in nature to 6. As cited in the TIAX report, the CCAP guidebook attributes a 1% reduction in VMT. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
6	**Pedestrian barriers minimized**	R,C, M	1	**Site design and building placement minimize barriers to pedestrian access and interconnectivity. Physical barriers such as walls, berms, landscaping, and slopes between residential and non-residential uses that impede bicycle or pedestrian circulation are eliminated**	1.0	0.946	0.9464742	general	The reduction is based on the TIAX report, which indicates a 1% reduction, and the CCAP report, which attributes a 1% to 5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
7	**Bus shelter for existing transit service**	R,C,M	.25-1.0	**Bus or Streetcar service provides headways of one hour or less for stops within 1/4 mile; project provides safe and convenient bicycle/pedestrian access to transit stop(s) and provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting).**	0.5	0.946	0.4732371	general	This reduction is based on the assumption that the measure applies to providing bus stop route information & benches. Emission reductions are based on conclusion obtained from the TIAX report and the CCAP guidebook. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
8	**Bus shelter for planned transit service**	R,C,M	0.25	**Project provides transit stops with safe and convenient bicycle/pedestrian access. Project provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting) in anticipation of future transit service**	0.5	0.946	0.4732371	general	This reduction is based on the assumption that the measure applies to providing bus stop route information & benches. Emission reductions are based on conclusion obtained from the TIAX report and the CCAP guidebook. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
9	**Traffic calming**	R,C,M	0.25-1.0	**Project design includes pedestrian/bicycle safety and traffic calming measures in excess of jurisdiction requirements. Roadways are designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips by featuring traffic calming features**	see table	0.946	see table*SF	general	SMAQMD appears to have the best information available as reflected in their Guidance for Land Use Emission Reductions, which allocates reductions by the percent of intersections with traffic calming improvements as indicated in the table below. We were unable to locate more specific information. Source: Draft Update to SMAQMD Guidance for Land Use Emission Reductions.
Parking Measures									
10a	**Paid parking**	R,C,M	1.0-7.2	**Employee and/or customer paid parking system**	see table	0.946	see table*SF	general	Shoupe, 2005. Parking Cash Out. [$5/day reduces drive-alone share by 21% for commuters to downtown LA, with elasticity of -0.18 (e.g., if price increases 10%, then solo driving goes down by 1.8% more (Wilson 1991)] [Reported 1-10% reduction in trips to central city sites, and 2-4% in suburban sites (Urban Institute)].

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
10b	**Parking cash out**	C, M	0.6-4.5	**Employer provides employees with a choice of forgoing subsidized parking for a cash payment equivalent to the cost of the parking space to the employer**	see table	0.946	see table*SF	specific	Shoupe, 2005. Parking Cash Out. [2/3 as effective as charging for parking (8 case studies - chapter 4, 13% reduction in solo driver trips, -12% VMT per employee, and -11% in vehicle trips per commuter)].
11	**Minimum parking**	R,C,M	0.1-6.0	**Provide minimum amount of parking required. Special review of parking required.**	see formula	0.946	see formula *SF	general	Nelson/Nygaard, 2005. pg. 16. (trip reduction = ((actual parking provision - ITE parking generation rate) / ITE parking generation rate) *0.5). (Note: this formula is not verbatim from that cited in the Nelson/Nygaard document, since the formula provided did not make sense for computing trip reductions. This is what EDAW believes was meant, and this method actually works.)
12	**Parking reduction beyond code**	R,C,M	2.5	**Provide parking reduction less than code. Special review of parking required. Recommend a Shared Parking strategy.**	see formula	0.946	see formula *SF	general	Nelson/Nygaard, 2005. pg. 16. (trip reduction = ((actual parking provision - ITE parking generation rate) / ITE parking generation rate) *0.5). (Note: this formula is not verbatim from that cited in the Nelson/Nygaard document, since the formula provided did not make sense for computing trip reductions. This is what EDAW believes was meant, and this method actually works.)

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
13	**Pedestrian pathway through parking**	R,C,M	0.5	**Provide a parking lot design that includes clearly marked and shaded pedestrian pathways between transit facilities and building entrances**	0.5	0.946	0.4732371	general	The CCAP guidebook attributes between 1% and 4% reduction from all pedestrian measures. There is no specific information related to providing shaded pedestrian pathways between transit facilities and building entrances. It could be said that providing covered carpool/vanpool spaces near the entrance to the buildings has the similar goal of increasing the comfort of the user while walking to the building entrance. The TIAX report assigns a 1% reduction to the covered carpool measure. Transit usage is most affected by the headway times and the proximity to the destination. Therefore, it would seem reasonable to assume .5% Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.
14	**Off street parking**	R,C,M	0.1-1.5	**Parking facilities are not adjacent to street frontage**	0.1-1.5	0.946	0.095-1.419	moderate	No empirical support for this specific measure; however, range of values is based on other pedestrian-oriented measures. The range recognizes the dependence of this measure on other measures. To be awarded 1.0 points, development must be in an area with density, wide sidewalks, and where other uses are also hiding parking. The efficacy of this measure is reduced to 0.1 if the development does not include other pedestrian and mixed-use measures. Parking structure with ground-floor retail is awarded 0.5.
Site Design measures									
15	**Office/Mixed-use density**	C, M	0.1-1.5	**Project provides high density office or mixed-use proximate to transit**	see table	0.946	see table*SF	moderate	No empirical support for this measure, beyond that provided by SMAQMD in its draft guidance. According to Nelson/Nygaard, 2005, trip generation at the non-residential end is influenced by density to a much lesser degree, so this is fairly consistent with the transit reductions applied in measure 20.

SMAQMD MEASURE #	***Measure Name***	***Land Use Type***	***SMAQMD Point Reductions***	***Measure Description***	***Unscaled %CO2 Emission Reduction***	***CO2 Emissions Scale Factors (SF)***	***Scaled % CO2 Emission Reduction***	***Measure Applicability (specific/ moderate/ or general basis)***	***Reduction Methodology and Source***
16	**Orientation toward existing transit, bikeway, or pedestrian corridor**	R,C,M	0.5	**Project is oriented towards existing transit, bicycle, or pedestrian corridor. Setback distance is minimized**	0.5	0.946	0.4732371	general	The CCAP guidebook attribute a 0.5% reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit rider ship would result in a 0.5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.
17	**Orientation toward planned transit, bikeway, or pedestrian corridor**	C, M	0.25	**Project is oriented towards planned transit, bicycle, or pedestrian corridor. Setback distance is minimized**	0.5	0.946	0.4732371	moderate	The CCAP guidebook attributes a 0.5 % reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit rider ship would result in a 0.5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.
18	**Residential density**	R	1.0-12	**Project provides high-density residential development**	see table	0.946	see table*EF	moderate	Nelson/Nygaard, 2005. pg 11. (trip reduction = 0.6*(1-(19749*((4.814+households per residential acre)/(4.814+7.14))^-.639)/25914) (Holtzclaw et al 2002). Asymptote of 60% reduction. **Relative to a 3 du/ac development.** Note that there is no direct empirical support for the added reductions for proximity to transit; the 60% asymptote in this equation is to correct for double-counting from transit services, mix-of-uses, and bicycle and pedestrian connections (which could contribute another 40% reduction).
19	**Street grid**	R, C, M	1	**Multiple and direct street routing (grid style)**	1.0	0.946	0.9464742	specific	Reductions are based on CCAP estimates for similar measures. Source: CCAP Transportation Emission Guidebook.

SMAQMD MEASURE #	*Measure Name*	*Land Use Type*	*SMAQMD Point Reductions*	*Measure Description*	*Unscaled %CO2 Emission Reduction*	*CO2 Emissions Scale Factors (SF)*	*Scaled % CO2 Emission Reduction*	*Measure Applicability (specific/ moderate/ or general basis)*	*Reduction Methodology and Source*
20	**Neighborhood Electric Vehicle access**	R,C,M	0.5-1.5	**Make physical development consistent with requirements for neighborhood electric vehicles**	0.5-1.5	0.946	0.473-1.419	specific	No direct empirical support for this measure available. May not be relevant/applicable in the near term, until NEVs become more common/inexpensive. Current studies show that for most trips, NEVs do not replace gas-fueled vehicles as the primary vehicle. For the purposes of providing incentives for developers to promote NEV use, assume that a neighborhood with internal NEV connections only receives 0.5 points, with external connections to other surrounding uses, 1.0 point, with external connections to other NEV networks, 1.5 points.
21	**Affordable Housing Component**	R	0.6-4.0	**Residential development projects of 5 or more dwelling units provide a deed-restricted low-income housing component on-site (as defined in Ch 22.35 of Sacramento County Ordinance Code) [Developers who pay into In-Lieu Fee Programs are not considered eligible to receive credit for this measure]**	0.6-4.0	0.946	0.568-3.784	general	Nelson/Nygaard, 2005. pg. 15. (trip reduction = % units deed-restricted below market rate housing * 0.04).
Mixed-use measures									
22	**Urban mixed-use**	M	3.0-9.0	**Development of projects predominantly characterized by properties on which various uses, such as office, commercial, institutional, and residential, are combined in a single building or on a single site in an integrated development project with functional interrelationships and a coherent physical design**	3.0-9.0	0.946	2.838-8.514	general	Nelson/Nygaard, 2005. pg. 12. (trip reduction = (1-(ABS(1.5*h-e)/(1.5*h+e))-0.25)/0.25*0.03) where h = study area housing units, e = study area employment (Criteron & Fehr & Peers, 2001). Asymptote of 9% reduction, and an ideal 1.5 jobs per household.

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
23	**Suburban mixed-use**	R,C,M	3	**Have at least three of the following on site and/or offsite within ¼ mile: Residential Development, Retail Development, Park, Open Space, or Office**	3.0	0.946	2.8394227	moderate	By definition, this type of land use implies that housing availability is greater than employment availability. On a project-by-project basis, use formula :Nelson/Nygaard, 2005. pg. 12. (trip reduction = (1-(ABS(1.5*h-e)/(1.5*h+e))-0.25)/0.25*0.03) where h = study area housing units, e = study area employment (Criteron & Fehr & Peers, 2001) to obtain higher than 3% reduction. Otherwise, assume 3% max reduction.
24	**Other mixed-use**	R, M	1	**All residential units are within ¼ mile of parks, schools or other civic uses.**	1.0	0.946	0.9464742	moderate	This measure has less to do with employment/housing balance. No empirical support for this measure, but logic from measures 24 and 25 still applies.
Building Component Measures									
25	**No fireplace**	R	1.0	**Project does not feature fireplaces or wood burning stoves**	-	-	-	general	Reductions assume a 100% emission reduction from baseline conditions, as calculated using the methodology documented in the Staff Report for SMAQMD Rule 417, Wood Burning Appliances, Appendix D. The approach is consistent with SMAQMD rule development, based on a conversation with SMAQMD staff (Mr. Donny Homer). Calculating emission reductions in the greater Sacramento area yields 1.0 point benefit to the project, consistent with the current point value of the measure. Emission reductions are calculated as follows: Emission Reduction = (Emissions) – [(New Emissions certified stove aesthetic x fraction of adoption) + (New Emissions certified stove heat x fraction of adoption) + (New EmissionsNG aesthetic x fraction of adoption) + (New EmissionsNG heat x fraction of adoption)+ (New Emissions electric aesthetic x fraction of adoption) + (New Emissions electric heat x fraction of adoption)]

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
26	**Ozone Destruction Catalyst**	R, C, M	1.25	**Install ozone destruction catalyst on air conditioning systems**	1.25	0.054	0.0669072	general	Reductions assume over 80% of harmful, ground level ozone is converted into oxygen through application of air conditioning system technology. The proposed point value for this operational mitigation measure is 1.5, a mid-point value consistent with the rating assigned to this measure by the Feather River Air Quality Management District as a Standard Mitigation Measures for All Projects. The SMAQMD has had point values for this measure ranging from 1.25 (i.e., Land Use Mitigation Measures), to 2.5 for specific projects (i.e., Lent Ranch Marketplace, City of Elk Grove). Air conditioning systems for commercial, office and residential buildings within the project will be treated with an ozone destruction catalyst ("cap" or coating of the condenser coils) to convert ozone to oxygen as the catalyst makes contact with air moving through the air conditioner. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, specifications and any available manufacturer's documentation on the devices to be used.
27a					0.5	0.054	0.0267629	specific	Reductions are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 0.5 for qualified roof products. Baseline conditions assume indirect emission reduction through more even temperature control of environmental space. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
27b	**Energy Star roof**	R,C,M	0.5-1.0	**Install Energy Star labeled roof materials**	1.0	0.054	0.0535258	specific	Additional emission reductions are available based on use of Energy Star compliant (highly reflective) and high emissivity roofing (emissivity of at least 0.9 when tested in accordance with ASTM 408) for a minimum of 75% of the roof surface. Based on the quantification methodology used by the SMAQMD Guidance for Land Use Reductions, an additional 0.5 point, for a total of 1.0 points, is available for qualified roof products that meet ATSM high emissivity requirements. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
28	**Onsite renewable energy system**	R,C,M	1.0-3.0	**Project provides onsite renewable energy system(s)**	3.0	0.054	0.1605773	general	Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that at least 12.5% of the buildings total energy use (as expressed as a fraction of annual energy cost) is supplied through the use of on-site renewable energy systems. Alternatively a project may use the Department of Energy (DOE) Commercial Buildings Energy Consumption Surevy (CBECS) database to determine the estimated electricity use. Non-polluting and renewable energy potential includes solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, projects may take advantage of net metering with the local utility. The measure is enforcable through LEED Letter certification and building design calculations demonstrating that at least 12.5% of total energy costs are supplied by the renewable energy system(s).

SMAQMD MEASURE #	*Measure Name*	*Land Use Type*	*SMAQMD Point Reductions*	*Measure Description*	*Unscaled %CO2 Emission Reduction*	*CO2 Emissions Scale Factors (SF)*	*Scaled % CO2 Emission Reduction*	*Measure Applicability (specific/ moderate/ or general basis)*	*Reduction Methodology and Source*
29	**Exceed title 24**	R,C,M	1.0	**Project Exceeds title 24 requirements by 20%**	1.0	0.054	0.0535258	specific	Reductions assume at least a 20% over Title 24 requirements, as calculated by the Sacramento Municipal Utility District (SMUD, 2006 Advantage Home Program Overview). The proposed point value for this operational mitigation measure is 1.0, consistent with the rating assigned to this measure by SMAQMD Land Use Mitigation Measures. Total compliance margin is based on energy savings relative to the total energy budget and cooling energy budget of the Title 24 Standard design home. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, specifications and any available manufacturer's documentation on the devices to be used. This measure's successful implementation may be verified by a site review following construction to confirm that the project as built contains ozone destruction catalysts as described in the Air Quality Plan.
30	**Solar orientation**	R	0.5	**Orient 75 or more percent of homes and/or buildings to face either north or south (within 30 degrees of N/S)**	0.5	0.054	0.0267629	specific	Reduction assumes that proper solar orientation can produce a total energy savings of 11% to 16.5% and reduce heating fuel consumption by up to 25% (Local Government Commission, 1998). Mitigation measure points are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 0.5 for proper orientation. Reduction methodology will be based on quantification of the difference in solar radiance from development with designed orientations (75 or more percent of homes and/or buildings to face within 30 degrees either north or south) compared to evenly distributed orientations. Project compliance will be based on the percentage of orientation buildings designed with proper design features (overhangs, landscaping).

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
31	**Non-Roof Surfaces**	R,C,M	1.0	**Provide shade (within 5 years) and/or use light-colored/high-albedo materials (reflectance of at least 0.3) and/or open grid pavement for at least 30% of the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc.; OR place a minimum of 50% of parking spaces underground or covered by structured parking; OR use an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area. Unshaded parking lot areas, driveways, fire lanes, and other paved areas have a minimum albedo of .3 or greater**	1.0	0.054	0.0535258	specific	Reductions are based on the Sustainable Site credits (SS Credit 7.1) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that the project provides any combination of the following strategies for 50% of the site landscape (including roads, sidewalks, courtyards nd parking lots): Shade (within 5 years of occupancy); paving materials with a solar Reflectance Index (SRI) of at least 29; open grid pavement system.
32	**Green Roof**	R,C,M	0.5	**Install a vegetated roof that covers at least 50% of roof area**	1.0	0.054	0.0535258	specific	Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that a vegetated roof is installed on a least 50% of the roof area or that a combination high albedo and vegetated roof surface is installed that meets the following standard: (Area of SRI Roof/0.75)+(Area of vegetated roof/0.5) >= Total Roof Area.
TDM and Misc. measures									

SMAQMD MEASURE #	Measure Name	Land Use Type	SMAQMD Point Reductions	Measure Description	Unscaled %CO2 Emission Reduction	CO2 Emissions Scale Factors (SF)	Scaled % CO2 Emission Reduction	Measure Applicability (specific/ moderate/ or general basis)	Reduction Methodology and Source
33	**Transportation Management Association membership**	R,C,M	5	**Include permanent TMA membership and funding requirement. Funding to be provided by Community Facilities District or County Service Area or other non-revocable funding mechanism.**	6.0	0.946	5.6788455	general	TCM Encyclopedia estimates a 6-7% reduction. Urbemis specifies percent reductions based on the number of elements adopted. CCAP estimated reductions from 3% to 25% for TDMs with complementary transit and land use measures. TDMs have been shown to reduce employee vehicle trips up to 28% with the largest reductions achieved through parking pricing and transit passes. The impact depends on the travel alternatives. Sources: TCM Encyclopedia, May 11, 2006; CCAP Transportation Emission Guidebook; Nygaard, 2005' Urbemis.
34	**Electric lawnmower**	R	1	**Provide a complimentary electric lawnmower to each residential buyer**	1.0	0.054	0.0535258	specific	Reduction is based on a 0.5% reduction in total airshed VOC emissions, as attributable to the Lawn Mower Buy-Back program (Portland, Oregon, ten-year ozone maintenance plan). Mitigation measure points are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 1.0 for electric lawnmowers. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.
99	**Other**	R,C,M	TBD	**Other proposed strategies, in consultation with project lead agency and SMAQMD**	TBD	TBD	TBD	TBD	TBD

general applicability: minimal project-specific information would be required to compute a reduction

moderate applicability: some special review of project details may be required

specific applicability: would apply to fewer projects and require some detailed project-specific information

Emission Fractions were obtained from the relative proportion of the emission type to the total of area- and mobile- source emissions as contained in the 2005 Emissions Inventory for Sacramento County

Since the Emissions Inventory does not contain CO2 data, scale factors for NOx were directly applied to CO2 also. The reasoning is that since both of these pollutants are combustion byproducts, the emis

(CARB 2005)
ssion fraction by activity type would be approximately the same for both.

SMAQMD MEASURE #	*Measure Name*	*Land Use Type*	*SMAQMD Point Reductions*	*Measure Description*	*Unscaled %CO2 Emission Reduction*	*CO2 Emissions Scale Factors (SF)*	*Scaled % CO2 Emission Reduction*	*Measure Applicability (specific/ moderate/ or general basis)*	*Reduction Methodology and Source*
1	**Bike parking**	C,M	0.625	**Non-residential projects provide plentiful short-term and long-term bicycle parking facilities to meet peak season maximum demand**	0.625	0.946	0.592	general	As a rule of thumb, the Center for Clean Air Policy (CCAP) guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
2	**End of trip facilities**	C,M	0.625	**Non-residential projects provide "end-of-trip" facilities including showers, lockers, and changing space**	0.625	0.946	0.592	general	The Transportation Demand Management (TDM) Encyclopedia allows a 2-5% reduction for worksite showers ad lockers. The CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: TDM Encyclopedia May 11, 2006; CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
3	**Bike parking at multi-unit residential**	R	0.625	**Long-term bicycle parking is provided at apartment complexes or condominiums without garages**	0.625	0.946	0.592	general	As a rule of thumb, the CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 25% of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

4	**Proximity to bike path/bike lanes**	R,C,M	0.625	**Entire project is located within 1/2 mile of an existing Class I or Class II bike lane and project design includes a comparable network that connects the project uses to the existing offsite facility**	0.625	0.946	0.592	general	As a rule of thumb, the CCAP guidebook attributes a 1% to 5% reduction associated with the use of bicycles, which reflects the assumption that their use is typically for shorter trips. Based on the CCAP guidebook, the TIAX report allots 2.5% reduction for all bicycle-related measures and a 1/4 of that for this measure alone. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
5	**Pedestrian network**	R,C,M	1	**The project provides a pedestrian access network that internally links all uses and connects to all existing or planned external streets and pedestrian facilities contiguous with the project site.**	1.0	0.946	0.946	general	Because this measure also eliminates physical barriers between residential and non-residential uses that impede bicycle or pedestrian circulation, this measure is similar in nature to 6. As cited in the TIAX report, the CCAP guidebook attributes a 1% reduction in VMT. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
6	**Pedestrian barriers minimized**	R,C, M	1	**Site design and building placement minimize barriers to pedestrian access and interconnectivity. Physical barriers such as walls, berms, landscaping, and slopes between residential and non-residential uses that impede bicycle or pedestrian circulation are eliminated**	1.0	0.946	0.946	general	The reduction is based on the TIAX report, which indicates a 1% reduction, and the CCAP report, which attributes a 1% to 5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
7	**Bus shelter for existing transit service**	R,C,M	.25-1.0	**Bus or Streetcar service provides headways of one hour or less for stops within 1/4 mile; project provides safe and convenient bicycle/pedestrian access to transit stop(s) and provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting).**	0.5	0.946	0.473	general	This reduction is based on the assumption that the measure applies to providing bus stop route information & benches. Emission reductions are based on conclusion obtained from the TIAX report and the CCAP guidebook. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.

8	**Bus shelter for planned transit service**	R,C,M	0.25	**Project provides transit stops with safe and convenient bicycle/pedestrian access. Project provides essential transit stop improvements (i.e., shelters, route information, benches, and lighting) in anticipation of future transit service.**	0.5	0.946	0.473	general	This reduction is based on the assumption that the measure applies to providing bus stop route information & benches. Emission reductions are based on conclusion obtained from the TIAX report and the CCAP guidebook. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by TIAX on behalf of SMAQMD.
9	**Traffic calming**	R,C,M	0.25-1.0	**Project design includes pedestrian/bicycle safety and traffic calming measures in excess of jurisdiction requirements. Roadways are designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips by featuring traffic calming features.**	see table	0.946	see table*SF	general	SMAQMD appears to have the best information available as reflected in their Guidance for Land Use Emission Reductions, which allocates reductions by the percent of intersections with traffic calming improvements as indicated in the table below. We were unable to locate more specific information. Source: Draft Update to SMAQMD Guidance for Land Use Emission Reductions.
10a	**Paid parking**	R,C,M	1.0-7.2	**Employee and/or customer paid parking system**	see table	0.946	see table*SF	general	Shoupe, 2005. Parking Cash Out. [$5/day reduces drive-alone share by 21% for commuters to downtown LA, with elasticity of -0.18 (e.g., if price increases 10%, then solo driving goes down by 1.8% more (Wilson 1991)] [Reported 1-10% reduction in trips to central city sites, and 2-4% in suburban sites (Urban Institute)].
11	**Minimum parking**	R,C,M	0.1-6.0	**Provide minimum amount of parking required. Special review of parking required.**	see formula	0.946	ee formula *S	general	Nelson/Nygaard, 2005. pg. 16. (trip reduction = ((actual parking provision - ITE parking generation rate) / ITE parking generation rate) *0.5). (Note: this formula is not verbatim from that cited in the Nelson/Nygaard document, since the formula provided did not make sense for computing trip reductions. This is what EDAW believes was meant, and this method actually works.)

12	**Parking reduction beyond code**	R,C,M	2.5	**Provide parking reduction less than code. Special review of parking required. Recommend a Shared Parking strategy.**	see formula	0.946	ee formula *S	general	Nelson/Nygaard, 2005. pg. 16. (trip reduction = ((actual parking provision - ITE parking generation rate) / ITE parking generation rate) *0.5). (Note: this formula is not verbatim from that cited in the Nelson/Nygaard document, since the formula provided did not make sense for computing trip reductions. This is what EDAW believes was meant, and this method actually works.)
13	**Pedestrian pathway through parking**	R,C,M	0.5	**Provide a parking lot design that includes clearly marked and shaded pedestrian pathways between transit facilities and building entrances**	0.5	0.946	0.473	general	The CCAP guidebook attributes between 1% and 4% reduction from all pedestrian measures. There is no specific information related to providing shaded pedestrian pathways between transit facilities and building entrances. It could be said that providing covered carpool/vanpool spaces near the entrance to the buildings has the similar goal of increasing the comfort of the user while walking to the building entrance. The TIAX report assigns a 1% reduction to the covered carpool measure. Transit usage is most affected by the headway times and the proximity to the destination. Therefore, it would seem reasonable to assume .5% Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.
16	**Orientation toward existing transit, bikeway, or pedestrian corridor**	R,C,M	0.5	**Project is oriented towards existing transit, bicycle, or pedestrian corridor. Setback distance is minimized**	0.5	0.946	0.473	general	The CCAP guidebook attribute a 0.5% reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit rider ship would result in a 0.5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.

21	**Affordable Housing Component**	R	0.6-4.0	**Residential development projects of 5 or more dwelling units provide a deed-restricted low-income housing component on-site (as defined in Ch 22.35 of Sacramento County Ordinance Code) [Developers who pay into In-Lieu Fee Programs are not considered eligible to receive credit for this measure]**	0.6-4.0	0.946	0.568-3.784	general	Nelson/Nygaard, 2005. pg. 15. (trip reduction = % units deed-restricted below market rate housing * 0.04).
22	**Urban mixed-use**	M	3.0-9.0	**Development of projects predominantly characterized by properties on which various uses, such as office, commercial, institutional, and residential, are combined in a single building or on a single site in an integrated development project with functional interrelationships and a coherent physical design**	3.0-9.0	0.946	2.838-8.514	general	Nelson/Nygaard, 2005. pg. 12. (trip reduction = (1-(ABS(1.5*h-e)/(1.5*h+e))-0.25)/0.25*0.03) where h = study area housing units, e = study area employment (Criteron & Fehr & Peers, 2001). Asymptote of 9% reduction, and an ideal 1.5 jobs per household.

25	**No fireplace**	R	1.0	**Project does not feature fireplaces or wood burning stoves**	-	-	-	general	Reductions assume a 100% emission reduction from baseline conditions, as calculated using the methodology documented in the Staff Report for SMAQMD Rule 417, Wood Burning Appliances, Appendix D. The approach is consistent with SMAQMD rule development, based on a conversation with SMAQMD staff (Mr. Donny Homer). Calculating emission reductions in the greater Sacramento area yields 1.0 point benefit to the project, consistent with the current point value of the measure. Emission reductions are calculated as follows: Emission Reduction = (Emissions) – [(New Emissions certified stove aesthetic x fraction of adoption) + (New Emissions certified stove heat x fraction of adoption) + (New EmissionsNG aesthetic x fraction of adoption) + (New EmissionsNG heat x fraction of adoption)+ (New Emissions electric aesthetic x fraction of adoption) + (New Emissions electric heat x fraction of adoption)]

26	**Ozone Destruction Catalyst**	R, C, M	1.25	**Install ozone destruction catalyst on air conditioning systems**	1.25	0.054	0.067	general	Reductions assume over 80% of harmful, ground level ozone is converted into oxygen through application of air conditioning system technology. The proposed point value for this operational mitigation measure is 1.5, a mid-point value consistent with the rating assigned to this measure by the Feather River Air Quality Management District as a Standard Mitigation Measures for All Projects. The SMAQMD has had point values for this measure ranging from 1.25 (i.e., Land Use Mitigation Measures), to 2.5 for specific projects (i.e., Lent Ranch Marketplace, City of Elk Grove). Air conditioning systems for commercial, office and residential buildings within the project will be treated with an ozone destruction catalyst ("cap" or coating of the condenser coils) to convert ozone to oxygen as the catalyst makes contact with air moving through the air conditioner. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, specifications and any available manufacturer's documentation on the devices to be used.

28	**Onsite renewable energy system**	R,C,M	1.0-3.0	**Project provides onsite renewable energy system(s)**	3.0	0.054	0.161	general	Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that at least 12.5% of the buildings total energy use (as expressed as a fraction of annual energy cost) is supplied through the use of on-site renewable energy systems. Alternatively a project may use the Department of Energy (DOE) Commercial Buildings Energy Consumption Surevy (CBECS) database to determine the estimated electricity use. Non-polluting and renewable energy potential includes solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, projects may take advantage of net metering with the local utility. The measure is enforcable through LEED Letter certification and building design calculations demonstrating that at least 12.5% of total energy costs are supplied by the renewable energy system(s).
33	**Transportation Management Association membership**	R,C,M	5	**Include permanent TMA membership and funding requirement. Funding to be provided by Community Facilities District or County Service Area or other non-revocable funding mechanism.**	6.0	0.946	5.679	general	TCM Encyclopedia estimates a 6-7% reduction. Urbemis specifies percent reductions based on the number of elements adopted. CCAP estimated reductions from 3% to 25% for TDMs with complementary transit and land use measures. TDMs have been shown to reduce employee vehicle trips up to 28% with the largest reductions achieved through parking pricing and transit passes. The impact depends on the travel alternatives. Sources: TCM Encyclopedia, May 11, 2006; CCAP Transportation Emission Guidebook; Nygaard, 2005' Urbemis.

14	**Off street parking**	R,C,M	0.1-1.5	**Parking facilities are not adjacent to street frontage**	0.1-1.5	0.946	0.095-1.419	moderate	No empirical support for this specific measure; however, range of values is based on other pedestrian-oriented measures. The range recognizes the dependence of this measure on other measures. To be awarded 1.0 points, development must be in an area with density, wide sidewalks, and where other uses are also hiding parking. The efficacy of this measure is reduced to 0.1 if the development does not include other pedestrian and mixed-use measures. Parking structure with ground-floor retail is awarded 0.5.
15	**Office/Mixed-use density**	C, M	0.1-1.5	**Project provides high density office or mixed-use proximate to transit**	see table	0.946	see table*SF	moderate	No empirical support for this measure, beyond that provided by SMAQMD in its draft guidance. According to Nelson/Nygaard, 2005, trip generation at the non-residential end is influenced by density to a much lesser degree, so this is fairly consistent with the transit reductions applied in measure 20.
17	**Orientation toward planned transit, bikeway, or pedestrian corridor**	C, M	0.25	**Project is oriented towards planned transit, bicycle, or pedestrian corridor. Setback distance is minimized**	0.5	0.946	0.473	moderate	The CCAP guidebook attributes a 0.5 % reduction per 1% improvement in transit frequency. Based on a case study presented in the CCAP report, a 10% increase in transit rider ship would result in a 0.5% reduction. Source: CCAP Transportation Emission Guidebook; TIAX Results of 2005 Literature Search Conducted by Tax on behalf of SMAQMD.
18	**Residential density**	R	1.0-12	**Project provides high-density residential development**	see table	0.946	see table*EF	moderate	Nelson/Nygaard, 2005. pg 11. (trip reduction = 0.6*(1-(19749*((4.814+households per residential acre)/(4.814+7.14))^-.639)/25914) (Holtzclaw et al 2002). Asymptote of 60% reduction. **Relative to a 3 du/ac development.** Note that there is no direct empirical support for the added reductions for proximity to transit; the 60% asymptote in this equation is to correct for double-counting from transit services, mix-of-uses, and bicycle and pedestrian connections (which could contribute another 40% reduction).

23	**Suburban mixed-use**	R,C,M	3	**Have at least three of the following on site and/or offsite within ¼ mile: Residential Development, Retail Development, Park, Open Space, or Office**	3.0	0.946	2.839	moderate	By definition, this type of land use implies that housing availability is greater than employment availability. On a project-by-project basis, use formula :Nelson/Nygaard, 2005. pg. 12. (trip reduction = (1-(ABS(1.5*h-e)/(1.5*h+e))-0.25)/0.25*0.03) where h = study area housing units, e = study area employment (Criteron & Fehr & Peers, 2001) to obtain higher than 3% reduction. Otherwise, assume 3% max reduction.
24	**Other mixed-use**	R, M	1	**All residential units are within ¼ mile of parks, schools or other civic uses.**	1.0	0.946	0.946	moderate	This measure has less to do with employment/housing balance. No empirical support for this measure, but logic from measures 24 and 25 still applies.
10b	**Parking cash out**	C, M	0.6-4.5	**Employer provides employees with a choice of forgoing subsidized parking for a cash payment equivalent to the cost of the parking space to the employer**	see table	0.946	see table*SF	specific	Shoupe, 2005. Parking Cash Out. [2/3 as effective as charging for parking (8 case studies - chapter 4, 13% reduction in solo driver trips, -12% VMT per employee, and -11% in vehicle trips per commuter)].
19	**Street grid**	R, C, M	1	**Multiple and direct street routing (grid style)**	1.0	0.946	0.946	specific	Reductions are based on CCAP estimates for similar measures. Source: CCAP Transportation Emission Guidebook.
20	**Neighborhood Electric Vehicle access**	R,C,M	0.5-1.5	**Make physical development consistent with requirements for neighborhood electric vehicles**	0.5-1.5	0.946	0.473-1.419	specific	No direct empirical support for this measure available. May not be relevant/applicable in the near term, until NEVs become more common/inexpensive. Current studies show that for most trips, NEVs do not replace gas-fueled vehicles as the primary vehicle. For the purposes of providing incentives for developers to promote NEV use, assume that a neighborhood with internal NEV connections only receives 0.5 points, with external connections to other surrounding uses, 1.0 point, with external connections to other NEV networks, 1.5 points.

27a	**Energy Star roof**	R,C,M	0.5-1.0	**Install Energy Star labeled roof materials**	0.5	0.054	0.027	specific	Reductions are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 0.5 for qualified roof products. Baseline conditions assume indirect emission reduction through more even temperature control of environmental space. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.
27b					1.0	0.054	0.054	specific	Additional emission reductions are available based on use of Energy Star compliant (highly reflective) and high emissivity roofing (emissivity of at least 0.9 when tested in accordance with ASTM 408) for a minimum of 75% of the roof surface. Based on the quantification methodology used by the SMAQMD Guidance for Land Use Reductions, an additional 0.5 point, for a total of 1.0 points, is available for qualified roof products that meet ATSM high emissivity requirements. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.

29	**Exceed title 24**	R,C,M	1.0	**Project Exceeds title 24 requirements by 20%**	1.0	0.054	0.054	specific	Reductions assume at least a 20% over Title 24 requirements, as calculated by the Sacramento Municipal Utility District (SMUD, 2006 Advantage Home Program Overview). The proposed point value for this operational mitigation measure is 1.0, consistent with the rating assigned to this measure by SMAQMD Land Use Mitigation Measures. Total compliance margin is based on energy savings relative to the total energy budget and cooling energy budget of the Title 24 Standard design home. Proponent shall provide information demonstrating compliance with measure requirements including, but not limited to, specifications and any available manufacturer's documentation on the devices to be used. This measure's successful implementation may be verified by a site review following construction to confirm that the project as built contains ozone destruction catalysts as described in the Air Quality Plan.
30	**Solar orientation**	R	0.5	**Orient 75 or more percent of homes and/or buildings to face either north or south (within 30 degrees of N/S)**	0.5	0.054	0.027	specific	Reduction assumes that proper solar orientation can produce a total energy savings of 11% to 16.5% and reduce heating fuel consumption by up to 25% (Local Government Commission, 1998). Mitigation measure points are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 0.5 for proper orientation. Reduction methodology will be based on quantification of the difference in solar radiance from development with designed orientations (75 or more percent of homes and/or buildings to face within 30 degrees either north or south) compared to evenly distributed orientations. Project compliance will be based on the percentage of orientation buildings designed with proper design features (overhangs, landscaping).

31	**Non-Roof Surfaces**	R,C,M	1.0	**Provide shade (within 5 years) and/or use light-colored/high-albedo materials (reflectance of at least 0.3) and/or open grid pavement for at least 30% of the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc.; OR place a minimum of 50% of parking spaces underground or covered by structured parking; OR use an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area. Unshaded parking lot areas, driveways, fire lanes, and other paved areas have a minimum albedo of .3 or greater**	1.0	0.054	0.054	specific	Reductions are based on the Sustainable Site credits (SS Credit 7.1) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that the project provides any combination of the following strategies for 50% of the site landscape (including roads, sidewalks, courtyards nd parking lots): Shade (within 5 years of occupancy); paving materials with a solar Reflectance Index (SRI) of at least 29; open grid pavement system.
32	**Green Roof**	R,C,M	0.5	**Install a vegetated roof that covers at least 50% of roof area**	1.0	0.054	0.054	specific	Reductions are based on the Energy & Atmosphere credits (EA Credit 2) documented in the Leadership in Energy & Environmental Design (LEED), Green Building Rating System for New Constructions and Major Renovations, Version 2.2, October 2005. The reduction assumes that a vegetated roof is installed on a least 50% of the roof area or that a combination high albedo and vegetated roof surface is installed that meets the following standard: (Area of SRI Roof/0.75)+(Area of vegetated roof/0.5) >= Total Roof Area.

34	**Electric lawnmower**	R	1	**Provide a complimentary electric lawnmower to each residential buyer**	1.0	0.054	0.054	specific	Reduction is based on a 0.5% reduction in total airshed VOC emissions, as attributable to the Lawn Mower Buy-Back program (Portland, Oregon, ten-year ozone maintenance plan). Mitigation measure points are based on the credits documented in the SMAQMD Guidance for Land Use Reductions and consistent with the point rating now set at 1.0 for electric lawnmowers. Approach is enforceable and may be monitored through site review and/or consultation with lead agency that roofing materials match those described in the SMAQMD Guidance for Land Use Reductions.
99	**Other**	R,C,M	TBD	**Other proposed strategies, in consultation with project lead agency and SMAQMD**	TBD	TBD	TBD	TBD	

general applicability: minimal project-specific information would be required to compute a reduction

moderate applicability: some special review of project details may be required

specific applicability: would apply to fewer projects and require some detailed project-specific information

Emission Fractions were obtained from the relative proportion of the emission type to the total of area- and mobile- source emissions as contained in the 2005 Emissions Inventory for Sacramento County

Since the Emissions Inventory does not contain CO_2 data, scale factors for NOx were directly applied to CO_2 also. The reasoning is that since both of these pollutants are combustion byproducts, the emis

(CARB 2005)

ssion fraction by activity type would be approximately the same for both.

Scale Factors from Emmission inventory
2005 Estimated Annual Average Emissions
SACRAMENTO COUNTY

All emissions are represented in Tons per Day and reflect
Download these results (as a comma delimited file).
Download more detailed data (as a comma delimited file).
Start a new query.

SACRAMENTO COUNTY - SACRAMENTO VALLEY

AREA-WIDE SOURCES	ROG	NOX	PM10
CONSUMER PRODUCTS	9.62	-	-
ARCHITECTURAL COATINGS AND RELATED PROCESS SOLVENTS	3.47	-	-
RESIDENTIAL FUEL COMBUSTION	2.16	2.93	5
**** TOTAL AREA-WIDE SOURCES**	**15.25**	**2.93**	**5**
MOBILE SOURCES	**ROG**	**NOX**	**PM10**
ON-ROAD MOTOR VEHICLES			
LIGHT DUTY PASSENGER (LDA)	11.67	9.2	0.57
LIGHT DUTY TRUCKS - 1 (LDT1)	4.85	4.1	0.18
LIGHT DUTY TRUCKS - 2 (LDT2)	3.84	4.88	0.22
MEDIUM DUTY TRUCKS (MDV)	1.78	2.51	0.09
LIGHT HEAVY DUTY GAS TRUCKS - 1 (LHDV1)	0.53	0.52	0.01
LIGHT HEAVY DUTY GAS TRUCKS - 2 (LHDV2)	0.2	0.2	0
MEDIUM HEAVY DUTY GAS TRUCKS (MHDV)	1.27	1.02	0.01
HEAVY HEAVY DUTY GAS TRUCKS (HHDV)	1.1	1.84	0
LIGHT HEAVY DUTY DIESEL TRUCKS - 1 (LHDV1)	0.04	0.67	0.01
LIGHT HEAVY DUTY DIESEL TRUCKS - 2 (LHDV2)	0.03	0.46	0.01
MEDIUM HEAVY DUTY DIESEL TRUCKS (MHDV)	0.16	5.85	0.18
HEAVY HEAVY DUTY DIESEL TRUCKS (HHDV)	0.71	17.91	0.43
MOTORCYCLES (MCY)	0.59	0.14	0.01

HEAVY DUTY DIESEL URBAN BUSES (UB)	0.06	1.33	0.03
HEAVY DUTY GAS URBAN BUSES (UB)	0.16	0.2	0
SCHOOL BUSES (SB)	0.08	0.43	0.02
MOTOR HOMES (MH)	0.22	0.55	0.01
*** TOTAL ON-ROAD MOTOR VEHICLES**	**27.29**	**51.81**	**1.78**
TOTAL SACRAMENTO IN SACRAMENTO VALLEY	**42.54**	**54.74**	**6.78**

Relative Proportions			
MOBILE SOURCE EMISSIONS	**0.64**	**0.95**	**0.26**
AREA SOURCE EMISSIONS	**0.36**	**0.05**	**0.74**

EMISSIONS INVENTORY CATEGORY	ROG	NOX	PM10
610-600-0230-0000 Methodology 600-WOOD COMBUSTION - WOOD STOVES 0230-WOOD 0000-SUB-CATEGORY UNSPECIFIED	0.36	0.07	0.76
610-602-0230-0000 Methodology 602-WOOD COMBUSTION - FIREPLACES 0230-WOOD 0000-SUB-CATEGORY UNSPECIFIED	1.67	0.32	3.98
610-606-0110-0000 Methodology 606-FUEL COMBUSTION - SPACE HEATING 0110-NATURAL GAS 0000-SUB-CATEGORY UNSPECIFIED	0.04	0.77	0.06
610-606-1220-0000 Methodology 606-FUEL COMBUSTION - SPACE HEATING 1220-DISTILLATE OIL (UNSPECIFIED) 0000-SUB-CATEGORY UNSPECIFIED	0	0.01	0
610-608-0110-0000 Methodology 608-FUEL COMBUSTION - WATER HEATING 0110-NATURAL GAS			

Category
Fireplaces

0000-SUB-CATEGORY UNSPECIFIED	0.07	1.4	0.17
610-610-0110-0000 Methodology 610-FUEL COMBUSTION - COOKING 0110-NATURAL GAS 0000-SUB-CATEGORY UNSPECIFIED	0	0.08	0.01
610-995-0110-0000 Methodology 995-OTHER 0110-NATURAL GAS 0000-SUB-CATEGORY	0.01	0.25	0.02
0-995-0120-0000 Methodology 995-OTHER 0120-LIQUIFIED PETROLEUM GAS (LPG) 0000-SUB-CATEGORY UNSPECIFIED	0	0.03	0
TOTAL SACRAMENTO IN SACRAMENTO VALLEY	2.16	2.93	5

ROG	*NOX*	*PM10*
2.14	2.57	4.97
0.05	**0.05**	**0.73**

HOMEWOOD MOUNTAIN RESORT

SNOWMAKING PLANNING

January 19, 2009

Table of Contents

1. Introduction

It is proposed that a vastly upgraded snowmaking system be installed at Homewood Mountain Resort in order to ensure early and late season snowpack. It is generally accepted that a ski trail requires a minimum of approximately 12" of packed snow over a fine groomed summer surface in order to provide a quality surface for skiing and snowboarding. Any less than this depth will accelerate melting of the snow pack, as well as exposure of vegetation through the snow surface which can damage the vegetation and skiers' or snowboarders' equipment. Having adequate snow depth will provide a predictable and safe sliding surface. Ideally, ski trails require in excess of four feet of snow to ensure a long lasting quality surface for a full season with typical weather conditions. This is especially important at Homewood due to its southern exposure and proximity to the lake.

A general overview of the basics of snowmaking follows. When nature does not cooperate by providing natural snow, snowmaking takes over. With a properly designed and operated snow system, the variable of having cold conditions and precipitation occur simultaneously is removed. With snowmaking, we only need cold temperature conditions to provide snow. Snowmaking requires large volumes of water, energy and temperature conditions below 28˚F.

In summary, a snowmaking machine:

a) breaks water into smaller molecules
b) cools the water
c) removes the heat of fusion
d) nucleates the water
e) provides throw to reduce grooming costs

Most requirements for snow involve very large quantities of water. For example, to cover one acre with one foot of snow requires around 200,000 gallons of water. In order to break the water droplets up into smaller particles, water pressures of at least 300 psi are advised.

A proper snowmaking plan includes providing adequate water supply and distribution, appropriate electrical supply and distribution along with the snowmaking technology to convert these resources into snow.

2. Existing System Highlights

Trails covered include:	NORTH SIDE				
	LENGTH	**WIDTH**	**PIPE**		**AREA**
Lower Rainbow/ Chute	2400ft	100ft	8”	9 Hydrants	5.5 Acres
Happy Platter	500ft	250ft	6”	3 Hydrants	2.9 Acres
Alpine Platter	500	300ft	6	5 Hydrants	3.4 Acres
Lombard Street	2700	40ft	6”	8 Hydrants	2.5
The Face	1000ft	200ft	6”	4 Hydrants	4.6
Pump House				1 Hydrants	
	SOUTH SIDE				
South Side Base Area	700ft	200ft	6”	3 Hydrants	3.2 Acres
Lower Homewood Bound	1500ft	50ft	6”	3 Hydrants	1.7 Acres

Existing snowmaking at Homewood covers 23.8 Acres
The current snowmaking at Homewood uses about 17,500,000 gallons of water per year.

The existing pumping at Homewood includes: 500gpm North Side Base Area,
500gpm Water Cooling
300gpm South Side Base Area

Existing Snowgun Summary:			
2	WizzKid	Carriage	Manual
1	WizzKid	Carriage	Auto
2	WizzKid	Tower	Auto
2	Super PoleCat	Tower	Manual/Auto Valve
3	Super PoleCat	Tower	Auto
1	Super Wizzard	Tower	Auto
1	Super Wizzard	Carriage	Manual
5	Super PoleCat	Carriage	Auto
3	PoleCat	Carriage	manual
1	Pole Kid	Carriage	Auto
21 Existing Snowguns			

3. Snowmaking Coverage Area Summary

A. Homewood Snowmaking Expansion Area Summary.

The following table represents the snowmaking expansion on the **North Side**

Trail Name	Acres	Open Depth (in)	Open Water Gallons (M)	Season Depth (ft)	Season Water Gallons (M)
Northern Return	1.7	12	0.34	4	1.36
Homeward Bound	6.9	12	1.38	4	5.5
Lombard Completion	1	12	0.20	4	0.8
Tailings	4.2	12	0.84	4	3.36
The Shaft	1.8	12	0.36	4	1.4
Pot O Gold	3.3	12	0.66	4	2.6
Rainbow Ridge	6.8	12	1.36	4	5.44
Bonanza	5.5	12	1.1	4	4.4
Miners	9	12	1.8	4	7.2
Totals	**40.2**	**12**	**8.04**	**4**	**32.06**

B. North Area Opening Snowmaking Conditions

The primary objective is to open by December 10 each year.

Based on an analysis of the weather and general experience in the Tahoe area, we can assume 150 hours at minimum 25˚F Wet Bulb between November 1 and December 25 each year in approximately 17 out of 20 years.

25˚F Wet Bulb is equivalent to 27˚F/80% RH, 26˚F/90% RH and 29˚F/60% RH.

However, colder conditions down to 15˚F can occur. Under these colder conditions, snowmaking efficiencies are greatly improved. Therefore, we suggest sizing the water capacity for 18˚F Wet Bulb. In simple terms, if the temperatures are colder, the snowmaking equipment using the same energy can convert double or triple the water volumes into snow.

So to open the proposed new snowmaking trails we need to convert 8,040,000 gallons into snow in 150 hours for average water to snow conversion rate of 900 gpm.

Plus we need to add the existing snowmaking areas @ 18.9 acres which require 3,780,000 gallons of water to cover trails 12" of snow in 150 hours for average water to snow conversion rate of 420 gpm

Total water required for 12" cover is 11,820,000 gallons

A typical snowgun converts 35 gpm at 25˚F Wet Bulb, so 38 snow guns are required to be operating.

We advise sizing the water capacity at 80 gpm/snowgun, for 18˚F x 38 snow guns which equals 3000 gpm for total future snowmaking expansion for the north side. However if Homewood would concentrate on opening trails in stages, 2000gpm on the north side would be sufficient to operate 25 machines @ 80gpm. Then open further trails in stages.

The North Side Pumping requirement is 2000gpm minimum. Total Build out 3000 gpm

The following table represents the snowmaking expansion on the **South Side**

Trail Name	Acres	Open Depth (in)	Open Water Gallons (M)	Season Depth (ft)	Season Water Gallons (M)
Mighty Mite	3	12	0.6	4	2.4
Short Cut	3.5	12	0.7	4	2.8
Mighty Fine	1.5	12	0.30	4	1.2
Martins Lane	4.6	12	0.92	4	3.6
Spill Way	1.7	12	0.34	4	1.36
Sunny Side	2.6	12	0.52	4	2.08
Prospector	1.8	12	0.36	4	1.44
El Capitan	3	12	0.60	4	2.4
Exhibition	4.5	12	0.90	4	3.6
Totals	**26.2**	**12**	**5.24**	**4**	**20.88**

D. South Area Opening Snowmaking Conditions

The primary objective is to open by December 10 each year.

So to open we need to convert 5,200,000 gallons into snow in 150 hours for average water to snow conversion rate of 600 gpm.

Plus we need to add the existing snowmaking areas @ 4.9 acres which require 980,000 gallons of water to cover trails 12" of snow in 150 hours for average water to snow conversion rate of 110gpm

Total water required for 12" cover is 6,180,000 gallons.

A typical snowgun converts 35 gpm at 25˚F Wet Bulb, so 17 snow guns are required to be operating.

We advise sizing the water capacity at 80 gpm/ snowgun for 18˚F x 17 snow guns which equals 1360 gpm. If Homewood opens these trails in stages, 1000gpm would be sufficient to operate 13 machines @ 80gpm. Then open further trails in stages.

The South Side Pumping requirement is 1000 gpm minimum. Total Buildout 1400 gpm.

4. Water Supply and Distribution

Suggested water supply pumping capacity totals follow:
North side base well 700gpm
McKinney well 1000gpm
Supply total 1700gpm
Reservoir on mountain

A. Water Supply

The Homewood snowmaking water requirements can be summarized as follows:

To open the totals are 11.82M and 5.28M gallons per side of the mountain. The snowmaking trails require around 17.1 million gallons to open.
Per season, it could be 35.46M and 15.84M per side of the mountain for a 3 to 4 foot depth
Anticipated total water usage per season would be 51.3 to 68.4 million gallons

The actual operating water consumptions would average between 1900 gpm and 3400 gpm.

The existing water supplies available for Homewood snowmaking are:

1. McKinney well – This well has been flow tested has potential for 1000 gpm

2. South Base Area - Domestic water of 300 gpm available from 6 p.m. to 6 a.m. only and the water is around 44˚F which needs a cooling tower installed to be more effective.

3. North Base Area - Domestic water of 300 gpm available from 6 p.m. to 6 a.m. Plus the existing well in the gravel parking lot which will flow up to 800gpm. At the moment this is restricted to 500gpm by the size of the pipe on the discharge side of the well pump and the tank in the pump house. A new pumphouse with another pump is suggested.

The water delivery system could also be utilized for fire protection in the forests and buildings on the mountain.

B. Pumping Alternatives

Snowmaking should have minimum 300 psi water pressures at top of system and to all snowmaking machines.

The basic methods for supplying water for snowmaking are summarized as follows:

A. 1000 gpm pumping at McKinney Well
B. 700- 1000gpm pumping from existing north base
C. 300gpm pumping from existing south side base

Total 2300gpm

Pumping Requirements as follows:

South base pump station to the top of the gondola will require (2) 300hp pumps rated at 500gpm to provide 250psi at 7300feet (top of the Gondola). Water cooling will be (2) 500gpm water cooling towers for the McKinney well water located at the south base pump house.

Top of the gondola pump station location to the top of the mountain is 600 vertical feet with friction and vertical pressure loss this comes to 700' total dynamic head. To maintain 300psi at the top of the mountain will require (1) 250HP pump in the Top of the gondola pump station.

The existing pump station at the North side base area will need to be moved to a new location. This location is still to be determined. One more 300HP pump will need to be added to this station to move 1000gpm to the top of the Gondola with sufficient pressures. There is already one existing 500gpm cooling tower so one more will need to be added to cool 1000gpm effectively.

The South side pump station will remain in the existing location, but will need to be upgraded to house more equipment. The piping and power supply mounted also need to be rerouted.

C. **Piping and Hydrant Summary**

Trail Name	Pipe				Pedestals & Hydrants
	4”	6”	8”	10”	
Northern Return	0	1800	0	0	7
Homeward Bound	0	0	0	8000	24
Lombard	800	1000	0	0	2
Tailings	0	0	0	2800	4
Shaft	0	2000	0	0	4
Pot O Gold	0	0	2000	0	5
Rainbow Ridge	0	0	2500	1500	16
Miners Delights	0	2400	0	0	13
Mighty Mite	750	0	0	0	1
Short Cut	0	0	0	1600	7
Bonanza	0	2400	0	0	9
Martins Lane	0	1700	0	0	8
Spillway	0	1000	0	0	4
Sunny Side	0	2300	0	0	9
Prospector	1000	0	0	0	3
El Capitan	0	1600	0	0	4
Exhibition	0	1100	0	0	4
Mighty Fine	1100	0	0	0	3
Mckinney well-south base pump station				2700	
Grand Totals	**3650’**	**17300’**	**4500’**	**16600’**	**127**

Piping to be buried with 4' of cover.
All trails should be final graded and excavated to final grade prior to placing piping on trails.
The existing systems would be tied into the new system.

A detailed plan for the piping and hydrants has been developed and is attached.

5. ELECTRICAL SUPPLY AND DISTRIBUTION

The snowmaking system at Homewood power requirements can be summarized as follows:

A. Estimated Loads

South base	Item	HP	Qty	Total
	Main Pumps	300	2	500
	Cooling Towers	25	2	50
	Snow guns	25	17	425
South base Total				**975 HP**
Top of gondola	Pumps	250	1	250
	Snow guns	25	28	700
Top of Gondola Total				**950 HP**
North Base	Pump	250,300	2	550
	Cooling tower	25	2	50
	Snow guns	25	28	700
North base Total				**1250 HP**
GRAND TOTAL				**3175 HP**

B. Secondary Mountain Power Distribution

The snow guns require electrical to be distributed along the trails. Next to each water hydrant will be an electrical outlet of 60 Amp capacities to plug the snowguns into. Typical circuits are 1000' to 3000' long with 5-10 pedestal outlets per circuit with 300Amp or 400Amp disconnects.

Transformers

The following are the known details and proposed upgrades of the existing electrical infrastructure, as it pertains to the chair lifts and snowmaking systems. Transformer numbers are referenced from either the transformer or SPPCO map provided by SPPCO, North Tahoe Office, dated 3-28-07. Project site map was created and provided by Snow Machines, Inc. (SMI).

Transformer #1 North Lodge snowmaking, 750kva
Existing Load; 400amp VFD, 3 fan circuits, 250 amps.
Proposed load addition; 1 fan circuit, 300 amps
Additional breaker to be used in existing switchgear.

Location; Bottom Terminal Quad chairlift
Existing transformer SPPCO # 81-3141-78789, 25kva
Ref #2 on SMI site map
Proposed upgrade; 500kva transformer
Proposed load addition; 2 fan-gun lines, 450 amps/373kva

Location; Top terminal Madden chairlift
Existing transformer SPPCO # 13333, 300kva
Ref #3 on SMI site map
Existing load; 250kva.
Proposed load addition; 4 fan-gun lines, 885amps/700 kva

Location; Bottom terminal Ellis chairlift
Existing transformer SPPCO # TS-267, 515539, 300kva
Ref #4 on SMI site map
Proposed load addition; new high speed chair lift 700 kva (motor and associated loads)
2 fan gun lines, 450kva
New load total 1150 kva

Location; Vehicle shop
Existing transformer SPPCO #?? , 750kva
Ref #5 on SMI site map
Proposed upgrade; 1000kva transformer
Proposed load addition; 7 Fan circuits, 400amps each
New 1000 amp switchgear w/breakers
New load total 1000 kva

Location; top of Quad
Existing transformer SPPCO #
Ref # 6 on SMI site map
This transformer has been upgraded to 1000 kva
Proposed are new 600amp switchgear w/breakers

Proposed transformer location “miners” ski run, no existing service
Ref #8 on SMI site map.
Proposed install; 300kva transformer

Proposed load addition; 2 fan-gun lines, 375 kva

Location; McKinney well and pump station
Existing transformer SPPCO # 80-3271, (3 pole mounted transformers, #103592, 93, 94)
Ref #9 on SMI site map
Proposed install; 1500kva transformer
Proposed load; Pump station- 5, 250 HP (1175kva) VFD and soft starters,
Misc. heaters and lights, 50kva
Need to add some space for cooling towers for well water.

A detailed plan for the secondary cabling and circuit has been developed and is attached.

6. Pumphouse Building

Consideration should be given to a larger pumphouse building to house snowguns for maintenance, hose drying and storage and for crew meetings and offices.

Once these decisions are concluded, more detailed space layouts can be developed.

7. Further Engineering

After this general concept plan is approved, more detailed engineering is required for all aspects of the project including pumping stations and buildings, water cooling towers, primary and secondary electrical supply and distribution and snow gun layouts

10. Assumptions

1. No Permits
2. No Taxes
3. No Blasting
4. No High Voltage Improvements
5. No Revegetation, Fencing, Signage or Hydrant Covers
6. No water supply improvements included

Addressing Climate Change at the Project Level
California Attorney General's Office

Under the California Environmental Quality Act (CEQA), local agencies have a very important role to play in California's fight against global warming – one of the most serious environmental effects facing the State today. Local agencies can lead by example in undertaking their own projects, insuring that sustainability is considered at the earliest stages. Moreover, they can help shape private development. Where a project as proposed will have significant global warming related effects, local agencies can require feasible changes or alternatives, and impose enforceable, verifiable, feasible mitigation to substantially lessen those effects. By the sum of their actions and decisions, local agencies will help to move the State away from "business as usual" and toward a low-carbon future.

Included in this document are various measures that may reduce the global warming related impacts at the individual project level. (For more information on actions that local governments can take at the program and general plan level, please visit the Attorney General's webpage, "CEQA, Global Warming, and General Plans" at http://ag.ca.gov/globalwarming/ceqa/generalplans.php.)

As appropriate, the measures can be included as design features of a project, required as changes to the project, or imposed as mitigation (whether undertaken directly by the project proponent or funded by mitigation fees). The measures set forth in this package are examples; the list is not intended to be exhaustive. Moreover, the measures cited may not be appropriate for every project. The decision of whether to approve a project – as proposed or with required changes or mitigation – is for the local agency, exercising its informed judgment in compliance with the law and balancing a variety of public objectives.

Mitigation Measures by Category

Energy Efficiency

Incorporate green building practices and design elements.	The California Department of Housing and Community Development's Green Building & Sustainability Resources handbook provides extensive links to green building resources. The handbook is available at http://www.hcd.ca.gov/hpd/green_build.pdf. The American Institute of Architects (AIA) has compiled fifty readily available strategies for reducing fossil fuel use in buildings by fifty percent. AIA "50 to 50" plan is presented in both guidebook and wiki format at http://wiki.aia.org/Wiki%20Pages/Home.aspx.

Meet recognized green building and energy efficiency benchmarks.	For example, an ENERGY STAR-qualified building uses less energy, is less expensive to operate, and causes fewer greenhouse gas emissions than comparable, conventional buildings. http://www.energystar.gov/index.cfm?c=business.bus_index. California has over 1600 ENERGY STAR-qualified school, commercial and industrial buildings. View U.S. EPA's list of Energy Star non-residential buildings at http://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.locator. Los Angeles and San Francisco top the list of U.S. cities with the most ENERGY STAR non-residential buildings. http://www.energystar.gov/ia/business/downloads/2008_Top_25_cities_chart.pdf. Qualified ENERGY STAR homes must surpass the state's Title 24 energy efficiency building code by at least 15%. Los Angeles, Sacramento, San Diego, and San Francisco-Oakland are among the top 20 markets for ENERGY STAR homes nationwide. http://www.energystar.gov/ia/new_homes/mil_homes/top_20_markets.html. Builders of ENERGY STAR homes can be more competitive in a tight market by providing a higher quality, more desirable product. See http://www.energystar.gov/ia/partners/manuf_res/Horton.pdf. There are a variety of private and non-profit green building certification programs in use in the U.S. See U.S. EPA's Green Building / Frequently Asked Questions website, http://www.epa.gov/greenbuilding/pubs/faqs.htm. Public-Private Partnership for Advancing Housing Technology maintains a list of national and state Green Building Certification Programs for housing. See http://www.pathnet.org/sp.asp?id=20978. These include the national Leadership in Energy and Environmental Design (LEED) program, and, at the state level, Build it Green's GreenPoint Rated system and the California Green Builder program. Other organizations may provide other relevant benchmarks.
Install energy efficient lighting (e.g., light emitting diodes (LEDs)), heating and cooling systems, appliances, equipment, and control systems.	Information about ENERGY STAR-certified products in over 60 categories is available at http://www.energystar.gov/index.cfm?fuseaction=find_a_product. The California Energy Commission maintains a database of all appliances meeting either federal efficiency standards or, where there are no federal efficiency standards, California's appliance efficiency standards. See http://www.appliances.energy.ca.gov/. The Electronic Product Environmental Assessment Tool (EPEAT) ranks computer products based on a set of environmental criteria, including energy efficiency. See http://www.epeat.net/AboutEPEAT.aspx. The nonprofit American Council for an Energy Efficient Economy maintains an Online Guide to Energy Efficient Commercial Equipment, available at http://www.aceee.org/ogeece/ch1_index.htm. Utilities offer many incentives for efficient appliances, lighting, heating and cooling. To search for available residential and commercial incentives, visit Flex Your Power's website at http://www.fypower.org/.

Use passive solar design, e.g., orient buildings and incorporate landscaping to maximize passive solar heating during cool seasons, minimize solar heat gain during hot seasons, and enhance natural ventilation. Design buildings to take advantage of sunlight.	See U.S. Department of Energy, Passive Solar Design (website) http://www.energysavers.gov/your_home/designing_remodeling/index.cfm/mytopic=10250. See also California Energy Commission, Consumer Energy Center, Passive Solar Design (website) http://www.consumerenergycenter.org/home/construction/solardesign/index.html. Lawrence Berkeley National Laboratories' Building Technologies Department is working to develop innovative building construction and design techniques. Information and publications on energy efficient buildings, including lighting, windows, and daylighting strategies, are available at the Department's website at http://btech.lbl.gov.
Install light colored "cool" roofs and cool pavements.	A white or light colored roof can reduce surface temperatures by up to 100 degrees Fahrenheit, which also reduces the heat transferred into the building below. This can reduce the building's cooling costs, save energy and reduce associated greenhouse gas emissions, and extend the life of the roof. Cool roofs can also reduce the temperature of surrounding areas, which can improve local air quality. See California Energy Commission, Consumer Energy Center, Cool Roofs (webpage) at http://www.consumerenergycenter.org/coolroof/. See also Lawrence Berkeley National Laboratories, Heat Island Group (webpage) at http://eetd.lbl.gov/HeatIsland/.
Install efficient lighting, (including LEDs) for traffic, street and other outdoor lighting.	LED lighting is substantially more energy efficient than conventional lighting and can save money. See http://www.energy.ca.gov/efficiency/partnership/case_studies/TechAsstCity.pdf (noting that installing LED traffic signals saved the City of Westlake about $34,000 per year). As of 2005, only about a quarter of California's cities and counties were using 100% LEDs in traffic signals. See California Energy Commission (CEC), Light Emitting Diode Traffic Signal Survey (2005) at p. 15, available at http://www.energy.ca.gov/2005publications/CEC 400 2005 003/CEC 400 2005 003.PDF. The California Energy Commission's Energy Partnership Program can help local governments take advantage of energy saving technology, including, but not limited to, LED traffic signals. See http://www.energy.ca.gov/efficiency/partnership/.
Reduce unnecessary outdoor lighting.	See California Energy Commission, Reduction of Outdoor Lighting (webpage) at http://www.energy.ca.gov/efficiency/lighting/outdoor_reduction.html.

Use automatic covers, efficient pumps and motors, and solar heating for pools and spas.	During the summer, a traditional backyard California pool can use enough energy to power an entire home for three months. Efficiency measures can substantially reduce this waste of energy and money. See California Energy Commission, Consumer Energy Center, Pools and Spas (webpage) at http://www.consumerenergycenter.org/home/outside/pools_spas.html. See also Sacramento Municipal Utilities District, Pool and Spa Efficiency Program (webpage) at http://www.smud.org/en/residential/saving-energy/Pages/poolspa.aspx.
Provide education on energy efficiency to residents, customers and/or tenants.	Many cities and counties provide energy efficiency education. See, for example, the City of Stockton's Energy Efficiency website at http://www.stocktongov.com/energysaving/index.cfm. See also "Green County San Bernardino," http://www.greencountysb.com at pp. 4-6. Businesses and development projects may also provide education. For example, a homeowners' association (HOA) could provide information to residents on energy-efficient mortgages and energy saving measures. See The Villas of Calvera Hills, Easy Energy Saving Tips to Help Save Electricity at http://www.thevillashoa.org/green/energy/. An HOA might also consider providing energy audits to its residents on a regular basis.

Renewable Energy and Energy Storage

Meet "reach" goals for building energy efficiency and renewable energy use.	A "zero net energy" building combines building energy efficiency and renewable energy generation so that, on an annual basis, any purchases of electricity or natural gas are offset by clean, renewable energy generation, either on-site or nearby. Both the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) have stated that residential buildings should be zero net energy by 2020, and commercial buildings by 2030. See CEC, 2009 Integrated Energy Policy Report (Dec. 2009) at p. 226, available at http://www.energy.ca.gov/2009publications/CEC-100-2009-003/CEC-100-2009-003-CMF.PDF; CPUC, Long Term Energy Efficiency Strategic Plan (Sept. 2008), available at http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/.
Install solar, wind, and geothermal power systems and solar hot water heaters.	The California Public Utilities Commission (CPUC) approved the California Solar Initiative on January 12, 2006. The initiative creates a $3.3 billion, ten-year program to install solar panels on one million roofs in the State. Visit the one-stop GoSolar website at http://www.gosolarcalifornia.org/. As mitigation, a developer could, for example, agree to participate in the New Solar Homes program. See http://www.gosolarcalifornia.org/builders/index.html. The CPUC is in the process of establishing a program to provide solar water heating incentives under the California Solar Initiative. For more information, visit the CPUC's website at http://www.cpuc.ca.gov/puc/energy/solar/swh.htm. To search for available residential and commercial renewable energy incentives, visit Flex Your Power's website at http://www.fypower.org/.

Install solar panels on unused roof and ground space and over carports and parking areas.	In 2008 Southern California Edison (SCE) launched the nation's largest installation of photovoltaic power generation modules. The utility plans to cover 65 million square feet of unused commercial rooftops with 250 megawatts of solar technology – generating enough energy to meet the needs of approximately 162,000 homes. Learn more about SCE's Solar Rooftop Program at http://www.sce.com/solarleadership/solar-rooftop-program/general-faq.htm. In 2009, Walmart announced its commitment to expand the company's solar power program in California. The company plans to add solar panels on 10 to 20 additional Walmart facilities in the near term. These new systems will be in addition to the 18 solar arrays currently installed at Walmart facilities in California. See http://walmartstores.com/FactsNews/NewsRoom/9091.aspx. Alameda County has installed two solar tracking carports, each generating 250 kilowatts. By 2005, the County had installed eight photovoltaic systems totaling over 2.3 megawatts. The County is able to meet 6 percent of its electricity needs through solar power. See http://www.acgov.org/gsa/Alameda%20County%20-%20Solar%20Case%20Study.pdf. In 2007, California State University, Fresno installed at 1.1-megawatt photovoltaic (PV)-paneled parking installation. The University expects to save more than $13 million in avoided utility costs over the project's 30-year lifespan. http://www.fresnostatenews.com/2007/11/solarwrapup2.htm.
Where solar systems cannot feasibly be incorporated into the project at the outset, build "solar ready" structures.	U.S. Department of Energy, A Homebuilder's Guide to Going Solar (brochure) (2008), available at http://www.eere.energy.gov/solar/pdfs/43076.pdf.
Incorporate wind and solar energy systems into agricultural projects where appropriate.	Wind energy can be a valuable crop for farmers and ranchers. Wind turbines can generate energy to be used on-site, reducing electricity bills, or they can yield lease revenues (as much as $4000 per turbine per year). Wind turbines generally are compatible with rural land uses, since crops can be grown and livestock can be grazed up to the base of the turbine. See National Renewable Energy Laboratory, Wind Powering America Fact Sheet Series, Wind Energy Benefits, available at http://www.nrel.gov/docs/fy05osti/37602.pdf. Solar PV is not just for urban rooftops. For example, the Scott Brothers' dairy in San Jacinto, California, has installed a 55-kilowatt solar array on its commodity barn, with plans to do more in the coming years. See http://www.dairyherd.com/directories.asp?pgID=724&ed_id=8409 (additional California examples are included in article.)

Include energy storage where appropriate to optimize renewable energy generation systems and avoid peak energy use.	See National Renewable Energy Laboratory, Energy Storage Basics (webpage) at http://www.nrel.gov/learning/eds_energy_storage.html. California Energy Storage Alliance (webpage) at http://storagealliance.org/about.html. Storage is not just for large, utility scale projects, but can be part of smaller industrial, commercial and residential projects. For example, Ice Storage Air Conditioning (ISAC) systems, designed for residential and nonresidential buildings, produce ice at night and use it during peak periods for cooling. See California Energy Commission, Staff Report, Ice Storage Air Conditioners, Compliance Options Application (May 2006), available at http://www.energy.ca.gov/2006publications/CEC-400-2006-006/CEC-400-2006-006-SF.PDF.
Use on-site generated biogas, including methane, in appropriate applications.	At the Hilarides Dairy in Lindsay, California, an anaerobic-lagoon digester processes the run-off of nearly 10,000 cows, generating 226,000 cubic feet of biogas per day and enough fuel to run two heavy duty trucks. This has reduced the dairy's diesel consumption by 650 gallons a day, saving the dairy money and improving local air quality. See http://www.arb.ca.gov/newsrel/nr021109b.htm; see also Public Interest Energy Research Program, Dairy Power Production Program, Dairy Methane Digester System, 90-Day Evaluation Report, Eden Vale Dairy (Dec. 2006) at http://www.energy.ca.gov/2006publications/CEC 500 2006 083/CEC 500 2006 083.PDF. Landfill gas is a current and potential source of substantial energy in California. See Tom Frankiewicz, Program Manager, U.S. EPA Landfill Methane Outreach Program, Landfill Gas Energy Potential in California, available at http://www.energy.ca.gov/2009_energypolicy/documents/2009-04-21_workshop/presentations/05-SCS_Engineers_Presentation.pdf. There are many current and emerging technologies for converting landfill methane that would otherwise be released as a greenhouse gas into clean energy. See California Integrated Waste Management Board, Emerging Technologies, Landfill Gas-to-Energy (webpage) at http://www.ciwmb.ca.gov/LEACentral/TechServices/EmergingTech/default.htm.

Use combined heat and power (CHP) in appropriate applications.	Many commercial, industrial, and campus-type facilities (such as hospitals, universities and prisons) use fuel to produce steam and heat for their own operations and processes. Unless captured, much of this heat is wasted. CHP captures waste heat and re-uses it, e.g., for residential or commercial space heating or to generate electricity. See U.S. EPA, Catalog of CHP Technologies at http://www.epa.gov/chp/documents/catalog_of_%20chp_tech_entire.pdf and California Energy Commission, Distributed Energy Resource Guide, Combined Heat and Power (webpage) at http://www.energy.ca.gov/distgen/equipment/chp/chp.html. The average efficiency of fossil-fueled power plants in the United States is 33 percent. By using waste heat recovery technology, CHP systems typically achieve total system efficiencies of 60 to 80 percent. CHP can also substantially reduce emissions of carbon dioxide. http://www.epa.gov/chp/basic/efficiency.html. Currently, CHP in California has a capacity of over 9 million kilowatts. See list of California CHP facilities at http://www.eea-inc.com/chpdata/States/CA.html. The Waste Heat and Carbon Emissions Reduction Act (Assembly Bill 1613 (2007), amended by Assembly Bill 2791 (2008)) is designed to encourage the development of new CHP systems in California with a generating capacity of not more than 20 megawatts. Among other things, the Act requires the California Public Utilities Commission to establish (1) a standard tariff allowing CHP generators to sell electricity for delivery to the grid and (2) a "pay as you save" pilot program requiring electricity corporations to finance the installation of qualifying CHP systems by nonprofit and government entities. For more information, see http://www.energy.ca.gov/wasteheat/.

Water Conservation and Efficiency

Incorporate water-reducing features into building and landscape design.	According to the California Energy Commission, water-related energy use – which includes conveyance, storage, treatment, distribution, wastewater collection, treatment, and discharge – consumes about 19 percent of the State's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel every year. See http://www.energy.ca.gov/2007publications/CEC 999 2007 008/CEC 999 2007 008.PDF. Reducing water use and improving water efficiency can help reduce energy use and greenhouse gas emissions.
Create water-efficient landscapes.	The California Department of Water Resources' updated Model Water Efficient Landscape Ordinance (Sept. 2009) is available at http://www.water.ca.gov/wateruseefficiency/landscapeordinance/technical.cfm. A landscape can be designed from the beginning to use little or no water, and to generate little or no waste. See California Integrated Waste Management Board, Xeriscaping (webpage) at http://www.ciwmb.ca.gov/organics/Xeriscaping/.

Install water-efficient irrigation systems and devices, such as soil moisture-based irrigation controls and use water-efficient irrigation methods.	U.S. Department of Energy, Best Management Practice: Water-Efficient Irrigation (webpage) at http://www1.eere.energy.gov/femp/program/waterefficiency_bmp5.html. California Department of Water Resources, Landscape Water Use Efficiency (webpage) at http://www.water.ca.gov/wateruseefficiency/landscape/. Pacific Institute, More with Less: Agricultural Water Conservation and Efficiency in California (2008), available at http://www.pacinst.org/reports/more_with_less_delta/index.htm.
Make effective use of graywater. (Graywater is untreated household waste water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines. Graywater to be used for landscape irrigation.)	California Building Standards Commission, 2008 California Green Building Standards Code, Section 604, pp. 31-32, available at http://www.documents.dgs.ca.gov/bsc/2009/part11_2008_calgreen_code.pdf. California Department of Water Resources, Dual Plumbing Code (webpage) at http://www.water.ca.gov/recycling/DualPlumbingCode/. See also Ahwahnee Water Principles, Principle 6, at http://www.lgc.org/ahwahnee/h2o_principles.html. The Ahwahnee Water Principles have been adopted by City of Willits, Town of Windsor, Menlo Park, Morgan Hill, Palo Alto, Petaluma, Port Hueneme, Richmond, Rohnert Park, Rolling Hills Estates, San Luis Obispo, Santa Paula, Santa Rosa, City of Sunnyvale, City of Ukiah, Ventura, Marin County, Marin Municipal Water District, and Ventura County.
Implement low-impact development practices that maintain the existing hydrology of the site to manage storm water and protect the environment.	Retaining storm water runoff on-site can drastically reduce the need for energy-intensive imported water at the site. See U.S. EPA, Low Impact Development (webpage) at http://www.epa.gov/nps/lid/. Office of Environmental Health Hazard Assessment and the California Water and Land Use Partnership, Low Impact Development at http://www.coastal.ca.gov/nps/lid-factsheet.pdf.
Devise a comprehensive water conservation strategy appropriate for the project and location.	The strategy may include many of the specific items listed above, plus other innovative measures that are appropriate to the specific project.
Design buildings to be water-efficient. Install water-efficient fixtures and appliances.	Department of General Services, Best Practices Manual, Water-Efficient Fixtures and Appliances (website) at http://www.green.ca.gov/EPP/building/SaveH2O.htm. Many ENERGY STAR products have achieved their certification because of water efficiency. See California Energy Commission's database, available at http://www.appliances.energy.ca.gov/.

Offset water demand from new projects so that there is no net increase in water use.	For example, the City of Lompoc has a policy requiring new development to offset new water demand with savings from existing water users. See http://www.cityoflompoc.com/utilities/pdf/2005_uwmp_final.pdf at p. 29.
Provide education about water conservation and available programs and incentives.	See, for example, the City of Santa Cruz, Water Conservation Office at http://www.ci.santa-cruz.ca.us/index.aspx?page=395; Santa Clara Valley Water District, Water Conservation at http://www.valleywater.org/conservation/index.shtm; and Metropolitan Water District and the Family of Southern California Water Agencies, Be Water Wise at http://www.bewaterwise.com. Private projects may provide or fund similar education.

Solid Waste Measures

Reuse and recycle construction and demolition waste (including, but not limited to, soil, vegetation, concrete, lumber, metal, and cardboard).	Construction and demolition materials account for almost 22 percent of the waste stream in California. Reusing and recycling these materials not only conserves natural resources and energy, but can also save money. For a list of best practices and other resources, see California Integrated Waste Management Board, Construction and Demolition Debris Recycling (webpage) at http://www.ciwmb.ca.gov/condemo/.
Integrate reuse and recycling into residential industrial, institutional and commercial projects.	Tips on developing a successful recycling program, and opportunities for cost-effective recycling, are available on the California Integrated Waste Management Board's Zero Waste California website. See http://zerowaste.ca.gov/. The Institute for Local Government's Waste Reduction & Recycling webpage contains examples of "best practices" for reducing greenhouse gas emissions, organized around waste reduction and recycling goals and additional examples and resources. See http://www.ca-ilg.org/wastereduction.
Provide easy and convenient recycling opportunities for residents, the public, and tenant businesses.	Tips on developing a successful recycling program, and opportunities for cost effective recycling, are available on the California Integrated Waste Management Board's Zero Waste California website. See http://zerowaste.ca.gov/.
Provide education and publicity about reducing waste and available recycling services.	Many cities and counties provide information on waste reduction and recycling. See, for example, the Butte County Guide to Recycling at http://www.recyclebutte.net. The California Integrated Waste Management Board's website contains numerous publications on recycling and waste reduction that may be helpful in devising an education project. See http://www.ciwmb.ca.gov/Publications/default.asp?cat=13. Private projects may also provide waste and recycling education directly, or fund education.

Land Use Measures

Ensure consistency with "smart growth" principles – mixed-use, infill, and higher density projects that provide alternatives to individual vehicle travel and promote the efficient delivery of services and goods.	U.S. EPA maintains an extensive Smart Growth webpage with links to examples, literature and technical assistance, and financial resources. See http://www.epa.gov/smartgrowth/index.htm. The National Oceanic and Atmospheric Administration's webpage provides smart growth recommendations for communities located near water. See Coastal & Waterfront Smart Growth (webpage) at http://coastalsmartgrowth.noaa.gov/. The webpage includes case studies from California. The California Energy Commission has recognized the important role that land use can play in meeting our greenhouse gas and energy efficiency goals. The agency's website, Smart Growth & Land Use Planning, contains useful information and links to relevant studies, reports, and other resources. See http://www.energy.ca.gov/landuse/. The Metropolitan Transportation Commission's webpage, Smart Growth / Transportation for Livable Communities, includes resources that may be useful to communities in the San Francisco Bay Area and beyond. See http://www.mtc.ca.gov/planning/smart_growth/. The Sacramento Area Council of Governments (SACOG) has published examples of smart growth in action in its region. See Examples from the Sacramento Region of the Seven Principles of Smart Growth / Better Ways to Grow, available at http://www.sacog.org/regionalfunding/betterways.pdf.
Meet recognized "smart growth" benchmarks.	For example, the LEED for Neighborhood Development (LEED-ND) rating system integrates the principles of smart growth, urbanism and green building into the first national system for neighborhood design. LEED-ND is a collaboration among the U.S. Green Building Council, Congress for the New Urbanism, and the Natural Resources Defense Council. For more information, see http://www.usgbc.org/DisplayPage.aspx?CMSPageID=148.
Educate the public about the many benefits of well-designed, higher density development.	See, for example, U.S. EPA, Growing Smarter, Living Healthier: A Guide to Smart Growth and Active Aging (webpage), discussing how compact, walkable communities can provide benefits to seniors. See http://www.epa.gov/aging/bhc/guide/index.html. U.S. EPA, Environmental Benefits of Smart Growth (webpage) at http://www.epa.gov/dced/topics/eb.htm (noting local air and water quality improvements). Centers for Disease Control and Prevention (CDC), Designing and Building Healthy Places (webpage), at http://www.cdc.gov/healthyplaces/. The CDC's website discusses the links between walkable communities and public health and includes numerous links to educational materials. California Department of Housing and Community Development, Myths and Facts About Affordable and High Density Housing (2002), available at http://www.hcd.ca.gov/hpd/mythsnfacts.pdf.

Incorporate public transit into the project's design.	Federal Transit Administration, Transit-Oriented Development (TOD) (webpage) at http://www.fta.dot.gov/planning/planning_environment_6932.html (describing the benefits of TOD as "social, environmental, and fiscal.") California Department of Transportation (Caltrans), Statewide Transit-Oriented Development Study: Factors for Success in California (2002), available at http://transitorienteddevelopment.dot.ca.gov/miscellaneous/StatewideTOD.htm Caltrans, California Transit-Oriented Development Searchable Database (includes detailed information on numerous TODs), available at http://transitorienteddevelopment.dot.ca.gov/miscellaneous/NewHome.jsp. California Department of Housing and Community Development, Transit Oriented Development (TOD) Resources (Aug. 2009), available at http://www.hcd.ca.gov/hpd/tod.pdf.
Preserve and create open space and parks. Preserve existing trees, and plant replacement trees at a set ratio.	U.S. EPA, Smart Growth and Open Space Conservation (webpage) at http://www.epa.gov/dced/openspace.htm.
Develop "brownfields" and other underused or defunct properties near existing public transportation and jobs.	U.S. EPA, Smart Growth and Brownfields (webpage) at http://www.epa.gov/dced/brownfields.htm. For example, as set forth in the Local Government Commission's case study, the Town of Hercules, California reclaimed a 426-acre brownfield site, transforming it into a transit-friendly, walkable neighborhood. See http://www.lgc.org/freepub/docs/community_design/fact_sheets/er_case_studies.pdf. For financial resources that can assist in brownfield development, see Center for Creative Land Recycling, Financial Resources for California Brownfields (July 2008), available at http://www.cclr.org/media/publications/8-Financial_Resources_2008.pdf.
Include pedestrian and bicycle facilities within projects and ensure that existing non-motorized routes are maintained and enhanced.	See U.S. Department of Transportation, Federal Highway Administration, Bicycle and Pedestrian Program (webpage) at http://www.fhwa.dot.gov/environment/bikeped/. Caltrans, Pedestrian and Bicycle Facilities in California / A Technical Reference and Technology Transfer Synthesis for Caltrans Planners and Engineers (July 2005), available at http://www.dot.ca.gov/hq/traffops/survey/pedestrian/TR_MAY0405.pdf. This reference includes standard and innovative practices for pedestrian facilities and traffic calming.

Transportation and Motor Vehicles

Meet an identified transportation-related benchmark.	A logical benchmark might be related to vehicles miles traveled (VMT), e.g., average VMT per capita, per household, or per employee. As the California Energy Commission has noted, VMT by California residents increased "a rate of more than 3 percent a year between 1975 and 2004, markedly faster than the population growth rate over the same period, which was less than 2 percent. This increase in VMT correlates to an increase in petroleum use and GHG production and has led to the transportation sector being responsible for 41 percent of the state's GHG emissions in 2004." CEC, The Role of Land Use in Meeting California's Energy and Climate Change Goals (Aug. 2007) at p. 9, available at http://www.energy.ca.gov/2007publications/CEC-600-2007-008/CEC-600-2007-008-SF.PDF. Even with regulations designed to increase vehicle efficiency and lower the carbon content of fuel, "reduced VMT growth will be required to meet GHG reductions goals." *Id.* at p. 18.
Adopt a comprehensive parking policy that discourages private vehicle use and encourages the use of alternative transportation.	For example, reduce parking for private vehicles while increasing options for alternative transportation; eliminate minimum parking requirements for new buildings; "unbundle" parking (require that parking is paid for separately and is not included in rent for residential or commercial space); and set appropriate pricing for parking. See U.S. EPA, Parking Spaces / Community Places, Finding the Balance Through Smart Growth Solutions (Jan. 2006), available at http://www.epa.gov/dced/pdf/EPAParkingSpaces06.pdf. Reforming Parking Policies to Support Smart Growth, Metropolitan Transportation Commission (June 2007) at http://www.mtc.ca.gov/planning/smart_growth/parking_seminar/Toolbox Handbook.pdf. See also the City of Ventura's Downtown Parking and Mobility Plan, available at http://www.cityofventura.net/community_development/resources/mobility_parking_plan.pdf, and Ventura's Downtown Parking Management Program, available at http://www.ci.ventura.ca.us/depts/comm_dev/downtownplan/chapters.asp.
Build or fund a major transit stop within or near the development.	"'Major transit stop' means a site containing an existing rail transit station, a ferry terminal served by either a bus or rail transit service, or the intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods." (Pub. Res. Code, § 21064.3.) Transit Oriented Development (TOD) is a moderate to higher density development located within an easy walk of a major transit stop. http://transitorienteddevelopment.dot.ca.gov/miscellaneous/NewWhatisTOD.htm. By building or funding a major transit stop, an otherwise ordinary development can become a TOD.

Provide public transit incentives such as free or low-cost monthly transit passes to employees, or free ride areas to residents and customers.	See U.S. Department of Transportation and U.S. EPA, Commuter Choice Primer / An Employer's Guide to Implementing Effective Commuter Choice Programs, available at http://www.its.dot.gov/JPODOCS/REPTS_PR/13669.html. The Emery Go Round shuttle is a private transportation service funded by commercial property owners in the citywide transportation business improvement district. The shuttle links a local shopping district to a Bay Area Rapid Transit stop. See http://www.emerygoround.com/. Seattle, Washington maintains a public transportation "ride free" zone in its downtown from 6:00 a.m. to 7:00 p.m. daily. See http://transit.metrokc.gov/tops/accessible/paccessible_map.html#fare.
Promote "least polluting" ways to connect people and goods to their destinations.	Promoting "least polluting" methods of moving people and goods is part of a larger, integrated "sustainable streets" strategy now being explored at U.C. Davis's Sustainable Transportation Center. Resources and links are available at the Center's website, http://stc.ucdavis.edu/outreach/ssp.php.
Incorporate bicycle lanes, routes and facilities into street systems, new subdivisions, and large developments.	Bicycling can have a profound impact on transportation choices and air pollution reduction. The City of Davis has the highest rate of bicycling in the nation. Among its 64,000 residents, 17 percent travel to work by bicycle and 41 percent consider the bicycle their primary mode of transportation. See Air Resources Board, Bicycle Awareness Program, Bicycle Fact Sheet, available at http://www.arb.ca.gov/planning/tsaq/bicycle/factsht.htm. For recommendations on best practices, see the many resources listed at the U.S. Department of Transportation, Federal Highway Administration's Bicycle and Pedestrian website at http://www.fhwa.dot.gov/environment/bikeped/publications.htm. See also Caltrans Division of Research and Innovation, Designing Highway Facilities To Encourage Walking, Biking and Transit (Preliminary Investigation) (March 2009), available at http://www.dot.ca.gov/research/researchreports/preliminary_investigations/docs/pi-design_for_walking_%20biking_and_transit%20final.pdf.
Require amenities for non-motorized transportation, such as secure and convenient bicycle parking.	According to local and national surveys of potential bicycle commuters, secure bicycle parking and workplace changing facilities are important complements to safe and convenient routes of travel. See Air Resources Board, Bicycle Awareness Program, Bicycle Fact Sheet, available at http://www.arb.ca.gov/planning/tsaq/bicycle/factsht.htm.

Ensure that the project enhances, and does not disrupt or create barriers to, non-motorized transportation.	See, e.g., U.S. EPA's list of transit-related "smart growth" publications at http://www.epa.gov/dced/publications.htm#air, including Pedestrian and Transit-Friendly Design: A Primer for Smart Growth (1999), available at www.epa.gov/dced/pdf/ptfd_primer.pdf. See also Toolkit for Improving Walkability in Alameda County, available at http://www.acta2002.com/ped toolkit/ped_toolkit_print.pdf. Pursuant to the California Complete Streets Act of 2008 (AB 1358, Gov. Code, §§ 65040.2 and 65302), commencing January 1, 2011, upon any substantive revision of the circulation element of the general plan, a city or county will be required to modify the circulation element to plan for a balanced, multimodal transportation network that meets the needs of all users.
Connect parks and open space through shared pedestrian/bike paths and trails to encourage walking and bicycling. Create bicycle lanes and walking paths directed to the location of schools, parks and other destination points.	Walk Score ranks the "walkability" of neighborhoods in the largest 40 U.S. cities, including seven California cities. Scores are based on the distance to nearby amenities. Explore Walk Score at http://www.walkscore.com/. In many markets, homes in walkable neighborhoods are worth more than similar properties where walking is more difficult. See Hoak, *Walk appeal / Homes in walkable neighborhoods sell for more: study*, Wall Street Journal (Aug. 18, 2009), available at http://www.marketwatch.com/story/homes-in-walkable-neighborhoods-sell-for-more-2009-08-18. By creating walkable neighborhoods with more transportation choices, Californians could save $31 million and cut greenhouse gas emissions by 34 percent, according to a study released by Transform, a coalition of unions and nonprofits. See Windfall for All / How Connected, Convenient Neighborhoods Can Protect Our Climate and Safeguard California's Economy (Nov. 2009), available at http://transformca.org/windfall-for-all#download-report.
Work with the school districts to improve pedestrian and bike access to schools and to restore or expand school bus service using lower-emitting vehicles.	In some communities, twenty to twenty-five percent of morning traffic is due to parents driving their children to school. Increased traffic congestion around schools in turn prompts even more parents to drive their children to school. Programs to create safe routes to schools can break this harmful cycle. See California Department of Public Health, Safe Routes to School (webpage) and associated links at http://www.cdph.ca.gov/HealthInfo/injviosaf/Pages/SafeRoutestoSchool.aspx. See also U.S. EPA, Smart Growth and Schools (webpage), available at http://www.epa.gov/dced/schools.htm. California Center for Physical Activity, California Walk to School (website) at http://www.cawalktoschool.com Regular school bus service (using lower-emitting buses) for children who cannot bike or walk to school could substantially reduce private vehicle congestion and air pollution around schools. See Air Resources Board, Lower Emissions School Bus Program (webpage) at http://www.arb.ca.gov/msprog/schoolbus/schoolbus.htm.

Institute teleconferencing, telecommute and/or flexible work hour programs to reduce unnecessary employee transportation.	There are numerous sites on the web with resources for employers seeking to establish telework or flexible work programs. These include U.S. EPA's Mobility Management Strategies: Commuter Programs website at http://www.epa.gov/otaq/stateresources/rellinks/mms_commprograms.htm; and Telework, the federal government's telework website, at http://www.telework.gov/. Through a continuing FlexWork Implementation Program, the Traffic Solutions division of the Santa Barbara County Association of Governments sponsors flexwork consulting, training and implementation services to a limited number of Santa Barbara County organizations that want to create or expand flexwork programs for the benefit of their organizations, employees and the community. See http://www.flexworksb.com/read_more_about_the_fSBp.html. Other local government entities provide similar services.
Provide information on alternative transportation options for consumers, residents, tenants and employees to reduce transportation-related emissions.	Many types of projects may provide opportunities for delivering more tailored transportation information. For example, a homeowner's association could provide information on its website, or an employer might create a Transportation Coordinator position as part of a larger Employee Commute Reduction Program. See, e.g., South Coast Air Quality Management District, Transportation Coordinator training, at http://www.aqmd.gov/trans/traing.html.
Educate consumers, residents, tenants and the public about options for reducing motor vehicle-related greenhouse gas emissions. Include information on trip reduction; trip linking; vehicle performance and efficiency (e.g., keeping tires inflated); and low or zero-emission vehicles.	See, for example U.S. EPA, SmartWay Transport Partnership: Innovative Carrier Strategies (webpage) at http://www.epa.gov/smartway/transport/what-smartway/carrier-strategies.htm. This webpage includes recommendations for actions that truck and rail fleets can take to make ground freight more efficient and cleaner. The Air Resources Board's Drive Clean website is a resource for car buyers to find clean and efficient vehicles. The web site is designed to educate Californians that pollution levels range greatly between vehicles. See http://www.driveclean.ca.gov/. The Oregon Department of Transportation and other public and private partners launched the Drive Less/Save More campaign. The comprehensive website contains fact sheets and educational materials to help people drive more efficiently. See http://www.drivelesssavemore.com/.
Purchase, or create incentives for purchasing, low or zero-emission vehicles.	See Air Resources Board, Low-Emission Vehicle Program (webpage) at http://www.arb.ca.gov/msprog/levprog/levprog.htm. Air Resource Board, Zero Emission Vehicle Program (webpage) at http://www.arb.ca.gov/msprog/zevprog/zevprog.htm. All new cars sold in California are now required to display an Environmental Performance (EP) Label, which scores a vehicle's global warming and smog emissions from 1 (dirtiest) to 10 (cleanest). To search and compare vehicle EP Labels, visit www.DriveClean.ca.gov.

Create a ride sharing program. Promote existing ride sharing programs e.g., by designating a certain percentage of parking spaces for ride sharing vehicles, designating adequate passenger loading and unloading for ride sharing vehicles, and providing a web site or message board for coordinating rides.	For example, the 511 Regional Rideshare Program is operated by the Metropolitan Transportation Commission (MTC) and is funded by grants from the Federal Highway Administration, U.S. Department of Transportation, the Metropolitan Transportation Commission, the Bay Area Air Quality Management District and county congestion management agencies. For more information, see http://rideshare.511.org/. As another example, San Bernardino Associated Governments works directly with large and small employers, as well as providing support to commuters who wish to share rides or use alternative forms of transportation. See http://www.sanbag.ca.gov/commuter/rideshare.html. Valleyrides.com is a ridesharing resource available to anyone commuting to and from Fresno and Tulare Counties and surrounding communities. See http://www.valleyrides.com/. There are many other similar websites throughout the state.
Create or accommodate car sharing programs, e.g., provide parking spaces for car share vehicles at convenient locations accessible by public transportation.	There are many existing car sharing companies in California. These include City CarShare (San Francisco Bay Area), see http://www.citycarshare.org/; and Zipcar, see http://www.zipcar.com/. Car sharing programs are being successfully used on many California campuses.
Provide a vanpool for employees.	Many local Transportation Management Agencies can assist in forming vanpools. See, for example, Sacramento Transportation Management Association, Check out Vanpooling (webpage) at http://www.sacramento-tma.org/vanpool.html.
Create local "light vehicle" networks, such as neighborhood electric vehicle systems.	See California Energy Commission, Consumer Energy Center, Urban Options - Neighborhood Electric Vehicles (NEVs) (webpage) at http://www.consumerenergycenter.org/transportation/urban_options/nev.html. The City of Lincoln has an innovative NEV program. See http://www.lincolnev.com/index.html.
Enforce and follow limits idling time for commercial vehicles, including delivery and construction vehicles.	Under existing law, diesel-fueled motor vehicles with a gross vehicle weight rating greater than 10,000 pounds are prohibited from idling for more than 5 minutes at any location. The minimum penalty for an idling violation is now $300 per violation. See http://www.arb.ca.gov/enf/complaints/idling_cv.htm.
Provide the necessary facilities and infrastructure to encourage the use of low or zero-emission vehicles.	For a list of existing alternative fuel stations in California, visit http://www.cleancarmaps.com/. See, e.g., Baker, *Charging-station network built along 101*, S.F. Chron. (9/23/09), available at http://articles.sfgate.com/2009-09-23/news/17207424_1_recharging-solar-array-tesla-motors.

Agriculture and Forestry (additional strategies noted above)

Require best management practices in agriculture and animal operations to reduce emissions, conserve energy and water, and utilize alternative energy sources, including biogas, wind and solar.	Air Resources Board (ARB), Economic Sectors Portal, Agriculture (webpage) at http://www.arb.ca.gov/cc/ghgsectors/ghgsectors.htm. ARB's webpage includes information on emissions from manure management, nitrogen fertilizer, agricultural offroad equipment, and agricultural engines. "A full 90% of an agricultural business' electricity bill is likely associated with water use. In addition, the 8 million acres in California devoted to crops consume 80% of the total water pumped in the state." See Flex Your Power, Agricultural Sector (webpage) at http://www.fypower.org/agri/. Flex Your Power, Best Practice Guide / Food and Beverage Growers and Processors, available at http://www.fypower.org/bpg/index.html?b=food_and_bev. Antle et al., Pew Center on Global Climate Change, Agriculture's Role in Greenhouse Gas Mitigation (2006), available at http://www.pewclimate.org/docUploads/Agriculture's%20Role%20in%20GHG%20Mitigation.pdf.
Preserve forested areas, agricultural lands, wildlife habitat and corridors, wetlands, watersheds, groundwater recharge areas and other open space that provide carbon sequestration benefits.	"There are three general means by which agricultural and forestry practices can reduce greenhouse gases: (1) avoiding emissions by maintaining existing carbon storage in trees and soils; (2) increasing carbon storage by, e.g., tree planting, conversion from conventional to conservation tillage practices on agricultural lands; (3) substituting bio-based fuels and products for fossil fuels, such as coal and oil, and energy-intensive products that generate greater quantities of CO_2 when used." U.S. EPA, Carbon Sequestration in Agriculture and Forestry, Frequently Asked Questions (webpage) at http://www.epa.gov/sequestration/faq.html. Air Resources Board, Economic Sectors Portal, Forestry (webpage) at http://www.arb.ca.gov/cc/ghgsectors/ghgsectors.htm.
Protect existing trees and encourage the planting of new trees. Adopt a tree protection and replacement ordinance.	Tree preservation and planting is not just for rural areas of the state; suburban and urban forests can also serve as carbon sinks. See Cal Fire, Urban and Community Forestry (webpage) at http://www.fire.ca.gov/resource_mgt/resource_mgt_urbanforestry.php.

Off-Site Mitigation

If, after analyzing and requiring all reasonable and feasible on-site mitigation measures for avoiding or reducing greenhouse gas-related impacts, the lead agency determines that additional mitigation is required, the agency may consider additional off-site mitigation. The project proponent could, for example, fund off-site mitigation projects that will reduce carbon emissions, conduct an audit of its other existing operations and agree to retrofit, or purchase verifiable carbon "credits" from another entity that will undertake mitigation.

The topic of off-site mitigation can be complicated. A full discussion is outside the scope of this summary document. Issues that the lead agency should consider include:

- The location of the off-site mitigation. (If the off-site mitigation is far from the project, any additional, non-climate related co-benefits of the mitigation may be lost to the local community.)

- Whether the emissions reductions from off-site mitigation can be quantified and verified. (The California Registry has developed a number of protocols for calculating, reporting and verifying greenhouse gas emissions. Currently, industry-specific protocols are available for the cement sector, power/utility sector, forest sector and local government operations. For more information, visit the California Registry's website at http://www.climateregistry.org/.)

- Whether the mitigation ratio should be greater than 1:1 to reflect any uncertainty about the effectiveness of the off-site mitigation.

Offsite mitigation measures that could be funded through mitigation fees include, but are not limited to, the following:

- Energy efficiency audits of existing buildings.

- Energy efficiency upgrades to existing buildings not otherwise required by law, including heating, ventilation, air conditioning, lighting, water heating equipment, insulation and weatherization (perhaps targeted to specific communities, such as low-income or senior residents).

- Programs to encourage the purchase and use of energy efficient vehicles, appliances, equipment and lighting.

- Programs that create incentives to replace or retire polluting vehicles and engines.

- Programs to expand the use of renewable energy and energy storage.

- Preservation and/or enhancement of existing natural areas (e.g., forested areas, agricultural lands, wildlife habitat and corridors, wetlands, watersheds, and groundwater recharge areas) that provide carbon sequestration benefits.

- Improvement and expansion of public transit and low- and zero-carbon transportation alternatives.

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November 4, 2009

VIA E-MAIL & U.S. MAIL

Dave Warner
Director of Permit Services
San Joaquin Valley Air Pollution Control District
1990 East Gettysburg Ave.
Fresno, CA 93726-0244

RE: Final Draft Staff Report on Greenhouse Gas Emissions Under CEQA

Dear Mr. Warner:

We have reviewed the San Joaquin Valley Air Pollution Control District's September 17, 2009, Final Draft Staff Report on "Addressing Greenhouse Gas Emissions Under the California Environmental Quality Act."[1] We appreciate the Air District's extensive efforts and leadership in this area.[2] We are concerned, however, that the approaches suggested in the Staff Report will not withstand legal scrutiny and may result in significant lost opportunities for the Air District and local governments to require mitigation of greenhouse gas (GHG) emissions.

The Staff Report sets out a proposed threshold of significance for GHG emissions for stationary source projects under the Air District's permitting authority. A threshold of significance is, in effect, a working definition of significance to be applied on a project-by-project basis that can help a lead agency determine which projects normally will be determined to be less than significant, and which normally will be determined to be significant.[3] In the context of GHG emissions, the relevant question is whether the project's emissions, when considered in conjunction with the emissions of past, current, and probable future projects, are

[1] The Attorney General submits these comments pursuant to his independent power and duty to protect the natural resources of the State. (See Cal. Const., art. V., § 13; Cal. Gov. Code, §§ 12511, 12600-12612; *D'Amico v. Board of Medical Examiners* (1974) 11 Cal.3d 1, 14-15.)
[2] The Staff Report states that "[n]o state agency has provided substantial and helpful guidance on how to adequately address GHG emissions under CEQA, nor has there been guidance on how to determine if such impacts are significant." (Report at p. 2.) In fact, there are numerous sources of guidance, including information on the Attorney General's website (http://ag.ca.gov/globalwarming/ceqa.php), a Technical Advisory issued by the Governor's Office of Planning and Research (http://opr.ca.gov/ceqa/pdfs/june08-ceqa.pdf); and the Resources Agency's proposed CEQA Guidelines amendments (http://ceres.ca.gov/ceqa/guidelines/), which is accompanied by a detailed, 78-page Initial Statement of Reasons (http://ceres.ca.gov/ceqa/docs/Initial_Statement_of_Reasons.pdf).
[3] Cal. Code Regs., tit. 14, § 15064.7, subd. (a).

cumulatively considerable.[4] Thresholds can be a useful interim tool until cities and counties have in place programmatic approaches, e.g., Climate Action Plans, which allow local government to consider a wide variety of mitigation opportunities and can substantially streamline the CEQA process for individual projects.[5] Staff's proposed stationary source GHG threshold relies on implementation of GHG emission control technologies. Under this proposal, projects that implement currently unspecified GHG Best Performance Standards ("BPS") would be deemed to not have significant impacts, regardless of the total amount of GHGs emitted.

The Staff Report also recommends a threshold of significance for cities and counties to use in determining whether a development or transportation project's GHG emissions are significant under CEQA. Like the stationary source threshold, this threshold would also rely on performance measures that are not currently identified. BPS for these projects would be any combination of identified GHG reduction measures that reduce project-specific GHG emission by at least 29 percent as compared to "business as usual," as calculated based on a point system to be developed in the future by the Air District.

The Staff Report contains a useful analysis of possible GHG mitigation measures for a variety of stationary sources and for development and transportation projects. This discussion will certainly assist lead agencies and project proponents in considering what mitigation measures currently are available and should be considered. It is not clear to us, however, how much additional analysis the Air District plans to do to support the proposed CEQA thresholds of significance recommended in the Staff Report. A public agency proposing to adopt a CEQA threshold of significance should be able to answer at least the following questions about its proposed approach:

What defined, relevant environmental objective is the threshold designed to meet, and what evidence supports selection of that objective?

The Staff Report does not discuss a particular environmental objective that would be achieved by implementing the proposed thresholds, such as meeting a GHG emissions reduction trajectory consistent with that set forth in AB 32 and Executive Order S-03-05 within the Air District's jurisdiction.[6] It appears that the Air District has not yet determined what amount of

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[4] Cal. Code Regs., tit. 14, § 15064, subd. (h)(1); see also Initial Statement of Reasons at p. 17 ("Due to the global nature of GHG emissions and their potential effects, GHG emissions will typically be addressed in a cumulative impacts analysis.")

[5] See Proposed Cal. Code Regs., tit. 14, § 15183.5, subd. (b) (describing tiering and streamlining available under "Plans for the Reduction of Greenhouse Gas Emissions"), available at http://ceres.ca.gov/ceqa/docs/FINAL_Text_of_Proposed_Amendemts.pdf; Draft Initial Statement of Reasons (discussing proposed § 15183.5) , available at http://ceres.ca.gov/ceqa/docs/Initial_Statement_of_Reasons.pdf#page=56; see also See Attorney General's General Plan/CEQA Frequently Asked Questions, available at http://ag.ca.gov/globalwarming/pdf/CEQA_GP_FAQs.pdf.

[6] Pursuant to these mandates, California is committed to reducing GHG emissions to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050. These objectives are consistent with the underlying environmental objective of stabilizing atmospheric concentrations of greenhouse gases at a level that will substantially reduce the risk of dangerous climate change. (See AB 32 Scoping Plan at p. 4 ["The 2020 goal was established to be an aggressive,

GHG reduction it is aiming to achieve. Setting a relevant environmental objective is an essential step in establishing any legally defensible threshold of significance; without it, there is nothing against which to gauge the success of the threshold in operation.

What is the evidence that adopting the threshold will meet this objective?

Because the BPS discussed in the Staff Report are described as "illustrative" only, it is not possible at this time to determine whether the BPS ultimately adopted will reduce GHG emissions in the San Joaquin Valley and, if so, by how much. There is no stated commitment to tie BPS proposed in the future to regional GHG reduction objectives.

How does the threshold take into account the presumptive need for new development to be more GHG-efficient than existing development?

The Staff Report seems to assume that if new development projects reduce emissions by 29 percent compared to "business as usual," the 2020 statewide target of 29 percent below "business as usual" will also be achieved, but it does not supply evidence of this. Indeed, it seems that new development must be more GHG-efficient than this average, given that past and current sources of emissions, which are substantially less efficient than this average, will continue to exist and emit.[7]

Will the threshold routinely require new projects to consider mitigation beyond what is already required by law?

Because "business as usual" for a development project is defined by the Staff Report as what was typically done in similar projects in the 2002-2004 timeframe, and requirements affecting GHG emissions have advanced substantially since that date, it appears that the Air District's proposal would award emission reduction "points" for undertaking mitigation measures that are already required by local or state law.[8]

Similarly, we are concerned that project proponents could "game" the system. Under the current proposal, each project will be considered against a hypothetical project that could have been built on the site in the 2002-2004 time period. It is not clear why the project should be compared against a hypothetical project if that hypothetical project could not legally be built

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but achievable, mid-term target, and the 2050 greenhouse gas emissions reduction goal represents the level scientists believe is necessary to reach levels that will stabilize climate."])

[7] We note that CAPCOA expressly found that an approach that would rely on 28 to 33 percent reductions from BAU would have a "low" GHG emissions reduction effectiveness. CAPCOA, CEQA and Climate Change (Jan. 2008) at p. 56, available at http://www.capcoa.org/CEQA/CAPCOA%20White%20Paper.pdf.

[8] To take one important example, Title 24 has undergone two updates since 2002-2004 – in 2005 and 2008. The 2008 Title 24 standards are approximately 15 percent more stringent that the 2005 version. In addition, a significant number of local governments have adopted green building ordinances that go beyond Title 24 in just the past few years, and many more are considering adopting such ordinances as part of their Climate Action Plans. See http://ag.ca.gov/globalwarming/pdf/green_building.pdf.

today,[9] and the approach would appear to offer an incentive to project proponents to artificially inflate the hypothetical project to show that the proposed project is, by comparison, GHG-efficient.[10]

Will operation of the threshold allow projects with large total GHG emissions to avoid environmental review? What evidence supports such a result?

It appears that any project employing certain, as of yet unidentified, mitigation measures would be considered to not be significant, regardless of the project's total GHG emissions, which could be very large. For instance, under the Air District's proposal, it would appear that even a new development on the scale of a small city would be considered to not have a significant GHG impact and would not have to undertake further mitigation, provided it employs the specified energy efficiency and transportation measures. This would be true even if the new development emitted hundreds of thousands of tons of GHG each year, and even though other feasible measures might exist to reduce those impacts.[11] The Staff Report has not supplied scientific or quantitative support for the conclusion that such a large-emitting project, even if it earned 29 "points," would not have a significant effect on the environment.

Will the threshold benefit lead agencies in their determinations of significance?

For the reasons set forth above, we fear that the recommended approach in its current form may unnecessarily subject lead agencies that follow them to CEQA litigation. This would be detrimental not only to the lead agencies, but to the many project proponents who may face unnecessary delay and legal uncertainty.[12]

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[9] The appropriate baseline under CEQA is not a hypothetical future project, but rather existing physical conditions. (Cal. Code Regs., tit. 14, § 15126.2, subd. (a).)

[10] A detailed analysis of the proposed amendments to Rule 2301 (emissions reduction credit banking) is beyond the scope of this letter. It is important, however, that any such plan comply with CEQA's requirements for additionality. As the most recent draft of the proposed CEQA Guidelines notes, only "[r]eductions in emissions that are not otherwise required may constitute mitigation pursuant to this subdivision." Proposed Cal. Code Regs., tit. 14, § 15126.4, subd. (c), available at http://ceres.ca.gov/ceqa/docs/Text_of_Proposed_Changes.pdf.

[11] In the advance of a programmatic approach to addressing GHG emissions, lead agencies must examine even GHG-efficient projects with some scrutiny where total emissions are large. Once a programmatic approach is in place, the lead agency will be able to determine whether even a larger-emitting project is, or is not, consistent with the lead agency's overall strategy for reducing GHG emissions. If it is, the lead agency may be able to determine that its incremental contribution to climate change is not cumulatively considerable.

[12] The Staff Report states that "[l]ocal land-use agencies are facing increasing difficulties in addressing GHG emissions in their efforts to comply with CEQA." (Report at p. 2.) We strongly believe that this experience is not universal. In fact, many cities and counties are actively taking up their role as "essential partners" in addressing climate change (see AB 32 Scoping Plan at p. 26) by making commitments to develop local Climate Action Plans.

We support staff's continued work in this area. However, before formally endorsing or adopting any particular threshold, we recommend that the Air District consider the issues that we have raised in this letter; if warranted, evaluate the approaches currently under consideration by other districts; and, if possible, work with those districts to devise approaches that are complementary and serve CEQA's objectives.

Sincerely,

/ s /

TIMOTHY E. SULLIVAN
Deputy Attorney General

For EDMUND G. BROWN JR.
Attorney General

Table 1: E-5 County/State Population and Housing Estimates, 1/1/2006

	------------POPULATION------------			---------------------------------- HOUSING UNITS ----------------------------------								PERSONS PER HOUSE-HOLD
					-------- SINGLE --------		----- MULTIPLE -----					
COUNTY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Alameda	1,507,310	1,478,805	28,505	562,470	301,518	39,257	61,808	152,241	7,646	545,649	2.99	2.710
Alpine	1,225	1,224	1	1,725	992	50	35	586	62	549	68.17	2.230
Amador	37,837	33,347	4,490	16,928	13,707	409	446	793	1,573	14,401	14.93	2.316
Butte	216,351	210,003	6,348	93,383	57,391	2,392	7,849	10,393	15,358	87,174	6.65	2.409
Calaveras	45,372	44,916	456	26,685	22,618	496	523	355	2,693	19,171	28.16	2.343
Colusa	21,330	20,910	420	7,587	5,654	229	412	463	829	6,841	9.83	3.057
Contra Costa	1,026,234	1,014,933	11,301	387,331	256,303	31,755	25,848	65,813	7,612	375,828	2.97	2.701
Del Norte	28,985	25,039	3,946	10,954	6,464	188	804	584	2,914	9,625	12.13	2.601
El Dorado	175,729	174,679	1,050	81,478	65,875	1,824	3,617	5,787	4,375	67,721	16.88	2.579
Fresno	897,835	879,031	18,804	297,408	197,762	10,060	24,941	50,872	13,773	278,195	6.46	3.160
Glenn	28,422	28,027	395	10,522	7,306	207	780	700	1,529	9,674	8.06	2.897
Humboldt	131,575	127,230	4,345	58,550	40,265	1,597	5,817	4,727	6,144	53,641	8.38	2.372
Imperial	166,232	154,385	11,847	51,792	31,253	2,003	3,784	6,956	7,796	46,673	9.88	3.308
Inyo	18,232	17,951	281	9,219	5,517	211	407	468	2,616	7,853	14.82	2.286
Kern	777,719	741,336	36,383	262,934	183,620	8,549	21,466	24,206	25,093	237,491	9.68	3.122
Kings	148,290	125,074	23,216	40,596	28,697	2,425	2,815	4,439	2,220	38,281	5.70	3.267
Lake	63,368	62,171	1,197	34,014	21,504	538	922	924	10,126	25,067	26.30	2.480
Lassen	35,246	25,815	9,431	12,827	8,843	352	517	509	2,606	10,354	19.28	2.493
Los Angeles	10,223,263	10,044,723	178,540	3,364,756	1,633,054	243,464	290,570	1,140,977	56,691	3,223,223	4.21	3.116
Madera	144,257	135,330	8,927	46,639	36,369	1,336	2,434	2,881	3,619	41,823	10.33	3.236
Marin	253,075	242,163	10,912	107,740	65,516	8,586	9,689	21,818	2,131	103,333	4.09	2.344
Mariposa	18,065	16,620	1,445	9,959	6,281	450	214	383	2,631	7,463	25.06	2.227
Mendocino	89,320	87,056	2,264	38,991	27,448	1,163	2,176	2,774	5,430	35,092	10.00	2.481
Merced	245,186	240,455	4,731	80,136	58,608	2,538	5,365	8,001	5,624	74,878	6.56	3.211
Modoc	9,646	9,237	409	5,105	3,470	90	97	159	1,289	4,010	21.45	2.303
Mono	13,586	13,045	541	13,551	5,155	1,259	2,187	3,915	1,035	5,984	55.84	2.180
Monterey	421,417	399,331	22,086	138,617	85,162	12,454	12,117	22,972	5,912	127,743	7.84	3.126
Napa	133,493	128,224	5,269	52,941	35,678	3,495	3,718	6,089	3,961	49,619	6.27	2.584
Nevada	98,798	97,831	967	49,001	40,007	875	1,919	2,399	3,801	40,637	17.07	2.407
Orange	3,066,483	3,022,661	43,822	1,018,418	515,782	127,407	90,540	252,396	32,293	984,564	3.32	3.070
Placer	317,702	314,452	3,250	140,330	108,956	4,142	6,188	16,306	4,738	125,110	10.85	2.513
Plumas	21,011	20,823	188	14,989	11,495	450	375	396	2,273	10,060	32.88	2.070
Riverside	1,962,801	1,926,652	36,149	722,532	475,686	43,103	31,931	86,865	84,947	627,352	13.17	3.071
Sacramento	1,387,257	1,361,754	25,503	535,788	345,444	32,297	36,496	105,842	15,709	512,870	4.28	2.655
San Benito	57,134	56,627	507	17,699	13,770	1,028	1,135	885	881	17,037	3.74	3.324
San Bernardino	1,990,967	1,938,359	52,608	661,668	464,606	27,913	39,658	85,936	43,555	584,076	11.73	3.319

Table 1: E-5 County/State Population and Housing Estimates, 1/1/2006

COUNTY	POPULATION: TOTAL	POPULATION: HOUSEHOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	SINGLE: DETACHED	SINGLE: ATTACHED	MULTIPLE: 2 TO 4	MULTIPLE: 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
San Diego	3,065,077	2,962,996	102,081	1,119,224	574,652	98,406	82,461	316,282	47,423	1,069,740	4.42	2.770
San Francisco	802,994	782,666	20,328	356,985	62,974	48,700	81,809	162,942	560	339,472	4.91	2.306
San Joaquin	665,157	648,042	17,115	219,717	157,953	11,299	13,525	27,367	9,573	211,074	3.93	3.070
San Luis Obispo	263,801	247,929	15,872	112,592	74,110	6,371	8,705	11,478	11,928	102,136	9.29	2.427
San Mateo	724,091	713,633	10,458	266,840	153,126	22,912	18,543	68,688	3,571	260,214	2.48	2.742
Santa Barbara	420,038	402,966	17,072	152,457	88,635	11,499	13,732	29,929	8,662	146,181	4.12	2.757
Santa Clara	1,776,586	1,746,430	30,156	612,129	333,923	54,153	46,861	157,534	19,658	598,061	2.30	2.920
Santa Cruz	261,294	251,710	9,584	103,290	65,254	8,877	8,521	13,384	7,254	95,194	7.84	2.644
Shasta	179,259	175,841	3,418	75,240	51,283	1,496	5,665	5,518	11,278	69,375	7.80	2.535
Sierra	3,470	3,434	36	2,272	1,879	49	47	63	234	1,574	30.72	2.182
Siskiyou	45,615	44,935	680	23,350	16,455	499	1,132	1,294	3,970	19,718	15.55	2.279
Solano	420,353	404,680	15,673	149,193	106,049	7,286	10,624	20,596	4,638	143,819	3.60	2.814
Sonoma	476,956	465,176	11,780	193,860	132,807	14,489	12,370	22,797	11,397	182,709	5.75	2.546
Stanislaus	511,848	504,055	7,793	171,719	128,040	7,520	11,117	15,850	9,192	165,310	3.73	3.049
Sutter	91,338	89,911	1,427	32,472	23,703	1,196	1,918	3,945	1,710	31,013	4.49	2.899
Tehama	60,790	59,768	1,022	25,881	15,822	508	1,253	1,663	6,635	23,076	10.84	2.590
Trinity	13,966	13,747	219	8,346	5,523	112	108	133	2,470	5,843	29.99	2.353
Tulare	418,060	412,117	5,943	132,469	98,813	4,914	9,315	8,092	11,335	122,377	7.62	3.368
Tuolumne	56,861	52,004	4,857	30,071	22,969	652	1,188	1,098	4,164	22,298	25.85	2.332
Ventura	815,758	802,323	13,435	270,587	174,228	27,918	16,748	39,387	12,306	261,639	3.31	3.067
Yolo	191,280	182,714	8,566	70,542	40,542	4,996	4,727	16,592	3,685	68,088	3.48	2.683
Yuba	69,253	68,046	1,207	25,662	16,697	1,291	1,609	2,250	3,815	22,911	10.72	2.970
California	37,114,598	36,255,342	859,256	13,140,161	7,533,213	949,735	1,051,578	3,018,692	586,943	12,370,884	5.85	2.931

Table 1: E-5 County/State Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Alameda	1,443,939	1,416,006	27,933	540,183	290,896	38,470	61,023	142,144	7,650	523,366	3.11	2.706
Alpine	1,208	1,207	1	1,514	880	7	35	530	62	483	68.10	2.499
Amador	35,100	30,519	4,581	15,035	12,238	389	372	550	1,486	12,759	15.14	2.392
Butte	203,171	197,327	5,844	85,523	51,685	2,356	7,644	9,643	14,195	79,566	6.97	2.480
Calaveras	40,554	40,129	425	22,946	19,394	465	495	355	2,237	16,469	28.23	2.437
Colusa	18,804	18,357	447	6,774	5,039	229	395	388	723	6,097	9.99	3.011
Contra Costa	948,816	937,479	11,337	354,577	232,051	29,939	24,919	60,089	7,579	344,129	2.95	2.724
Del Norte	27,507	23,674	3,833	10,434	6,118	182	797	584	2,753	9,170	12.11	2.582
El Dorado	156,299	155,247	1,052	71,278	57,094	1,598	3,410	4,803	4,373	58,939	17.31	2.634
Fresno	799,407	781,740	17,667	270,767	175,370	10,063	24,162	47,830	13,342	252,940	6.58	3.091
Glenn	26,453	26,065	388	9,982	6,961	207	722	705	1,387	9,172	8.11	2.842
Humboldt	126,518	122,445	4,073	55,912	38,282	1,542	5,613	4,547	5,928	51,238	8.36	2.390
Imperial	142,361	131,317	11,044	43,891	25,153	1,916	3,516	5,608	7,698	39,384	10.27	3.334
Inyo	18,071	17,788	283	9,042	5,445	210	407	468	2,512	7,703	14.81	2.309
Kern	661,653	631,683	29,970	231,567	156,361	8,383	20,462	23,308	23,053	208,655	9.89	3.027
Kings	129,461	109,332	20,129	36,563	25,393	2,144	2,722	4,226	2,078	34,418	5.87	3.177
Lake	58,325	57,220	1,105	32,528	20,076	533	897	804	10,218	23,974	26.30	2.387
Lassen	33,828	24,918	8,910	12,000	8,164	296	515	519	2,506	9,625	19.79	2.589
Los Angeles	9,519,330	9,344,078	175,252	3,270,906	1,593,449	241,575	287,511	1,091,766	56,605	3,133,771	4.19	2.982
Madera	123,109	115,009	8,100	40,387	30,876	1,336	2,107	2,691	3,377	36,155	10.48	3.181
Marin	247,289	235,803	11,486	104,990	63,686	8,455	9,343	21,383	2,123	100,650	4.13	2.343
Mariposa	17,130	15,704	1,426	8,826	5,946	71	214	383	2,212	6,613	25.07	2.375
Mendocino	86,265	84,124	2,141	36,937	25,724	1,163	2,107	2,648	5,295	33,266	9.94	2.529
Merced	210,554	207,699	2,855	68,373	48,005	2,533	5,168	7,418	5,249	63,815	6.67	3.255
Modoc	9,449	9,037	412	4,807	3,275	87	98	159	1,188	3,784	21.28	2.388
Mono	12,853	12,495	358	11,757	4,597	1,175	1,836	3,213	936	5,137	56.31	2.432
Monterey	401,762	380,786	20,976	131,708	79,412	12,345	11,818	22,490	5,643	121,236	7.95	3.141
Napa	124,279	119,046	5,233	48,554	32,562	3,216	3,638	5,207	3,931	45,402	6.49	2.622
Nevada	92,033	91,167	866	44,282	36,327	871	1,583	2,116	3,385	36,894	16.68	2.471
Orange	2,846,289	2,803,924	42,365	969,484	489,657	124,702	88,804	233,871	32,450	935,287	3.53	2.998
Placer	248,399	245,511	2,888	107,302	81,465	4,136	5,675	11,357	4,669	93,382	12.97	2.629
Plumas	20,824	20,636	188	13,386	10,137	444	375	396	2,034	9,000	32.77	2.293
Riverside	1,545,387	1,511,034	34,353	584,674	356,451	42,301	30,192	72,842	82,888	506,218	13.42	2.985
Sacramento	1,223,499	1,198,004	25,495	474,814	297,063	32,245	36,309	93,713	15,484	453,602	4.47	2.641
San Benito	53,234	52,727	507	16,499	12,646	1,028	1,106	845	874	15,885	3.72	3.319

California Department of Finance
Demographic Research Unit

Table 1: E-5 County/State Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
San Bernardino	1,710,139	1,664,402	45,737	601,369	416,123	26,829	38,912	77,665	41,840	528,594	12.10	3.149
San Diego	2,813,833	2,716,820	97,013	1,040,149	530,435	98,109	77,223	287,429	46,953	994,677	4.37	2.731
San Francisco	776,733	756,976	19,757	346,527	62,653	48,752	80,851	153,711	560	329,700	4.86	2.296
San Joaquin	563,598	544,827	18,771	189,160	129,306	11,218	13,345	26,100	9,191	181,629	3.98	3.000
San Luis Obispo	246,681	231,110	15,571	102,275	66,090	6,071	8,169	10,874	11,071	92,739	9.32	2.492
San Mateo	707,163	696,713	10,450	260,578	150,286	22,702	18,252	65,854	3,484	254,104	2.48	2.742
Santa Barbara	399,347	382,730	16,617	142,901	82,813	9,733	13,191	28,545	8,619	136,622	4.39	2.801
Santa Clara	1,682,585	1,652,871	29,714	579,329	323,913	52,739	46,371	136,628	19,678	565,863	2.32	2.921
Santa Cruz	255,602	246,574	9,028	98,873	62,751	8,744	8,353	11,773	7,252	91,139	7.82	2.705
Shasta	163,256	159,897	3,359	68,810	46,171	1,457	5,264	5,309	10,609	63,426	7.82	2.521
Sierra	3,555	3,519	36	2,202	1,810	49	47	63	233	1,520	30.97	2.315
Siskiyou	44,301	43,611	690	21,947	15,401	488	1,089	1,259	3,710	18,556	15.45	2.350
Solano	394,930	378,568	16,362	134,513	95,378	6,596	10,217	17,696	4,626	130,403	3.06	2.903
Sonoma	458,614	447,512	11,102	183,153	125,436	13,955	11,706	20,676	11,380	172,403	5.87	2.596
Stanislaus	446,997	439,508	7,489	150,807	109,520	7,188	10,520	15,117	8,462	145,146	3.75	3.028
Sutter	78,930	77,547	1,383	28,319	19,775	1,186	1,886	3,780	1,692	27,033	4.54	2.869
Tehama	56,039	55,034	1,005	23,547	14,187	486	1,214	1,591	6,069	21,013	10.76	2.619
Trinity	13,022	12,780	242	7,980	5,243	112	106	117	2,402	5,587	29.99	2.287
Tulare	368,021	361,980	6,041	119,639	87,838	4,740	8,514	7,819	10,728	110,385	7.73	3.279
Tuolumne	54,504	49,665	4,839	28,336	21,717	653	1,162	1,074	3,730	21,004	25.88	2.365
Ventura	753,197	739,985	13,212	251,711	160,532	27,324	16,408	35,285	12,162	243,234	3.37	3.042
Yolo	168,660	161,145	7,515	61,587	33,924	4,944	4,431	14,679	3,609	59,375	3.59	2.714
Yuba	60,219	58,885	1,334	22,636	13,927	1,241	1,675	2,288	3,505	20,535	9.28	2.868
California	33,873,086	33,051,896	821,190	12,214,550	6,883,107	931,928	1,024,896	2,804,931	569,688	11,502,871	5.83	2.873

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Alameda County												
Alameda	72,259	71,182	1,077	31,644	12,776	3,943	4,984	9,641	300	30,226	4.48	2.355
Albany	16,444	16,411	33	7,248	3,777	181	813	2,471	6	7,011	3.27	2.341
Berkeley	102,743	96,921	5,822	46,875	20,097	1,757	9,298	15,664	59	44,955	4.10	2.156
Dublin	30,023	24,731	5,292	9,895	5,813	1,304	412	2,339	27	9,348	5.53	2.646
Emeryville	6,882	6,815	67	4,274	267	275	484	3,211	37	3,975	7.00	1.714
Fremont	203,413	201,654	1,759	69,452	41,567	7,136	2,968	17,025	756	68,237	1.75	2.955
Hayward	140,030	137,892	2,138	45,922	22,755	3,398	3,349	14,121	2,299	44,804	2.43	3.078
Livermore	73,464	73,147	317	26,613	19,351	2,154	1,147	3,530	431	26,126	1.83	2.800
Newark	42,471	42,382	89	13,150	8,945	1,238	762	2,146	59	12,992	1.20	3.262
Oakland	399,566	392,309	7,257	157,508	71,425	6,645	28,973	50,009	456	150,790	4.27	2.602
Piedmont	10,952	10,950	2	3,859	3,782	0	35	34	8	3,804	1.43	2.879
Pleasanton	63,654	63,419	235	23,968	15,628	2,704	1,138	4,042	456	23,311	2.74	2.721
San Leandro	79,452	78,625	827	31,334	19,021	1,914	2,246	7,249	904	30,642	2.21	2.566
Union City	66,869	66,527	342	18,877	11,971	2,352	1,106	2,525	923	18,642	1.24	3.569
Balance Of County	135,717	133,041	2,676	49,564	33,721	3,469	3,308	8,137	929	48,503	2.14	2.743
Incorporated	1,308,222	1,282,965	25,257	490,619	257,175	35,001	57,715	134,007	6,721	474,863	3.21	2.702
County Total	1,443,939	1,416,006	27,933	540,183	290,896	38,470	61,023	142,144	7,650	523,366	3.11	2.706
Alpine County												
County Total	1,208	1,207	1	1,514	880	7	35	530	62	483	68.10	2.499
Amador County												
Amador	196	196	0	91	74	12	5	0	0	85	6.59	2.306
Ione	7,129	2,898	4,231	1,155	872	54	64	87	78	1,081	6.41	2.681
Jackson	3,989	3,721	268	1,859	1,140	112	148	247	212	1,746	6.08	2.131
Plymouth	980	980	0	457	269	23	24	26	115	392	14.22	2.500
Sutter Creek	2303	2,302	1	1,106	741	105	45	143	72	1,025	7.32	2.246
Balance Of County	20,503	20,422	81	10,367	9,142	83	86	47	1,009	8,430	18.68	2.423
Incorporated	14,597	10,097	4,500	4,668	3,096	306	286	503	477	4,329	7.26	2.332
County Total	35,100	30,519	4,581	15,035	12,238	389	372	550	1,486	12,759	15.14	2.392

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Butte County												
Biggs	1,793	1,793	0	613	505	28	28	5	47	571	6.85	3.140
Chico	60,516	56,891	3,625	24,386	11,875	944	4,043	6,891	633	23,476	3.73	2.423
Gridley	5,408	5,286	122	1,973	1,580	43	135	141	74	1,851	6.18	2.856
Oroville	13,004	12,184	820	5,419	2,879	134	770	1,257	379	4,881	9.93	2.496
Paradise	26,408	25,788	620	12,374	8,536	338	741	290	2,469	11,591	6.33	2.225
Balance Of County	96,042	95,385	657	40,758	26,310	869	1,927	1,059	10,593	37,196	8.74	2.564
Incorporated	107,129	101,942	5,187	44,765	25,375	1,487	5,717	8,584	3,602	42,370	5.35	2.406
County Total	203,171	197,327	5,844	85,523	51,685	2,356	7,644	9,643	14,195	79,566	6.97	2.480
Calaveras County												
Angels City	3,004	3,004	0	1,422	906	67	122	113	214	1,286	9.56	2.336
Balance Of County	37,550	37,125	425	21,524	18,488	398	373	242	2,023	15,183	29.46	2.445
Incorporated	3,004	3,004	0	1,422	906	67	122	113	214	1,286	9.56	2.336
County Total	40,554	40,129	425	22,946	19,394	465	495	355	2,237	16,469	28.23	2.437
Colusa County												
Colusa	5,402	5,329	73	2,016	1,510	84	189	183	50	1,897	5.90	2.809
Williams	3,670	3,420	250	968	694	33	83	91	67	924	4.55	3.701
Balance Of County	9,732	9,608	124	3,790	2,835	112	123	114	606	3,276	13.56	2.933
Incorporated	9,072	8,749	323	2,984	2,204	117	272	274	117	2,821	5.46	3.101
County Total	18,804	18,357	447	6,774	5,039	229	395	388	723	6,097	9.99	3.011
Contra Costa County												
Antioch	90,532	90,116	416	30,116	22,926	1,357	1,769	3,795	269	29,338	2.58	3.072
Brentwood	23,302	23,265	37	7,788	6,413	355	267	405	348	7,497	3.74	3.103
Clayton	10,762	10,736	26	3,924	3,192	681	19	27	5	3,883	1.04	2.765
Concord	121,872	120,428	1,444	45,084	26,952	2,851	2,871	11,033	1,377	44,021	2.36	2.736
Danville	41,715	41,251	464	15,130	11,622	2,557	269	682	0	14,816	2.08	2.784
El Cerrito	23,171	22,995	176	10,462	7,296	343	1,303	1,488	32	10,208	2.43	2.253

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Hercules	19,488	19,449	39	6,546	4,031	1,617	294	604	0	6,423	1.88	3.028
Lafayette	23,908	23,772	136	9,334	7,467	294	425	1,148	0	9,152	1.95	2.597
Martinez	35,866	34,516	1,350	14,597	9,275	2,213	984	2,101	24	14,300	2.03	2.414
Moraga	16,290	14,659	1,631	5,760	3,997	968	243	545	7	5,662	1.70	2.589
Oakley	25,619	25,552	67	7,946	7,279	84	54	110	419	7,832	1.43	3.263
Orinda	17,599	17,532	67	6,744	6,243	188	87	219	7	6,596	2.19	2.658
Pinole	19,039	18,821	218	6,828	5,023	498	359	933	15	6,743	1.24	2.791
Pittsburg	56,769	56,263	506	18,300	11,944	1,296	1,330	3,060	670	17,741	3.05	3.171
Pleasant Hill	32,837	32,377	460	14,034	8,338	1,466	704	3,465	61	13,753	2.00	2.354
Richmond	99,216	97,588	1,628	36,044	20,468	2,928	5,252	7,275	121	34,625	3.94	2.818
San Pablo	30,256	29,791	465	9,354	4,145	760	1,293	2,361	795	9,065	3.09	3.286
San Ramon	44,722	44,637	85	17,552	10,720	1,988	1,009	3,824	11	16,944	3.46	2.634
Walnut Creek	64,296	63,332	964	31,425	12,032	4,791	4,030	10,524	48	30,301	3.58	2.090
Balance Of County	151,557	150,399	1,158	57,609	42,688	2,704	2,357	6,490	3,370	55,229	4.13	2.723
Incorporated	797,259	787,080	10,179	296,968	189,363	27,235	22,562	53,599	4,209	288,900	2.72	2.724
County Total	948,816	937,479	11,337	354,577	232,051	29,939	24,919	60,089	7,579	344,129	2.95	2.724
Del Norte County												
Crescent City	7,347	3,793	3,554	1,754	862	50	389	424	29	1,578	10.03	2.404
Balance Of County	20,160	19,881	279	8,680	5,256	132	408	160	2,724	7,592	12.53	2.619
Incorporated	7,347	3,793	3,554	1,754	862	50	389	424	29	1,578	10.03	2.404
County Total	27,507	23,674	3,833	10,434	6,118	182	797	584	2,753	9,170	12.11	2.582
El Dorado County												
Placerville	9,610	9,348	262	4,242	2,640	256	540	647	159	4,001	5.68	2.336
South Lake Tahoe	23,609	23,481	128	14,005	8,754	366	1,973	2,244	668	9,410	32.81	2.495
Balance Of County	123,080	122,418	662	53,031	45,700	976	897	1,912	3,546	45,528	14.15	2.689
Incorporated	33,219	32,829	390	18,247	11,394	622	2,513	2,891	827	13,411	26.50	2.448
County Total	156,299	155,247	1,052	71,278	57,094	1,598	3,410	4,803	4,373	58,939	17.31	2.634

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Fresno County												
Clovis	68,516	68,036	480	25,265	16,337	549	3,086	4,377	916	24,362	3.57	2.793
Coalinga	15,798	10,448	5,350	3,714	2,440	127	283	546	318	3,381	8.97	3.090
Firebaugh	5,743	5,682	61	1,581	1,009	156	189	141	86	1,418	10.31	4.007
Fowler	4,046	3,997	49	1,305	888	50	157	163	47	1,270	2.68	3.147
Fresno	427,652	419,465	8,187	149,025	86,592	6,028	16,308	36,174	3,923	140,079	6.00	2.994
Huron	6,310	6,138	172	1,415	470	204	228	445	68	1,379	2.54	4.451
Kerman	8,548	8,517	31	2,461	1,606	153	246	340	116	2,388	2.97	3.567
Kingsburg	9,231	9,140	91	3,377	2,448	104	222	439	164	3,245	3.91	2.817
Mendota	7,890	7,882	8	1,878	1,124	139	230	313	72	1,825	2.82	4.319
Orange Cove	7,722	7,722	0	1,767	1,072	206	222	241	26	1,694	4.13	4.558
Parlier	11,145	11,043	102	2,644	1,808	234	184	404	14	2,446	7.49	4.515
Reedley	20,756	20,361	395	5,972	4,136	216	578	851	191	5,761	3.53	3.534
Sanger	18,931	18,791	140	5,420	3,812	194	563	688	163	5,220	3.69	3.600
San Joaquin	3,270	3,270	0	735	417	80	115	63	60	702	4.49	4.658
Selma	19,444	19,314	130	5,815	4,247	148	246	752	422	5,596	3.77	3.451
Balance Of County	164,405	161,934	2,471	58,393	46,964	1,475	1,305	1,893	6,756	52,174	10.65	3.104
Incorporated	635,002	619,806	15,196	212,374	128,406	8,588	22,857	45,937	6,586	200,766	5.47	3.087
County Total	799,407	781,740	17,667	270,767	175,370	10,063	24,162	47,830	13,342	252,940	6.58	3.091
Glenn County												
Orland	6,281	6,257	24	2,309	1,709	44	322	202	32	2,190	5.15	2.857
Willows	6,220	6,039	181	2,368	1,544	54	305	458	7	2,134	9.88	2.830
Balance Of County	13,952	13,769	183	5,305	3,708	109	95	45	1,348	4,848	8.61	2.840
Incorporated	12,501	12,296	205	4,677	3,253	98	627	660	39	4,324	7.55	2.844
County Total	26,453	26,065	388	9,982	6,961	207	722	705	1,387	9,172	8.11	2.842
Humboldt County												
Arcata	16,651	15,220	1,431	7,272	3,328	249	1,169	1,843	683	7,051	3.04	2.159
Blue Lake	1,137	1,137	0	557	361	21	68	36	71	505	9.34	2.251
Eureka	26,128	24,773	1,355	11,637	7,204	381	2,193	1,685	174	10,957	5.84	2.261
Ferndale	1,382	1,382	0	663	537	27	80	10	9	611	7.84	2.262
Fortuna	10,498	10,263	235	4,414	2,912	229	520	311	442	4,185	5.19	2.452

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Rio Dell	3,174	3,164	10	1,434	995	26	150	36	227	1,221	14.85	2.591
Trinidad	312	312	0	228	179	7	11	0	31	168	26.32	1.857
Balance Of County	67,236	66,194	1,042	29,707	22,766	602	1,422	626	4,291	26,540	10.66	2.494
Incorporated	59,282	56,251	3,031	26,205	15,516	940	4,191	3,921	1,637	24,698	5.75	2.278
County Total	126,518	122,445	4,073	55,912	38,282	1,542	5,613	4,547	5,928	51,238	8.36	2.390
Imperial County												
Brawley	22,052	21,740	312	7,038	4,479	361	637	1,105	456	6,631	5.78	3.279
Calexico	27,109	27,006	103	6,983	4,465	439	888	986	205	6,814	2.42	3.963
Calipatria	7,289	3,194	4,095	961	710	38	75	76	62	899	6.45	3.553
El Centro	38,025	37,138	887	12,323	6,479	563	1,063	2,900	1,318	11,499	6.69	3.230
Holtville	5,612	5,482	130	1,617	1,035	111	117	162	192	1,564	3.28	3.505
Imperial	7,560	7,528	32	2,385	1,874	91	227	164	29	2,308	3.23	3.262
Westmorland	2,131	2,131	0	667	421	16	90	102	38	625	6.30	3.410
Balance Of County	32,583	27,098	5,485	11,917	5,690	297	419	113	5,398	9,044	24.11	2.996
Incorporated	109,778	104,219	5,559	31,974	19,463	1,619	3,097	5,495	2,300	30,340	5.11	3.435
County Total	142,361	131,317	11,044	43,891	25,153	1,916	3,516	5,608	7,698	39,384	10.27	3.334
Inyo County												
Bishop	3,575	3,498	77	1,867	843	76	262	323	363	1,684	9.80	2.077
Balance Of County	14,496	14,290	206	7,175	4,602	134	145	145	2,149	6,019	16.11	2.374
Incorporated	3,575	3,498	77	1,867	843	76	262	323	363	1,684	9.80	2.077
County Total	18,071	17,788	283	9,042	5,445	210	407	468	2,512	7,703	14.81	2.309
Kern County												
Arvin	12,956	12,885	71	3,145	2,129	217	264	279	256	3,010	4.29	4.281
Bakersfield	246,899	243,254	3,645	88,266	57,632	3,224	10,002	14,868	2,540	83,445	5.46	2.915
California City	8,385	8,327	58	3,560	2,660	68	312	214	306	3,067	13.85	2.715
Delano	39,499	33,777	5,722	8,832	6,130	547	589	1,117	449	8,411	4.77	4.016
Maricopa	1,111	1,111	0	460	247	7	5	9	192	404	12.17	2.750

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Mcfarland	9,835	8,547	1,288	2,030	1,555	153	235	60	27	1,989	2.02	4.297
Ridgecrest	24,927	24,618	309	11,309	7,445	412	1,697	765	990	9,826	13.11	2.505
Shafter	12,731	12,084	647	3,623	2,718	177	280	237	211	3,292	9.14	3.671
Taft	8,811	5,841	2,970	2,478	1,781	52	315	234	96	2,233	9.89	2.616
Tehachapi	11,125	6,558	4,567	2,914	1,843	135	385	281	270	2,533	13.07	2.589
Wasco	21,263	15,044	6,219	4,256	3,069	326	413	318	130	3,971	6.70	3.788
Balance Of County	264,111	259,637	4,474	100,694	69,152	3,065	5,965	4,926	17,586	86,474	14.12	3.002
Incorporated	397,542	372,046	25,496	130,873	87,209	5,318	14,497	18,382	5,467	122,181	6.64	3.045
County Total	661,653	631,683	29,970	231,567	156,361	8,383	20,462	23,308	23,053	208,655	9.89	3.027
Kings County												
Avenal	14,674	7,973	6,701	2,061	1,392	50	303	224	92	1,928	6.45	4.135
Corcoran	20,843	9,539	11,304	3,020	2,144	180	270	303	123	2,772	8.21	3.441
Hanford	41,687	40,839	848	14,722	10,401	552	1,387	2,041	341	13,932	5.37	2.931
Lemoore	19,712	19,710	2	6,823	4,349	143	459	1,543	329	6,450	5.47	3.056
Balance Of County	32,545	31,271	1,274	9,937	7,107	1,219	303	115	1,193	9,336	6.05	3.350
Incorporated	96,916	78,061	18,855	26,626	18,286	925	2,419	4,111	885	25,082	5.80	3.112
County Total	129,461	109,332	20,129	36,563	25,393	2,144	2,722	4,226	2,078	34,418	5.87	3.177
Lake County												
Clearlake	13,147	13,028	119	7,607	3,632	99	249	220	3,407	5,534	27.25	2.354
Lakeport	4,820	4,646	174	2,394	1,438	119	158	223	456	1,967	17.84	2.362
Balance Of County	40,358	39,546	812	22,527	15,006	315	490	361	6,355	16,473	26.87	2.401
Incorporated	17,967	17,674	293	10,001	5,070	218	407	443	3,863	7,501	25.00	2.356
County Total	58,325	57,220	1,105	32,528	20,076	533	897	804	10,218	23,974	26.30	2.387
Lassen County												
Susanville	17,465	8,777	8,688	3,899	2,721	131	377	460	210	3,533	9.39	2.484
Balance Of County	16,363	16,141	222	8,101	5,443	165	138	59	2,296	6,092	24.80	2.650

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Incorporated	17,465	8,777	8,688	3,899	2,721	131	377	460	210	3,533	9.39	2.484
County Total	33,828	24,918	8,910	12,000	8,164	296	515	519	2,506	9,625	19.79	2.589
Los Angeles County												
Agoura Hills	20,537	20,514	23	6,993	5,220	979	176	618	0	6,874	1.70	2.984
Alhambra	85,757	83,834	1,923	30,045	12,752	3,266	3,950	10,060	17	29,087	3.19	2.882
Arcadia	53,054	52,473	581	19,970	11,799	1,609	1,379	5,157	26	19,149	4.11	2.740
Artesia	16,380	15,808	572	4,598	3,184	329	316	673	96	4,470	2.78	3.536
Avalon	3,279	3,217	62	1,881	495	487	545	345	9	1,200	36.20	2.681
Azusa	44,712	42,763	1,949	13,013	5,733	1,766	1,465	3,460	589	12,549	3.57	3.408
Baldwin Park	75,837	75,231	606	17,430	11,747	1,861	601	2,878	343	16,961	2.69	4.436
Bell	36,664	36,126	538	9,215	3,557	1,517	1,453	2,228	460	8,918	3.22	4.051
Bellflower	72,878	72,255	623	24,247	11,239	2,085	1,432	7,889	1,602	23,367	3.63	3.092
Bell Gardens	44,054	43,598	456	9,788	3,950	2,469	1,447	1,526	396	9,466	3.29	4.606
Beverly Hills	33,784	33,745	39	15,856	5,664	236	1,802	8,126	28	15,035	5.18	2.244
Bradbury	855	855	0	311	309	0	2	0	0	284	8.68	3.011
Burbank	100,316	99,490	826	42,847	19,895	1,744	4,737	16,359	112	41,608	2.89	2.391
Calabasas	21,356	21,296	60	8,107	5,512	804	204	1,334	253	7,844	3.24	2.715
Carson	89,730	88,520	1,210	25,337	17,676	2,280	716	2,160	2,505	24,648	2.72	3.591
Cerritos	51,488	51,395	93	15,607	13,359	1,220	600	396	32	15,390	1.39	3.340
Claremont	33,998	28,894	5,104	11,559	8,136	843	620	1,947	13	11,281	2.41	2.561
Commerce	12,568	12,465	103	3,377	1,943	551	328	551	4	3,284	2.75	3.796
Compton	93,493	92,843	650	23,795	15,826	2,140	2,266	2,925	638	22,327	6.17	4.158
Covina	46,837	46,235	602	16,364	9,333	1,297	977	4,169	588	15,971	2.40	2.895
Cudahy	24,208	24,196	12	5,542	1,640	1,291	345	1,853	413	5,419	2.22	4.465
Culver City	38,816	38,292	524	17,130	6,605	1,903	2,301	6,140	181	16,611	3.03	2.305
Diamond Bar	56,287	56,169	118	17,959	12,606	2,501	823	1,696	333	17,651	1.72	3.182
Downey	107,323	105,558	1,765	34,759	20,347	1,662	1,623	10,934	193	33,989	2.22	3.106
Duarte	21,488	20,998	490	6,806	4,284	872	224	1,197	229	6,636	2.50	3.164
El Monte	115,965	114,695	1,270	27,758	14,646	3,388	2,024	6,298	1,402	27,034	2.61	4.243
El Segundo	16,033	16,010	23	7,261	3,093	416	817	2,924	11	7,060	2.77	2.268
Gardena	57,746	56,942	804	21,041	8,916	1,711	2,675	6,636	1,103	20,324	3.41	2.802
Glendale	194,973	192,109	2,864	73,713	26,035	3,814	6,917	36,850	97	71,805	2.59	2.675
Glendora	49,415	48,408	1,007	17,145	12,444	1,094	695	2,029	883	16,819	1.90	2.878
Hawaiian Gardens	14,779	14,775	4	3,624	1,492	469	444	944	275	3,507	3.23	4.213
Hawthorne	84,112	83,612	500	29,629	8,165	2,429	3,313	15,549	173	28,536	3.69	2.930
Hermosa Beach	18,566	18,453	113	9,840	4,035	986	2,173	2,564	82	9,476	3.70	1.947

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Hidden Hills	1,875	1,875	0	592	590	2	0	0	0	568	4.05	3.301
Huntington Park	61,348	61,167	181	15,335	5,266	2,370	2,209	5,476	14	14,860	3.10	4.116
Industry	777	513	264	124	101	23	0	0	0	121	2.42	4.240
Inglewood	112,580	111,210	1,370	38,648	13,919	3,224	4,734	16,533	238	36,805	4.77	3.022
Irwindale	1,446	1,444	2	378	318	15	13	24	8	365	3.44	3.956
La Canada Flintridge	20,318	20,129	189	6,989	6,482	200	132	175	0	6,823	2.38	2.950
La Habra Heights	5,712	5,712	0	1,951	1,919	24	8	0	0	1,887	3.28	3.027
Lakewood	79,345	79,151	194	27,310	22,219	741	686	3,566	98	26,853	1.67	2.948
La Mirada	46,783	45,144	1,639	14,811	11,756	794	358	1,737	166	14,580	1.56	3.096
Lancaster	118,718	111,703	7,015	41,745	27,022	1,200	2,726	7,303	3,494	38,224	8.43	2.922
La Puente	41,063	41,031	32	9,660	6,330	640	340	2,241	109	9,461	2.06	4.337
La Verne	31,638	30,930	708	11,286	7,483	599	734	707	1,763	11,070	1.91	2.794
Lawndale	31,711	31,625	86	9,869	4,925	1,606	905	2,305	128	9,555	3.18	3.310
Lomita	20,046	19,913	133	8,295	4,003	766	581	2,447	498	8,015	3.38	2.484
Long Beach	461,522	451,341	10,181	171,632	69,003	10,091	23,382	66,627	2,529	163,088	4.98	2.767
Los Angeles	3,694,742	3,612,145	82,597	1,337,654	524,781	87,775	129,066	586,950	9,082	1,275,360	4.66	2.832
Lynwood	69,845	67,645	2,200	14,987	8,171	1,677	1,713	3,314	112	14,395	3.95	4.699
Malibu	12,575	12,275	300	6,126	3,819	475	400	822	610	5,137	16.14	2.390
Manhattan Beach	33,852	33,838	14	15,034	10,150	1,342	2,622	887	33	14,474	3.72	2.338
Maywood	28,083	27,989	94	6,701	2,809	1,110	1,435	1,339	8	6,469	3.46	4.327
Monrovia	36,929	36,636	293	13,957	7,649	1,549	1,328	3,316	115	13,502	3.26	2.713
Montebello	62,150	61,841	309	19,416	9,357	1,573	2,863	5,390	233	18,844	2.95	3.282
Monterey Park	60,051	59,774	277	20,209	11,480	2,206	2,044	4,399	80	19,564	3.19	3.055
Norwalk	104,323	101,951	2,372	27,555	20,198	1,412	823	4,667	455	26,888	2.42	3.792
Palmdale	116,670	116,576	94	37,096	28,254	905	940	5,215	1,782	34,285	7.58	3.400
Palos Verdes Estates	13,340	13,335	5	5,202	4,780	40	44	338	0	4,993	4.02	2.671
Paramount	55,266	54,946	320	14,591	6,042	2,169	1,086	3,922	1,372	13,972	4.24	3.933
Pasadena	133,936	130,418	3,518	54,132	24,785	4,137	4,647	20,490	73	51,844	4.23	2.516
Pico Rivera	63,428	63,078	350	16,807	12,634	934	337	2,312	590	16,468	2.02	3.830
Pomona	149,473	144,432	5,041	39,598	24,174	3,339	3,233	7,147	1,705	37,855	4.40	3.815
Rancho Palos Verdes	41,145	40,636	509	15,709	12,126	1,287	245	2,051	0	15,256	2.88	2.664
Redondo Beach	63,261	63,074	187	29,543	11,452	4,207	4,063	9,441	380	28,566	3.31	2.208
Rolling Hills	1,871	1,871	0	682	675	7	0	0	0	645	5.43	2.901
Rolling Hills Estates	7,676	7,664	12	2,880	2,263	565	41	7	4	2,806	2.57	2.731
Rosemead	53,505	52,893	612	14,345	9,791	2,030	909	1,211	404	13,913	3.01	3.802
San Dimas	34,980	33,771	1,209	12,503	7,481	2,100	361	1,618	943	12,163	2.72	2.777
San Fernando	23,564	23,518	46	5,932	3,985	634	478	762	73	5,774	2.66	4.073
San Gabriel	39,804	39,049	755	12,909	6,983	1,156	1,077	3,649	44	12,587	2.49	3.102
San Marino	12,945	12,938	7	4,437	4,401	19	8	9	0	4,266	3.85	3.033

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Clarita	151,131	149,738	1,393	52,456	31,784	6,314	2,547	9,571	2,240	50,798	3.16	2.948
Santa Fe Springs	16,413	16,195	218	4,932	3,095	286	158	1,266	127	4,833	2.01	3.351
Santa Monica	84,084	81,568	2,516	47,863	9,265	1,928	5,559	30,822	289	44,497	7.03	1.833
Sierra Madre	10,578	10,451	127	4,923	3,400	205	377	914	27	4,756	3.39	2.197
Signal Hill	9,333	9,279	54	3,797	977	461	676	1,675	8	3,621	4.64	2.563
South El Monte	21,144	21,126	18	4,724	2,934	458	233	595	504	4,620	2.20	4.573
South Gate	96,375	96,234	141	24,269	12,339	3,261	3,695	4,696	278	23,213	4.35	4.146
South Pasadena	24,339	24,152	187	10,874	5,058	621	1,103	4,078	14	10,501	3.43	2.300
Temple City	33,377	32,866	511	11,674	9,410	802	421	983	58	11,338	2.88	2.899
Torrance	137,946	136,697	1,249	55,967	30,131	3,693	3,241	17,719	1,183	54,542	2.55	2.506
Vernon	91	91	0	26	19	0	0	7	0	25	3.85	3.640
Walnut	30,004	29,964	40	8,395	8,038	119	46	192	0	8,260	1.61	3.628
West Covina	105,080	104,272	808	32,058	21,007	2,812	1,570	6,321	348	31,411	2.02	3.320
West Hollywood	35,794	35,564	230	24,162	1,817	683	1,840	19,822	0	23,172	4.10	1.535
Westlake Village	8,368	8,359	9	3,347	2,205	608	158	201	175	3,270	2.30	2.556
Whittier	83,639	81,291	2,348	28,958	19,038	1,480	2,052	6,174	214	28,252	2.44	2.877
Balance Of County	986,050	969,276	16,774	293,304	201,719	22,882	17,874	39,918	10,911	279,781	4.61	3.464
Incorporated	8,533,280	8,374,802	158,478	2,977,602	1,391,730	218,693	269,637	1,051,848	45,694	2,853,990	4.15	2.934
County Total	9,519,330	9,344,078	175,252	3,270,906	1,593,449	241,575	287,511	1,091,766	56,605	3,133,771	4.19	2.982
Madera County												
Chowchilla	14,416	7,540	6,876	2,711	2,143	31	254	247	36	2,562	5.50	2.943
Madera	43,205	42,767	438	12,520	8,158	742	1,292	2,027	301	11,977	4.34	3.571
Balance Of County	65,488	64,702	786	25,156	20,575	563	561	417	3,040	21,616	14.07	2.993
Incorporated	57,621	50,307	7,314	15,231	10,301	773	1,546	2,274	337	14,539	4.54	3.460
County Total	123,109	115,009	8,100	40,387	30,876	1,336	2,107	2,691	3,377	36,155	10.48	3.181
Marin County												
Belvedere	2,125	2,125	0	1,059	868	54	94	43	0	956	9.73	2.223
Corte Madera	9,100	9,092	8	3,850	2,613	416	251	561	9	3,776	1.92	2.408
Fairfax	7,319	7,289	30	3,418	2,329	193	492	393	11	3,306	3.28	2.205
Larkspur	12,014	11,859	155	6,413	2,432	365	544	2,833	239	6,142	4.23	1.931
Mill Valley	13,600	13,509	91	6,286	4,091	536	532	1,127	0	6,147	2.21	2.198

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Novato	47,630	46,648	982	18,994	10,938	2,607	1,164	3,572	713	18,524	2.47	2.518
Ross	2,329	2,235	94	805	785	0	12	0	8	761	5.47	2.937
San Anselmo	12,378	12,122	256	5,408	3,971	185	458	776	18	5,267	2.61	2.301
San Rafael	56,063	54,043	2,020	22,947	10,482	1,991	2,431	7,554	489	22,370	2.51	2.416
Sausalito	7,330	7,318	12	4,511	1,706	423	1,353	805	224	4,254	5.70	1.720
Tiburon	8,666	8,560	106	3,893	2,376	237	443	837	0	3,712	4.65	2.306
Balance Of County	68,735	61,003	7,732	27,406	21,095	1,448	1,569	2,882	412	25,435	7.19	2.398
Incorporated	178,554	174,800	3,754	77,584	42,591	7,007	7,774	18,501	1,711	75,215	3.05	2.324
County Total	247,289	235,803	11,486	104,990	63,686	8,455	9,343	21,383	2,123	100,650	4.13	2.343
Mariposa County												
County Total	17,130	15,704	1,426	8,826	5,946	71	214	383	2,212	6,613	25.07	2.375
Mendocino County												
Fort Bragg	6,814	6,688	126	3,051	1,977	158	312	459	145	2,840	6.92	2.355
Point Arena	474	474	0	218	134	7	45	13	19	191	12.39	2.482
Ukiah	15,497	14,763	734	6,137	3,445	379	752	1,099	462	5,985	2.48	2.467
Willits	5,073	4,947	126	2,013	1,185	84	303	299	142	1,935	3.87	2.557
Balance Of County	58,407	57,252	1,155	25,518	18,983	535	695	778	4,527	22,315	12.55	2.566
Incorporated	27,858	26,872	986	11,419	6,741	628	1,412	1,870	768	10,951	4.10	2.454
County Total	86,265	84,124	2,141	36,937	25,724	1,163	2,107	2,648	5,295	33,266	9.94	2.529
Merced County												
Atwater	23,113	22,848	265	8,114	5,199	584	834	990	507	7,247	10.69	3.153
Dos Palos	4,385	4,361	24	1,437	1,222	55	44	78	38	1,370	4.66	3.183
Gustine	4,698	4,698	0	1,763	1,402	30	98	105	128	1,683	4.54	2.791
Livingston	10,473	10,436	37	2,449	1,860	80	168	305	36	2,390	2.41	4.367
Los Banos	25,869	25,694	175	8,049	6,328	263	526	658	274	7,721	4.08	3.328
Merced	63,893	62,523	1,370	21,532	12,459	941	2,716	4,708	708	20,435	5.09	3.060
Balance Of County	78,123	77,139	984	25,029	19,535	580	782	574	3,558	22,969	8.23	3.358
Incorporated	132,431	130,560	1,871	43,344	28,470	1,953	4,386	6,844	1,691	40,846	5.76	3.196

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County Total	210,554	207,699	2,855	68,373	48,005	2,533	5,168	7,418	5,249	63,815	6.67	3.255
Modoc County												
Alturas	2,892	2,812	80	1,367	1,020	54	48	144	101	1,181	13.61	2.381
Balance Of County	6,557	6,225	332	3,440	2,255	33	50	15	1,087	2,603	24.33	2.391
Incorporated	2,892	2,812	80	1,367	1,020	54	48	144	101	1,181	13.61	2.381
County Total	9,449	9,037	412	4,807	3,275	87	98	159	1,188	3,784	21.28	2.388
Mono County												
Mammoth Lakes	7,093	6,875	218	7,960	2,123	965	1,540	3,139	193	2,814	64.65	2.443
Balance Of County	5,760	5,620	140	3,797	2,474	210	296	74	743	2,323	38.82	2.419
Incorporated	7,093	6,875	218	7,960	2,123	965	1,540	3,139	193	2,814	64.65	2.443
County Total	12,853	12,495	358	11,757	4,597	1,175	1,836	3,213	936	5,137	56.31	2.432
Monterey County												
Carmel-By-The-Sea	4,081	4,081	0	3,334	2,739	111	214	270	0	2,285	31.46	1.786
Del Rey Oaks	1,650	1,650	0	727	567	25	23	109	3	704	3.16	2.344
Gonzales	7,564	7,491	73	1,724	1,216	128	169	169	42	1,695	1.68	4.419
Greenfield	12,648	12,552	96	2,726	1,838	282	274	247	85	2,643	3.04	4.749
King City	11,204	11,020	184	2,822	1,556	278	284	415	289	2,736	3.05	4.028
Marina	18,925	18,794	131	8,537	3,382	1,537	1,455	1,743	420	6,745	20.99	2.786
Monterey	29,696	26,839	2,857	13,383	5,895	913	2,248	4,306	21	12,601	5.84	2.130
Pacific Grove	15,522	15,347	175	8,032	5,002	448	981	1,510	91	7,316	8.91	2.098
Salinas	142,685	140,248	2,437	39,658	20,991	3,439	3,454	10,508	1,266	38,297	3.43	3.662
Sand City	261	197	64	87	50	5	18	9	5	80	8.05	2.463
Seaside	33,097	31,593	1,504	11,005	6,107	2,279	929	1,258	432	9,833	10.65	3.213
Soledad	23,015	11,212	11,803	2,534	1,681	205	315	210	123	2,472	2.45	4.536
Balance Of County	101,414	99,762	1,652	37,139	28,388	2,695	1,454	1,736	2,866	33,829	8.91	2.949
Incorporated	300,348	281,024	19,324	94,569	51,024	9,650	10,364	20,754	2,777	87,407	7.57	3.215

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County Total	401,762	380,786	20,976	131,708	79,412	12,345	11,818	22,490	5,643	121,236	7.95	3.141
Napa County												
American Canyon	9,774	9,640	134	3,274	2,339	23	70	61	781	3,209	1.99	3.004
Calistoga	5,190	5,123	67	2,249	1,045	97	186	361	560	2,042	9.20	2.509
Napa	72,585	71,126	1,459	27,776	17,342	2,059	2,766	4,220	1,389	26,978	2.87	2.636
St Helena	5,950	5,898	52	2,707	1,643	215	210	478	161	2,380	12.08	2.478
Yountville	3,297	2,067	1,230	1,148	598	172	35	35	308	1,057	7.93	1.956
Balance Of County	27,483	25,192	2,291	11,400	9,595	650	371	52	732	9,736	14.60	2.588
Incorporated	96,796	93,854	2,942	37,154	22,967	2,566	3,267	5,155	3,199	35,666	4.00	2.631
County Total	124,279	119,046	5,233	48,554	32,562	3,216	3,638	5,207	3,931	45,402	6.49	2.622
Nevada County												
Grass Valley	10,922	10,662	260	5,266	2,450	256	743	1,317	500	5,016	4.75	2.126
Nevada City	2,996	2,809	187	1,414	1,094	53	117	78	72	1,312	7.21	2.141
Truckee	13,864	13,823	41	9,757	8,319	242	493	406	297	5,149	47.23	2.685
Balance Of County	64,251	63,873	378	27,845	24,464	320	230	315	2,516	25,417	8.72	2.513
Incorporated	27,782	27,294	488	16,437	11,863	551	1,353	1,801	869	11,477	30.18	2.378
County Total	92,033	91,167	866	44,282	36,327	871	1,583	2,116	3,385	36,894	16.68	2.471
Orange County												
Anaheim	328,014	324,218	3,796	99,719	42,929	8,923	10,393	33,090	4,384	96,969	2.76	3.344
Brea	35,410	35,282	128	13,327	7,477	1,077	428	3,475	870	13,067	1.95	2.700
Buena Park	77,962	77,028	934	23,690	13,911	1,864	1,417	6,207	291	23,199	2.07	3.320
Costa Mesa	108,724	105,454	3,270	40,406	15,350	4,117	5,855	13,871	1,213	39,206	2.97	2.690
Cypress	46,549	46,228	321	16,164	9,975	2,466	517	2,842	364	15,787	2.33	2.928
Dana Point	35,110	34,868	242	15,682	7,678	2,266	2,796	2,573	369	14,456	7.82	2.412
Fountain Valley	54,978	54,466	512	18,473	12,361	2,194	644	2,876	398	18,162	1.68	2.999
Fullerton	126,003	123,233	2,770	44,771	22,485	3,728	3,636	14,001	921	43,609	2.60	2.826
Garden Grove	165,196	162,962	2,234	46,703	26,402	4,486	3,407	10,591	1,817	45,791	1.95	3.559
Huntington Beach	189,627	188,835	792	75,679	36,952	9,457	9,666	16,463	3,141	73,674	2.65	2.563
Irvine	143,072	135,960	7,112	53,711	21,363	12,964	4,007	14,355	1,022	51,199	4.68	2.656

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Laguna Beach	23,727	23,605	122	12,965	8,051	758	1,758	2,074	324	11,511	11.21	2.051
Laguna Hills	29,891	29,467	424	10,324	5,473	1,899	608	2,127	217	10,003	3.11	2.946
Laguna Niguel	61,891	61,588	303	23,885	13,167	5,007	1,341	4,354	16	23,217	2.80	2.653
Laguna Woods	17,794	17,720	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.407
La Habra	58,974	58,379	595	19,441	10,194	1,659	1,344	5,508	736	18,947	2.54	3.081
Lake Forest	58,707	57,869	838	20,486	10,856	2,828	1,251	4,265	1,286	20,008	2.33	2.892
La Palma	15,408	15,377	31	5,066	3,632	376	102	929	27	4,979	1.72	3.088
Los Alamitos	11,536	11,130	406	4,329	1,914	243	1,029	1,014	129	4,246	1.92	2.621
Mission Viejo	93,102	92,037	1,065	32,985	24,246	4,021	1,117	3,512	89	32,449	1.62	2.836
Newport Beach	70,032	69,092	940	37,288	16,095	6,685	5,351	8,294	863	33,071	11.31	2.089
Orange	128,868	123,536	5,332	41,920	23,769	5,149	4,654	7,009	1,339	40,946	2.32	3.017
Placentia	46,488	46,185	303	15,326	9,209	2,033	1,098	2,426	560	15,037	1.89	3.071
Rancho Santa Margarita	47,214	47,200	14	16,515	8,976	3,889	571	3,079	0	16,253	1.59	2.904
San Clemente	49,936	49,644	292	20,653	10,886	2,384	3,748	3,232	403	19,395	6.09	2.560
San Juan Capistrano	33,826	33,400	426	11,320	5,730	2,395	944	775	1,476	10,930	3.45	3.056
Santa Ana	337,977	332,353	5,624	74,588	33,504	6,387	7,522	23,266	3,909	73,002	2.13	4.553
Seal Beach	24,157	23,903	254	14,267	4,539	2,121	1,169	6,275	163	13,048	8.54	1.832
Stanton	37,403	36,885	518	11,011	2,934	1,873	988	3,954	1,262	10,767	2.22	3.426
Tustin	67,504	67,086	418	25,501	8,075	3,459	3,836	9,223	908	23,831	6.55	2.815
Villa Park	5,952	5,931	21	1,992	1,963	18	0	6	5	1,934	2.91	3.067
Westminster	88,207	87,655	552	26,940	14,740	2,445	2,069	4,618	3,068	26,406	1.98	3.320
Yorba Linda	58,918	58,783	135	19,567	15,369	2,081	534	1,272	311	19,252	1.61	3.053
Balance Of County	168,132	166,565	1,567	61,161	38,725	9,438	2,530	9,925	543	58,345	4.60	2.855
Incorporated	2,678,157	2,637,359	40,798	908,323	450,932	115,264	86,274	223,946	31,907	876,942	3.45	3.007
County Total	2,846,289	2,803,924	42,365	969,484	489,657	124,702	88,804	233,871	32,450	935,287	3.53	2.998
Placer County												
Auburn	12,462	12,256	206	5,457	3,646	211	655	945	0	5,302	2.84	2.312
Colfax	1,520	1,519	1	647	438	15	108	63	23	625	3.40	2.430
Lincoln	11,205	11,091	114	4,146	3,088	196	174	593	95	3,874	6.56	2.863
Loomis	6,260	6,226	34	2,273	1,896	199	58	9	111	2,206	2.95	2.822
Rocklin	36,330	36,310	20	14,421	10,267	517	574	2,624	439	13,258	8.06	2.739
Roseville	79,921	78,993	928	31,925	23,653	1,082	1,627	5,020	543	30,783	3.58	2.566
Balance Of County	100,701	99,116	1,585	48,433	38,477	1,916	2,479	2,103	3,458	37,334	22.92	2.655
Incorporated	147,698	146,395	1,303	58,869	42,988	2,220	3,196	9,254	1,211	56,048	4.79	2.612

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	248,399	245,511	2,888	107,302	81,465	4,136	5,675	11,357	4,669	93,382	12.97	2.629
Plumas County												
Portola	2,227	2,206	21	1,008	763	11	72	110	52	899	10.81	2.454
Balance Of County	18,597	18,430	167	12,378	9,374	433	303	286	1,982	8,101	34.55	2.275
Incorporated	2,227	2,206	21	1,008	763	11	72	110	52	899	10.81	2.454
County Total	20,824	20,636	188	13,386	10,137	444	375	396	2,034	9,000	32.77	2.293
Riverside County												
Banning	23,562	23,224	338	9,761	6,847	728	426	604	1,156	8,923	8.59	2.603
Beaumont	11,384	11,229	155	4,258	2,693	172	340	706	347	3,881	8.85	2.893
Blythe	20,465	11,956	8,509	4,892	2,705	151	421	801	814	4,104	16.11	2.913
Calimesa	7,139	7,043	96	3,248	1,761	111	57	64	1,255	2,982	8.19	2.362
Canyon Lake	9,952	9,936	16	4,047	3,738	78	6	84	141	3,643	9.98	2.727
Cathedral City	42,647	42,502	145	17,893	8,824	2,587	2,280	1,566	2,636	14,027	21.61	3.030
Coachella	22,724	22,680	44	5,024	3,100	319	640	510	455	4,807	4.32	4.718
Corona	124,966	124,334	632	39,271	25,991	2,186	2,225	7,587	1,282	37,839	3.65	3.286
Desert Hot Springs	16,582	16,408	174	7,034	3,780	180	1,193	1,313	568	5,859	16.70	2.800
Hemet	58,812	57,133	1,679	29,401	11,858	1,748	2,125	4,426	9,244	25,252	14.11	2.263
Indian Wells	3,816	3,816	0	3,843	2,370	884	112	469	8	1,982	48.43	1.925
Indio	49,116	48,260	856	16,909	7,662	878	1,419	3,780	3,170	13,871	17.97	3.479
Lake Elsinore	28,930	28,857	73	9,506	6,214	707	735	1,099	751	8,818	7.24	3.273
La Quinta	23,694	23,654	40	11,812	9,511	1,277	280	485	259	8,445	28.50	2.801
Moreno Valley	142,379	141,682	697	41,430	34,568	891	1,389	3,540	1,042	39,224	5.32	3.612
Murrieta	44,282	44,096	186	14,921	12,501	211	147	1,522	540	14,320	4.03	3.079
Norco	24,157	19,330	4,827	6,277	5,903	137	9	137	91	6,136	2.25	3.150
Palm Desert	41,155	40,928	227	28,021	11,100	9,534	2,459	3,731	1,197	19,184	31.54	2.133
Palm Springs	42,805	42,109	696	30,822	10,111	6,160	2,489	9,827	2,235	20,515	33.44	2.053
Perris	36,189	35,957	232	10,553	7,049	321	359	1,126	1,698	9,652	8.54	3.725
Rancho Mirage	13,249	13,112	137	11,816	4,376	3,680	614	1,147	1,999	6,813	42.34	1.925
Riverside	255,166	247,368	7,798	85,974	54,484	4,185	5,743	19,181	2,381	82,005	4.62	3.016
San Jacinto	23,779	23,589	190	9,476	5,074	596	656	561	2,589	8,314	12.26	2.837
Temecula	57,716	57,694	22	19,099	14,540	386	598	3,254	321	18,293	4.22	3.154

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Balance Of County	420,721	414,137	6,584	159,386	99,691	4,194	3,470	5,322	46,709	137,329	13.84	3.016
Incorporated	1,124,666	1,096,897	27,769	425,288	256,760	38,107	26,722	67,520	36,179	368,889	13.26	2.974
County Total	1,545,387	1,511,034	34,353	584,674	356,451	42,301	30,192	72,842	82,888	506,218	13.42	2.985
Sacramento County												
Citrus Heights	85,071	84,214	857	34,897	19,332	3,531	3,021	7,135	1,878	33,478	4.07	2.516
Folsom	51,884	44,940	6,944	17,968	13,443	635	627	2,402	861	17,196	4.30	2.613
Galt	19,472	19,284	188	6,211	4,959	198	336	346	372	5,974	3.82	3.228
Isleton	828	828	0	384	222	2	77	36	47	343	10.68	2.414
Sacramento	407,018	398,016	9,002	163,957	95,907	11,350	15,863	37,166	3,671	154,581	5.72	2.575
Balance Of County	659,226	650,722	8,504	251,397	163,200	16,529	16,385	46,628	8,655	242,030	3.73	2.689
Incorporated	564,273	547,282	16,991	223,417	133,863	15,716	19,924	47,085	6,829	211,572	5.30	2.587
County Total	1,223,499	1,198,004	25,495	474,814	297,063	32,245	36,309	93,713	15,484	453,602	4.47	2.641
San Benito County												
Hollister	34,424	34,253	171	9,928	7,371	531	979	741	306	9,720	2.10	3.524
San Juan Bautista	1,549	1,549	0	615	410	70	57	62	16	567	7.80	2.732
Balance Of County	17,261	16,925	336	5,956	4,865	427	70	42	552	5,598	6.01	3.023
Incorporated	35,973	35,802	171	10,543	7,781	601	1,036	803	322	10,287	2.43	3.480
County Total	53,234	52,727	507	16,499	12,646	1,028	1,106	845	874	15,885	3.72	3.319
San Bernardino County												
Adelanto	18,130	16,638	1,492	5,547	3,756	161	387	750	493	4,714	15.02	3.529
Apple Valley	54,239	53,876	363	20,163	14,952	726	2,074	1,377	1,034	18,557	7.97	2.903
Barstow	21,119	20,724	395	9,153	5,133	367	1,084	1,474	1,095	7,647	16.45	2.710
Big Bear Lake	5,438	5,413	25	8,705	7,295	326	342	359	383	2,343	73.08	2.310
Chino	67,168	59,352	7,816	17,898	12,462	952	786	3,170	528	17,304	3.32	3.430
Chino Hills	66,787	66,636	151	20,414	16,508	1,378	284	1,558	686	20,039	1.84	3.325
Colton	47,662	47,398	264	15,680	9,097	602	1,056	4,110	815	14,520	7.40	3.264
Fontana	128,928	128,429	499	35,907	26,539	1,198	1,579	5,709	882	34,013	5.27	3.776
Grand Terrace	11,626	11,417	209	4,458	2,863	175	265	905	250	4,221	5.32	2.705

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Hesperia	62,590	62,259	331	21,352	17,163	363	1,004	1,624	1,198	19,970	6.47	3.118
Highland	44,625	44,385	240	14,862	10,800	512	612	2,129	809	13,482	9.29	3.292
Loma Linda	19,228	18,193	1,035	8,084	3,193	642	1,282	2,405	562	7,536	6.78	2.414
Montclair	33,049	32,437	612	9,066	5,198	762	1,002	1,350	754	8,800	2.93	3.686
Needles	4,830	4,819	11	2,551	1,390	86	254	287	534	1,940	23.95	2.484
Ontario	158,007	156,866	1,141	45,182	26,773	3,633	3,960	8,749	2,067	43,525	3.67	3.604
Rancho Cucamonga	127,743	124,117	3,626	42,134	29,220	2,532	1,794	7,216	1,372	40,863	3.02	3.037
Redlands	63,591	61,625	1,966	24,790	15,823	900	2,361	4,801	905	23,593	4.83	2.612
Rialto	91,882	91,078	804	26,048	18,483	586	1,764	3,421	1,794	24,662	5.32	3.693
San Bernardino	185,382	179,533	5,849	63,531	37,365	2,716	5,752	13,218	4,480	56,326	11.34	3.187
Twentynine Palms	14,764	14,720	44	6,952	4,465	244	1,361	377	505	5,653	18.69	2.604
Upland	68,393	67,808	585	25,467	14,578	1,733	2,675	5,636	845	24,551	3.60	2.762
Victorville	64,029	63,359	670	22,498	16,068	389	1,333	2,951	1,757	20,893	7.13	3.033
Yucaipa	41,207	40,635	572	16,112	10,210	394	737	545	4,226	15,193	5.70	2.675
Yucca Valley	16,865	16,554	311	7,952	6,088	140	639	378	707	6,949	12.61	2.382
Balance Of County	292,857	276,131	16,726	126,863	100,701	5,312	4,525	3,166	13,159	91,300	28.03	3.024
Incorporated	1,417,282	1,388,271	29,011	474,506	315,422	21,517	34,387	74,499	28,681	437,294	7.84	3.175
County Total	1,710,139	1,664,402	45,737	601,369	416,123	26,829	38,912	77,665	41,840	528,594	12.10	3.149
San Diego County												
Carlsbad	78,306	77,519	787	33,812	17,827	5,727	2,072	6,895	1,291	31,535	6.73	2.458
Chula Vista	173,543	172,464	1,079	59,492	30,217	5,454	3,992	15,983	3,846	57,702	3.01	2.989
Coronado	24,100	17,560	6,540	9,494	4,417	874	804	3,376	23	7,734	18.54	2.270
Del Mar	4,389	4,387	2	2,557	1,331	360	194	672	0	2,178	14.82	2.014
El Cajon	94,869	92,386	2,483	35,190	13,382	1,548	2,244	15,981	2,035	34,199	2.82	2.701
Encinitas	57,955	57,396	559	23,829	13,149	4,535	2,061	3,315	769	22,816	4.25	2.516
Escondido	133,663	131,898	1,765	45,092	21,562	2,922	3,096	13,762	3,750	43,859	2.73	3.007
Imperial Beach	26,992	26,326	666	9,739	3,979	687	1,057	3,676	340	9,272	4.80	2.839
La Mesa	54,749	53,703	1,046	24,943	11,089	1,920	2,001	9,574	359	24,186	3.03	2.220
Lemon Grove	24,918	24,327	591	8,722	5,748	713	694	1,470	97	8,488	2.68	2.866
National City	54,260	50,917	3,343	15,422	6,590	1,330	1,685	5,380	437	15,018	2.62	3.390
Oceanside	161,039	159,759	1,280	59,583	30,254	8,222	4,348	13,339	3,420	56,490	5.19	2.828
Poway	48,044	47,618	426	15,714	11,765	877	318	2,063	691	15,467	1.57	3.079
San Diego	1,223,415	1,177,597	45,818	469,694	219,275	45,766	41,984	156,237	6,432	450,696	4.04	2.613
San Marcos	54,977	54,829	148	18,862	9,393	1,038	694	4,077	3,660	18,111	3.98	3.027
Santee	52,946	51,903	1,043	18,824	10,617	1,615	1,196	2,893	2,503	18,461	1.93	2.811

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Solana Beach	12,979	12,945	34	6,456	2,909	1,265	612	1,631	39	5,754	10.87	2.250
Vista	89,857	87,591	2,266	29,814	14,620	2,029	2,140	8,896	2,129	28,877	3.14	3.033
Balance Of County	442,832	415,695	27,137	152,910	102,311	11,227	6,031	18,209	15,132	143,834	5.94	2.890
Incorporated	2,371,001	2,301,125	69,876	887,239	428,124	86,882	71,192	269,220	31,821	850,843	4.10	2.705
County Total	2,813,833	2,716,820	97,013	1,040,149	530,435	98,109	77,223	287,429	46,953	994,677	4.37	2.731
San Francisco County												
City and County Total	776,733	756,976	19,757	346,527	62,653	48,752	80,851	153,711	560	329,700	4.86	2.296
San Joaquin County												
Escalon	5,963	5,937	26	2,132	1,726	20	153	98	135	2,056	3.56	2.888
Lathrop	10,445	10,435	10	2,991	2,473	63	92	12	351	2,908	2.77	3.588
Lodi	57,011	55,987	1,024	21,381	13,221	1,454	1,742	4,500	464	20,695	3.21	2.705
Manteca	49,255	48,778	477	16,936	11,883	739	1,099	2,346	869	16,367	3.36	2.980
Ripon	10,158	10,047	111	3,448	2,913	95	137	294	9	3,370	2.26	2.981
Stockton	243,771	238,455	5,316	82,042	49,088	6,592	8,413	16,661	1,288	78,556	4.25	3.035
Tracy	56,929	56,584	345	18,087	14,061	1,015	939	1,597	475	17,620	2.58	3.211
Balance Of County	130,066	118,604	11,462	42,143	33,941	1,240	770	592	5,600	40,057	4.95	2.961
Incorporated	433,532	426,223	7,309	147,017	95,365	9,978	12,575	25,508	3,591	141,572	3.70	3.011
County Total	563,598	544,827	18,771	189,160	129,306	11,218	13,345	26,100	9,191	181,629	3.98	3.000
San Luis Obispo County												
Arroyo Grande	15,851	15,641	210	6,750	4,479	585	489	649	548	6,478	4.03	2.414
Atascadero	26,411	24,945	1,466	9,848	6,794	441	862	1,200	551	9,531	3.22	2.617
El Paso De Robles	24,297	23,370	927	8,791	5,507	805	1,019	1,180	280	8,556	2.67	2.731
Grover Beach	13,067	12,941	126	5,382	3,067	786	703	579	247	5,023	6.67	2.576
Morro Bay	10,350	10,152	198	6,251	4,057	352	619	464	759	4,986	20.24	2.036
Pismo Beach	8,551	8,524	27	5,496	2,927	576	439	467	1,087	4,230	23.03	2.015
San Luis Obispo	44,179	42,317	1,862	19,308	9,087	1,248	2,191	5,281	1,501	18,641	3.45	2.270
Balance Of County	103,975	93,220	10,755	40,449	30,172	1,278	1,847	1,054	6,098	35,294	12.74	2.641
Incorporated	142,706	137,890	4,816	61,826	35,918	4,793	6,322	9,820	4,973	57,445	7.09	2.400

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
County Total	246,681	231,110	15,571	102,275	66,090	6,071	8,169	10,874	11,071	92,739	9.32	2.492
San Mateo County												
Atherton	7,194	6,876	318	2,505	2,466	32	0	7	0	2,413	3.67	2.850
Belmont	25,123	24,496	627	10,577	6,228	581	275	3,493	0	10,418	1.50	2.351
Brisbane	3,597	3,557	40	1,831	1,008	260	175	345	43	1,620	11.52	2.196
Burlingame	28,158	27,672	486	12,869	6,116	409	984	5,360	0	12,511	2.78	2.212
Colma	1,187	1,138	49	341	204	39	71	21	6	327	4.11	3.480
Daly City	103,625	102,835	790	31,313	15,886	4,469	2,806	7,596	556	30,777	1.71	3.341
East Palo Alto	29,506	29,317	189	7,091	3,617	375	360	2,580	159	6,976	1.62	4.203
Foster City	28,803	28,716	87	12,009	4,808	2,464	767	3,963	7	11,613	3.30	2.473
Half Moon Bay	11,842	10,994	848	4,114	2,574	536	258	319	427	4,004	2.67	2.746
Hillsborough	10,825	10,823	2	3,804	3,787	8	9	0	0	3,689	3.02	2.934
Menlo Park	30,785	29,833	952	12,714	6,839	930	1,574	3,366	5	12,387	2.57	2.408
Millbrae	20,718	20,386	332	8,113	5,316	269	424	2,093	11	7,956	1.94	2.562
Pacifica	38,392	38,211	181	14,246	10,269	775	707	2,397	98	13,995	1.76	2.730
Portola Valley	4,462	4,392	70	1,772	1,479	33	0	260	0	1,700	4.06	2.584
Redwood City	75,402	73,475	1,927	28,921	13,493	3,653	2,596	8,346	833	28,060	2.98	2.618
San Bruno	40,165	39,944	221	14,980	9,058	566	1,188	4,146	22	14,677	2.02	2.722
San Carlos	27,718	27,535	183	11,691	8,226	608	463	2,378	16	11,455	2.02	2.404
San Mateo	92,482	91,166	1,316	38,249	17,674	3,492	3,003	14,035	45	37,338	2.38	2.442
South San Francisco	60,552	60,109	443	20,138	11,815	2,485	1,668	3,761	409	19,677	2.29	3.055
Woodside	5,352	5,346	6	2,030	1,969	28	28	5	0	1,949	3.99	2.743
Balance Of County	61,275	59,892	1,383	21,270	17,454	690	896	1,383	847	20,562	3.33	2.913
Incorporated	645,888	636,821	9,067	239,308	132,832	22,012	17,356	64,471	2,637	233,542	2.41	2.727
County Total	707,163	696,713	10,450	260,578	150,286	22,702	18,252	65,854	3,484	254,104	2.48	2.742
Santa Barbara County												
Buellton	3,828	3,822	6	1,483	886	63	30	86	418	1,433	3.37	2.667
Carpinteria	14,194	14,069	125	5,464	2,151	422	520	1,431	940	4,989	8.69	2.820
Guadalupe	5,659	5,659	0	1,450	1,015	161	169	99	6	1,414	2.48	4.002
Lompoc	41,103	37,664	3,439	13,621	7,209	1,044	1,859	2,569	940	13,059	4.13	2.884
Santa Barbara	89,606	87,814	1,792	37,078	17,045	2,873	5,472	11,170	518	35,607	3.97	2.466
Santa Maria	77,423	75,261	2,162	22,847	13,923	1,293	1,651	4,408	1,572	22,146	3.07	3.398

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Solvang	5,332	5,172	160	2,288	1,299	151	166	453	219	2,185	4.50	2.367
Balance Of County	162,202	153,269	8,933	58,670	39,285	3,726	3,324	8,329	4,006	55,789	4.91	2.747
Incorporated	237,145	229,461	7,684	84,231	43,528	6,007	9,867	20,216	4,613	80,833	4.03	2.839
County Total	399,347	382,730	16,617	142,901	82,813	9,733	13,191	28,545	8,619	136,622	4.39	2.801
Santa Clara County												
Campbell	38,138	37,848	290	16,286	6,837	1,975	2,442	4,755	277	15,920	2.25	2.377
Cupertino	50,602	50,154	448	18,701	11,425	2,028	1,663	3,576	9	18,223	2.56	2.752
Gilroy	41,464	41,034	430	12,152	7,759	741	1,259	1,962	431	11,869	2.33	3.457
Los Altos	27,693	27,274	419	10,727	9,185	364	259	903	16	10,462	2.47	2.607
Los Altos Hills	8,025	7,960	65	2,871	2,807	32	17	9	6	2,795	2.65	2.848
Los Gatos	28,592	27,890	702	12,367	6,947	1,827	927	2,543	123	11,988	3.06	2.326
Milpitas	62,698	59,524	3,174	17,364	10,915	2,225	1,472	2,180	572	17,132	1.34	3.474
Monte Sereno	3,483	3,483	0	1,237	1,133	13	18	73	0	1,211	2.10	2.876
Morgan Hill	33,586	33,073	513	11,100	6,899	1,520	629	1,126	926	10,855	2.21	3.047
Mountain View	70,708	70,204	504	32,432	9,145	3,700	2,670	15,686	1,231	31,242	3.67	2.247
Palo Alto	58,598	57,930	668	26,048	15,324	974	1,721	7,865	164	25,216	3.19	2.297
San Jose	895,131	884,267	10,864	281,937	162,094	27,583	23,173	58,059	11,028	276,694	1.86	3.196
Santa Clara	102,361	99,574	2,787	39,630	17,645	3,588	3,875	14,413	109	38,526	2.79	2.585
Saratoga	29,849	29,598	251	10,652	9,537	560	197	351	7	10,453	1.87	2.832
Sunnyvale	131,844	130,969	875	53,787	21,020	3,927	4,911	19,833	4,096	52,573	2.26	2.491
Balance Of County	99,813	92,089	7,724	32,038	25,241	1,682	1,138	3,294	683	30,704	4.16	2.999
Incorporated	1,582,772	1,560,782	21,990	547,291	298,672	51,057	45,233	133,334	18,995	535,159	2.22	2.916
County Total	1,682,585	1,652,871	29,714	579,329	323,913	52,739	46,371	136,628	19,678	565,863	2.32	2.921
Santa Cruz County												
Capitola	10,033	9,877	156	5,309	1,932	514	1,139	1,074	650	4,692	11.62	2.105
Santa Cruz	54,593	49,959	4,634	21,504	12,111	1,897	2,568	4,488	440	20,442	4.94	2.444
Scotts Valley	11,385	10,933	452	4,423	2,428	403	371	417	804	4,273	3.39	2.559
Watsonville	44,246	43,693	553	11,689	5,927	1,597	1,315	1,978	872	11,375	2.69	3.841
Balance Of County	135,345	132,112	3,233	55,948	40,353	4,333	2,960	3,816	4,486	50,357	9.99	2.624
Incorporated	120,257	114,462	5,795	42,925	22,398	4,411	5,393	7,957	2,766	40,782	4.99	2.807

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
County Total	255,602	246,574	9,028	98,873	62,751	8,744	8,353	11,773	7,252	91,139	7.82	2.705
Shasta County												
Anderson	9,027	8,909	118	3,581	2,268	209	372	560	172	3,374	5.78	2.640
Redding	80,865	78,488	2,377	33,802	21,702	949	4,288	4,437	2,426	32,103	5.03	2.445
Shasta Lake	9,093	9,041	52	3,767	2,893	27	237	114	496	3,426	9.05	2.639
Balance Of County	64,271	63,459	812	27,660	19,308	272	367	198	7,515	24,523	11.34	2.588
Incorporated	98,985	96,438	2,547	41,150	26,863	1,185	4,897	5,111	3,094	38,903	5.46	2.479
County Total	163,256	159,897	3,359	68,810	46,171	1,457	5,264	5,309	10,609	63,426	7.82	2.521
Sierra County												
Loyalton	862	832	30	347	300	13	3	0	31	323	6.92	2.576
Balance Of County	2,693	2,687	6	1,855	1,510	36	44	63	202	1,197	35.47	2.245
Incorporated	862	832	30	347	300	13	3	0	31	323	6.92	2.576
County Total	3,555	3,519	36	2,202	1,810	49	47	63	233	1,520	30.97	2.315
Siskiyou County												
Dorris	886	886	0	396	318	4	16	0	58	342	13.64	2.591
Dunsmuir	1,923	1,923	0	1,170	791	23	126	184	46	867	25.90	2.218
Etna	781	781	0	362	265	10	19	13	55	329	9.12	2.374
Fort Jones	660	660	0	328	232	11	34	2	49	298	9.15	2.215
Montague	1,456	1,437	19	609	468	6	10	43	82	560	8.05	2.566
Mount Shasta	3,621	3,573	48	1,798	1,144	89	247	245	73	1,669	7.17	2.141
Tulelake	1,020	1,020	0	459	316	2	44	19	78	358	22.00	2.849
Weed	2,978	2,854	124	1,293	889	19	136	190	59	1,184	8.43	2.410
Yreka	7,290	7,070	220	3,303	2,184	140	283	467	229	3,114	5.72	2.270
Balance Of County	23,686	23,407	279	12,229	8,794	184	174	96	2,981	9,835	19.58	2.380
Incorporated	20,615	20,204	411	9,718	6,607	304	915	1,163	729	8,721	10.26	2.317
County Total	44,301	43,611	690	21,947	15,401	488	1,089	1,259	3,710	18,556	15.45	2.350

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Solano County												
Benicia	26,865	26,811	54	10,547	6,811	1,045	916	1,449	326	10,328	2.08	2.596
Dixon	16,103	16,062	41	5,172	4,250	213	374	249	86	5,073	1.91	3.166
Fairfield	96,178	91,949	4,229	31,792	21,285	2,159	2,155	5,279	914	30,870	2.90	2.979
Rio Vista	4,571	4,571	0	1,974	1,556	34	103	171	110	1,881	4.71	2.430
Suisun City	26,118	26,024	94	8,146	6,810	189	327	754	66	7,987	1.95	3.258
Vacaville	88,642	79,424	9,218	28,702	20,430	1,035	2,130	3,799	1,308	28,111	2.06	2.825
Vallejo	117,148	115,015	2,133	41,219	28,377	1,701	3,919	5,876	1,346	39,601	3.93	2.904
Balance Of County	19,305	18,712	593	6,961	5,859	220	293	119	470	6,552	5.88	2.856
Incorporated	375,625	359,856	15,769	127,552	89,519	6,376	9,924	17,577	4,156	123,851	2.90	2.906
County Total	394,930	378,568	16,362	134,513	95,378	6,596	10,217	17,696	4,626	130,403	3.06	2.903
Sonoma County												
Cloverdale	6,831	6,754	77	2,619	1,885	121	112	293	208	2,495	4.73	2.707
Cotati	6,471	6,453	18	2,585	1,520	372	295	277	121	2,532	2.05	2.549
Healdsburg	10,915	10,792	123	4,191	3,057	230	427	378	99	4,021	4.06	2.684
Petaluma	54,550	53,810	740	20,305	14,735	1,652	1,199	1,788	931	19,933	1.83	2.700
Rohnert Park	42,236	41,135	1,101	15,808	7,656	1,698	929	4,112	1,413	15,503	1.93	2.653
Santa Rosa	147,595	143,789	3,806	57,578	34,158	5,617	4,733	10,401	2,669	56,036	2.68	2.566
Sebastopol	7,774	7,563	211	3,321	1,990	253	523	497	58	3,250	2.14	2.327
Sonoma	9,275	9,184	91	4,740	2,627	662	439	568	444	4,442	6.29	2.068
Windsor	22,744	22,653	91	7,728	5,934	460	171	341	822	7,589	1.80	2.985
Balance Of County	150,223	145,379	4,844	64,278	51,874	2,890	2,878	2,021	4,615	56,602	11.94	2.568
Incorporated	308,391	302,133	6,258	118,875	73,562	11,065	8,828	18,655	6,765	115,801	2.59	2.609
County Total	458,614	447,512	11,102	183,153	125,436	13,955	11,706	20,676	11,380	172,403	5.87	2.596
Stanislaus County												
Ceres	34,609	34,510	99	10,773	8,129	343	603	986	712	10,435	3.14	3.307
Hughson	3,980	3,974	6	1,252	980	65	50	68	89	1,223	2.32	3.249
Modesto	188,861	185,653	3,208	67,180	45,921	4,005	6,079	9,231	1,944	64,960	3.30	2.858
Newman	7,092	7,026	66	2,175	1,803	76	153	117	26	2,078	4.46	3.381

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Oakdale	15,503	15,324	179	5,805	4,234	204	473	683	211	5,610	3.36	2.732
Patterson	11,606	11,377	229	3,262	2,730	190	151	63	128	3,146	3.56	3.616
Riverbank	15,826	15,691	135	4,698	3,909	185	180	182	242	4,544	3.28	3.453
Turlock	55,811	53,731	2,080	19,096	12,524	963	1,746	3,259	604	18,409	3.60	2.919
Waterford	6,924	6,907	17	2,080	1,722	47	170	112	29	1,990	4.33	3.471
Balance Of County	106,785	105,315	1,470	34,486	27,568	1,110	915	416	4,477	32,751	5.03	3.216
Incorporated	340,212	334,193	6,019	116,321	81,952	6,078	9,605	14,701	3,985	112,395	3.38	2.973
County Total	446,997	439,508	7,489	150,807	109,520	7,188	10,520	15,117	8,462	145,146	3.75	3.028
Sutter County												
Live Oak	6,229	5,926	303	1,818	1,368	75	131	104	140	1,729	4.90	3.427
Yuba City	36,758	35,842	916	13,912	7,690	796	1,480	3,502	444	13,290	4.47	2.697
Balance Of County	35,943	35,779	164	12,589	10,717	315	275	174	1,108	12,014	4.57	2.978
Incorporated	42,987	41,768	1,219	15,730	9,058	871	1,611	3,606	584	15,019	4.52	2.781
County Total	78,930	77,547	1,383	28,319	19,775	1,186	1,886	3,780	1,692	27,033	4.54	2.869
Tehama County												
Corning	6,741	6,684	57	2,614	1,541	70	274	495	234	2,422	7.35	2.760
Red Bluff	13,147	12,612	535	5,567	3,280	216	693	1,018	360	5,109	8.23	2.469
Tehama	432	432	0	196	166	4	10	0	16	179	8.67	2.413
Balance Of County	35,719	35,306	413	15,170	9,200	196	237	78	5,459	13,303	12.31	2.654
Incorporated	20,320	19,728	592	8,377	4,987	290	977	1,513	610	7,710	7.96	2.559
County Total	56,039	55,034	1,005	23,547	14,187	486	1,214	1,591	6,069	21,013	10.76	2.619
Trinity County												
County Total	13,022	12,780	242	7,980	5,243	112	106	117	2,402	5,587	29.99	2.287
Tulare County												
Dinuba	16,844	16,730	114	4,670	3,453	280	268	465	204	4,493	3.79	3.724

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Exeter	9,168	9,076	92	3,168	2,488	107	201	184	188	3,001	5.27	3.024
Farmersville	8,737	8,718	19	2,269	1,825	84	155	109	96	2,151	5.20	4.053
Lindsay	10,297	10,148	149	2,865	1,944	135	243	358	185	2,717	5.17	3.735
Porterville	39,615	37,983	1,632	12,691	8,599	485	1,521	1,448	638	11,884	6.36	3.196
Tulare	43,994	43,547	447	14,253	10,619	511	1,215	1,134	774	13,543	4.98	3.215
Visalia	91,891	90,269	1,622	32,827	23,357	1,572	3,503	2,926	1,469	31,030	5.47	2.909
Woodlake	6,653	6,644	9	1,875	1,213	126	152	324	60	1,778	5.17	3.737
Balance Of County	140,822	138,865	1,957	45,021	34,340	1,440	1,256	871	7,114	39,788	11.62	3.490
Incorporated	227,199	223,115	4,084	74,618	53,498	3,300	7,258	6,948	3,614	70,597	5.39	3.160
County Total	368,021	361,980	6,041	119,639	87,838	4,740	8,514	7,819	10,728	110,385	7.73	3.279
Tuolumne County												
Sonora	4,423	4,224	199	2,197	1,255	86	383	447	26	2,051	6.65	2.059
Balance Of County	50,081	45,441	4,640	26,139	20,462	567	779	627	3,704	18,953	27.49	2.398
Incorporated	4,423	4,224	199	2,197	1,255	86	383	447	26	2,051	6.65	2.059
County Total	54,504	49,665	4,839	28,336	21,717	653	1,162	1,074	3,730	21,004	25.88	2.365
Ventura County												
Camarillo	57,084	56,145	939	21,947	12,856	4,495	826	2,712	1,058	21,440	2.31	2.619
Fillmore	13,643	13,397	246	3,852	2,704	273	227	322	326	3,762	2.34	3.561
Moorpark	31,415	31,403	12	9,094	6,598	1,234	223	709	330	8,994	1.10	3.492
Ojai	7,862	7,672	190	3,229	2,214	266	289	452	8	3,088	4.37	2.484
Oxnard	170,358	167,761	2,597	45,166	24,909	4,576	4,353	8,389	2,939	43,576	3.52	3.850
Port Hueneme	21,845	20,798	1,047	7,908	2,286	2,204	1,205	2,171	42	7,268	8.09	2.862
San Buenaventura	100,916	98,546	2,370	39,803	22,238	3,428	4,126	7,388	2,623	38,524	3.21	2.558
Santa Paula	28,598	28,355	243	8,341	4,987	729	762	1,076	787	8,136	2.46	3.485
Simi Valley	111,351	110,551	800	37,272	27,668	2,620	1,655	4,437	892	36,421	2.28	3.035
Thousand Oaks	117,005	115,054	1,951	42,958	28,540	5,152	1,733	6,461	1,072	41,793	2.71	2.753
Balance Of County	93,120	90,303	2,817	32,141	25,532	2,347	1,009	1,168	2,085	30,232	5.94	2.987
Incorporated	660,077	649,682	10,395	219,570	135,000	24,977	15,399	34,117	10,077	213,002	2.99	3.050
County Total	753,197	739,985	13,212	251,711	160,532	27,324	16,408	35,285	12,162	243,234	3.37	3.042

Table 2: E-5 City/County Population and Housing Estimates, 4/1/2000 DRU Benchmark

	------------POPULATION------------			---------------------------------- HOUSING UNITS ----------------------------------								PERSONS PER HOUSE-HOLD
					-------- SINGLE --------		----- MULTIPLE -----					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Yolo County												
Davis	60,308	57,338	2,970	23,617	10,577	2,348	2,123	8,184	385	22,948	2.83	2.499
West Sacramento	31,615	31,409	206	12,133	6,708	877	926	2,091	1,531	11,404	6.01	2.754
Winters	6,125	6,119	6	1,954	1,522	105	67	182	78	1,907	2.41	3.209
Woodland	49,155	48,365	790	17,121	10,590	1,309	1,123	3,418	681	16,752	2.16	2.887
Balance Of County	21,457	17,914	3,543	6,762	4,527	305	192	804	934	6,364	5.89	2.815
Incorporated	147,203	143,231	3,972	54,825	29,397	4,639	4,239	13,875	2,675	53,011	3.31	2.702
County Total	168,660	161,145	7,515	61,587	33,924	4,944	4,431	14,679	3,609	59,375	3.59	2.714
Yuba County												
Marysville	12,268	11,661	607	4,999	2,766	339	767	1,119	8	4,687	6.24	2.488
Wheatland	2,272	2,272	0	815	531	35	155	55	39	784	3.80	2.898
Balance Of County	45,679	44,952	727	16,822	10,630	867	753	1,114	3,458	15,064	10.45	2.984
Incorporated	14,540	13,933	607	5,814	3,297	374	922	1,174	47	5,471	5.90	2.547
County Total	60,219	58,885	1,334	22,636	13,927	1,241	1,675	2,288	3,505	20,535	9.28	2.868
California												
Incorporated Total	27,536,281	26,899,576	636,705	9,846,002	5,183,266	812,524	924,998	2,618,798	306,416	9,382,415	4.71	2.867
Balance Of State Total	6,336,805	6,152,320	184,485	2,368,548	1,699,841	119,404	99,898	186,133	263,272	2,120,456	10.47	2.901
State Total	33,873,086	33,051,896	821,190	12,214,550	6,883,107	931,928	1,024,896	2,804,931	569,688	11,502,871	5.83	2.873

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2001

COUNTY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Alameda	1,465,332	1,437,463	27,869	543,799	293,204	38,520	61,096	143,329	7,650	527,078	3.07	2.727
Alpine	1,222	1,221	1	1,534	893	7	35	537	62	489	68.12	2.497
Amador	35,590	31,020	4,570	15,205	12,398	390	374	550	1,493	12,904	15.13	2.404
Butte	205,150	198,964	6,186	86,218	52,316	2,356	7,644	9,660	14,242	80,293	6.87	2.478
Calaveras	41,136	40,705	431	23,253	19,666	465	495	355	2,272	16,699	28.19	2.438
Colusa	19,057	18,614	443	6,811	5,062	229	395	388	737	6,131	9.98	3.036
Contra Costa	966,012	954,700	11,312	357,381	234,541	29,939	25,169	60,160	7,572	346,848	2.95	2.753
Del Norte	27,535	23,724	3,811	10,480	6,137	182	797	584	2,780	9,210	12.12	2.576
El Dorado	160,409	159,356	1,053	72,228	57,890	1,598	3,500	4,867	4,373	59,756	17.27	2.667
Fresno	812,189	794,213	17,976	272,985	177,448	10,063	24,220	47,910	13,344	255,062	6.57	3.114
Glenn	26,720	26,351	369	10,012	6,983	207	718	700	1,404	9,200	8.11	2.864
Humboldt	127,123	122,921	4,202	56,182	38,489	1,544	5,646	4,553	5,950	51,483	8.36	2.388
Imperial	144,762	133,779	10,983	44,218	25,450	1,917	3,523	5,608	7,720	39,714	10.19	3.369
Inyo	18,220	17,938	282	9,062	5,465	210	407	468	2,512	7,721	14.80	2.323
Kern	673,277	642,654	30,623	234,059	158,471	8,434	20,493	23,419	23,242	211,366	9.70	3.040
Kings	131,357	111,219	20,138	36,761	25,667	2,051	2,724	4,226	2,093	34,624	5.81	3.212
Lake	59,327	58,145	1,182	32,670	20,214	533	903	804	10,216	24,079	26.30	2.415
Lassen	33,883	24,986	8,897	12,089	8,253	296	515	519	2,506	9,768	19.20	2.558
Los Angeles	9,656,730	9,480,340	176,390	3,278,902	1,598,659	241,673	287,697	1,094,261	56,612	3,141,549	4.19	3.018
Madera	125,742	117,840	7,902	40,845	31,196	1,336	2,147	2,743	3,423	36,569	10.47	3.222
Marin	248,852	237,714	11,138	105,335	64,016	8,459	9,368	21,364	2,128	101,025	4.09	2.353
Mariposa	17,092	15,669	1,423	8,907	6,006	71	214	383	2,233	6,674	25.07	2.348
Mendocino	86,936	84,714	2,222	37,147	25,900	1,163	2,109	2,656	5,319	33,453	9.94	2.532
Merced	214,517	211,662	2,855	69,391	48,917	2,534	5,166	7,467	5,307	64,773	6.66	3.268
Modoc	9,494	9,089	405	4,840	3,293	87	98	159	1,203	3,809	21.30	2.386
Mono	12,910	12,630	280	11,988	4,656	1,190	1,900	3,295	947	5,229	56.38	2.415
Monterey	406,953	386,334	20,619	132,610	80,250	12,345	11,826	22,526	5,663	122,044	7.97	3.166
Napa	125,913	120,638	5,275	49,019	32,901	3,221	3,644	5,322	3,931	45,846	6.47	2.631
Nevada	93,335	92,381	954	44,884	36,845	871	1,611	2,116	3,441	37,370	16.74	2.472
Orange	2,890,312	2,847,789	42,523	976,037	494,196	124,798	89,188	235,387	32,468	941,565	3.53	3.025
Placer	258,762	255,754	3,008	110,727	84,397	4,137	5,698	11,803	4,692	97,216	12.20	2.631
Plumas	20,761	20,573	188	13,489	10,214	444	375	396	2,060	9,068	32.77	2.269
Riverside	1,589,950	1,554,967	34,983	595,682	365,716	42,329	30,291	74,410	82,936	515,958	13.38	3.014
Sacramento	1,252,712	1,227,241	25,471	480,497	301,176	32,245	36,315	95,277	15,484	459,655	4.34	2.670
San Benito	54,485	53,978	507	16,716	12,863	1,028	1,106	845	874	16,093	3.73	3.354

California Department of Finance
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Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2001

COUNTY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
San Bernardino	1,746,732	1,696,677	50,055	605,809	420,336	26,862	38,870	77,821	41,920	534,030	11.85	3.177
San Diego	2,865,208	2,772,244	92,964	1,049,910	537,074	98,130	77,721	289,982	47,003	1,003,305	4.44	2.763
San Francisco	784,419	764,965	19,454	347,489	62,737	48,731	81,032	154,429	560	330,627	4.85	2.314
San Joaquin	579,977	561,168	18,809	192,268	132,349	11,218	13,363	26,111	9,227	184,634	3.97	3.039
San Luis Obispo	250,298	234,429	15,869	103,548	67,184	6,096	8,196	10,904	11,168	93,894	9.32	2.497
San Mateo	712,267	701,812	10,455	261,637	151,083	22,705	18,288	66,050	3,511	255,133	2.49	2.751
Santa Barbara	403,237	386,997	16,240	143,697	83,340	9,765	13,311	28,698	8,583	137,483	4.32	2.815
Santa Clara	1,701,605	1,671,345	30,260	584,163	325,819	52,844	46,480	139,362	19,658	570,832	2.28	2.928
Santa Cruz	257,136	248,295	8,841	99,200	62,985	8,762	8,368	11,833	7,252	91,490	7.77	2.714
Shasta	166,435	163,087	3,348	69,394	46,705	1,457	5,313	5,309	10,610	63,979	7.80	2.549
Sierra	3,618	3,582	36	2,211	1,819	49	47	63	233	1,526	30.98	2.347
Siskiyou	44,490	43,794	696	22,066	15,506	488	1,091	1,270	3,711	18,657	15.45	2.347
Solano	401,649	385,278	16,371	136,035	96,248	6,596	10,266	18,321	4,604	131,741	3.16	2.925
Sonoma	464,543	452,535	12,008	185,005	127,037	13,977	11,781	20,831	11,379	174,193	5.84	2.598
Stanislaus	458,512	451,146	7,366	153,262	111,651	7,189	10,638	15,302	8,482	147,512	3.75	3.058
Sutter	80,165	78,740	1,425	28,535	19,978	1,186	1,898	3,780	1,693	27,241	4.53	2.890
Tehama	56,221	55,224	997	23,699	14,274	486	1,214	1,591	6,134	21,147	10.77	2.611
Trinity	12,986	12,749	237	8,003	5,266	112	106	117	2,402	5,603	29.99	2.275
Tulare	372,722	366,686	6,036	120,795	88,848	4,738	8,518	7,819	10,872	111,468	7.72	3.290
Tuolumne	55,117	50,304	4,813	28,490	21,846	653	1,168	1,074	3,749	21,119	25.87	2.382
Ventura	765,962	752,601	13,361	254,584	162,835	27,365	16,440	35,769	12,175	246,016	3.37	3.059
Yolo	172,887	164,850	8,037	62,887	34,671	4,950	4,439	15,218	3,609	60,801	3.32	2.711
Yuba	61,027	59,664	1,363	22,635	13,980	1,241	1,611	2,250	3,553	20,516	9.36	2.908
California	34,430,970	33,605,458	825,512	12,307,285	6,953,319	932,472	1,027,566	2,822,951	570,977	11,593,268	5.80	2.899

California Department of Finance
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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Alameda County												
Alameda	73,057	71,995	1,062	31,846	12,889	3,960	5,029	9,668	300	30,422	4.47	2.37
Albany	16,612	16,579	33	7,264	3,777	181	823	2,477	6	7,026	3.28	2.36
Berkeley	103,571	97,710	5,861	46,881	20,100	1,757	9,301	15,664	59	44,961	4.10	2.17
Dublin	32,732	27,540	5,192	10,706	6,400	1,304	412	2,563	27	10,327	3.54	2.67
Emeryville	7,232	7,165	67	4,458	267	275	484	3,395	37	4,146	7.00	1.73
Fremont	206,797	205,038	1,759	70,056	41,846	7,136	2,968	17,350	756	68,830	1.75	2.98
Hayward	142,428	140,277	2,151	46,345	22,985	3,398	3,349	14,314	2,299	45,217	2.43	3.10
Livermore	74,903	74,587	316	26,921	19,622	2,187	1,151	3,530	431	26,428	1.83	2.82
Newark	43,106	43,017	89	13,241	9,034	1,238	764	2,146	59	13,082	1.20	3.29
Oakland	403,065	395,808	7,257	157,649	71,571	6,645	28,968	50,009	456	150,925	4.27	2.62
Piedmont	11,040	11,038	2	3,859	3,782	0	35	34	8	3,804	1.43	2.90
Pleasanton	65,181	64,946	235	24,350	15,786	2,704	1,148	4,256	456	23,683	2.74	2.74
San Leandro	80,370	79,543	827	31,448	19,135	1,914	2,246	7,249	904	30,753	2.21	2.59
Union City	68,027	67,685	342	19,053	12,147	2,352	1,106	2,525	923	18,816	1.24	3.60
Balance Of County	137,211	134,535	2,676	49,722	33,863	3,469	3,312	8,149	929	48,658	2.14	2.77
Incorporated	1,328,121	1,302,928	25,193	494,077	259,341	35,051	57,784	135,180	6,721	478,420	3.17	2.72
County Total	1,465,332	1,437,463	27,869	543,799	293,204	38,520	61,096	143,329	7,650	527,078	3.07	2.73
Alpine County												
County Total	1,222	1,221	1	1,534	893	7	35	537	62	489	68.12	2.50
Amador County												
Amador	201	201	0	93	76	12	5	0	0	87	6.45	2.31
Ione	7,250	3,020	4,230	1,198	913	54	64	87	80	1,121	6.43	2.69
Jackson	4,014	3,746	268	1,863	1,144	112	148	247	212	1,750	6.07	2.14
Plymouth	993	993	0	461	273	23	24	26	115	395	14.32	2.51
Sutter Creek	2,339	2,338	1	1,118	746	105	47	143	77	1,036	7.33	2.26
Balance Of County	20,793	20,722	71	10,472	9,246	84	86	47	1,009	8,515	18.69	2.43
Incorporated	14,797	10,298	4,499	4,733	3,152	306	288	503	484	4,389	7.27	2.35
County Total	35,590	31,020	4,570	15,205	12,398	390	374	550	1,493	12,904	15.13	2.40

California Department of Finance
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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSEHOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	SINGLE: DETACHED	SINGLE: ATTACHED	MULTIPLE: 2 TO 4	MULTIPLE: 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Butte County												
Biggs	1,796	1,796	0	614	506	28	28	5	47	572	6.84	3.14
Chico	65,100	61,145	3,955	26,207	12,311	944	4,152	7,694	1,106	25,229	3.73	2.42
Gridley	5,531	5,409	122	2,019	1,626	43	135	141	74	1,894	6.19	2.86
Oroville	13,015	12,183	832	5,418	2,883	134	767	1,252	382	4,880	9.93	2.50
Paradise	26,477	25,857	620	12,406	8,568	338	741	290	2,469	11,621	6.33	2.23
Balance Of County	93,231	92,574	657	39,554	26,422	869	1,821	278	10,164	36,097	8.74	2.57
Incorporated	111,919	106,390	5,529	46,664	25,894	1,487	5,823	9,382	4,078	44,196	5.29	2.41
County Total	205,150	198,964	6,186	86,218	52,316	2,356	7,644	9,660	14,242	80,293	6.87	2.48
Calaveras County												
Angels City	3,150	3,150	0	1,490	974	67	122	113	214	1,347	9.60	2.34
Balance Of County	37,986	37,555	431	21,763	18,692	398	373	242	2,058	15,352	29.46	2.45
Incorporated	3,150	3,150	0	1,490	974	67	122	113	214	1,347	9.60	2.34
County Total	41,136	40,705	431	23,253	19,666	465	495	355	2,272	16,699	28.19	2.44
Colusa County												
Colusa	5,451	5,378	73	2,019	1,512	84	189	183	51	1,900	5.89	2.83
Williams	3,768	3,518	250	988	714	33	83	91	67	943	4.55	3.73
Balance Of County	9,838	9,718	120	3,804	2,836	112	123	114	619	3,288	13.56	2.96
Incorporated	9,219	8,896	323	3,007	2,226	117	272	274	118	2,843	5.45	3.13
County Total	19,057	18,614	443	6,811	5,062	229	395	388	737	6,131	9.98	3.04
Contra Costa County												
Antioch	93,141	92,725	416	30,683	23,497	1,357	1,765	3,795	269	29,890	2.58	3.10
Brentwood	26,179	26,142	37	8,665	7,286	355	267	405	352	8,341	3.74	3.13
Clayton	10,937	10,911	26	3,949	3,217	681	19	27	5	3,908	1.04	2.79
Concord	123,412	121,990	1,422	45,220	27,082	2,851	2,871	11,039	1,377	44,154	2.36	2.76
Danville	42,697	42,233	464	15,338	11,820	2,557	279	682	0	15,020	2.07	2.81
El Cerrito	23,412	23,236	176	10,468	7,300	343	1,305	1,488	32	10,214	2.43	2.28

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Hercules	19,826	19,787	39	6,594	4,079	1,617	294	604	0	6,470	1.88	3.06
Lafayette	24,134	23,998	136	9,330	7,463	294	425	1,148	0	9,148	1.95	2.62
Martinez	36,316	34,969	1,347	14,643	9,321	2,213	984	2,101	24	14,345	2.04	2.44
Moraga	16,459	14,828	1,631	5,769	4,006	968	243	545	7	5,671	1.70	2.62
Oakley	26,009	25,942	67	7,988	7,319	84	54	110	421	7,873	1.44	3.30
Orinda	17,773	17,706	67	6,744	6,243	188	87	219	7	6,596	2.19	2.68
Pinole	19,326	19,108	218	6,864	5,058	498	360	933	15	6,779	1.24	2.82
Pittsburg	57,964	57,458	506	18,505	12,149	1,296	1,330	3,060	670	17,940	3.05	3.20
Pleasant Hill	33,187	32,727	460	14,046	8,375	1,466	688	3,465	52	13,765	2.00	2.38
Richmond	100,363	98,735	1,628	36,109	20,533	2,928	5,252	7,275	121	34,687	3.94	2.85
San Pablo	30,565	30,100	465	9,358	4,149	760	1,293	2,361	795	9,069	3.09	3.32
San Ramon	45,876	45,791	85	17,829	10,902	1,988	1,039	3,889	11	17,211	3.47	2.66
Walnut Creek	65,550	64,586	964	31,732	12,112	4,791	4,257	10,524	48	30,597	3.58	2.11
Balance Of County	152,886	151,728	1,158	57,547	42,630	2,704	2,357	6,490	3,366	55,170	4.13	2.75
Incorporated	813,126	802,972	10,154	299,834	191,911	27,235	22,812	53,670	4,206	291,678	2.72	2.75
County Total	966,012	954,700	11,312	357,381	234,541	29,939	25,169	60,160	7,572	346,848	2.95	2.75
Del Norte County												
Crescent City	7,316	3,782	3,534	1,753	861	50	389	424	29	1,577	10.04	2.40
Balance Of County	20,219	19,942	277	8,727	5,276	132	408	160	2,751	7,633	12.54	2.61
Incorporated	7,316	3,782	3,534	1,753	861	50	389	424	29	1,577	10.04	2.40
County Total	27,535	23,724	3,811	10,480	6,137	182	797	584	2,780	9,210	12.12	2.58
El Dorado County												
Placerville	9,954	9,692	262	4,344	2,664	256	618	647	159	4,097	5.69	2.37
South Lake Tahoe	23,970	23,842	128	14,046	8,793	366	1,975	2,244	668	9,438	32.81	2.53
Balance Of County	126,485	125,822	663	53,838	46,433	976	907	1,976	3,546	46,221	14.15	2.72
Incorporated	33,924	33,534	390	18,390	11,457	622	2,593	2,891	827	13,535	26.40	2.48
County Total	160,409	159,356	1,053	72,228	57,890	1,598	3,500	4,867	4,373	59,756	17.27	2.67

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Fresno County												
Clovis	70,456	69,976	480	25,793	16,865	549	3,086	4,377	916	24,871	3.57	2.81
Coalinga	15,929	10,551	5,378	3,723	2,449	127	283	546	318	3,389	8.97	3.11
Firebaugh	5,792	5,731	61	1,583	1,011	156	189	141	86	1,420	10.30	4.04
Fowler	4,096	4,030	66	1,306	889	50	157	163	47	1,271	2.68	3.17
Fresno	435,015	426,566	8,449	150,425	87,992	6,028	16,308	36,174	3,923	141,395	6.00	3.02
Huron	6,399	6,227	172	1,425	478	204	228	445	70	1,389	2.53	4.48
Kerman	8,796	8,765	31	2,514	1,659	153	246	340	116	2,439	2.98	3.59
Kingsburg	9,716	9,625	91	3,530	2,595	104	228	439	164	3,392	3.91	2.84
Mendota	7,949	7,941	8	1,878	1,124	139	230	313	72	1,825	2.82	4.35
Orange Cove	8,326	8,326	0	1,891	1,116	206	222	321	26	1,813	4.12	4.59
Parlier	11,417	11,315	102	2,689	1,853	234	184	404	14	2,488	7.47	4.55
Reedley	20,983	20,588	395	5,994	4,142	216	594	851	191	5,782	3.54	3.56
Sanger	19,235	19,095	140	5,467	3,859	194	563	688	163	5,265	3.69	3.63
San Joaquin	3,335	3,335	0	744	426	80	115	63	60	711	4.44	4.69
Selma	19,940	19,810	130	5,920	4,316	148	282	752	422	5,697	3.77	3.48
Balance Of County	164,805	162,332	2,473	58,103	46,674	1,475	1,305	1,893	6,756	51,915	10.65	3.13
Incorporated	647,384	631,881	15,503	214,882	130,774	8,588	22,915	46,017	6,588	203,147	5.46	3.11
County Total	812,189	794,213	17,976	272,985	177,448	10,063	24,220	47,910	13,344	255,062	6.57	3.11
Glenn County												
Orland	6,342	6,318	24	2,313	1,722	44	318	197	32	2,194	5.14	2.88
Willows	6,271	6,090	181	2,369	1,545	54	305	458	7	2,135	9.88	2.85
Balance Of County	14,107	13,943	164	5,330	3,716	109	95	45	1,365	4,871	8.61	2.86
Incorporated	12,613	12,408	205	4,682	3,267	98	623	655	39	4,329	7.54	2.87
County Total	26,720	26,351	369	10,012	6,983	207	718	700	1,404	9,200	8.11	2.86
Humboldt County												
Arcata	16,867	15,259	1,608	7,298	3,352	251	1,169	1,843	683	7,076	3.04	2.16
Blue Lake	1,144	1,144	0	561	365	21	68	36	71	509	9.27	2.25
Eureka	26,135	24,785	1,350	11,654	7,213	381	2,195	1,691	174	10,973	5.84	2.26
Ferndale	1,379	1,379	0	662	533	27	83	10	9	610	7.85	2.26
Fortuna	10,558	10,323	235	4,444	2,942	229	520	311	442	4,213	5.20	2.45

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Rio Dell	3,171	3,161	10	1,434	995	26	150	36	227	1,221	14.85	2.59
Trinidad	313	313	0	229	180	7	11	0	31	169	26.20	1.85
Balance Of County	67,556	66,557	999	29,900	22,909	602	1,450	626	4,313	26,712	10.66	2.49
Incorporated	59,567	56,364	3,203	26,282	15,580	942	4,196	3,927	1,637	24,771	5.75	2.28
County Total	127,123	122,921	4,202	56,182	38,489	1,544	5,646	4,553	5,950	51,483	8.36	2.39
Imperial County												
Brawley	22,365	22,053	312	7,068	4,506	362	639	1,105	456	6,659	5.79	3.31
Calexico	28,049	27,946	103	7,154	4,634	439	890	986	205	6,981	2.42	4.00
Calipatria	7,280	3,229	4,051	962	711	38	75	76	62	900	6.44	3.59
El Centro	38,476	37,589	887	12,348	6,501	563	1,066	2,900	1,318	11,522	6.69	3.26
Holtville	5,674	5,544	130	1,619	1,037	111	117	162	192	1,566	3.27	3.54
Imperial	7,766	7,734	32	2,426	1,915	91	227	164	29	2,348	3.22	3.29
Westmorland	2,175	2,175	0	674	427	16	90	102	39	632	6.23	3.44
Balance Of County	32,977	27,509	5,468	11,967	5,719	297	419	113	5,419	9,106	23.91	3.02
Incorporated	111,785	106,270	5,515	32,251	19,731	1,620	3,104	5,495	2,301	30,608	5.09	3.47
County Total	144,762	133,779	10,983	44,218	25,450	1,917	3,523	5,608	7,720	39,714	10.19	3.37
Inyo County												
Bishop	3,606	3,529	77	1,872	848	76	262	323	363	1,689	9.78	2.09
Balance Of County	14,614	14,409	205	7,190	4,617	134	145	145	2,149	6,032	16.11	2.39
Incorporated	3,606	3,529	77	1,872	848	76	262	323	363	1,689	9.78	2.09
County Total	18,220	17,938	282	9,062	5,465	210	407	468	2,512	7,721	14.80	2.32
Kern County												
Arvin	13,161	13,090	71	3,179	2,162	218	264	279	256	3,043	4.28	4.30
Bakersfield	249,507	245,861	3,646	88,761	57,902	3,221	10,042	15,065	2,531	83,913	5.46	2.93
California City	9,191	8,357	834	3,555	2,659	68	310	214	304	3,063	13.84	2.73
Delano	39,982	34,353	5,629	8,937	6,237	547	593	1,111	449	8,511	4.77	4.04
Maricopa	1,122	1,122	0	462	248	7	5	9	193	406	12.12	2.76

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Mcfarland	9,861	8,616	1,245	2,036	1,558	153	238	60	27	1,995	2.01	4.32
Ridgecrest	26,226	26,014	212	11,310	7,445	412	1,697	765	991	10,325	8.71	2.52
Shafter	12,883	12,213	670	3,643	2,756	177	262	237	211	3,310	9.14	3.69
Taft	8,890	5,906	2,984	2,493	1,796	52	315	234	96	2,247	9.87	2.63
Tehachapi	11,414	6,635	4,779	2,933	1,859	135	385	281	273	2,550	13.06	2.60
Wasco	21,426	15,291	6,135	4,304	3,116	326	413	318	131	4,016	6.69	3.81
Balance Of County	269,614	265,196	4,418	102,446	70,733	3,118	5,969	4,846	17,780	87,987	14.11	3.01
Incorporated	403,663	377,458	26,205	131,613	87,738	5,316	14,524	18,573	5,462	123,379	6.26	3.06
County Total	673,277	642,654	30,623	234,059	158,471	8,434	20,493	23,419	23,242	211,366	9.70	3.04
Kings County												
Avenal	15,197	8,095	7,102	2,066	1,397	50	303	224	92	1,933	6.44	4.19
Corcoran	20,793	9,701	11,092	3,032	2,156	180	270	303	123	2,783	8.21	3.49
Hanford	42,689	41,841	848	14,891	10,568	552	1,389	2,041	341	14,092	5.37	2.97
Lemoore	20,224	20,222	2	6,911	4,432	148	459	1,543	329	6,533	5.47	3.10
Balance Of County	32,454	31,360	1,094	9,861	7,114	1,121	303	115	1,208	9,283	5.86	3.38
Incorporated	98,903	79,859	19,044	26,900	18,553	930	2,421	4,111	885	25,341	5.80	3.15
County Total	131,357	111,219	20,138	36,761	25,667	2,051	2,724	4,226	2,093	34,624	5.81	3.21
Lake County												
Clearlake	13,276	13,157	119	7,593	3,620	99	249	220	3,405	5,524	27.25	2.38
Lakeport	4,879	4,705	174	2,396	1,440	119	158	223	456	1,969	17.82	2.39
Balance Of County	41,172	40,283	889	22,681	15,154	315	496	361	6,355	16,586	26.87	2.43
Incorporated	18,155	17,862	293	9,989	5,060	218	407	443	3,861	7,493	24.99	2.38
County Total	59,327	58,145	1,182	32,670	20,214	533	903	804	10,216	24,079	26.30	2.41
Lassen County												
Susanville	17,409	8,733	8,676	3,927	2,749	131	377	460	210	3,558	9.40	2.45
Balance Of County	16,474	16,253	221	8,162	5,504	165	138	59	2,296	6,210	23.92	2.62

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Incorporated	17,409	8,733	8,676	3,927	2,749	131	377	460	210	3,558	9.40	2.45
County Total	33,883	24,986	8,897	12,089	8,253	296	515	519	2,506	9,768	19.20	2.56
Los Angeles County												
Agoura Hills	20,789	20,766	23	6,995	5,222	979	176	618	0	6,876	1.70	3.02
Alhambra	86,808	84,885	1,923	30,061	12,751	3,266	3,967	10,060	17	29,102	3.19	2.92
Arcadia	53,806	53,225	581	20,016	11,784	1,670	1,379	5,157	26	19,193	4.11	2.77
Artesia	16,618	16,046	572	4,612	3,194	329	320	673	96	4,484	2.78	3.58
Avalon	3,321	3,259	62	1,883	497	487	545	345	9	1,201	36.22	2.71
Azusa	45,238	43,289	1,949	13,017	5,737	1,766	1,465	3,460	589	12,553	3.56	3.45
Baldwin Park	77,198	76,592	606	17,535	11,777	1,861	601	2,953	343	17,063	2.69	4.49
Bell	37,097	36,559	538	9,215	3,557	1,517	1,453	2,228	460	8,918	3.22	4.10
Bellflower	73,781	73,158	623	24,259	11,251	2,085	1,432	7,889	1,602	23,379	3.63	3.13
Bell Gardens	44,568	44,112	456	9,786	3,948	2,469	1,447	1,526	396	9,464	3.29	4.66
Beverly Hills	34,383	34,344	39	15,946	5,672	236	1,805	8,205	28	15,120	5.18	2.27
Bradbury	865	865	0	311	309	0	2	0	0	284	8.68	3.05
Burbank	101,460	100,634	826	42,826	19,899	1,744	4,702	16,369	112	41,588	2.89	2.42
Calabasas	21,633	21,573	60	8,115	5,520	804	204	1,334	253	7,852	3.24	2.75
Carson	92,015	90,689	1,326	25,650	17,926	2,280	716	2,223	2,505	24,952	2.72	3.64
Cerritos	52,118	52,025	93	15,611	13,363	1,220	600	396	32	15,394	1.39	3.38
Claremont	34,692	29,324	5,368	11,592	8,154	843	621	1,961	13	11,313	2.41	2.59
Commerce	12,729	12,626	103	3,380	1,943	554	328	551	4	3,287	2.75	3.84
Compton	94,623	93,973	650	23,799	15,828	2,140	2,268	2,925	638	22,331	6.17	4.21
Covina	47,417	46,815	602	16,373	9,342	1,297	977	4,169	588	15,980	2.40	2.93
Cudahy	24,724	24,712	12	5,593	1,652	1,291	344	1,893	413	5,469	2.22	4.52
Culver City	39,307	38,783	524	17,144	6,619	1,903	2,301	6,140	181	16,625	3.03	2.33
Diamond Bar	57,034	56,916	118	17,982	12,629	2,501	823	1,696	333	17,674	1.71	3.22
Downey	108,780	107,015	1,765	34,821	20,367	1,662	1,634	10,965	193	34,050	2.21	3.14
Duarte	21,752	21,262	490	6,810	4,284	876	224	1,197	229	6,640	2.50	3.20
El Monte	117,445	116,175	1,270	27,783	14,674	3,388	2,021	6,298	1,402	27,058	2.61	4.29
El Segundo	16,263	16,240	23	7,278	3,100	416	817	2,934	11	7,077	2.76	2.30
Gardena	58,725	57,921	804	21,149	9,017	1,711	2,682	6,636	1,103	20,428	3.41	2.84
Glendale	197,352	194,488	2,864	73,741	26,044	3,814	6,919	36,867	97	71,832	2.59	2.71
Glendora	50,156	49,149	1,007	17,201	12,500	1,094	695	2,029	883	16,874	1.90	2.91
Hawaiian Gardens	14,968	14,964	4	3,627	1,495	469	444	944	275	3,510	3.23	4.26
Hawthorne	85,141	84,641	500	29,638	8,166	2,429	3,321	15,549	173	28,545	3.69	2.97
Hermosa Beach	18,814	18,701	113	9,854	4,068	986	2,154	2,564	82	9,489	3.70	1.97

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Hidden Hills	1,920	1,920	0	599	597	2	0	0	0	575	4.01	3.34
Huntington Park	62,082	61,901	181	15,335	5,266	2,370	2,209	5,476	14	14,860	3.10	4.17
Industry	783	519	264	124	101	23	0	0	0	121	2.42	4.29
Inglewood	113,835	112,465	1,370	38,621	13,932	3,224	4,736	16,491	238	36,779	4.77	3.06
Irwindale	1,463	1,461	2	378	318	15	13	24	8	365	3.44	4.00
La Canada Flintridge	20,609	20,420	189	7,006	6,499	200	132	175	0	6,840	2.37	2.99
La Habra Heights	5,807	5,807	0	1,960	1,928	24	8	0	0	1,896	3.27	3.06
Lakewood	80,301	80,107	194	27,312	22,219	741	688	3,566	98	26,855	1.67	2.98
La Mirada	47,325	45,686	1,639	14,811	11,756	794	358	1,737	166	14,580	1.56	3.13
Lancaster	120,760	113,591	7,169	41,947	27,225	1,200	2,724	7,303	3,495	38,409	8.43	2.96
La Puente	41,581	41,549	32	9,666	6,331	640	340	2,246	109	9,467	2.06	4.39
La Verne	32,034	31,326	708	11,295	7,492	599	734	707	1,763	11,079	1.91	2.83
Lawndale	32,077	31,991	86	9,865	4,921	1,606	905	2,305	128	9,551	3.18	3.35
Lomita	20,280	20,147	133	8,293	4,001	766	581	2,447	498	8,013	3.38	2.51
Long Beach	467,072	456,823	10,249	171,657	69,059	10,091	23,310	66,668	2,529	163,112	4.98	2.80
Los Angeles	3,745,083	3,662,274	82,809	1,340,036	526,104	87,775	129,213	587,859	9,085	1,277,773	4.65	2.87
Lynwood	70,762	68,562	2,200	15,010	8,194	1,677	1,713	3,314	112	14,417	3.95	4.76
Malibu	12,805	12,505	300	6,167	3,860	475	400	822	610	5,171	16.15	2.42
Manhattan Beach	34,559	34,545	14	15,166	10,260	1,342	2,644	887	33	14,601	3.73	2.37
Maywood	28,457	28,363	94	6,710	2,812	1,110	1,441	1,339	8	6,478	3.46	4.38
Monrovia	37,400	37,107	293	13,969	7,661	1,549	1,328	3,316	115	13,514	3.26	2.75
Montebello	62,892	62,583	309	19,416	9,357	1,573	2,863	5,390	233	18,844	2.95	3.32
Monterey Park	61,400	61,123	277	20,420	11,546	2,206	2,044	4,544	80	19,768	3.19	3.09
Norwalk	105,523	103,190	2,333	27,559	20,199	1,412	823	4,667	458	26,892	2.42	3.84
Palmdale	119,828	119,734	94	37,649	28,607	905	940	5,415	1,782	34,796	7.58	3.44
Palos Verdes Estates	13,508	13,503	5	5,205	4,783	40	44	338	0	4,996	4.02	2.70
Paramount	55,929	55,609	320	14,592	6,043	2,169	1,086	3,922	1,372	13,973	4.24	3.98
Pasadena	135,511	131,993	3,518	54,136	24,786	4,137	4,650	20,490	73	51,848	4.23	2.55
Pico Rivera	64,189	63,839	350	16,808	12,635	934	337	2,312	590	16,469	2.02	3.88
Pomona	151,833	146,494	5,339	39,687	24,199	3,339	3,233	7,211	1,705	37,940	4.40	3.86
Rancho Palos Verdes	41,748	41,239	509	15,753	12,170	1,287	245	2,051	0	15,299	2.88	2.70
Redondo Beach	64,195	64,008	187	29,625	11,503	4,238	4,063	9,441	380	28,645	3.31	2.24
Rolling Hills	1,896	1,896	0	683	676	7	0	0	0	646	5.42	2.94
Rolling Hills Estates	7,797	7,785	12	2,891	2,274	565	41	7	4	2,817	2.56	2.76
Rosemead	54,554	53,942	612	14,456	9,828	2,030	911	1,283	404	14,021	3.01	3.85
San Dimas	35,456	34,247	1,209	12,529	7,507	2,100	361	1,618	943	12,188	2.72	2.81
San Fernando	23,903	23,857	46	5,946	3,999	634	478	762	73	5,788	2.66	4.12
San Gabriel	40,340	39,585	755	12,931	7,005	1,156	1,077	3,649	44	12,608	2.50	3.14
San Marino	13,085	13,078	7	4,432	4,396	19	8	9	0	4,261	3.86	3.07

California Department of Finance
Demographic Research Unit

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Santa Clarita	153,892	152,499	1,393	52,790	32,092	6,314	2,573	9,571	2,240	51,121	3.16	2.98
Santa Fe Springs	16,610	16,392	218	4,933	3,096	286	158	1,266	127	4,834	2.01	3.39
Santa Monica	85,528	83,012	2,516	48,133	9,309	1,928	5,565	31,042	289	44,748	7.03	1.86
Sierra Madre	10,697	10,570	127	4,920	3,397	205	377	914	27	4,753	3.39	2.22
Signal Hill	9,624	9,570	54	3,870	1,050	461	676	1,675	8	3,691	4.63	2.59
South El Monte	21,397	21,379	18	4,724	2,934	458	233	595	504	4,620	2.20	4.63
South Gate	97,538	97,397	141	24,271	12,340	3,262	3,695	4,696	278	23,215	4.35	4.20
South Pasadena	24,662	24,475	187	10,889	5,070	621	1,106	4,078	14	10,515	3.43	2.33
Temple City	33,774	33,263	511	11,675	9,411	802	421	983	58	11,339	2.88	2.93
Torrance	139,876	138,627	1,249	56,084	30,241	3,693	3,254	17,713	1,183	54,656	2.55	2.54
Vernon	92	92	0	26	19	0	0	7	0	25	3.85	3.68
Walnut	30,378	30,338	40	8,399	8,042	119	46	192	0	8,264	1.61	3.67
West Covina	107,404	106,596	808	32,384	21,015	2,812	1,570	6,639	348	31,730	2.02	3.36
West Hollywood	36,197	35,961	236	24,142	1,805	681	1,836	19,820	0	23,153	4.10	1.55
Westlake Village	8,468	8,459	9	3,347	2,205	608	158	201	175	3,270	2.30	2.59
Whittier	84,555	82,260	2,295	28,956	19,036	1,480	2,052	6,174	214	28,250	2.44	2.91
Balance Of County	1,003,836	986,950	16,886	295,111	203,259	22,882	17,909	40,150	10,911	281,505	4.61	3.51
Incorporated	8,652,894	8,493,390	159,504	2,983,791	1,395,400	218,791	269,788	1,054,111	45,701	2,860,044	4.15	2.97
County Total	9,656,730	9,480,340	176,390	3,278,902	1,598,659	241,673	287,697	1,094,261	56,612	3,141,549	4.19	3.02
Madera County												
Chowchilla	14,416	7,738	6,678	2,747	2,179	31	254	247	36	2,596	5.50	2.98
Madera	44,386	43,948	438	12,703	8,249	742	1,332	2,079	301	12,152	4.34	3.62
Balance Of County	66,940	66,154	786	25,395	20,768	563	561	417	3,086	21,821	14.07	3.03
Incorporated	58,802	51,686	7,116	15,450	10,428	773	1,586	2,326	337	14,748	4.54	3.50
County Total	125,742	117,840	7,902	40,845	31,196	1,336	2,147	2,743	3,423	36,569	10.47	3.22
Marin County												
Belvedere	2,140	2,140	0	1,062	871	54	94	43	0	959	9.70	2.23
Corte Madera	9,140	9,132	8	3,851	2,614	416	251	561	9	3,777	1.92	2.42
Fairfax	7,349	7,319	30	3,418	2,329	193	492	393	11	3,306	3.28	2.21
Larkspur	12,068	11,913	155	6,415	2,434	365	544	2,833	239	6,144	4.22	1.94
Mill Valley	13,694	13,603	91	6,303	4,105	536	535	1,127	0	6,164	2.21	2.21

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Novato	48,323	47,341	982	19,196	11,133	2,607	1,166	3,572	718	18,721	2.47	2.53
Ross	2,341	2,247	94	806	786	0	12	0	8	762	5.46	2.95
San Anselmo	12,395	12,139	256	5,393	3,975	185	458	757	18	5,252	2.61	2.31
San Rafael	56,429	54,409	2,020	23,006	10,517	1,995	2,451	7,554	489	22,428	2.51	2.43
Sausalito	7,372	7,360	12	4,518	1,713	423	1,353	805	224	4,261	5.69	1.73
Tiburon	8,722	8,616	106	3,902	2,385	237	443	837	0	3,721	4.64	2.32
Balance Of County	68,879	61,495	7,384	27,465	21,154	1,448	1,569	2,882	412	25,530	7.05	2.41
Incorporated	179,973	176,219	3,754	77,870	42,862	7,011	7,799	18,482	1,716	75,495	3.05	2.33
County Total	248,852	237,714	11,138	105,335	64,016	8,459	9,368	21,364	2,128	101,025	4.09	2.35
Mariposa County												
County Total	17,092	15,669	1,423	8,907	6,006	71	214	383	2,233	6,674	25.07	2.35
Mendocino County												
Fort Bragg	6,858	6,732	126	3,067	1,991	158	312	459	147	2,855	6.91	2.36
Point Arena	479	479	0	220	136	7	45	13	19	193	12.27	2.48
Ukiah	15,580	14,846	734	6,163	3,461	379	754	1,107	462	6,010	2.48	2.47
Willits	5,085	4,959	126	2,015	1,186	84	303	299	143	1,937	3.87	2.56
Balance Of County	58,934	57,698	1,236	25,682	19,126	535	695	778	4,548	22,458	12.55	2.57
Incorporated	28,002	27,016	986	11,465	6,774	628	1,414	1,878	771	10,995	4.10	2.46
County Total	86,936	84,714	2,222	37,147	25,900	1,163	2,109	2,656	5,319	33,453	9.94	2.53
Merced County												
Atwater	23,408	23,143	265	8,186	5,271	584	834	990	507	7,311	10.69	3.17
Dos Palos	4,409	4,385	24	1,439	1,224	55	44	78	38	1,372	4.66	3.20
Gustine	4,845	4,845	0	1,811	1,450	30	98	105	128	1,729	4.53	2.80
Livingston	10,524	10,487	37	2,451	1,862	80	168	305	36	2,392	2.41	4.38
Los Banos	27,367	27,192	175	8,484	6,762	263	526	658	275	8,138	4.08	3.34
Merced	64,668	63,298	1,370	21,712	12,646	941	2,714	4,703	708	20,606	5.09	3.07
Balance Of County	79,296	78,312	984	25,308	19,702	581	782	628	3,615	23,225	8.23	3.37
Incorporated	135,221	133,350	1,871	44,083	29,215	1,953	4,384	6,839	1,692	41,548	5.75	3.21

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
	214,517	211,662	2,855	69,391	48,917	2,534	5,166	7,467	5,307	64,773		
County Total	214,517	211,662	2,855	69,391	48,917	2,534	5,166	7,467	5,307	64,773	6.66	3.27
Modoc County												
Alturas	2,890	2,810	80	1,367	1,020	54	48	144	101	1,181	13.61	2.38
Balance Of County	6,604	6,279	325	3,473	2,273	33	50	15	1,102	2,628	24.33	2.39
Incorporated	2,890	2,810	80	1,367	1,020	54	48	144	101	1,181	13.61	2.38
County Total	9,494	9,089	405	4,840	3,293	87	98	159	1,203	3,809	21.30	2.39
Mono County												
Mammoth Lakes	7,207	6,989	218	8,150	2,171	965	1,600	3,221	193	2,881	64.65	2.43
Balance Of County	5,703	5,641	62	3,838	2,485	225	300	74	754	2,348	38.82	2.40
Incorporated	7,207	6,989	218	8,150	2,171	965	1,600	3,221	193	2,881	64.65	2.43
County Total	12,910	12,630	280	11,988	4,656	1,190	1,900	3,295	947	5,229	56.38	2.42
Monterey County												
Carmel-By-The-Sea	4,117	4,117	0	3,338	2,743	111	214	270	0	2,288	31.46	1.80
Del Rey Oaks	1,663	1,663	0	727	567	25	23	109	3	704	3.16	2.36
Gonzales	7,937	7,864	73	1,796	1,288	128	169	169	42	1,766	1.67	4.45
Greenfield	12,744	12,648	96	2,726	1,838	282	274	247	85	2,643	3.04	4.79
King City	11,363	11,179	184	2,841	1,575	278	284	415	289	2,754	3.06	4.06
Marina	19,073	18,942	131	8,539	3,384	1,537	1,455	1,743	420	6,747	20.99	2.81
Monterey	29,665	27,042	2,623	13,424	5,900	913	2,248	4,342	21	12,658	5.71	2.14
Pacific Grove	15,643	15,468	175	8,034	5,004	448	981	1,510	91	7,318	8.91	2.11
Salinas	144,696	142,244	2,452	39,918	21,225	3,439	3,460	10,508	1,286	38,548	3.43	3.69
Sand City	270	206	64	90	51	5	20	9	5	83	7.78	2.48
Seaside	33,530	31,637	1,893	11,011	6,115	2,279	927	1,258	432	9,737	11.57	3.25
Soledad	22,636	11,360	11,276	2,548	1,695	205	315	210	123	2,486	2.43	4.57
Balance Of County	103,616	101,964	1,652	37,618	28,865	2,695	1,456	1,736	2,866	34,312	8.79	2.97
Incorporated	303,337	284,370	18,967	94,992	51,385	9,650	10,370	20,790	2,797	87,732	7.64	3.24

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	406,953	386,334	20,619	132,610	80,250	12,345	11,826	22,526	5,663	122,044	7.97	3.17
Napa County												
American Canyon	10,063	9,929	134	3,361	2,426	23	70	61	781	3,294	1.99	3.01
Calistoga	5,216	5,149	67	2,253	1,049	97	186	361	560	2,046	9.19	2.52
Napa	73,567	72,108	1,459	28,065	17,470	2,064	2,778	4,364	1,389	27,259	2.87	2.65
St Helena	5,994	5,942	52	2,718	1,654	215	210	478	161	2,390	12.07	2.49
Yountville	3,275	2,092	1,183	1,158	604	172	39	35	308	1,066	7.94	1.96
Balance Of County	27,798	25,418	2,380	11,464	9,698	650	361	23	732	9,791	14.59	2.60
Incorporated	98,115	95,220	2,895	37,555	23,203	2,571	3,283	5,299	3,199	36,055	3.99	2.64
County Total	125,913	120,638	5,275	49,019	32,901	3,221	3,644	5,322	3,931	45,846	6.47	2.63
Nevada County												
Grass Valley	11,855	11,505	350	5,673	2,543	256	743	1,439	692	5,404	4.74	2.13
Nevada City	3,025	2,838	187	1,426	1,106	53	117	78	72	1,323	7.22	2.15
Truckee	14,220	14,179	41	9,992	8,525	242	521	406	298	5,273	47.23	2.69
Balance Of County	64,235	63,859	376	27,793	24,671	320	230	193	2,379	25,370	8.72	2.52
Incorporated	29,100	28,522	578	17,091	12,174	551	1,381	1,923	1,062	12,000	29.79	2.38
County Total	93,335	92,381	954	44,884	36,845	871	1,611	2,116	3,441	37,370	16.74	2.47
Orange County												
Anaheim	331,362	327,566	3,796	99,808	43,018	8,923	10,393	33,090	4,384	97,056	2.76	3.38
Brea	35,911	35,783	128	13,390	7,518	1,077	434	3,491	870	13,129	1.95	2.73
Buena Park	78,787	77,853	934	23,720	13,938	1,864	1,420	6,207	291	23,228	2.07	3.35
Costa Mesa	109,749	106,487	3,262	40,421	15,355	4,127	5,855	13,871	1,213	39,221	2.97	2.72
Cypress	47,066	46,745	321	16,192	9,981	2,485	520	2,842	364	15,814	2.33	2.96
Dana Point	35,560	35,318	242	15,736	7,732	2,266	2,796	2,573	369	14,506	7.82	2.44
Fountain Valley	55,501	54,989	512	18,476	12,364	2,194	644	2,876	398	18,165	1.68	3.03
Fullerton	127,842	125,059	2,783	45,010	22,724	3,728	3,636	14,001	921	43,842	2.59	2.85
Garden Grove	167,285	165,051	2,234	46,860	26,559	4,486	3,407	10,591	1,817	45,945	1.95	3.59
Huntington Beach	192,412	191,620	792	76,078	37,351	9,457	9,666	16,463	3,141	74,062	2.65	2.59
Irvine	148,813	141,552	7,261	55,398	22,132	12,964	4,233	15,047	1,022	52,807	4.68	2.68

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

	POPULATION			HOUSING UNITS								PERSONS
					SINGLE		MULTIPLE					PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Laguna Beach	24,023	23,901	122	13,005	8,091	758	1,758	2,074	324	11,547	11.21	2.07
Laguna Hills	32,381	31,957	424	11,092	5,817	2,183	608	2,267	217	10,747	3.11	2.97
Laguna Niguel	62,841	62,538	303	24,027	13,309	5,007	1,341	4,354	16	23,355	2.80	2.68
Laguna Woods	17,961	17,887	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.42
La Habra	59,969	59,374	595	19,588	10,340	1,659	1,344	5,508	737	19,090	2.54	3.11
Lake Forest	76,078	75,234	844	26,310	14,166	3,923	1,276	5,659	1,286	25,639	2.55	2.93
La Palma	15,553	15,522	31	5,066	3,632	376	102	929	27	4,979	1.72	3.12
Los Alamitos	11,641	11,235	406	4,329	1,914	243	1,029	1,014	129	4,246	1.92	2.65
Mission Viejo	94,273	93,208	1,065	33,093	24,354	4,021	1,117	3,512	89	32,555	1.63	2.86
Newport Beach	71,602	70,662	940	37,779	16,200	6,685	5,389	8,642	863	33,506	11.31	2.11
Orange	131,421	126,089	5,332	42,387	23,870	5,149	4,692	7,337	1,339	41,402	2.32	3.05
Placentia	47,106	46,803	303	15,386	9,234	2,033	1,100	2,442	577	15,096	1.88	3.10
Rancho Santa Margarita	47,988	47,974	14	16,629	9,063	3,889	598	3,079	0	16,365	1.59	2.93
San Clemente	53,216	52,924	292	21,812	11,822	2,386	3,937	3,264	403	20,483	6.09	2.58
San Juan Capistrano	34,236	33,810	426	11,352	5,762	2,395	944	775	1,476	10,961	3.44	3.09
Santa Ana	341,218	335,594	5,624	74,612	33,512	6,403	7,522	23,266	3,909	73,025	2.13	4.60
Seal Beach	24,561	24,303	258	14,273	4,545	2,121	1,169	6,275	163	13,143	7.92	1.85
Stanton	37,744	37,226	518	11,009	2,932	1,873	988	3,954	1,262	10,765	2.22	3.46
Tustin	68,402	67,984	418	25,597	8,142	3,488	3,836	9,223	908	23,924	6.54	2.84
Villa Park	6,038	6,017	21	2,002	1,973	18	0	6	5	1,944	2.90	3.10
Westminster	89,073	88,521	552	26,952	14,748	2,445	2,073	4,618	3,068	26,418	1.98	3.35
Yorba Linda	59,648	59,513	135	19,625	15,427	2,081	534	1,272	311	19,309	1.61	3.08
Balance Of County	153,051	151,490	1,561	55,394	35,944	8,079	2,353	8,475	543	52,700	4.86	2.88
Incorporated	2,737,261	2,696,299	40,962	920,643	458,252	116,719	86,835	226,912	31,925	888,865	3.45	3.03
County Total	2,890,312	2,847,789	42,523	976,037	494,196	124,798	89,188	235,387	32,468	941,565	3.53	3.02
Placer County												
Auburn	12,556	12,350	206	5,489	3,678	211	655	945	0	5,333	2.84	2.32
Colfax	1,575	1,574	1	669	446	15	112	63	33	646	3.44	2.44
Lincoln	13,621	13,507	114	5,184	4,006	196	174	713	95	4,883	5.81	2.77
Loomis	6,307	6,273	34	2,286	1,909	199	58	9	111	2,219	2.93	2.83
Rocklin	39,550	39,530	20	14,996	10,824	518	591	2,624	439	14,438	3.72	2.74
Roseville	83,195	82,141	1,054	33,139	24,602	1,082	1,627	5,285	543	31,954	3.58	2.57
Balance Of County	101,958	100,379	1,579	48,964	38,932	1,916	2,481	2,164	3,471	37,743	22.92	2.66
Incorporated	156,804	155,375	1,429	61,763	45,465	2,221	3,217	9,639	1,221	59,473	3.71	2.61

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	258,762	255,754	3,008	110,727	84,397	4,137	5,698	11,803	4,692	97,216	12.20	2.63
Plumas County												
Portola	2,211	2,190	21	1,011	766	11	72	110	52	902	10.78	2.43
Balance Of County	18,550	18,383	167	12,478	9,448	433	303	286	2,008	8,166	34.56	2.25
Incorporated	2,211	2,190	21	1,011	766	11	72	110	52	902	10.78	2.43
County Total	20,761	20,573	188	13,489	10,214	444	375	396	2,060	9,068	32.77	2.27
Riverside County												
Banning	23,955	23,617	338	9,831	6,926	728	426	595	1,156	8,987	8.59	2.63
Beaumont	11,554	11,399	155	4,281	2,716	172	340	706	347	3,902	8.85	2.92
Blythe	20,830	12,333	8,497	4,998	2,727	151	505	801	814	4,193	16.11	2.94
Calimesa	7,209	7,113	96	3,249	1,762	111	57	64	1,255	2,983	8.19	2.39
Canyon Lake	10,157	10,141	16	4,091	3,782	78	6	84	141	3,683	9.97	2.75
Cathedral City	44,081	43,899	182	18,304	9,215	2,587	2,288	1,566	2,648	14,349	21.61	3.06
Coachella	23,353	23,309	44	5,114	3,190	319	640	510	455	4,893	4.32	4.76
Corona	129,708	129,076	632	40,378	27,098	2,186	2,225	7,587	1,282	38,906	3.65	3.32
Desert Hot Springs	16,769	16,595	174	7,046	3,792	180	1,193	1,313	568	5,869	16.70	2.83
Hemet	60,564	58,885	1,679	29,731	12,188	1,748	2,125	4,426	9,244	25,777	13.30	2.28
Indian Wells	4,147	4,147	0	4,136	2,663	884	112	469	8	2,133	48.43	1.94
Indio	50,430	49,574	856	17,203	7,956	878	1,419	3,780	3,170	14,112	17.97	3.51
Lake Elsinore	30,024	29,951	73	9,772	6,476	707	735	1,099	755	9,065	7.23	3.30
La Quinta	26,079	26,039	40	12,878	10,549	1,305	280	485	259	9,207	28.51	2.83
Moreno Valley	144,302	143,605	697	41,590	34,727	891	1,389	3,540	1,043	39,375	5.33	3.65
Murrieta	46,433	46,247	186	15,499	13,079	211	147	1,522	540	14,875	4.03	3.11
Norco	24,483	19,666	4,817	6,325	5,951	137	9	137	91	6,183	2.25	3.18
Palm Desert	42,070	41,843	227	28,373	11,451	9,534	2,459	3,731	1,198	19,425	31.54	2.15
Palm Springs	43,392	42,696	696	30,952	10,241	6,160	2,489	9,827	2,235	20,602	33.44	2.07
Perris	36,901	36,669	232	10,659	7,075	321	363	1,202	1,698	9,749	8.54	3.76
Rancho Mirage	13,840	13,548	292	12,092	4,590	3,680	620	1,203	1,999	6,972	42.34	1.94
Riverside	262,135	253,884	8,251	87,393	55,058	4,185	5,743	20,026	2,381	83,358	4.62	3.05
San Jacinto	24,610	24,420	190	9,716	5,281	596	653	567	2,619	8,525	12.26	2.87
Temecula	61,761	61,739	22	20,242	15,319	386	598	3,618	321	19,388	4.22	3.18

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Balance Of County	431,163	424,572	6,591	161,829	101,904	4,194	3,470	5,552	46,709	139,447	13.83	3.05
Incorporated	1,158,787	1,130,395	28,392	433,853	263,812	38,135	26,821	68,858	36,227	376,511	13.22	3.00
County Total	1,589,950	1,554,967	34,983	595,682	365,716	42,329	30,291	74,410	82,936	515,958	13.38	3.01
Sacramento County												
Citrus Heights	86,363	85,486	877	35,052	19,423	3,531	3,019	7,201	1,878	33,627	4.07	2.54
Elk Grove	75,637	75,351	286	25,057	22,196	919	525	1,144	273	24,498	2.23	3.08
Folsom	56,741	49,770	6,971	19,690	14,227	635	627	3,340	861	18,844	4.30	2.64
Galt	20,103	19,915	188	6,347	5,095	198	336	346	372	6,105	3.81	3.26
Isleton	837	837	0	384	222	2	77	36	47	343	10.68	2.44
Sacramento	414,618	405,500	9,118	165,281	97,071	11,350	15,871	37,318	3,671	155,833	5.72	2.60
Balance Of County	598,413	590,382	8,031	228,686	142,942	15,610	15,860	45,892	8,382	220,405	3.62	2.68
Incorporated	654,299	636,859	17,440	251,811	158,234	16,635	20,455	49,385	7,102	239,250	4.99	2.66
County Total	1,252,712	1,227,241	25,471	480,497	301,176	32,245	36,315	95,277	15,484	459,655	4.34	2.67
San Benito County												
Hollister	35,141	34,970	171	10,028	7,471	531	979	741	306	9,818	2.09	3.56
San Juan Bautista	1,571	1,571	0	617	412	70	57	62	16	569	7.78	2.76
Balance Of County	17,773	17,437	336	6,071	4,980	427	70	42	552	5,706	6.01	3.06
Incorporated	36,712	36,541	171	10,645	7,883	601	1,036	803	322	10,387	2.42	3.52
County Total	54,485	53,978	507	16,716	12,863	1,028	1,106	845	874	16,093	3.73	3.35
San Bernardino County												
Adelanto	18,304	16,798	1,506	5,547	3,756	161	387	750	493	4,714	15.02	3.56
Apple Valley	55,475	55,112	363	20,429	15,178	726	2,074	1,417	1,034	18,802	7.96	2.93
Barstow	21,248	20,900	348	9,143	5,123	367	1,084	1,474	1,095	7,639	16.45	2.74
Big Bear Lake	5,577	5,552	25	8,843	7,380	326	342	410	385	2,380	73.09	2.33
Chino	67,800	60,231	7,569	17,990	12,558	952	782	3,170	528	17,393	3.32	3.46
Chino Hills	68,617	68,466	151	20,775	16,869	1,378	284	1,558	686	20,393	1.84	3.36
Colton	48,213	47,949	264	15,711	9,128	602	1,056	4,110	815	14,549	7.40	3.30
Fontana	133,207	132,708	499	36,750	27,382	1,198	1,579	5,709	882	34,812	5.27	3.81

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Grand Terrace	11,736	11,527	209	4,458	2,863	175	265	905	250	4,221	5.32	2.73
Hesperia	63,601	63,270	331	21,492	17,301	363	1,004	1,624	1,200	20,101	6.47	3.15
Highland	45,015	44,775	240	14,850	10,801	512	598	2,129	810	13,471	9.29	3.32
Loma Linda	19,767	18,802	965	8,275	3,355	642	1,291	2,425	562	7,714	6.78	2.44
Montclair	33,466	32,854	612	9,095	5,227	762	1,002	1,350	754	8,828	2.94	3.72
Needles	4,913	4,902	11	2,570	1,400	86	254	287	543	1,954	23.97	2.51
Ontario	159,628	158,567	1,061	45,237	26,848	3,633	3,960	8,749	2,047	43,578	3.67	3.64
Rancho Cucamonga	131,373	127,747	3,626	42,953	30,039	2,532	1,794	7,216	1,372	41,657	3.02	3.07
Redlands	64,709	62,743	1,966	24,999	15,973	900	2,358	4,863	905	23,792	4.83	2.64
Rialto	93,147	92,343	804	26,158	18,593	586	1,764	3,421	1,794	24,766	5.32	3.73
San Bernardino	187,856	181,961	5,895	63,563	37,434	2,716	5,732	13,201	4,480	56,544	11.04	3.22
Twentynine Palms	27,656	18,814	8,842	8,505	4,616	1,263	1,650	445	531	7,034	17.30	2.68
Upland	69,411	68,826	585	25,603	14,681	1,766	2,675	5,636	845	24,682	3.60	2.79
Victorville	66,789	64,753	2,036	22,774	16,344	389	1,333	2,951	1,757	21,149	7.14	3.06
Yucaipa	41,934	41,362	572	16,244	10,348	394	731	545	4,226	15,317	5.71	2.70
Yucca Valley	17,110	16,799	311	7,993	6,129	140	639	378	707	6,985	12.61	2.41
Balance Of County	290,180	278,916	11,264	125,852	101,010	4,293	4,232	3,098	13,219	91,555	27.25	3.05
Incorporated	1,456,552	1,417,761	38,791	479,957	319,326	22,569	34,638	74,723	28,701	442,475	7.81	3.20
County Total	1,746,732	1,696,677	50,055	605,809	420,336	26,862	38,870	77,821	41,920	534,030	11.85	3.18
San Diego County												
Carlsbad	83,270	82,483	787	35,571	19,075	5,746	2,100	7,359	1,291	33,176	6.73	2.49
Chula Vista	181,516	180,326	1,190	61,502	31,761	5,454	4,020	16,421	3,846	59,652	3.01	3.02
Coronado	23,990	17,815	6,175	9,519	4,435	874	804	3,383	23	7,763	18.45	2.30
Del Mar	4,453	4,451	2	2,565	1,335	360	198	672	0	2,185	14.81	2.04
El Cajon	96,182	93,699	2,483	35,287	13,480	1,548	2,244	15,981	2,034	34,293	2.82	2.73
Encinitas	59,095	58,536	559	24,028	13,320	4,535	2,089	3,315	769	23,007	4.25	2.54
Escondido	135,696	133,931	1,765	45,270	21,738	2,922	3,094	13,762	3,754	44,032	2.73	3.04
Imperial Beach	27,356	26,665	691	9,753	3,993	687	1,057	3,676	340	9,285	4.80	2.87
La Mesa	55,371	54,325	1,046	24,947	11,091	1,922	2,001	9,574	359	24,190	3.03	2.25
Lemon Grove	25,227	24,636	591	8,733	5,759	713	694	1,470	97	8,499	2.68	2.90
National City	55,945	51,498	4,447	15,422	6,590	1,330	1,685	5,380	437	15,018	2.62	3.43
Oceanside	164,311	163,031	1,280	60,117	30,676	8,222	4,348	13,451	3,420	56,996	5.19	2.86
Poway	48,983	48,557	426	15,843	11,894	877	318	2,063	691	15,594	1.57	3.11
San Diego	1,242,148	1,197,194	44,954	472,141	220,434	45,766	42,012	157,497	6,432	453,006	4.05	2.64
San Marcos	57,703	57,554	149	19,576	9,835	1,038	694	4,349	3,660	18,797	3.98	3.06

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santee	53,553	52,510	1,043	18,829	10,622	1,615	1,196	2,893	2,503	18,466	1.93	2.84
Solana Beach	13,208	13,174	34	6,496	2,947	1,265	614	1,631	39	5,790	10.87	2.28
Vista	91,258	88,992	2,266	29,949	14,755	2,029	2,140	8,896	2,129	29,008	3.14	3.07
Balance Of County	445,943	422,867	23,076	154,362	103,334	11,227	6,413	18,209	15,179	144,548	6.36	2.93
Incorporated	2,419,265	2,349,377	69,888	895,548	433,740	86,903	71,308	271,773	31,824	858,757	4.11	2.74
County Total	2,865,208	2,772,244	92,964	1,049,910	537,074	98,130	77,721	289,982	47,003	1,003,305	4.44	2.76
San Francisco County												
City and County Total	784,419	764,965	19,454	347,489	62,737	48,731	81,032	154,429	560	330,627	4.85	2.31
San Joaquin County												
Escalon	6,150	6,124	26	2,171	1,765	20	153	98	135	2,094	3.55	2.93
Lathrop	10,822	10,812	10	3,063	2,545	63	92	12	351	2,977	2.81	3.63
Lodi	58,342	57,318	1,024	21,611	13,443	1,454	1,750	4,500	464	20,918	3.21	2.74
Manteca	51,648	51,171	477	17,541	12,482	739	1,105	2,346	869	16,952	3.36	3.02
Ripon	10,674	10,563	111	3,579	3,044	95	137	294	9	3,498	2.26	3.02
Stockton	249,046	243,754	5,292	82,798	49,829	6,592	8,417	16,672	1,288	79,280	4.25	3.08
Tracy	61,103	60,758	345	19,174	15,148	1,015	939	1,597	475	18,679	2.58	3.25
Balance Of County	132,192	120,668	11,524	42,331	34,093	1,240	770	592	5,636	40,236	4.95	3.00
Incorporated	447,785	440,500	7,285	149,937	98,256	9,978	12,593	25,519	3,591	144,398	3.69	3.05
County Total	579,977	561,168	18,809	192,268	132,349	11,218	13,363	26,111	9,227	184,634	3.97	3.04
San Luis Obispo County												
Arroyo Grande	16,020	15,810	210	6,814	4,543	585	489	649	548	6,539	4.04	2.42
Atascadero	26,725	25,229	1,496	9,947	6,873	441	862	1,220	551	9,627	3.22	2.62
El Paso De Robles	25,032	24,138	894	9,068	5,757	805	1,019	1,180	307	8,826	2.67	2.74
Grover Beach	13,149	13,023	126	5,409	3,094	786	703	579	247	5,048	6.67	2.58
Morro Bay	10,426	10,228	198	6,290	4,093	355	619	464	759	5,017	20.24	2.04
Pismo Beach	8,587	8,560	27	5,512	2,941	576	441	467	1,087	4,242	23.04	2.02
San Luis Obispo	44,341	42,479	1,862	19,357	9,122	1,270	2,194	5,270	1,501	18,688	3.46	2.27
Balance Of County	106,018	94,962	11,056	41,151	30,761	1,278	1,869	1,075	6,168	35,907	12.74	2.65

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Incorporated	144,280	139,467	4,813	62,397	36,423	4,818	6,327	9,829	5,000	57,987	7.07	2.41
County Total	250,298	234,429	15,869	103,548	67,184	6,096	8,196	10,904	11,168	93,894	9.32	2.50
San Mateo County												
Atherton	7,212	6,894	318	2,505	2,466	32	0	7	0	2,413	3.67	2.86
Belmont	25,214	24,587	627	10,588	6,239	581	275	3,493	0	10,429	1.50	2.36
Brisbane	3,617	3,577	40	1,836	1,013	260	175	345	43	1,624	11.55	2.20
Burlingame	28,321	27,835	486	12,910	6,132	409	984	5,385	0	12,551	2.78	2.22
Colma	1,190	1,141	49	341	204	39	71	21	6	327	4.11	3.49
Daly City	104,019	103,229	790	31,349	15,877	4,469	2,825	7,596	582	30,812	1.71	3.35
East Palo Alto	30,517	30,328	189	7,316	3,752	375	360	2,670	159	7,197	1.63	4.21
Foster City	28,878	28,791	87	12,008	4,807	2,464	767	3,963	7	11,612	3.30	2.48
Half Moon Bay	11,960	11,112	848	4,147	2,605	536	260	319	427	4,036	2.68	2.75
Hillsborough	10,888	10,886	2	3,816	3,799	8	9	0	0	3,701	3.01	2.94
Menlo Park	30,931	29,974	957	12,740	6,865	930	1,574	3,366	5	12,412	2.57	2.42
Millbrae	20,776	20,444	332	8,114	5,317	269	424	2,093	11	7,957	1.93	2.57
Pacifica	38,637	38,456	181	14,299	10,310	778	711	2,402	98	14,047	1.76	2.74
Portola Valley	4,474	4,404	70	1,772	1,479	33	0	260	0	1,700	4.06	2.59
Redwood City	75,666	73,739	1,927	28,947	13,512	3,653	2,603	8,346	833	28,085	2.98	2.63
San Bruno	40,277	40,056	221	14,982	9,060	566	1,188	4,146	22	14,679	2.02	2.73
San Carlos	27,804	27,621	183	11,696	8,231	608	463	2,378	16	11,460	2.02	2.41
San Mateo	92,794	91,478	1,316	38,277	17,702	3,492	3,003	14,035	45	37,365	2.38	2.45
South San Francisco	60,833	60,390	443	20,178	11,815	2,485	1,668	3,801	409	19,716	2.29	3.06
Woodside	5,377	5,371	6	2,034	1,972	28	28	5	1	1,953	3.98	2.75
Balance Of County	62,882	61,499	1,383	21,782	17,926	690	900	1,419	847	21,057	3.33	2.92
Incorporated	649,385	640,313	9,072	239,855	133,157	22,015	17,388	64,631	2,664	234,076	2.41	2.74
County Total	712,267	701,812	10,455	261,637	151,083	22,705	18,288	66,050	3,511	255,133	2.49	2.75
Santa Barbara County												
Buellton	3,918	3,912	6	1,511	902	63	30	98	418	1,460	3.38	2.68
Carpinteria	14,361	14,236	125	5,504	2,152	422	523	1,467	940	5,026	8.68	2.83
Guadalupe	5,889	5,889	0	1,502	1,067	161	169	99	6	1,465	2.46	4.02
Lompoc	41,509	38,313	3,196	13,793	7,209	1,044	1,927	2,673	940	13,224	4.13	2.90
Santa Barbara	90,129	88,337	1,792	37,130	17,074	2,874	5,493	11,171	518	35,657	3.97	2.48

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSE-HOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	SINGLE: DETACHED	SINGLE: ATTACHED	MULTIPLE: 2 TO 4	MULTIPLE: 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Maria	78,602	76,440	2,162	23,100	14,145	1,324	1,651	4,408	1,572	22,391	3.07	3.41
Solvang	5,390	5,230	160	2,303	1,314	151	166	453	219	2,199	4.52	2.38
Balance Of County	163,439	154,640	8,799	58,854	39,477	3,726	3,352	8,329	3,970	56,061	4.75	2.76
Incorporated	239,798	232,357	7,441	84,843	43,863	6,039	9,959	20,369	4,613	81,422	4.03	2.85
County Total	403,237	386,997	16,240	143,697	83,340	9,765	13,311	28,698	8,583	137,483	4.32	2.81
Santa Clara County												
Campbell	38,260	37,970	290	16,302	6,873	1,975	2,442	4,755	257	15,936	2.25	2.38
Cupertino	50,913	50,432	481	18,763	11,490	2,028	1,666	3,570	9	18,283	2.56	2.76
Gilroy	42,763	42,333	430	12,509	8,105	741	1,264	1,968	431	12,218	2.33	3.47
Los Altos	27,863	27,444	419	10,770	9,218	364	269	903	16	10,504	2.47	2.61
Los Altos Hills	8,073	8,008	65	2,882	2,818	32	17	9	6	2,806	2.64	2.85
Los Gatos	28,833	28,131	702	12,446	7,010	1,827	931	2,555	123	12,065	3.06	2.33
Milpitas	62,999	59,825	3,174	17,413	10,917	2,225	1,502	2,197	572	17,180	1.34	3.48
Monte Sereno	3,497	3,497	0	1,239	1,135	13	18	73	0	1,213	2.10	2.88
Morgan Hill	34,165	33,652	513	11,269	7,003	1,552	627	1,161	926	11,020	2.21	3.05
Mountain View	71,370	70,866	504	32,665	9,157	3,761	2,670	15,846	1,231	31,466	3.67	2.25
Palo Alto	60,270	59,602	668	26,740	15,392	974	1,733	8,477	164	25,886	3.19	2.30
San Jose	905,542	894,395	11,147	284,531	163,088	27,583	23,220	59,612	11,028	279,240	1.86	3.20
Santa Clara	103,387	100,600	2,787	39,949	17,699	3,588	3,875	14,678	109	38,836	2.79	2.59
Saratoga	29,932	29,681	251	10,658	9,543	560	197	351	7	10,459	1.87	2.84
Sunnyvale	132,507	131,632	875	53,939	21,081	3,938	4,911	19,913	4,096	52,722	2.26	2.50
Balance Of County	101,231	93,277	7,954	32,088	25,290	1,683	1,138	3,294	683	30,998	3.40	3.01
Incorporated	1,600,374	1,578,068	22,306	552,075	300,529	51,161	45,342	136,068	18,975	539,834	2.22	2.92
County Total	1,701,605	1,671,345	30,260	584,163	325,819	52,844	46,480	139,362	19,658	570,832	2.28	2.93
Santa Cruz County												
Capitola	10,091	9,935	156	5,341	1,941	514	1,137	1,099	650	4,720	11.63	2.11
Santa Cruz	54,449	49,998	4,451	21,526	12,128	1,905	2,576	4,477	440	20,463	4.94	2.44
Scotts Valley	11,446	10,994	452	4,449	2,438	413	377	417	804	4,298	3.39	2.56
Watsonville	47,012	46,459	553	12,432	6,238	1,597	1,673	2,024	900	12,098	2.69	3.84
Balance Of County	134,138	130,909	3,229	55,452	40,240	4,333	2,605	3,816	4,458	49,911	9.99	2.62

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Incorporated	122,998	117,386	5,612	43,748	22,745	4,429	5,763	8,017	2,794	41,579	4.96	2.82
County Total	257,136	248,295	8,841	99,200	62,985	8,762	8,368	11,833	7,252	91,490	7.77	2.71
Shasta County												
Anderson	9,233	9,115	118	3,623	2,309	209	372	560	173	3,414	5.77	2.67
Redding	82,906	80,529	2,377	34,293	21,986	949	4,337	4,437	2,584	32,569	5.03	2.47
Shasta Lake	9,287	9,235	52	3,805	2,931	27	237	114	496	3,461	9.04	2.67
Balance Of County	65,009	64,208	801	27,673	19,479	272	367	198	7,357	24,535	11.34	2.62
Incorporated	101,426	98,879	2,547	41,721	27,226	1,185	4,946	5,111	3,253	39,444	5.46	2.51
County Total	166,435	163,087	3,348	69,394	46,705	1,457	5,313	5,309	10,610	63,979	7.80	2.55
Sierra County												
Loyalton	874	844	30	347	300	13	3	0	31	323	6.92	2.61
Balance Of County	2,744	2,738	6	1,864	1,519	36	44	63	202	1,203	35.46	2.28
Incorporated	874	844	30	347	300	13	3	0	31	323	6.92	2.61
County Total	3,618	3,582	36	2,211	1,819	49	47	63	233	1,526	30.98	2.35
Siskiyou County												
Dorris	887	887	0	397	318	4	16	0	59	343	13.60	2.59
Dunsmuir	1,923	1,923	0	1,171	792	23	126	184	46	868	25.88	2.22
Etna	782	782	0	363	266	10	19	13	55	330	9.09	2.37
Fort Jones	663	663	0	330	234	11	34	2	49	300	9.09	2.21
Montague	1,456	1,437	19	610	469	6	10	43	82	561	8.03	2.56
Mount Shasta	3,661	3,613	48	1,820	1,153	89	249	256	73	1,689	7.20	2.14
Tulelake	1,021	1,021	0	460	317	2	44	19	78	359	21.96	2.84
Weed	2,978	2,849	129	1,292	888	19	136	190	59	1,183	8.44	2.41
Yreka	7,297	7,077	220	3,310	2,191	140	283	467	229	3,121	5.71	2.27
Balance Of County	23,822	23,542	280	12,313	8,878	184	174	96	2,981	9,903	19.57	2.38
Incorporated	20,668	20,252	416	9,753	6,628	304	917	1,174	730	8,754	10.24	2.31

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	44,490	43,794	696	22,066	15,506	488	1,091	1,270	3,711	18,657	15.45	2.35
Solano County												
Benicia	27,127	27,073	54	10,580	6,843	1,045	917	1,449	326	10,360	2.08	2.61
Dixon	16,193	16,152	41	5,167	4,251	213	368	249	86	5,068	1.92	3.19
Fairfield	98,592	94,308	4,284	32,430	21,601	2,159	2,207	5,571	892	31,347	3.34	3.01
Rio Vista	4,769	4,769	0	2,046	1,628	34	103	171	110	1,950	4.69	2.45
Suisun City	26,496	26,402	94	8,210	6,874	189	327	754	66	8,050	1.95	3.28
Vacaville	90,686	81,499	9,187	29,258	20,651	1,035	2,132	4,132	1,308	28,656	2.06	2.84
Vallejo	118,259	116,142	2,117	41,349	28,507	1,701	3,919	5,876	1,346	39,726	3.93	2.92
Balance Of County	19,527	18,933	594	6,995	5,893	220	293	119	470	6,584	5.88	2.88
Incorporated	382,122	366,345	15,777	129,040	90,355	6,376	9,973	18,202	4,134	125,157	3.01	2.93
County Total	401,649	385,278	16,371	136,035	96,248	6,596	10,266	18,321	4,604	131,741	3.16	2.92
Sonoma County												
Cloverdale	7,082	7,005	77	2,714	1,980	121	112	293	208	2,586	4.72	2.71
Cotati	6,612	6,594	18	2,639	1,528	372	341	277	121	2,585	2.05	2.55
Healdsburg	11,378	11,255	123	4,367	3,149	252	427	440	99	4,190	4.05	2.69
Petaluma	55,435	54,695	740	20,621	15,047	1,652	1,203	1,788	931	20,243	1.83	2.70
Rohnert Park	42,272	41,171	1,101	15,808	7,656	1,698	929	4,112	1,413	15,503	1.93	2.66
Santa Rosa	149,520	145,714	3,806	58,297	34,765	5,617	4,759	10,483	2,673	56,736	2.68	2.57
Sebastopol	7,799	7,588	211	3,329	1,997	253	523	497	59	3,258	2.13	2.33
Sonoma	9,498	9,407	91	4,851	2,729	662	448	568	444	4,546	6.29	2.07
Windsor	23,533	23,442	91	7,990	6,185	460	171	352	822	7,846	1.80	2.99
Balance Of County	151,414	145,664	5,750	64,389	52,001	2,890	2,868	2,021	4,609	56,700	11.94	2.57
Incorporated	313,129	306,871	6,258	120,616	75,036	11,087	8,913	18,810	6,770	117,493	2.59	2.61
County Total	464,543	452,535	12,008	185,005	127,037	13,977	11,781	20,831	11,379	174,193	5.84	2.60
Stanislaus County												
Ceres	35,104	35,005	99	10,818	8,174	343	603	986	712	10,479	3.13	3.34
Hughson	4,123	4,117	6	1,284	1,012	65	50	68	89	1,254	2.34	3.28
Modesto	193,640	190,567	3,073	68,265	46,917	4,006	6,147	9,232	1,963	66,009	3.30	2.89

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Newman	7,503	7,437	66	2,279	1,867	76	193	117	26	2,177	4.48	3.42
Oakdale	15,757	15,578	179	5,842	4,271	204	473	683	211	5,646	3.36	2.76
Patterson	12,221	11,992	229	3,404	2,872	190	151	63	128	3,283	3.55	3.65
Riverbank	16,191	16,056	135	4,759	3,923	185	180	182	289	4,603	3.28	3.49
Turlock	58,386	56,294	2,092	19,806	13,046	963	1,750	3,443	604	19,093	3.60	2.95
Waterford	7,037	7,020	17	2,093	1,733	47	172	112	29	2,002	4.35	3.51
Balance Of County	108,550	107,080	1,470	34,712	27,836	1,110	919	416	4,431	32,966	5.03	3.25
Incorporated	349,962	344,066	5,896	118,550	83,815	6,079	9,719	14,886	4,051	114,546	3.38	3.00
County Total	458,512	451,146	7,366	153,262	111,651	7,189	10,638	15,302	8,482	147,512	3.75	3.06
Sutter County												
Live Oak	6,375	6,066	309	1,831	1,370	75	141	104	141	1,741	4.92	3.48
Yuba City	45,931	44,973	958	16,512	10,020	839	1,530	3,600	523	15,812	4.24	2.84
Balance Of County	27,859	27,701	158	10,192	8,588	272	227	76	1,029	9,688	4.95	2.86
Incorporated	52,306	51,039	1,267	18,343	11,390	914	1,671	3,704	664	17,553	4.31	2.91
County Total	80,165	78,740	1,425	28,535	19,978	1,186	1,898	3,780	1,693	27,241	4.53	2.89
Tehama County												
Corning	6,731	6,674	57	2,618	1,545	70	274	495	234	2,426	7.33	2.75
Red Bluff	13,155	12,620	535	5,587	3,295	218	695	1,018	361	5,127	8.23	2.46
Tehama	431	431	0	196	166	4	10	0	16	179	8.67	2.41
Balance Of County	35,904	35,499	405	15,298	9,268	194	235	78	5,523	13,415	12.31	2.65
Incorporated	20,317	19,725	592	8,401	5,006	292	979	1,513	611	7,732	7.96	2.55
County Total	56,221	55,224	997	23,699	14,274	486	1,214	1,591	6,134	21,147	10.77	2.61
Trinity County												
County Total	12,986	12,749	237	8,003	5,266	112	106	117	2,402	5,603	29.99	2.28
Tulare County												

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PER HOUSE-HOLD
Dinuba	17,125	17,011	114	4,732	3,515	280	268	465	204	4,553	3.78	3.74
Exeter	9,300	9,208	92	3,203	2,521	107	203	184	188	3,034	5.28	3.04
Farmersville	8,856	8,837	19	2,292	1,846	84	155	109	98	2,173	5.19	4.07
Lindsay	10,340	10,191	149	2,867	1,946	135	243	358	185	2,719	5.16	3.75
Porterville	40,215	38,591	1,624	12,849	8,753	483	1,523	1,448	642	12,032	6.36	3.21
Tulare	44,588	44,141	447	14,397	10,763	511	1,215	1,134	774	13,680	4.98	3.23
Visalia	93,625	92,003	1,622	33,341	23,846	1,572	3,503	2,951	1,469	31,516	5.47	2.92
Woodlake	6,766	6,757	9	1,900	1,238	126	152	324	60	1,802	5.16	3.75
Balance Of County	141,907	139,947	1,960	45,214	34,420	1,440	1,256	846	7,252	39,959	11.62	3.50
Incorporated	230,815	226,739	4,076	75,581	54,428	3,298	7,262	6,973	3,620	71,509	5.39	3.17
County Total	372,722	366,686	6,036	120,795	88,848	4,738	8,518	7,819	10,872	111,468	7.72	3.29
Tuolumne County												
Sonora	4,483	4,284	199	2,212	1,267	86	385	447	27	2,065	6.65	2.08
Balance Of County	50,634	46,020	4,614	26,278	20,579	567	783	627	3,722	19,054	27.49	2.42
Incorporated	4,483	4,284	199	2,212	1,267	86	385	447	27	2,065	6.65	2.07
County Total	55,117	50,304	4,813	28,490	21,846	653	1,168	1,074	3,749	21,119	25.87	2.38
Ventura County												
Camarillo	58,115	57,060	1,055	22,191	13,063	4,495	845	2,730	1,058	21,699	2.22	2.63
Fillmore	13,852	13,606	246	3,898	2,750	273	227	322	326	3,807	2.33	3.57
Moorpark	31,862	31,850	12	9,190	6,694	1,234	223	709	330	9,089	1.10	3.50
Ojai	7,914	7,724	190	3,239	2,224	266	289	452	8	3,098	4.35	2.49
Oxnard	174,699	172,102	2,597	46,168	25,444	4,576	4,353	8,855	2,940	44,543	3.52	3.86
Port Hueneme	22,350	21,251	1,099	7,921	2,303	2,204	1,201	2,171	42	7,253	8.43	2.93
San Buenaventura	101,640	99,270	2,370	39,951	22,383	3,428	4,129	7,388	2,623	38,667	3.21	2.57
Santa Paula	28,762	28,519	243	8,359	4,991	729	776	1,076	787	8,154	2.45	3.50
Simi Valley	113,969	113,169	800	38,017	28,372	2,661	1,655	4,437	892	37,149	2.28	3.05
Thousand Oaks	118,588	116,637	1,951	43,392	28,974	5,152	1,733	6,461	1,072	42,215	2.71	2.76
Balance Of County	94,211	91,413	2,798	32,258	25,637	2,347	1,009	1,168	2,097	30,342	5.94	3.01
Incorporated	671,751	661,188	10,563	222,326	137,198	25,018	15,431	34,601	10,078	215,674	2.99	3.07

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2001

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	765,962	752,601	13,361	254,584	162,835	27,365	16,440	35,769	12,175	246,016	3.37	3.06
Yolo County												
Davis	61,928	58,822	3,106	24,081	10,919	2,351	2,123	8,303	385	23,564	2.15	2.50
West Sacramento	32,038	31,832	206	12,308	6,740	877	934	2,226	1,531	11,568	6.01	2.75
Winters	6,160	6,154	6	1,967	1,535	105	67	182	78	1,920	2.39	3.21
Woodland	50,885	50,095	790	17,750	10,931	1,312	1,123	3,703	681	17,367	2.16	2.88
Balance Of County	21,876	17,947	3,929	6,781	4,546	305	192	804	934	6,382	5.88	2.81
Incorporated	151,011	146,903	4,108	56,106	30,125	4,645	4,247	14,414	2,675	54,419	3.01	2.70
County Total	172,887	164,850	8,037	62,887	34,671	4,950	4,439	15,218	3,609	60,801	3.32	2.71
Yuba County												
Marysville	12,528	11,921	607	4,999	2,766	339	767	1,119	8	4,687	6.24	2.54
Wheatland	2,340	2,340	0	821	537	35	155	55	39	790	3.78	2.96
Balance Of County	46,159	45,403	756	16,815	10,677	867	689	1,076	3,506	15,039	10.56	3.02
Incorporated	14,868	14,261	607	5,820	3,303	374	922	1,174	47	5,477	5.89	2.60
County Total	61,027	59,664	1,363	22,635	13,980	1,241	1,611	2,250	3,553	20,516	9.36	2.91
California												
Incorporated Total	28,114,860	27,465,135	649,725	9,958,551	5,266,013	816,437	928,719	2,639,528	307,854	9,491,668	4.69	2.89
Balance Of State Total	6,316,110	6,140,323	175,787	2,348,734	1,687,306	116,035	98,847	183,423	263,123	2,101,600	10.52	2.92
State Total	34,430,970	33,605,458	825,512	12,307,285	6,953,319	932,472	1,027,566	2,822,951	570,977	11,593,268	5.80	2.90

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2002

COUNTY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Alameda	1,482,842	1,454,811	28,031	547,210	295,088	38,588	61,190	144,694	7,650	530,373	3.08	2.743
Alpine	1,245	1,244	1	1,554	911	9	35	537	62	495	68.15	2.513
Amador	36,227	31,617	4,610	15,496	12,664	390	378	552	1,512	13,154	15.11	2.404
Butte	207,662	201,459	6,203	87,361	53,234	2,358	7,655	9,824	14,290	81,379	6.85	2.476
Calaveras	41,903	41,471	432	23,887	20,214	465	501	355	2,352	17,163	28.15	2.416
Colusa	19,405	18,958	447	6,852	5,094	229	395	389	745	6,169	9.97	3.073
Contra Costa	981,536	970,229	11,307	362,260	238,601	29,945	25,205	60,934	7,575	351,578	2.95	2.760
Del Norte	27,736	23,992	3,744	10,543	6,182	182	797	584	2,798	9,265	12.12	2.590
El Dorado	163,826	162,773	1,053	73,791	59,331	1,643	3,500	4,944	4,373	61,104	17.19	2.664
Fresno	828,307	810,095	18,212	276,499	180,725	10,063	24,325	48,041	13,345	258,390	6.55	3.135
Glenn	26,979	26,597	382	10,093	7,038	207	718	700	1,430	9,275	8.10	2.868
Humboldt	128,055	123,835	4,220	56,567	38,772	1,546	5,648	4,613	5,988	51,834	8.37	2.389
Imperial	147,749	136,964	10,785	45,035	26,018	1,894	3,536	5,866	7,721	40,476	10.12	3.384
Inyo	18,330	18,049	281	9,097	5,473	212	407	468	2,537	7,751	14.80	2.329
Kern	689,735	658,064	31,671	237,650	161,646	8,512	20,490	23,467	23,535	214,695	9.66	3.065
Kings	133,988	114,122	19,866	37,218	25,982	2,160	2,728	4,226	2,122	35,056	5.81	3.255
Lake	60,552	59,356	1,196	32,760	20,314	533	902	802	10,209	24,145	26.30	2.458
Lassen	33,827	25,160	8,667	12,188	8,352	296	515	519	2,506	9,848	19.20	2.555
Los Angeles	9,816,492	9,639,959	176,533	3,292,706	1,605,664	241,726	287,681	1,101,014	56,621	3,154,727	4.19	3.056
Madera	128,209	121,099	7,110	41,596	31,850	1,336	2,187	2,800	3,423	37,245	10.46	3.251
Marin	249,846	238,725	11,121	105,829	64,352	8,460	9,494	21,394	2,129	101,505	4.09	2.352
Mariposa	17,294	15,868	1,426	9,043	6,083	71	214	383	2,292	6,776	25.07	2.342
Mendocino	87,677	85,447	2,230	37,449	26,147	1,163	2,117	2,671	5,351	33,720	9.96	2.534
Merced	220,867	217,959	2,908	70,672	50,061	2,535	5,210	7,467	5,399	65,974	6.65	3.304
Modoc	9,450	9,047	403	4,845	3,298	87	98	159	1,203	3,813	21.30	2.373
Mono	13,083	12,785	298	12,176	4,704	1,190	1,972	3,356	954	5,302	56.46	2.411
Monterey	412,376	392,054	20,322	133,933	81,262	12,345	11,930	22,691	5,705	123,290	7.95	3.180
Napa	127,892	122,555	5,337	49,713	33,593	3,221	3,646	5,322	3,931	46,512	6.44	2.635
Nevada	94,838	93,882	956	45,739	37,524	871	1,631	2,188	3,525	38,022	16.87	2.469
Orange	2,938,821	2,895,729	43,092	985,962	500,191	124,863	89,722	238,716	32,470	951,101	3.54	3.045
Placer	271,308	268,314	2,994	116,580	89,012	4,137	5,766	12,960	4,705	102,762	11.85	2.611
Plumas	20,827	20,639	188	13,702	10,427	444	375	396	2,060	9,208	32.80	2.241
Riverside	1,652,537	1,617,113	35,424	613,667	381,418	42,359	30,435	76,493	82,962	531,908	13.32	3.040

California Department of Finance
Demographic Research Unit

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2002

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Sacramento	1,287,583	1,262,094	25,489	490,482	309,342	32,263	36,324	97,066	15,487	469,279	4.32	2.689
San Benito	55,613	55,106	507	17,266	13,388	1,028	1,131	845	874	16,626	3.71	3.314
San Bernardino	1,792,367	1,745,722	46,645	613,139	426,413	26,877	39,160	78,767	41,922	540,398	11.86	3.230
San Diego	2,922,758	2,820,905	101,853	1,062,918	545,764	98,235	78,615	293,292	47,012	1,015,737	4.44	2.777
San Francisco	789,984	770,336	19,648	349,502	62,811	48,689	81,192	156,250	560	332,543	4.85	2.317
San Joaquin	599,246	580,576	18,670	197,316	137,317	11,218	13,378	26,124	9,279	189,510	3.96	3.064
San Luis Obispo	253,635	238,090	15,545	105,435	68,681	6,111	8,244	11,073	11,326	95,600	9.33	2.490
San Mateo	714,529	704,095	10,434	263,223	151,660	22,720	18,334	66,993	3,516	256,681	2.49	2.743
Santa Barbara	407,494	391,331	16,163	144,578	84,046	9,765	13,398	28,789	8,580	138,332	4.32	2.829
Santa Clara	1,715,975	1,685,594	30,381	590,109	327,618	52,959	46,676	143,198	19,658	576,670	2.28	2.923
Santa Cruz	258,029	248,939	9,090	99,709	63,457	8,762	8,398	11,840	7,252	91,965	7.77	2.707
Shasta	169,869	166,514	3,355	70,433	47,566	1,457	5,492	5,309	10,609	64,945	7.79	2.564
Sierra	3,598	3,562	36	2,220	1,828	49	47	63	233	1,532	30.99	2.325
Siskiyou	44,597	43,847	750	22,197	15,625	488	1,099	1,270	3,715	18,765	15.46	2.337
Solano	408,835	392,229	16,606	138,604	98,386	6,850	10,275	18,489	4,604	134,221	3.16	2.922
Sonoma	468,501	456,588	11,913	187,013	128,553	13,988	11,890	21,203	11,379	176,128	5.82	2.592
Stanislaus	472,185	464,816	7,369	156,824	114,756	7,141	10,718	15,382	8,827	150,946	3.75	3.079
Sutter	81,818	80,413	1,405	28,981	20,420	1,186	1,902	3,780	1,693	27,667	4.53	2.906
Tehama	56,915	55,908	1,007	23,966	14,402	486	1,216	1,663	6,199	21,384	10.77	2.614
Trinity	13,097	12,860	237	8,046	5,309	112	106	117	2,402	5,633	29.99	2.283
Tulare	379,768	373,712	6,056	122,440	90,405	4,744	8,588	7,831	10,872	113,002	7.71	3.307
Tuolumne	55,827	50,974	4,853	28,757	22,052	652	1,170	1,074	3,809	21,318	25.87	2.391
Ventura	779,992	766,954	13,038	258,797	166,072	27,432	16,493	36,602	12,198	250,213	3.32	3.065
Yolo	177,959	170,140	7,819	64,353	35,944	4,950	4,443	15,395	3,621	62,198	3.35	2.735
Yuba	62,364	61,003	1,361	22,731	14,076	1,241	1,611	2,250	3,553	20,603	9.36	2.961
California	35,063,959	34,232,279	831,680	12,448,712	7,057,116	933,443	1,031,303	2,854,190	572,660	11,725,911	5.81	2.919

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Alameda County												
Alameda	73,495	72,438	1,057	31,868	12,889	3,960	5,045	9,674	300	30,443	4.47	2.379
Albany	16,704	16,671	33	7,265	3,778	181	823	2,477	6	7,027	3.28	2.372
Berkeley	104,296	98,360	5,936	46,937	20,119	1,757	9,301	15,701	59	45,015	4.09	2.185
Dublin	34,149	28,871	5,278	11,184	6,764	1,304	412	2,677	27	10,765	3.75	2.682
Emeryville	7,274	7,207	67	4,460	269	275	484	3,395	37	4,148	7.00	1.737
Fremont	208,997	207,238	1,759	70,424	41,961	7,136	2,968	17,603	756	69,192	1.75	2.995
Hayward	143,863	141,711	2,152	46,565	23,205	3,398	3,349	14,314	2,299	45,432	2.43	3.119
Livermore	76,537	76,216	321	27,360	20,010	2,187	1,202	3,530	431	26,859	1.83	2.838
Newark	43,536	43,447	89	13,301	9,094	1,238	764	2,146	59	13,141	1.20	3.306
Oakland	407,365	400,108	7,257	158,498	71,659	6,645	28,983	50,755	456	151,738	4.27	2.637
Piedmont	11,103	11,101	2	3,860	3,783	0	35	34	8	3,805	1.42	2.917
Pleasanton	65,982	65,747	235	24,517	15,953	2,704	1,148	4,256	456	23,845	2.74	2.757
San Leandro	81,073	80,246	827	31,554	19,188	1,967	2,246	7,249	904	30,857	2.21	2.601
Union City	69,999	69,657	342	19,502	12,424	2,367	1,106	2,682	923	19,259	1.25	3.617
Balance Of County	138,469	135,793	2,676	49,915	33,992	3,469	3,324	8,201	929	48,847	2.14	2.780
Incorporated	1,344,373	1,319,018	25,355	497,295	261,096	35,119	57,866	136,493	6,721	481,526	3.17	2.739
County Total	1,482,842	1,454,811	28,031	547,210	295,088	38,588	61,190	144,694	7,650	530,373	3.08	2.743
Alpine County												
County Total	1,245	1,244	1	1,554	911	9	35	537	62	495	68.15	2.513
Amador County												
Amador	207	207	0	96	77	12	5	2	0	90	6.25	2.300
Ione	7,463	3,201	4,262	1,271	985	54	64	87	81	1,189	6.45	2.692
Jackson	4,045	3,777	268	1,880	1,161	112	148	247	212	1,766	6.06	2.139
Plymouth	1,033	1,033	0	480	277	23	24	26	130	411	14.38	2.513
Sutter Creek	2,381	2,380	1	1,139	760	105	51	143	80	1,055	7.37	2.256
Balance Of County	21,098	21,019	79	10,630	9,404	84	86	47	1,009	8,643	18.69	2.432
Incorporated	15,129	10,598	4,531	4,866	3,260	306	292	505	503	4,511	7.30	2.349
County Total	36,227	31,617	4,610	15,496	12,664	390	378	552	1,512	13,154	15.11	2.404
Butte County												
Biggs	1,803	1,803	0	617	509	28	28	5	47	575	6.81	3.136
Chico	66,975	63,003	3,972	27,027	12,776	944	4,174	8,002	1,131	26,018	3.73	2.422
Gridley	5,679	5,557	122	2,076	1,680	45	135	141	75	1,947	6.21	2.854
Oroville	13,074	12,242	832	5,449	2,917	134	765	1,247	386	4,908	9.93	2.494
Paradise	26,585	25,965	620	12,469	8,620	338	752	290	2,469	11,680	6.33	2.223
Balance Of County	93,546	92,889	657	39,723	26,732	869	1,801	139	10,182	36,251	8.74	2.562
Incorporated	114,116	108,570	5,546	47,638	26,502	1,489	5,854	9,685	4,108	45,128	5.27	2.406

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
County Total	207,662	201,459	6,203	87,361	53,234	2,358	7,655	9,824	14,290	81,379	6.85	2.476
Calaveras County												
Angels City	3,296	3,296	0	1,573	1,057	67	122	113	214	1,422	9.60	2.318
Balance Of County	38,607	38,175	432	22,314	19,157	398	379	242	2,138	15,741	29.46	2.425
Incorporated	3,296	3,296	0	1,573	1,057	67	122	113	214	1,422	9.60	2.318
County Total	41,903	41,471	432	23,887	20,214	465	501	355	2,352	17,163	28.15	2.416
Colusa County												
Colusa	5,533	5,460	73	2,026	1,519	84	189	183	51	1,907	5.87	2.863
Williams	3,878	3,628	250	1,007	733	33	83	91	67	961	4.57	3.775
Balance Of County	9,994	9,870	124	3,819	2,842	112	123	115	627	3,301	13.56	2.990
Incorporated	9,411	9,088	323	3,033	2,252	117	272	274	118	2,868	5.44	3.169
County Total	19,405	18,958	447	6,852	5,094	229	395	389	745	6,169	9.97	3.073
Contra Costa County												
Antioch	96,589	96,173	416	31,779	24,593	1,357	1,765	3,795	269	30,958	2.58	3.107
Brentwood	29,953	29,916	37	9,902	8,518	360	267	405	352	9,532	3.74	3.138
Clayton	10,960	10,934	26	3,952	3,220	681	19	27	5	3,911	1.04	2.796
Concord	124,398	122,976	1,422	45,521	27,205	2,851	2,871	11,217	1,377	44,448	2.36	2.767
Danville	42,939	42,475	464	15,404	11,886	2,557	279	682	0	15,085	2.07	2.816
El Cerrito	23,476	23,300	176	10,482	7,310	343	1,309	1,488	32	10,228	2.42	2.278
Hercules	20,109	20,070	39	6,679	4,164	1,617	294	604	0	6,553	1.89	3.063
Lafayette	24,374	24,238	136	9,410	7,468	294	425	1,223	0	9,226	1.96	2.627
Martinez	36,662	35,320	1,342	14,769	9,447	2,213	984	2,101	24	14,468	2.04	2.441
Moraga	16,485	14,854	1,631	5,771	4,008	968	243	545	7	5,673	1.70	2.618
Oakley	26,979	26,912	67	8,275	7,594	84	66	110	421	8,156	1.44	3.300
Orinda	17,806	17,739	67	6,747	6,246	188	87	219	7	6,599	2.19	2.688
Pinole	19,400	19,182	218	6,881	5,075	498	360	933	15	6,796	1.24	2.823
Pittsburg	59,821	59,315	506	19,076	12,516	1,296	1,330	3,264	670	18,494	3.05	3.207
Pleasant Hill	33,310	32,850	460	14,079	8,408	1,466	688	3,465	52	13,797	2.00	2.381
Richmond	100,925	99,297	1,628	36,263	20,686	2,929	5,252	7,275	121	34,835	3.94	2.850
San Pablo	30,598	30,133	465	9,355	4,143	760	1,293	2,361	798	9,066	3.09	3.324
San Ramon	46,746	46,661	85	18,142	11,215	1,988	1,039	3,889	11	17,513	3.47	2.664
Walnut Creek	65,784	64,820	964	31,802	12,162	4,791	4,277	10,524	48	30,664	3.58	2.114
Balance Of County	154,222	153,064	1,158	57,971	42,737	2,704	2,357	6,807	3,366	55,576	4.13	2.754
Incorporated	827,314	817,165	10,149	304,289	195,864	27,241	22,848	54,127	4,209	296,002	2.72	2.761
County Total	981,536	970,229	11,307	362,260	238,601	29,945	25,205	60,934	7,575	351,578	2.95	2.760

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Del Norte County												
Crescent City	7,272	3,802	3,470	1,753	861	50	389	424	29	1,577	10.04	2.411
Balance Of County	20,464	20,190	274	8,790	5,321	132	408	160	2,769	7,688	12.54	2.626
Incorporated	7,272	3,802	3,470	1,753	861	50	389	424	29	1,577	10.04	2.411
County Total	27,736	23,992	3,744	10,543	6,182	182	797	584	2,798	9,265	12.12	2.590
El Dorado County												
Placerville	10,253	9,991	262	4,484	2,723	256	618	728	159	4,229	5.69	2.362
South Lake Tahoe	23,986	23,858	128	14,073	8,825	363	1,977	2,240	668	9,456	32.81	2.523
Balance Of County	129,587	128,924	663	55,234	47,783	1,024	905	1,976	3,546	47,419	14.15	2.719
Incorporated	34,239	33,849	390	18,557	11,548	619	2,595	2,968	827	13,685	26.25	2.473
County Total	163,826	162,773	1,053	73,791	59,331	1,643	3,500	4,944	4,373	61,104	17.19	2.664
Fresno County												
Clovis	73,161	72,681	480	26,611	17,683	549	3,086	4,377	916	25,660	3.57	2.832
Coalinga	16,022	10,667	5,355	3,739	2,465	127	283	546	318	3,404	8.96	3.134
Firebaugh	5,965	5,904	61	1,620	1,048	156	189	141	86	1,453	10.31	4.063
Fowler	4,237	4,163	74	1,340	920	50	160	163	47	1,304	2.69	3.192
Fresno	442,729	434,072	8,657	152,048	89,486	6,028	16,346	36,265	3,923	142,921	6.00	3.037
Huron	6,634	6,462	172	1,469	479	204	231	485	70	1,432	2.52	4.513
Kerman	9,585	9,554	31	2,722	1,865	153	248	340	116	2,641	2.98	3.618
Kingsburg	10,097	10,006	91	3,645	2,704	104	234	439	164	3,503	3.90	2.856
Mendota	8,071	8,063	8	1,894	1,139	139	230	313	73	1,841	2.80	4.380
Orange Cove	8,528	8,528	0	1,924	1,149	206	222	321	26	1,845	4.11	4.622
Parlier	12,082	11,980	102	2,828	1,992	234	184	404	14	2,617	7.46	4.578
Reedley	21,208	20,813	395	6,019	4,167	216	594	851	191	5,806	3.54	3.585
Sanger	19,578	19,438	140	5,528	3,918	194	565	688	163	5,324	3.69	3.651
San Joaquin	3,407	3,407	0	755	437	80	115	63	60	722	4.37	4.719
Selma	20,376	20,246	130	6,010	4,355	148	333	752	422	5,784	3.76	3.500
Balance Of County	166,627	164,111	2,516	58,347	46,918	1,475	1,305	1,893	6,756	52,133	10.65	3.148
Incorporated	661,680	645,984	15,696	218,152	133,807	8,588	23,020	46,148	6,589	206,257	5.45	3.132
County Total	828,307	810,095	18,212	276,499	180,725	10,063	24,325	48,041	13,345	258,390	6.55	3.135
Glenn County												
Orland	6,375	6,351	24	2,322	1,731	44	318	197	32	2,203	5.12	2.883
Willows	6,289	6,108	181	2,373	1,549	54	305	458	7	2,139	9.86	2.856
Balance Of County	14,315	14,138	177	5,398	3,758	109	95	45	1,391	4,933	8.61	2.866
Incorporated	12,664	12,459	205	4,695	3,280	98	623	655	39	4,342	7.52	2.869

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	26,979	26,597	382	10,093	7,038	207	718	700	1,430	9,275	8.10	2.868
Humboldt County												
Arcata	16,945	15,322	1,623	7,325	3,377	253	1,169	1,843	683	7,102	3.04	2.157
Blue Lake	1,169	1,169	0	573	377	21	68	36	71	520	9.25	2.248
Eureka	26,173	24,823	1,350	11,666	7,225	381	2,195	1,691	174	10,984	5.85	2.260
Ferndale	1,390	1,390	0	667	538	27	83	10	9	615	7.80	2.260
Fortuna	10,779	10,544	235	4,537	2,995	229	520	351	442	4,301	5.20	2.452
Rio Dell	3,183	3,173	10	1,439	997	26	150	36	230	1,225	14.87	2.590
Trinidad	314	314	0	230	181	7	11	0	31	170	26.09	1.847
Balance Of County	68,102	67,100	1,002	30,130	23,082	602	1,452	646	4,348	26,917	10.66	2.493
Incorporated	59,953	56,735	3,218	26,437	15,690	944	4,196	3,967	1,640	24,917	5.75	2.277
County Total	128,055	123,835	4,220	56,567	38,772	1,546	5,648	4,613	5,988	51,834	8.37	2.389
Imperial County												
Brawley	22,497	22,185	312	7,089	4,527	362	639	1,105	456	6,679	5.78	3.322
Calexico	29,783	29,680	103	7,575	4,969	439	896	1,066	205	7,392	2.42	4.015
Calipatria	7,612	3,519	4,093	1,045	712	38	75	158	62	978	6.41	3.598
El Centro	38,738	37,851	887	12,397	6,543	563	1,073	2,900	1,318	11,568	6.69	3.272
Holtville	5,694	5,564	130	1,620	1,037	111	117	162	193	1,567	3.27	3.551
Imperial	8,112	8,080	32	2,527	2,016	91	227	164	29	2,446	3.21	3.303
Westmorland	2,195	2,195	0	678	431	16	90	102	39	636	6.19	3.451
Balance Of County	33,118	27,890	5,228	12,104	5,783	274	419	209	5,419	9,210	23.91	3.028
Incorporated	114,631	109,074	5,557	32,931	20,235	1,620	3,117	5,657	2,302	31,266	5.06	3.489
County Total	147,749	136,964	10,785	45,035	26,018	1,894	3,536	5,866	7,721	40,476	10.12	3.384
Inyo County												
Bishop	3,622	3,545	77	1,876	847	78	262	323	366	1,693	9.75	2.094
Balance Of County	14,708	14,504	204	7,221	4,626	134	145	145	2,171	6,058	16.11	2.394
Incorporated	3,622	3,545	77	1,876	847	78	262	323	366	1,693	9.75	2.094
County Total	18,330	18,049	281	9,097	5,473	212	407	468	2,537	7,751	14.80	2.329
Kern County												
Arvin	13,553	13,482	71	3,247	2,230	218	264	279	256	3,108	4.28	4.338
Bakersfield	258,391	254,734	3,657	91,203	60,295	3,221	10,068	15,065	2,554	86,222	5.46	2.954
California City	10,829	8,467	2,362	3,572	2,668	68	310	226	300	3,078	13.83	2.751
Delano	41,003	35,361	5,642	9,123	6,419	547	597	1,111	449	8,688	4.77	4.070
Maricopa	1,131	1,131	0	462	248	7	5	9	193	406	12.12	2.786
Mcfarland	10,040	8,722	1,318	2,044	1,564	153	240	60	27	2,003	2.01	4.354

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Ridgecrest	26,589	26,272	317	11,313	7,447	412	1,697	765	992	10,328	8.71	2.544
Shafter	13,071	12,433	638	3,678	2,821	177	232	237	211	3,342	9.14	3.720
Taft	8,943	5,969	2,974	2,499	1,814	52	315	222	96	2,252	9.88	2.651
Tehachapi	11,081	6,727	4,354	2,949	1,867	135	385	281	281	2,564	13.06	2.624
Wasco	21,695	15,712	5,983	4,386	3,198	326	413	318	131	4,093	6.68	3.839
Balance Of County	273,409	269,054	4,355	103,174	71,075	3,196	5,964	4,894	18,045	88,611	14.11	3.036
Incorporated	416,326	389,010	27,316	134,476	90,571	5,316	14,526	18,573	5,490	126,084	6.24	3.085
County Total	689,735	658,064	31,671	237,650	161,646	8,512	20,490	23,467	23,535	214,695	9.66	3.065
Kings County												
Avenal	14,874	8,189	6,685	2,075	1,406	50	303	224	92	1,941	6.46	4.219
Corcoran	21,194	9,806	11,388	3,043	2,167	180	270	303	123	2,793	8.22	3.511
Hanford	43,824	42,976	848	15,185	10,858	552	1,393	2,041	341	14,370	5.37	2.991
Lemoore	20,771	20,769	2	7,047	4,564	152	459	1,543	329	6,662	5.46	3.118
Balance Of County	33,325	32,382	943	9,868	6,987	1,226	303	115	1,237	9,290	5.86	3.486
Incorporated	100,663	81,740	18,923	27,350	18,995	934	2,425	4,111	885	25,766	5.79	3.172
County Total	133,988	114,122	19,866	37,218	25,982	2,160	2,728	4,226	2,122	35,056	5.81	3.255
Lake County												
Clearlake	13,450	13,331	119	7,557	3,608	99	247	218	3,385	5,498	27.25	2.425
Lakeport	4,970	4,796	174	2,399	1,443	119	158	223	456	1,971	17.84	2.433
Balance Of County	42,132	41,229	903	22,804	15,263	315	497	361	6,368	16,676	26.87	2.472
Incorporated	18,420	18,127	293	9,956	5,051	218	405	441	3,841	7,469	24.98	2.427
County Total	60,552	59,356	1,196	32,760	20,314	533	902	802	10,209	24,145	26.30	2.458
Lassen County												
Susanville	17,240	8,794	8,446	3,958	2,780	131	377	460	210	3,586	9.40	2.452
Balance Of County	16,587	16,366	221	8,230	5,572	165	138	59	2,296	6,262	23.91	2.614
Incorporated	17,240	8,794	8,446	3,958	2,780	131	377	460	210	3,586	9.40	2.452
County Total	33,827	25,160	8,667	12,188	8,352	296	515	519	2,506	9,848	19.20	2.555
Los Angeles County												
Agoura Hills	21,595	21,572	23	7,176	5,243	979	176	778	0	7,054	1.70	3.058
Alhambra	87,865	85,942	1,923	30,056	12,743	3,265	3,963	10,068	17	29,097	3.19	2.954
Arcadia	54,860	54,279	581	20,158	11,926	1,670	1,379	5,157	26	19,329	4.11	2.808
Artesia	16,810	16,238	572	4,609	3,191	329	320	673	96	4,481	2.78	3.624
Avalon	3,367	3,305	62	1,886	500	487	545	345	9	1,203	36.21	2.747

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSEHOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	HOUSING UNITS: SINGLE: DETACHED	HOUSING UNITS: SINGLE: ATTACHED	HOUSING UNITS: MULTIPLE: 2 TO 4	HOUSING UNITS: MULTIPLE: 5 PLUS	HOUSING UNITS: MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Azusa	46,084	44,135	1,949	13,106	5,826	1,766	1,465	3,460	589	12,639	3.56	3.492
Baldwin Park	78,310	77,704	606	17,568	11,807	1,861	604	2,953	343	17,095	2.69	4.545
Bell	37,554	37,016	538	9,214	3,556	1,517	1,453	2,228	460	8,917	3.22	4.151
Bellflower	75,004	74,381	623	24,357	11,328	2,085	1,438	7,904	1,602	23,473	3.63	3.169
Bell Gardens	45,166	44,710	456	9,795	3,953	2,469	1,451	1,526	396	9,473	3.29	4.720
Beverly Hills	34,839	34,800	39	15,956	5,682	236	1,805	8,205	28	15,129	5.18	2.300
Bradbury	893	893	0	317	315	0	2	0	0	289	8.83	3.090
Burbank	102,761	101,935	826	42,839	19,919	1,728	4,702	16,378	112	41,601	2.89	2.450
Calabasas	22,067	22,007	60	8,175	5,580	804	204	1,334	253	7,910	3.24	2.782
Carson	93,114	92,130	984	25,733	17,995	2,280	716	2,237	2,505	25,033	2.72	3.680
Cerritos	53,105	53,012	93	15,709	13,363	1,220	600	494	32	15,491	1.39	3.422
Claremont	35,529	30,155	5,374	11,772	8,207	843	618	2,091	13	11,489	2.40	2.625
Commerce	12,956	12,853	103	3,398	1,943	570	330	551	4	3,305	2.74	3.889
Compton	95,856	95,206	650	23,811	15,843	2,140	2,265	2,925	638	22,342	6.17	4.261
Covina	48,079	47,477	602	16,398	9,367	1,297	977	4,169	588	16,004	2.40	2.967
Cudahy	25,112	25,100	12	5,610	1,668	1,291	344	1,893	414	5,486	2.21	4.575
Culver City	39,801	39,277	524	17,146	6,621	1,903	2,301	6,140	181	16,627	3.03	2.362
Diamond Bar	58,047	57,929	118	18,074	12,721	2,501	823	1,696	333	17,764	1.72	3.261
Downey	110,363	108,598	1,765	34,896	20,426	1,662	1,644	10,971	193	34,123	2.22	3.183
Duarte	22,093	21,603	490	6,833	4,307	876	224	1,197	229	6,662	2.50	3.243
El Monte	119,390	118,120	1,270	27,896	14,775	3,396	2,021	6,298	1,406	27,168	2.61	4.348
El Segundo	16,479	16,456	23	7,283	3,105	416	817	2,934	11	7,082	2.76	2.324
Gardena	59,794	58,990	804	21,271	9,133	1,711	2,688	6,636	1,103	20,546	3.41	2.871
Glendale	200,014	197,150	2,864	73,819	26,083	3,814	6,920	36,905	97	71,908	2.59	2.742
Glendora	50,799	49,792	1,007	17,209	12,508	1,094	695	2,029	883	16,882	1.90	2.949
Hawaiian Gardens	15,290	15,286	4	3,659	1,514	470	450	950	275	3,541	3.22	4.317
Hawthorne	86,310	85,810	500	29,673	8,201	2,429	3,321	15,549	173	28,579	3.69	3.003
Hermosa Beach	19,161	19,048	113	9,912	4,137	986	2,148	2,559	82	9,545	3.70	1.996
Hidden Hills	1,957	1,957	0	603	601	2	0	0	0	579	3.98	3.380
Huntington Park	62,863	62,682	181	15,335	5,266	2,370	2,209	5,476	14	14,860	3.10	4.218
Industry	790	526	264	124	101	23	0	0	0	121	2.42	4.347
Inglewood	115,286	113,916	1,370	38,632	13,934	3,224	4,745	16,491	238	36,789	4.77	3.096
Irwindale	1,477	1,475	2	377	317	15	13	24	8	364	3.45	4.052
La Canada Flintridge	20,931	20,742	189	7,028	6,521	200	132	175	0	6,861	2.38	3.023
La Habra Heights	5,931	5,931	0	1,977	1,945	24	8	0	0	1,912	3.29	3.102
Lakewood	81,318	81,124	194	27,314	22,219	741	690	3,566	98	26,857	1.67	3.021
La Mirada	47,901	46,262	1,639	14,811	11,756	794	358	1,737	166	14,580	1.56	3.173
Lancaster	123,063	116,129	6,934	42,350	27,493	1,200	2,724	7,435	3,498	38,778	8.43	2.995
La Puente	42,122	42,090	32	9,670	6,335	640	340	2,246	109	9,471	2.06	4.444
La Verne	32,488	31,780	708	11,316	7,513	599	734	707	1,763	11,100	1.91	2.863
Lawndale	32,467	32,381	86	9,861	4,917	1,606	905	2,305	128	9,547	3.18	3.392
Lomita	20,579	20,446	133	8,311	4,019	766	581	2,447	498	8,030	3.38	2.546
Long Beach	472,809	462,565	10,244	171,649	69,117	10,091	23,266	66,646	2,529	163,104	4.98	2.836
Los Angeles	3,804,577	3,720,987	83,590	1,344,503	527,661	87,775	129,134	590,847	9,086	1,282,033	4.65	2.902
Lynwood	71,715	69,515	2,200	15,029	8,195	1,677	1,713	3,332	112	14,435	3.95	4.816
Malibu	13,039	12,739	300	6,204	3,897	475	400	822	610	5,202	16.15	2.449
Manhattan Beach	35,435	35,421	14	15,363	10,451	1,342	2,650	887	33	14,792	3.72	2.395
Maywood	28,823	28,729	94	6,712	2,814	1,110	1,441	1,339	8	6,480	3.46	4.433
Monrovia	37,933	37,640	293	13,993	7,687	1,549	1,326	3,316	115	13,537	3.26	2.781

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Montebello	63,705	63,396	309	19,423	9,357	1,580	2,863	5,390	233	18,851	2.94	3.363
Monterey Park	62,583	62,306	277	20,556	11,568	2,206	2,044	4,658	80	19,900	3.19	3.131
Norwalk	107,585	105,315	2,270	27,776	20,177	1,412	829	4,900	458	27,104	2.42	3.886
Palmdale	123,628	123,534	94	38,360	29,318	905	940	5,415	1,782	35,453	7.58	3.484
Palos Verdes Estates	13,746	13,741	5	5,231	4,809	40	44	338	0	5,021	4.01	2.737
Paramount	56,669	56,349	320	14,602	6,053	2,169	1,086	3,922	1,372	13,983	4.24	4.030
Pasadena	138,742	135,224	3,518	54,770	24,789	4,171	4,650	21,087	73	52,455	4.23	2.578
Pico Rivera	65,121	64,771	350	16,841	12,668	934	337	2,312	590	16,501	2.02	3.925
Pomona	153,832	148,514	5,318	39,733	24,245	3,339	3,233	7,211	1,705	37,984	4.40	3.910
Rancho Palos Verdes	42,293	41,784	509	15,762	12,179	1,287	245	2,051	0	15,308	2.88	2.730
Redondo Beach	65,608	65,421	187	29,902	11,780	4,238	4,063	9,441	380	28,913	3.31	2.263
Rolling Hills	1,914	1,914	0	681	674	7	0	0	0	644	5.43	2.972
Rolling Hills Estates	7,911	7,899	12	2,897	2,280	565	41	7	4	2,823	2.55	2.798
Rosemead	55,250	54,638	612	14,460	9,832	2,030	911	1,283	404	14,025	3.01	3.896
San Dimas	35,921	34,712	1,209	12,541	7,519	2,100	361	1,618	943	12,200	2.72	2.845
San Fernando	24,212	24,166	46	5,948	4,001	634	478	762	73	5,790	2.66	4.174
San Gabriel	40,920	40,165	755	12,957	7,013	1,156	1,077	3,667	44	12,633	2.50	3.179
San Marino	13,271	13,264	7	4,439	4,403	19	8	9	0	4,268	3.85	3.108
Santa Clarita	158,221	156,828	1,393	53,612	32,549	6,314	2,601	9,908	2,240	51,917	3.16	3.021
Santa Fe Springs	16,904	16,686	218	4,959	3,097	286	158	1,291	127	4,859	2.02	3.434
Santa Monica	87,892	85,376	2,516	48,887	9,308	1,928	5,560	31,802	289	45,449	7.03	1.879
Sierra Madre	10,848	10,721	127	4,928	3,405	205	377	914	27	4,761	3.39	2.252
Signal Hill	9,925	9,871	54	3,942	1,120	461	678	1,675	8	3,760	4.62	2.625
South El Monte	21,699	21,681	18	4,731	2,941	458	233	595	504	4,627	2.20	4.686
South Gate	99,100	98,959	141	24,353	12,344	3,262	3,695	4,774	278	23,293	4.35	4.248
South Pasadena	24,982	24,795	187	10,894	5,069	625	1,108	4,078	14	10,520	3.43	2.357
Temple City	34,303	33,792	511	11,713	9,449	802	421	983	58	11,376	2.88	2.970
Torrance	141,970	140,721	1,249	56,222	30,340	3,693	3,283	17,723	1,183	54,790	2.55	2.568
Vernon	93	93	0	26	19	0	0	7	0	25	3.85	3.720
Walnut	30,874	30,834	40	8,430	8,073	119	46	192	0	8,295	1.60	3.717
West Covina	109,005	108,197	808	32,461	21,092	2,812	1,570	6,639	348	31,805	2.02	3.402
West Hollywood	36,851	36,615	236	24,275	1,807	681	1,840	19,947	0	23,281	4.09	1.573
Westlake Village	8,578	8,569	9	3,348	2,206	608	158	201	175	3,271	2.30	2.620
Whittier	85,494	83,370	2,124	28,981	19,057	1,480	2,056	6,174	214	28,274	2.44	2.949
Balance Of County	1,024,871	1,007,792	17,079	297,589	204,878	22,882	17,909	41,009	10,911	283,869	4.61	3.550
Incorporated	8,791,621	8,632,167	159,454	2,995,117	1,400,786	218,844	269,772	1,060,005	45,710	2,870,858	4.15	3.007
County Total	9,816,492	9,639,959	176,533	3,292,706	1,605,664	241,726	287,681	1,101,014	56,621	3,154,727	4.19	3.056
Madera County												
Chowchilla	13,938	8,052	5,886	2,833	2,210	31	252	304	36	2,677	5.51	3.008
Madera	45,610	45,172	438	12,940	8,484	742	1,334	2,079	301	12,379	4.34	3.649
Balance Of County	68,661	67,875	786	25,823	21,156	563	601	417	3,086	22,189	14.07	3.059
Incorporated	59,548	53,224	6,324	15,773	10,694	773	1,586	2,383	337	15,056	4.55	3.535
County Total	128,209	121,099	7,110	41,596	31,850	1,336	2,187	2,800	3,423	37,245	10.46	3.251

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	------------POPULATION------------			---------- HOUSING UNITS ----------								PERSONS
					-------- SINGLE --------		----- MULTIPLE -----					PER
	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Marin County												
Belvedere	2,143	2,143	0	1,064	873	54	94	43	0	961	9.68	2.230
Corte Madera	9,416	9,408	8	3,970	2,614	416	369	561	10	3,894	1.91	2.416
Fairfax	7,348	7,318	30	3,420	2,331	193	492	393	11	3,308	3.27	2.212
Larkspur	12,067	11,912	155	6,419	2,438	365	544	2,833	239	6,148	4.22	1.938
Mill Valley	13,691	13,600	91	6,306	4,108	536	535	1,127	0	6,167	2.20	2.205
Novato	48,760	47,778	982	19,386	11,323	2,607	1,166	3,572	718	18,906	2.48	2.527
Ross	2,350	2,256	94	810	790	0	12	0	8	766	5.43	2.945
San Anselmo	12,398	12,142	256	5,398	3,980	185	458	757	18	5,257	2.61	2.310
San Rafael	56,605	54,585	2,020	23,096	10,566	1,995	2,462	7,584	489	22,516	2.51	2.424
Sausalito	7,374	7,362	12	4,522	1,717	423	1,353	805	224	4,265	5.68	1.726
Tiburon	8,740	8,634	106	3,913	2,399	237	440	837	0	3,731	4.65	2.314
Balance Of County	68,954	61,587	7,367	27,525	21,213	1,449	1,569	2,882	412	25,586	7.04	2.407
Incorporated	180,892	177,138	3,754	78,304	43,139	7,011	7,925	18,512	1,717	75,919	3.05	2.333
County Total	249,846	238,725	11,121	105,829	64,352	8,460	9,494	21,394	2,129	101,505	4.09	2.352
Mariposa County												
County Total	17,294	15,868	1,426	9,043	6,083	71	214	383	2,292	6,776	25.07	2.342
Mendocino County												
Fort Bragg	6,882	6,756	126	3,076	2,000	158	312	459	147	2,863	6.92	2.360
Point Arena	479	479	0	220	136	7	45	13	19	193	12.27	2.482
Ukiah	15,666	14,932	734	6,195	3,472	379	760	1,122	462	6,041	2.49	2.472
Willits	5,093	4,967	126	2,017	1,188	84	303	299	143	1,939	3.87	2.562
Balance Of County	59,557	58,313	1,244	25,941	19,351	535	697	778	4,580	22,684	12.56	2.571
Incorporated	28,120	27,134	986	11,508	6,796	628	1,420	1,893	771	11,036	4.10	2.459
County Total	87,677	85,447	2,230	37,449	26,147	1,163	2,117	2,671	5,351	33,720	9.96	2.534
Merced County												
Atwater	24,259	23,941	318	8,376	5,461	584	834	990	507	7,481	10.69	3.200
Dos Palos	4,507	4,483	24	1,455	1,240	55	44	78	38	1,387	4.67	3.232
Gustine	5,034	5,034	0	1,861	1,500	30	98	105	128	1,777	4.51	2.833
Livingston	10,930	10,893	37	2,518	1,893	80	204	305	36	2,457	2.42	4.433
Los Banos	28,431	28,256	175	8,720	6,993	263	530	658	276	8,364	4.08	3.378
Merced	66,657	65,287	1,370	22,150	13,083	942	2,714	4,703	708	21,022	5.09	3.106
Balance Of County	81,049	80,065	984	25,592	19,891	581	786	628	3,706	23,486	8.23	3.409
Incorporated	139,818	137,894	1,924	45,080	30,170	1,954	4,424	6,839	1,693	42,488	5.75	3.245
	220,867	217,959	2,908	70,672	50,061	2,535	5,210	7,467	5,399	65,974		
County Total	220,867	217,959	2,908	70,672	50,061	2,535	5,210	7,467	5,399	65,974	6.65	3.304

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Modoc County												
Alturas	2,874	2,794	80	1,367	1,020	54	48	144	101	1,181	13.61	2.366
Balance Of County	6,576	6,253	323	3,478	2,278	33	50	15	1,102	2,632	24.32	2.376
Incorporated	2,874	2,794	80	1,367	1,020	54	48	144	101	1,181	13.61	2.366
County Total	9,450	9,047	403	4,845	3,298	87	98	159	1,203	3,813	21.30	2.373
Mono County												
Mammoth Lakes	7,333	7,115	218	8,312	2,204	965	1,668	3,282	193	2,938	64.65	2.422
Balance Of County	5,750	5,670	80	3,864	2,500	225	304	74	761	2,364	38.82	2.398
Incorporated	7,333	7,115	218	8,312	2,204	965	1,668	3,282	193	2,938	64.65	2.422
County Total	13,083	12,785	298	12,176	4,704	1,190	1,972	3,356	954	5,302	56.46	2.411
Monterey County												
Carmel-By-The-Sea	4,137	4,137	0	3,344	2,749	111	214	270	0	2,292	31.46	1.805
Del Rey Oaks	1,668	1,668	0	727	567	25	23	109	3	704	3.16	2.369
Gonzales	8,204	8,131	73	1,851	1,343	128	169	169	42	1,820	1.67	4.468
Greenfield	12,948	12,852	96	2,761	1,873	282	274	247	85	2,677	3.04	4.801
King City	11,494	11,310	184	2,865	1,597	278	286	415	289	2,777	3.07	4.073
Marina	19,153	19,022	131	8,547	3,392	1,537	1,455	1,743	420	6,753	20.99	2.817
Monterey	30,064	27,074	2,990	13,444	5,910	913	2,258	4,342	21	12,677	5.71	2.136
Pacific Grove	15,708	15,533	175	8,042	5,012	448	981	1,510	91	7,325	8.92	2.121
Salinas	146,689	144,237	2,452	40,346	21,493	3,439	3,460	10,668	1,286	38,961	3.43	3.702
Sand City	271	207	64	90	51	5	20	9	5	83	7.78	2.494
Seaside	34,139	31,887	2,252	11,011	6,115	2,279	927	1,258	432	9,737	11.57	3.275
Soledad	22,482	12,229	10,253	2,734	1,881	205	315	210	123	2,667	2.45	4.585
Balance Of County	105,419	103,767	1,652	38,171	29,279	2,695	1,548	1,741	2,908	34,817	8.79	2.980
Incorporated	306,957	288,287	18,670	95,762	51,983	9,650	10,382	20,950	2,797	88,473	7.61	3.258
County Total	412,376	392,054	20,322	133,933	81,262	12,345	11,930	22,691	5,705	123,290	7.95	3.180
Napa County												
American Canyon	11,258	11,124	134	3,765	2,830	23	70	61	781	3,690	1.99	3.015
Calistoga	5,224	5,157	67	2,256	1,052	97	186	361	560	2,049	9.18	2.517
Napa	74,040	72,581	1,459	28,245	17,648	2,064	2,780	4,364	1,389	27,434	2.87	2.646
St Helena	6,012	5,960	52	2,726	1,662	215	210	478	161	2,397	12.07	2.486
Yountville	3,293	2,094	1,199	1,159	605	172	39	35	308	1,067	7.94	1.963
Balance Of County	28,065	25,639	2,426	11,562	9,796	650	361	23	732	9,875	14.59	2.596
Incorporated	99,827	96,916	2,911	38,151	23,797	2,571	3,285	5,299	3,199	36,637	3.97	2.645

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSE-HOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	HOUSING UNITS: SINGLE DETACHED	HOUSING UNITS: SINGLE ATTACHED	HOUSING UNITS: MULTIPLE 2 TO 4	HOUSING UNITS: MULTIPLE 5 PLUS	HOUSING UNITS: MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	127,892	122,555	5,337	49,713	33,593	3,221	3,646	5,322	3,931	46,512	6.44	2.635
Nevada County												
Grass Valley	11,952	11,602	350	5,730	2,600	256	743	1,439	692	5,458	4.75	2.126
Nevada City	3,030	2,843	187	1,431	1,111	53	117	78	72	1,328	7.20	2.141
Truckee	14,677	14,636	41	10,330	8,771	242	541	478	298	5,451	47.23	2.685
Balance Of County	65,179	64,801	378	28,248	25,042	320	230	193	2,463	25,785	8.72	2.513
Incorporated	29,659	29,081	578	17,491	12,482	551	1,401	1,995	1,062	12,237	30.04	2.376
County Total	94,838	93,882	956	45,739	37,524	871	1,631	2,188	3,525	38,022	16.87	2.469
Orange County												
Aliso Viejo	42,443	42,283	160	17,243	6,374	4,935	739	5,180	15	16,765	2.77	2.522
Anaheim	334,743	330,947	3,796	100,064	43,063	8,923	10,401	33,293	4,384	97,305	2.76	3.401
Brea	36,888	36,760	128	13,650	7,762	1,077	445	3,496	870	13,384	1.95	2.747
Buena Park	79,495	78,561	934	23,752	13,962	1,864	1,420	6,215	291	23,259	2.08	3.378
Costa Mesa	110,811	107,569	3,242	40,518	15,452	4,127	5,855	13,871	1,213	39,315	2.97	2.736
Cypress	47,599	47,278	321	16,251	10,040	2,485	520	2,842	364	15,872	2.33	2.979
Dana Point	36,021	35,779	242	15,819	7,781	2,266	2,796	2,607	369	14,583	7.81	2.453
Fountain Valley	55,933	55,421	512	18,478	12,366	2,194	644	2,876	398	18,167	1.68	3.051
Fullerton	129,422	126,639	2,783	45,229	22,932	3,728	3,641	14,007	921	44,055	2.60	2.875
Garden Grove	168,782	166,548	2,234	46,922	26,618	4,486	3,410	10,591	1,817	46,006	1.95	3.620
Huntington Beach	194,781	193,989	792	76,427	37,694	9,457	9,666	16,469	3,141	74,402	2.65	2.607
Irvine	157,523	149,842	7,681	58,192	23,123	12,964	4,384	16,699	1,022	55,470	4.68	2.701
Laguna Beach	24,319	24,197	122	13,065	8,133	759	1,758	2,091	324	11,600	11.21	2.086
Laguna Hills	32,634	32,210	424	11,094	5,819	2,183	608	2,267	217	10,749	3.11	2.997
Laguna Niguel	63,595	63,292	303	24,130	13,412	5,007	1,341	4,354	16	23,455	2.80	2.698
Laguna Woods	18,099	18,025	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.432
La Habra	60,752	60,157	595	19,694	10,444	1,659	1,344	5,508	739	19,193	2.54	3.134
Lake Forest	76,660	75,816	844	26,310	14,166	3,923	1,276	5,659	1,286	25,639	2.55	2.957
La Palma	15,859	15,828	31	5,126	3,632	376	102	989	27	5,038	1.72	3.142
Los Alamitos	11,728	11,322	406	4,329	1,914	243	1,029	1,014	129	4,246	1.92	2.667
Mission Viejo	96,749	95,684	1,065	33,711	24,472	4,021	1,201	3,928	89	33,163	1.63	2.885
Newport Beach	72,582	71,642	940	38,009	16,273	6,685	5,385	8,803	863	33,710	11.31	2.125
Orange	133,101	127,769	5,332	42,622	24,038	5,149	4,692	7,404	1,339	41,632	2.32	3.069
Placentia	48,360	48,057	303	15,677	9,328	2,050	1,104	2,618	577	15,382	1.88	3.124
Rancho Santa Margarita	48,519	48,505	14	16,684	9,118	3,889	598	3,079	0	16,419	1.59	2.954
San Clemente	57,142	56,850	292	23,250	13,178	2,386	3,996	3,287	403	21,833	6.09	2.604
San Juan Capistrano	34,737	34,311	426	11,432	5,842	2,395	944	775	1,476	11,038	3.45	3.108
Santa Ana	343,986	338,339	5,647	74,645	33,524	6,426	7,520	23,266	3,909	73,057	2.13	4.631
Seal Beach	24,865	24,581	284	14,325	4,597	2,121	1,169	6,275	163	13,191	7.92	1.863
Stanton	38,118	37,600	518	11,034	2,957	1,873	988	3,954	1,262	10,789	2.22	3.485
Tustin	69,143	68,725	418	25,674	8,219	3,488	3,836	9,223	908	23,999	6.52	2.864
Villa Park	6,121	6,100	21	2,014	1,985	18	0	6	5	1,956	2.88	3.119
Westminster	89,758	89,206	552	26,952	14,748	2,445	2,073	4,618	3,068	26,418	1.98	3.377

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Yorba Linda	60,857	60,722	135	19,870	15,672	2,081	534	1,272	311	19,550	1.61	3.106
Balance Of County	116,696	115,175	1,521	40,141	30,826	3,168	1,829	3,790	528	37,870	5.66	3.041
Incorporated	2,822,125	2,780,554	41,571	945,821	469,365	121,695	87,893	234,926	31,942	913,231	3.45	3.045
County Total	2,938,821	2,895,729	43,092	985,962	500,191	124,863	89,722	238,716	32,470	951,101	3.54	3.045
Placer County												
Auburn	12,597	12,391	206	5,532	3,721	211	655	945	0	5,375	2.84	2.305
Colfax	1,713	1,712	1	731	482	15	138	63	33	706	3.42	2.425
Lincoln	16,839	16,725	114	6,766	5,587	196	174	713	96	6,455	4.60	2.591
Loomis	6,309	6,275	34	2,297	1,920	199	58	9	111	2,230	2.92	2.814
Rocklin	43,160	43,140	20	16,440	11,913	518	610	2,960	439	15,828	3.72	2.726
Roseville	87,695	86,641	1,054	35,113	25,773	1,082	1,627	6,088	543	33,857	3.58	2.559
Balance Of County	102,995	101,430	1,565	49,701	39,616	1,916	2,504	2,182	3,483	38,311	22.92	2.648
Incorporated	168,313	166,884	1,429	66,879	49,396	2,221	3,262	10,778	1,222	64,451	3.63	2.589
County Total	271,308	268,314	2,994	116,580	89,012	4,137	5,766	12,960	4,705	102,762	11.85	2.611
Plumas County												
Portola	2,189	2,168	21	1,013	768	11	72	110	52	904	10.76	2.398
Balance Of County	18,638	18,471	167	12,689	9,659	433	303	286	2,008	8,304	34.56	2.224
Incorporated	2,189	2,168	21	1,013	768	11	72	110	52	904	10.76	2.398
County Total	20,827	20,639	188	13,702	10,427	444	375	396	2,060	9,208	32.80	2.241
Riverside County												
Banning	24,618	24,280	338	10,077	7,172	728	426	595	1,156	9,231	8.40	2.630
Beaumont	12,260	12,105	155	4,508	2,943	172	340	706	347	4,109	8.85	2.946
Blythe	21,282	12,758	8,524	5,127	2,854	151	505	801	816	4,301	16.11	2.966
Calimesa	7,305	7,209	96	3,265	1,778	111	57	64	1,255	2,998	8.18	2.405
Canyon Lake	10,393	10,377	16	4,151	3,842	78	6	84	141	3,737	9.97	2.777
Cathedral City	45,624	45,439	185	18,787	9,648	2,587	2,308	1,566	2,678	14,728	21.61	3.085
Coachella	24,392	24,348	44	5,297	3,293	319	640	590	455	5,068	4.32	4.804
Corona	134,576	133,944	632	41,549	28,269	2,186	2,225	7,587	1,282	40,034	3.65	3.346
Desert Hot Springs	16,962	16,788	174	7,068	3,814	180	1,193	1,313	568	5,887	16.71	2.852
Hemet	62,751	61,072	1,679	30,370	12,756	1,748	2,125	4,497	9,244	26,510	12.71	2.304
Indian Wells	4,368	4,368	0	4,320	2,847	884	112	469	8	2,228	48.43	1.961
Indio	52,422	51,566	856	17,744	8,497	878	1,419	3,780	3,170	14,556	17.97	3.543
Lake Elsinore	31,198	31,125	73	10,070	6,773	707	735	1,099	756	9,341	7.24	3.332
La Quinta	28,846	28,806	40	14,127	11,556	1,351	276	685	259	10,100	28.51	2.852
Moreno Valley	147,100	146,403	697	42,044	35,181	891	1,389	3,540	1,043	39,805	5.33	3.678
Murrieta	51,865	51,679	186	17,174	14,224	211	147	2,052	540	16,483	4.02	3.135
Norco	24,991	20,359	4,632	6,493	6,119	137	9	137	91	6,347	2.25	3.208

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Palm Desert	43,058	42,831	227	28,799	11,761	9,534	2,459	3,847	1,198	19,717	31.54	2.172
Palm Springs	43,909	43,213	696	31,064	10,336	6,160	2,506	9,827	2,235	20,677	33.44	2.090
Perris	37,680	37,448	232	10,794	7,135	321	371	1,264	1,703	9,872	8.54	3.793
Rancho Mirage	14,409	14,039	370	12,425	4,935	3,680	620	1,203	1,987	7,164	42.34	1.960
Riverside	270,574	261,766	8,808	89,356	56,231	4,185	5,825	20,734	2,381	85,230	4.62	3.071
San Jacinto	25,405	25,215	190	9,948	5,515	596	651	567	2,619	8,729	12.25	2.889
Temecula	73,045	73,023	22	23,543	18,376	386	598	3,862	321	22,555	4.20	3.238
Balance Of County	443,504	436,952	6,552	165,567	105,563	4,178	3,493	5,624	46,709	142,501	13.93	3.066
Incorporated	1,209,033	1,180,161	28,872	448,100	275,855	38,181	26,942	70,869	36,253	389,407	13.10	3.031
County Total	1,652,537	1,617,113	35,424	613,667	381,418	42,359	30,435	76,493	82,962	531,908	13.32	3.040
Sacramento County												
Citrus Heights	87,708	86,831	877	35,358	19,572	3,531	3,021	7,355	1,879	33,921	4.06	2.560
Elk Grove	81,253	80,683	570	26,645	23,784	919	525	1,144	273	26,051	2.23	3.097
Folsom	60,973	54,259	6,714	21,318	15,093	635	627	4,102	861	20,402	4.30	2.659
Galt	21,019	20,831	188	6,593	5,261	198	336	426	372	6,342	3.81	3.285
Isleton	843	843	0	384	222	2	77	36	47	343	10.68	2.458
Sacramento	426,440	417,283	9,157	168,842	99,814	11,366	15,878	38,111	3,673	159,255	5.68	2.620
Balance Of County	609,347	601,364	7,983	231,342	145,596	15,612	15,860	45,892	8,382	222,965	3.62	2.697
Incorporated	678,236	660,730	17,506	259,140	163,746	16,651	20,464	51,174	7,105	246,314	4.95	2.682
County Total	1,287,583	1,262,094	25,489	490,482	309,342	32,263	36,324	97,066	15,487	469,279	4.32	2.689
San Benito County												
Hollister	36,148	35,977	171	10,449	7,879	531	992	741	306	10,230	2.10	3.517
San Juan Bautista	1,589	1,589	0	632	415	70	69	62	16	583	7.75	2.726
Balance Of County	17,876	17,540	336	6,185	5,094	427	70	42	552	5,813	6.01	3.017
Incorporated	37,737	37,566	171	11,081	8,294	601	1,061	803	322	10,813	2.42	3.474
County Total	55,613	55,106	507	17,266	13,388	1,028	1,131	845	874	16,626	3.71	3.314
San Bernardino County												
Adelanto	18,788	17,387	1,401	5,645	3,849	161	382	750	503	4,797	15.02	3.625
Apple Valley	57,197	56,834	363	20,713	15,462	726	2,074	1,417	1,034	19,063	7.97	2.981
Barstow	22,623	22,200	423	9,501	5,275	356	1,286	1,489	1,095	7,946	16.37	2.794
Big Bear Lake	5,735	5,710	25	8,941	7,478	326	342	410	385	2,406	73.09	2.373
Chino	69,179	61,656	7,523	18,106	12,674	952	782	3,170	528	17,505	3.32	3.522
Chino Hills	71,424	71,273	151	21,263	17,357	1,378	284	1,558	686	20,872	1.84	3.415
Colton	49,405	49,141	264	15,831	9,245	602	1,059	4,110	815	14,660	7.40	3.352
Fontana	140,061	139,562	499	37,998	28,630	1,198	1,579	5,709	882	35,994	5.27	3.877
Grand Terrace	11,993	11,784	209	4,481	2,886	175	265	905	250	4,243	5.31	2.777
Hesperia	65,584	65,253	331	21,793	17,598	363	1,004	1,624	1,204	20,383	6.47	3.201

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Highland	46,112	45,872	240	14,958	10,909	512	598	2,129	810	13,569	9.29	3.381
Loma Linda	20,311	19,345	966	8,371	3,404	673	1,307	2,425	562	7,803	6.79	2.479
Montclair	34,080	33,468	612	9,109	5,245	758	1,002	1,350	754	8,842	2.93	3.785
Needles	5,162	5,151	11	2,655	1,405	86	254	367	543	2,019	23.95	2.551
Ontario	163,345	162,284	1,061	45,519	27,074	3,633	3,960	8,749	2,103	43,850	3.67	3.701
Rancho Cucamonga	138,011	134,385	3,626	44,425	31,004	2,532	1,794	7,723	1,372	43,085	3.02	3.119
Redlands	66,413	64,447	1,966	25,246	16,134	900	2,390	4,915	907	24,027	4.83	2.682
Rialto	95,416	94,612	804	26,350	18,685	586	1,806	3,479	1,794	24,948	5.32	3.792
San Bernardino	191,643	185,446	6,197	63,691	37,562	2,716	5,732	13,201	4,480	56,658	11.04	3.273
Twentynine Palms	22,996	17,587	5,409	8,506	4,619	1,262	1,650	445	530	6,685	21.41	2.631
Upland	70,961	70,376	585	25,739	14,817	1,766	2,675	5,636	845	24,813	3.60	2.836
Victorville	69,786	67,370	2,416	23,296	16,807	389	1,333	3,009	1,758	21,634	7.13	3.114
Yucaipa	43,802	43,230	572	16,692	10,566	394	731	774	4,227	15,739	5.71	2.747
Yucca Valley	17,562	17,251	311	8,070	6,206	140	639	378	707	7,052	12.61	2.446
Balance Of County	294,778	284,098	10,680	126,240	101,522	4,293	4,232	3,045	13,148	91,805	27.28	3.095
Incorporated	1,497,589	1,461,624	35,965	486,899	324,891	22,584	34,928	75,722	28,774	448,593	7.87	3.258
County Total	1,792,367	1,745,722	46,645	613,139	426,413	26,877	39,160	78,767	41,922	540,398	11.86	3.230
San Diego County												
Carlsbad	88,125	87,338	787	37,500	20,361	5,748	2,358	7,742	1,291	34,975	6.73	2.497
Chula Vista	191,046	189,761	1,285	64,437	33,832	5,454	4,168	17,137	3,846	62,499	3.01	3.036
Coronado	25,966	17,957	8,009	9,552	4,450	874	822	3,383	23	7,791	18.44	2.305
Del Mar	4,501	4,499	2	2,581	1,347	364	198	672	0	2,199	14.80	2.046
El Cajon	96,582	94,099	2,483	35,283	13,500	1,548	2,244	15,957	2,034	34,289	2.82	2.744
Encinitas	59,922	59,363	559	24,261	13,543	4,535	2,099	3,315	769	23,230	4.25	2.555
Escondido	137,137	135,372	1,765	45,557	21,998	2,922	3,100	13,782	3,755	44,311	2.74	3.055
Imperial Beach	27,551	26,872	679	9,786	4,010	687	1,059	3,690	340	9,316	4.80	2.884
La Mesa	55,673	54,627	1,046	24,976	11,102	1,922	2,003	9,590	359	24,218	3.03	2.256
Lemon Grove	25,343	24,752	591	8,736	5,762	713	694	1,470	97	8,502	2.68	2.911
National City	58,135	51,734	6,401	15,425	6,595	1,330	1,683	5,380	437	15,021	2.62	3.444
Oceanside	167,342	166,062	1,280	60,967	31,351	8,222	4,353	13,620	3,421	57,802	5.19	2.873
Poway	49,685	49,259	426	16,002	11,951	877	318	2,165	691	15,751	1.57	3.127
San Diego	1,256,643	1,212,646	43,997	476,143	222,176	45,766	42,394	159,375	6,432	456,849	4.05	2.654
San Marcos	60,828	60,759	69	20,576	10,765	1,038	700	4,413	3,660	19,757	3.98	3.075
Santee	53,658	52,615	1,043	18,784	10,623	1,615	1,194	2,849	2,503	18,422	1.93	2.856
Solana Beach	13,288	13,254	34	6,507	2,958	1,265	614	1,631	39	5,800	10.87	2.285
Vista	92,120	89,854	2,266	30,107	14,913	2,029	2,140	8,896	2,129	29,161	3.14	3.081
Balance Of County	459,213	430,082	29,131	155,738	104,527	11,326	6,474	18,225	15,186	145,844	6.35	2.949
Incorporated	2,463,545	2,390,823	72,722	907,180	441,237	86,909	72,141	275,067	31,826	869,893	4.11	2.748
County Total	2,922,758	2,820,905	101,853	1,062,918	545,764	98,235	78,615	293,292	47,012	1,015,737	4.44	2.777
San Francisco County												
City and County Total	789,984	770,336	19,648	349,502	62,811	48,689	81,192	156,250	560	332,543	4.85	2.317

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COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
San Joaquin County												
Escalon	6,394	6,368	26	2,241	1,835	20	153	98	135	2,162	3.53	2.945
Lathrop	11,644	11,634	10	3,271	2,753	63	92	12	351	3,179	2.81	3.660
Lodi	59,775	58,751	1,024	21,988	13,818	1,454	1,752	4,500	464	21,283	3.21	2.760
Manteca	55,281	54,804	477	18,648	13,588	739	1,106	2,346	869	18,022	3.36	3.041
Ripon	11,231	11,120	111	3,740	3,168	95	151	316	10	3,655	2.27	3.042
Stockton	255,208	250,026	5,182	84,303	51,345	6,592	8,415	16,663	1,288	80,721	4.25	3.097
Tracy	66,014	65,669	345	20,571	16,545	1,015	939	1,597	475	20,040	2.58	3.277
Balance Of County	133,699	122,204	11,495	42,554	34,265	1,240	770	592	5,687	40,448	4.95	3.021
Incorporated	465,547	458,372	7,175	154,762	103,052	9,978	12,608	25,532	3,592	149,062	3.68	3.075
County Total	599,246	580,576	18,670	197,316	137,317	11,218	13,378	26,124	9,279	189,510	3.96	3.064
San Luis Obispo County												
Arroyo Grande	16,302	16,092	210	6,957	4,686	585	489	649	548	6,676	4.04	2.410
Atascadero	27,005	25,508	1,497	10,088	7,013	441	862	1,220	552	9,763	3.22	2.613
El Paso De Robles	25,822	25,032	790	9,433	6,065	816	1,019	1,188	345	9,181	2.67	2.727
Grover Beach	13,138	13,012	126	5,421	3,103	786	706	579	247	5,059	6.68	2.572
Morro Bay	10,514	10,316	198	6,364	4,159	359	623	464	759	5,076	20.24	2.032
Pismo Beach	8,675	8,648	27	5,586	2,999	576	451	473	1,087	4,299	23.04	2.012
San Luis Obispo	44,448	42,586	1,862	19,466	9,205	1,270	2,197	5,292	1,502	18,793	3.46	2.266
Balance Of County	107,731	96,896	10,835	42,120	31,451	1,278	1,897	1,208	6,286	36,753	12.74	2.636
Incorporated	145,904	141,194	4,710	63,315	37,230	4,833	6,347	9,865	5,040	58,847	7.06	2.399
County Total	253,635	238,090	15,545	105,435	68,681	6,111	8,244	11,073	11,326	95,600	9.33	2.490
San Mateo County												
Atherton	7,189	6,871	318	2,505	2,466	32	0	7	0	2,413	3.67	2.847
Belmont	25,140	24,513	627	10,591	6,242	581	275	3,493	0	10,432	1.50	2.350
Brisbane	3,640	3,600	40	1,854	1,016	260	177	358	43	1,640	11.54	2.195
Burlingame	28,283	27,797	486	12,935	6,140	423	987	5,385	0	12,575	2.78	2.210
Colma	1,196	1,147	49	344	207	39	71	21	6	330	4.07	3.476
Daly City	103,923	103,133	790	31,424	15,947	4,469	2,825	7,596	587	30,886	1.71	3.339
East Palo Alto	31,817	31,628	189	7,655	3,828	376	360	2,932	159	7,530	1.63	4.200
Foster City	28,788	28,701	87	12,010	4,809	2,464	767	3,963	7	11,614	3.30	2.471
Half Moon Bay	12,116	11,268	848	4,219	2,649	536	288	319	427	4,106	2.68	2.744
Hillsborough	10,923	10,921	2	3,841	3,824	8	9	0	0	3,725	3.02	2.932
Menlo Park	30,905	29,969	936	12,780	6,905	930	1,574	3,366	5	12,451	2.57	2.407
Millbrae	20,718	20,386	332	8,118	5,319	269	426	2,093	11	7,961	1.93	2.561
Pacifica	38,575	38,394	181	14,323	10,332	778	713	2,402	98	14,071	1.76	2.729
Portola Valley	4,486	4,416	70	1,783	1,490	33	0	260	0	1,711	4.04	2.581
Redwood City	75,975	74,048	1,927	29,165	13,524	3,653	2,603	8,552	833	28,297	2.98	2.617
San Bruno	40,144	39,923	221	14,982	9,060	566	1,188	4,146	22	14,679	2.02	2.720

California Department of Finance
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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
San Carlos	27,762	27,579	183	11,717	8,245	608	470	2,378	16	11,481	2.01	2.402
San Mateo	93,621	92,305	1,316	38,751	17,735	3,492	3,003	14,476	45	37,828	2.38	2.440
South San Francisco	60,696	60,253	443	20,199	11,815	2,485	1,668	3,822	409	19,737	2.29	3.053
Woodside	5,362	5,356	6	2,035	1,973	28	28	5	1	1,954	3.98	2.741
Balance Of County	63,270	61,887	1,383	21,992	18,134	690	902	1,419	847	21,260	3.33	2.911
Incorporated	651,259	642,208	9,051	241,231	133,526	22,030	17,432	65,574	2,669	235,421	2.41	2.728
County Total	714,529	704,095	10,434	263,223	151,660	22,720	18,334	66,993	3,516	256,681	2.49	2.743
Santa Barbara County												
Buellton	3,983	3,977	6	1,530	921	63	30	98	418	1,478	3.40	2.691
Carpinteria	14,428	14,303	125	5,507	2,152	422	526	1,467	940	5,029	8.68	2.844
Guadalupe	6,090	6,090	0	1,547	1,112	161	169	99	6	1,509	2.46	4.036
Lompoc	41,656	38,475	3,181	13,794	7,210	1,044	1,927	2,673	940	13,225	4.12	2.909
Santa Barbara	90,668	88,876	1,792	37,202	17,120	2,874	5,519	11,171	518	35,726	3.97	2.488
Santa Maria	80,481	78,283	2,198	23,559	14,515	1,324	1,667	4,481	1,572	22,836	3.07	3.428
Solvang	5,442	5,282	160	2,316	1,324	151	169	453	219	2,211	4.53	2.389
Balance Of County	164,746	156,045	8,701	59,123	39,692	3,726	3,391	8,347	3,967	56,318	4.74	2.771
Incorporated	242,748	235,286	7,462	85,455	44,354	6,039	10,007	20,442	4,613	82,014	4.03	2.869
County Total	407,494	391,331	16,163	144,578	84,046	9,765	13,398	28,789	8,580	138,332	4.32	2.829
Santa Clara County												
Campbell	38,313	38,023	290	16,365	6,930	1,981	2,442	4,755	257	15,998	2.24	2.377
Cupertino	52,169	51,688	481	19,188	11,901	2,028	1,666	3,584	9	18,700	2.54	2.764
Gilroy	43,833	43,403	430	12,857	8,437	741	1,280	1,968	431	12,558	2.33	3.456
Los Altos	27,805	27,386	419	10,774	9,222	364	269	903	16	10,508	2.47	2.606
Los Altos Hills	8,111	8,046	65	2,903	2,839	32	17	9	6	2,826	2.65	2.847
Los Gatos	28,862	28,160	702	12,490	7,044	1,837	931	2,555	123	12,108	3.06	2.326
Milpitas	63,625	60,451	3,174	17,639	10,922	2,225	1,609	2,311	572	17,403	1.34	3.474
Monte Sereno	3,480	3,480	0	1,236	1,132	13	18	73	0	1,210	2.10	2.876
Morgan Hill	34,734	34,221	513	11,488	7,121	1,597	649	1,195	926	11,234	2.21	3.046
Mountain View	71,443	70,939	504	32,780	9,176	3,813	2,670	15,890	1,231	31,577	3.67	2.247
Palo Alto	60,347	59,679	668	26,841	15,493	974	1,733	8,477	164	25,984	3.19	2.297
San Jose	916,025	904,830	11,195	288,566	164,033	27,583	23,268	62,654	11,028	283,200	1.86	3.195
Santa Clara	104,067	101,280	2,787	40,319	17,760	3,588	3,878	14,984	109	39,196	2.79	2.584
Saratoga	30,379	30,018	361	10,806	9,575	560	197	467	7	10,604	1.87	2.831
Sunnyvale	132,600	131,725	875	54,111	21,085	3,940	4,911	20,079	4,096	52,890	2.26	2.491
Balance Of County	100,182	92,265	7,917	31,746	24,948	1,683	1,138	3,294	683	30,674	3.38	3.008
Incorporated	1,615,793	1,593,329	22,464	558,363	302,670	51,276	45,538	139,904	18,975	545,996	2.21	2.918
County Total	1,715,975	1,685,594	30,381	590,109	327,618	52,959	46,676	143,198	19,658	576,670	2.28	2.923

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Cruz County												
Capitola	10,087	9,931	156	5,356	1,956	514	1,137	1,099	650	4,733	11.63	2.098
Santa Cruz	54,649	49,957	4,692	21,577	12,162	1,905	2,586	4,484	440	20,511	4.94	2.436
Scotts Valley	11,502	11,050	452	4,486	2,455	413	397	417	804	4,334	3.39	2.550
Watsonville	47,510	46,957	553	12,605	6,411	1,597	1,673	2,024	900	12,266	2.69	3.828
Balance Of County	134,281	131,044	3,237	55,685	40,473	4,333	2,605	3,816	4,458	50,121	9.99	2.615
Incorporated	123,748	117,895	5,853	44,024	22,984	4,429	5,793	8,024	2,794	41,844	4.95	2.817
County Total	258,029	248,939	9,090	99,709	63,457	8,762	8,398	11,840	7,252	91,965	7.77	2.707
Shasta County												
Anderson	9,414	9,296	118	3,673	2,359	209	372	560	173	3,461	5.77	2.686
Redding	84,896	82,501	2,395	34,926	22,440	949	4,516	4,437	2,584	33,170	5.03	2.487
Shasta Lake	9,513	9,461	52	3,875	3,002	27	237	114	495	3,525	9.03	2.684
Balance Of County	66,046	65,256	790	27,959	19,765	272	367	198	7,357	24,789	11.34	2.632
Incorporated	103,823	101,258	2,565	42,474	27,801	1,185	5,125	5,111	3,252	40,156	5.46	2.522
County Total	169,869	166,514	3,355	70,433	47,566	1,457	5,492	5,309	10,609	64,945	7.79	2.564
Sierra County												
Loyalton	868	838	30	348	301	13	3	0	31	324	6.90	2.586
Balance Of County	2,730	2,724	6	1,872	1,527	36	44	63	202	1,208	35.47	2.255
Incorporated	868	838	30	348	301	13	3	0	31	324	6.90	2.586
County Total	3,598	3,562	36	2,220	1,828	49	47	63	233	1,532	30.99	2.325
Siskiyou County												
Dorris	885	885	0	398	316	4	16	0	62	344	13.57	2.573
Dunsmuir	1,914	1,914	0	1,171	792	23	126	184	46	868	25.88	2.205
Etna	778	778	0	363	266	10	19	13	55	330	9.09	2.358
Fort Jones	662	662	0	331	235	11	34	2	49	301	9.06	2.199
Montague	1,456	1,437	19	613	472	6	10	43	82	564	7.99	2.548
Mount Shasta	3,658	3,610	48	1,827	1,158	89	251	256	73	1,695	7.22	2.130
Tulelake	1,018	1,018	0	461	317	2	44	19	79	360	21.91	2.828
Weed	3,014	2,836	178	1,292	888	19	136	190	59	1,183	8.44	2.397
Yreka	7,282	7,062	220	3,318	2,197	140	285	467	229	3,129	5.70	2.257
Balance Of County	23,930	23,645	285	12,423	8,984	184	178	96	2,981	9,991	19.58	2.367
Incorporated	20,667	20,202	465	9,774	6,641	304	921	1,174	734	8,774	10.23	2.302
County Total	44,597	43,847	750	22,197	15,625	488	1,099	1,270	3,715	18,765	15.46	2.337

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Solano County												
Benicia	27,166	27,112	54	10,591	6,852	1,045	919	1,449	326	10,371	2.08	2.614
Dixon	16,240	16,199	41	5,180	4,264	213	368	249	86	5,081	1.91	3.188
Fairfield	101,167	96,853	4,314	33,452	22,369	2,413	2,207	5,571	892	32,340	3.32	2.995
Rio Vista	5,363	5,363	0	2,300	1,882	34	103	171	110	2,192	4.70	2.447
Suisun City	26,784	26,690	94	8,296	6,960	189	327	754	66	8,134	1.95	3.281
Vacaville	92,734	83,362	9,372	29,915	21,133	1,035	2,139	4,300	1,308	29,299	2.06	2.845
Vallejo	119,657	117,517	2,140	41,822	28,980	1,701	3,919	5,876	1,346	40,180	3.93	2.925
Balance Of County	19,724	19,133	591	7,048	5,946	220	293	119	470	6,624	6.02	2.888
Incorporated	389,111	373,096	16,015	131,556	92,440	6,630	9,982	18,370	4,134	127,597	3.01	2.924
County Total	408,835	392,229	16,606	138,604	98,386	6,850	10,275	18,489	4,604	134,221	3.16	2.922
Sonoma County												
Cloverdale	7,333	7,256	77	2,818	2,084	121	112	293	208	2,685	4.72	2.702
Cotati	6,816	6,798	18	2,727	1,568	372	341	325	121	2,671	2.05	2.545
Healdsburg	11,640	11,517	123	4,479	3,210	252	439	479	99	4,297	4.06	2.680
Petaluma	55,730	54,990	740	20,780	15,131	1,652	1,237	1,829	931	20,399	1.83	2.696
Rohnert Park	42,198	41,097	1,101	15,816	7,657	1,698	929	4,119	1,413	15,511	1.93	2.650
Santa Rosa	151,933	148,127	3,806	59,398	35,608	5,628	4,780	10,702	2,680	57,808	2.68	2.562
Sebastopol	7,809	7,598	211	3,341	2,003	253	529	497	59	3,270	2.13	2.324
Sonoma	9,474	9,383	91	4,850	2,717	662	448	586	437	4,545	6.29	2.064
Windsor	24,112	24,021	91	8,206	6,371	460	201	352	822	8,058	1.80	2.981
Balance Of County	151,456	145,801	5,655	64,598	52,204	2,890	2,874	2,021	4,609	56,884	11.94	2.563
Incorporated	317,045	310,787	6,258	122,415	76,349	11,098	9,016	19,182	6,770	119,244	2.59	2.606
County Total	468,501	456,588	11,913	187,013	128,553	13,988	11,890	21,203	11,379	176,128	5.82	2.592
Stanislaus County												
Ceres	35,794	35,695	99	10,956	8,312	343	603	986	712	10,613	3.13	3.363
Hughson	4,248	4,242	6	1,314	1,042	65	50	68	89	1,283	2.36	3.306
Modesto	199,398	196,325	3,073	69,849	48,429	4,006	6,219	9,232	1,963	67,541	3.30	2.907
Newman	7,567	7,501	66	2,283	1,871	76	193	117	26	2,181	4.47	3.439
Oakdale	16,280	16,101	179	5,997	4,414	208	481	683	211	5,796	3.35	2.778
Patterson	13,076	12,847	229	3,622	3,090	190	151	63	128	3,493	3.56	3.678
Riverbank	17,068	16,933	135	4,985	4,149	185	180	182	289	4,822	3.27	3.512
Turlock	60,474	58,379	2,095	20,400	13,560	963	1,750	3,523	604	19,666	3.60	2.969
Waterford	7,193	7,176	17	2,125	1,765	47	172	112	29	2,033	4.33	3.530
Balance Of County	111,087	109,617	1,470	35,293	28,124	1,058	919	416	4,776	33,518	5.03	3.270
Incorporated	361,098	355,199	5,899	121,531	86,632	6,083	9,799	14,966	4,051	117,428	3.38	3.025
County Total	472,185	464,816	7,369	156,824	114,756	7,141	10,718	15,382	8,827	150,946	3.75	3.079

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Sutter County												
Live Oak	6,442	6,150	292	1,846	1,385	75	141	104	141	1,755	4.93	3.504
Yuba City	47,167	46,212	955	16,872	10,376	839	1,534	3,600	523	16,157	4.24	2.860
Balance Of County	28,209	28,051	158	10,263	8,659	272	227	76	1,029	9,755	4.95	2.876
Incorporated	53,609	52,362	1,247	18,718	11,761	914	1,675	3,704	664	17,912	4.31	2.923
County Total	81,818	80,413	1,405	28,981	20,420	1,186	1,902	3,780	1,693	27,667	4.53	2.906
Tehama County												
Corning	6,767	6,710	57	2,629	1,556	70	274	495	234	2,436	7.34	2.755
Red Bluff	13,351	12,816	535	5,667	3,301	218	695	1,090	363	5,200	8.24	2.465
Tehama	432	432	0	196	166	4	10	0	16	179	8.67	2.413
Balance Of County	36,365	35,950	415	15,474	9,379	194	237	78	5,586	13,569	12.31	2.649
Incorporated	20,550	19,958	592	8,492	5,023	292	979	1,585	613	7,815	7.97	2.554
County Total	56,915	55,908	1,007	23,966	14,402	486	1,216	1,663	6,199	21,384	10.77	2.614
Trinity County												
County Total	13,097	12,860	237	8,046	5,309	112	106	117	2,402	5,633	29.99	2.283
Tulare County												
Dinuba	17,527	17,413	114	4,816	3,599	280	268	465	204	4,634	3.78	3.758
Exeter	9,469	9,377	92	3,243	2,561	107	203	184	188	3,072	5.27	3.052
Farmersville	9,035	9,016	19	2,325	1,873	90	155	109	98	2,204	5.20	4.091
Lindsay	10,399	10,250	149	2,867	1,946	135	243	358	185	2,719	5.16	3.770
Porterville	41,066	39,425	1,641	13,051	8,955	483	1,523	1,448	642	12,221	6.36	3.226
Tulare	45,358	44,911	447	14,564	10,930	511	1,215	1,134	774	13,839	4.98	3.245
Visalia	96,269	94,647	1,622	34,102	24,587	1,572	3,505	2,969	1,469	32,235	5.47	2.936
Woodlake	6,855	6,846	9	1,914	1,252	126	152	324	60	1,815	5.17	3.772
Balance Of County	143,790	141,827	1,963	45,558	34,702	1,440	1,324	840	7,252	40,263	11.62	3.523
Incorporated	235,978	231,885	4,093	76,882	55,703	3,304	7,264	6,991	3,620	72,739	5.39	3.188
County Total	379,768	373,712	6,056	122,440	90,405	4,744	8,588	7,831	10,872	113,002	7.71	3.307
Tuolumne County												
Sonora	4,543	4,344	199	2,234	1,289	86	385	447	27	2,086	6.62	2.082
Balance Of County	51,284	46,630	4,654	26,523	20,763	566	785	627	3,782	19,232	27.49	2.425
Incorporated	4,543	4,344	199	2,234	1,289	86	385	447	27	2,086	6.62	2.082
County Total	55,827	50,974	4,853	28,757	22,052	652	1,170	1,074	3,809	21,318	25.87	2.391

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2002

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Ventura County												
Camarillo	59,486	58,405	1,081	22,670	13,384	4,493	845	2,890	1,058	22,168	2.21	2.635
Fillmore	14,450	14,204	246	4,062	2,906	277	231	322	326	3,967	2.34	3.581
Moorpark	33,150	33,138	12	9,544	6,926	1,234	223	831	330	9,439	1.10	3.511
Ojai	7,940	7,750	190	3,244	2,229	266	289	452	8	3,103	4.35	2.498
Oxnard	178,918	176,321	2,597	47,213	26,065	4,576	4,382	9,250	2,940	45,551	3.52	3.871
Port Hueneme	22,367	21,429	938	7,965	2,347	2,204	1,201	2,171	42	7,399	7.11	2.896
San Buenaventura	102,705	100,335	2,370	40,305	22,692	3,428	4,143	7,419	2,623	39,010	3.21	2.572
Santa Paula	28,835	28,592	243	8,365	4,997	729	776	1,076	787	8,160	2.45	3.504
Simi Valley	115,943	115,143	800	38,609	28,900	2,725	1,655	4,437	892	37,727	2.28	3.052
Thousand Oaks	121,402	119,451	1,951	44,357	29,808	5,152	1,739	6,586	1,072	43,154	2.71	2.768
Balance Of County	94,796	92,186	2,610	32,463	25,818	2,348	1,009	1,168	2,120	30,535	5.94	3.019
Incorporated	685,196	674,768	10,428	226,334	140,254	25,084	15,484	35,434	10,078	219,678	2.94	3.072
County Total	779,992	766,954	13,038	258,797	166,072	27,432	16,493	36,602	12,198	250,213	3.32	3.065
Yolo County												
Davis	63,487	60,396	3,091	24,503	11,182	2,351	2,125	8,460	385	23,977	2.15	2.519
West Sacramento	34,796	34,590	206	13,254	7,684	877	936	2,226	1,531	12,457	6.01	2.777
Winters	6,317	6,311	6	1,999	1,567	105	67	182	78	1,951	2.40	3.235
Woodland	51,475	50,685	790	17,798	10,959	1,312	1,123	3,723	681	17,414	2.16	2.911
Balance Of County	21,884	18,158	3,726	6,799	4,552	305	192	804	946	6,399	5.88	2.838
Incorporated	156,075	151,982	4,093	57,554	31,392	4,645	4,251	14,591	2,675	55,799	3.05	2.724
County Total	177,959	170,140	7,819	64,353	35,944	4,950	4,443	15,395	3,621	62,198	3.35	2.735
Yuba County												
Marysville	12,768	12,161	607	5,001	2,768	339	767	1,119	8	4,689	6.24	2.594
Wheatland	2,430	2,430	0	836	552	35	155	55	39	804	3.83	3.022
Balance Of County	47,166	46,412	754	16,894	10,756	867	689	1,076	3,506	15,110	10.56	3.072
Incorporated	15,198	14,591	607	5,837	3,320	374	922	1,174	47	5,493	5.89	2.656
County Total	62,364	61,003	1,361	22,731	14,076	1,241	1,611	2,250	3,553	20,603	9.36	2.961
California												
Incorporated Total	28,684,509	28,033,004	651,505	10,092,614	5,355,852	822,075	932,586	2,673,995	308,106	9,619,300	4.69	2.914
Balance Of State Total	6,379,450	6,199,275	180,175	2,356,098	1,701,264	111,368	98,717	180,195	264,554	2,106,611	10.59	2.943
State Total	35,063,959	34,232,279	831,680	12,448,712	7,057,116	933,443	1,031,303	2,854,190	572,660	11,725,911	5.81	2.919

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2003

COUNTY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Alameda	1,490,473	1,462,880	27,593	551,072	296,776	38,788	61,272	146,586	7,650	534,008	3.10	2.739
Alpine	1,252	1,251	1	1,615	935	38	35	545	62	514	68.17	2.434
Amador	36,712	32,237	4,475	15,806	12,911	390	384	571	1,550	13,420	15.10	2.402
Butte	210,235	204,028	6,207	88,574	54,260	2,387	7,681	9,903	14,343	82,523	6.83	2.472
Calaveras	42,801	42,372	429	24,494	20,730	465	503	355	2,441	17,600	28.15	2.408
Colusa	19,805	19,385	420	6,921	5,126	229	407	389	770	6,232	9.96	3.111
Contra Costa	993,668	982,387	11,281	366,986	241,941	31,073	25,284	61,097	7,591	356,153	2.95	2.758
Del Norte	28,046	24,225	3,821	10,618	6,231	182	803	584	2,818	9,330	12.13	2.596
El Dorado	166,834	165,781	1,053	75,336	60,816	1,694	3,508	4,944	4,374	62,425	17.14	2.656
Fresno	846,485	828,294	18,191	279,933	183,939	10,061	24,400	48,188	13,345	261,636	6.54	3.166
Glenn	27,375	26,986	389	10,150	7,065	207	718	700	1,460	9,328	8.10	2.893
Humboldt	129,335	125,004	4,331	57,099	39,135	1,562	5,698	4,683	6,021	52,318	8.37	2.389
Imperial	151,815	140,669	11,146	45,944	26,714	1,893	3,552	6,064	7,721	41,350	10.00	3.402
Inyo	18,431	18,146	285	9,114	5,489	212	407	468	2,538	7,765	14.80	2.337
Kern	708,753	676,470	32,283	242,231	165,514	8,581	20,564	23,724	23,848	218,957	9.61	3.090
Kings	137,411	116,228	21,183	38,018	26,566	2,357	2,728	4,226	2,141	35,812	5.80	3.246
Lake	61,465	60,265	1,200	33,015	20,556	533	902	830	10,194	24,333	26.30	2.477
Lassen	34,076	25,161	8,915	12,299	8,473	296	515	509	2,506	9,935	19.22	2.533
Los Angeles	9,961,407	9,785,113	176,294	3,308,901	1,611,677	241,984	288,065	1,110,554	56,621	3,170,188	4.19	3.087
Madera	131,821	124,412	7,409	42,493	32,671	1,336	2,263	2,800	3,423	38,059	10.43	3.269
Marin	250,464	239,171	11,293	106,348	64,562	8,511	9,520	21,624	2,131	101,999	4.09	2.345
Mariposa	17,535	16,132	1,403	9,340	6,083	270	214	383	2,390	6,999	25.06	2.305
Mendocino	88,368	86,134	2,234	37,891	26,488	1,163	2,117	2,766	5,357	34,118	9.96	2.525
Merced	227,132	222,765	4,367	71,888	51,275	2,535	5,212	7,467	5,399	67,116	6.64	3.319
Modoc	9,491	9,082	409	4,886	3,318	87	97	159	1,225	3,844	21.33	2.363
Mono	13,212	12,914	298	12,346	4,716	1,259	2,019	3,380	972	5,380	56.42	2.400
Monterey	417,419	395,214	22,205	134,837	81,898	12,369	11,934	22,892	5,744	124,196	7.89	3.182
Napa	129,780	124,519	5,261	50,403	34,147	3,221	3,653	5,449	3,933	47,177	6.40	2.639
Nevada	96,107	95,168	939	46,484	38,130	871	1,674	2,188	3,621	38,637	16.88	2.463
Orange	2,980,809	2,937,132	43,677	994,025	504,921	125,386	90,011	241,237	32,470	958,859	3.54	3.063
Placer	284,057	280,984	3,073	122,954	94,256	4,137	5,902	13,954	4,705	108,749	11.55	2.584
Plumas	20,880	20,692	188	13,974	10,646	444	375	396	2,113	9,388	32.82	2.204
Riverside	1,723,976	1,688,012	35,964	634,197	399,671	42,366	30,634	78,484	83,042	549,979	13.28	3.069

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2003

COUNTY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Sacramento	1,317,992	1,292,598	25,394	502,159	318,072	32,268	36,365	99,874	15,580	480,503	4.31	2.690
San Benito	56,317	55,810	507	17,487	13,564	1,028	1,135	885	875	16,838	3.71	3.315
San Bernardino	1,839,885	1,792,908	46,977	621,964	433,083	27,363	39,247	80,185	42,086	548,492	11.81	3.269
San Diego	2,975,082	2,869,685	105,397	1,077,167	554,011	98,303	79,364	298,413	47,076	1,029,378	4.44	2.788
San Francisco	793,064	773,311	19,753	352,502	62,816	48,696	81,401	159,029	560	335,553	4.81	2.305
San Joaquin	616,477	598,102	18,375	201,375	141,040	11,223	13,381	26,379	9,352	193,423	3.95	3.092
San Luis Obispo	255,942	240,581	15,361	107,299	70,177	6,174	8,314	11,107	11,527	97,306	9.31	2.472
San Mateo	716,065	705,706	10,359	264,625	152,184	22,720	18,385	67,799	3,537	258,051	2.48	2.735
Santa Barbara	411,643	394,781	16,862	146,205	85,009	10,363	13,472	28,792	8,569	140,197	4.11	2.816
Santa Clara	1,727,157	1,696,900	30,257	595,879	329,191	53,057	46,758	147,215	19,658	582,319	2.28	2.914
Santa Cruz	258,426	248,749	9,677	100,198	63,789	8,761	8,405	11,991	7,252	92,419	7.76	2.692
Shasta	172,987	169,631	3,356	71,698	48,624	1,457	5,500	5,309	10,808	66,106	7.80	2.566
Sierra	3,582	3,546	36	2,236	1,844	49	47	63	233	1,544	30.95	2.297
Siskiyou	44,835	44,091	744	22,433	15,807	487	1,099	1,314	3,726	18,966	15.45	2.325
Solano	413,153	396,563	16,590	141,153	100,120	6,927	10,301	19,202	4,603	136,699	3.16	2.901
Sonoma	470,829	458,896	11,933	189,045	129,874	14,051	12,037	21,718	11,365	178,073	5.80	2.577
Stanislaus	483,705	476,243	7,462	159,724	117,321	7,141	10,766	15,527	8,969	153,742	3.75	3.098
Sutter	84,035	82,631	1,404	29,534	20,966	1,186	1,908	3,780	1,694	28,196	4.53	2.931
Tehama	57,835	56,821	1,014	24,282	14,623	486	1,224	1,663	6,286	21,664	10.78	2.623
Trinity	13,319	13,078	241	8,092	5,355	112	106	117	2,402	5,665	29.99	2.309
Tulare	388,608	382,564	6,044	124,177	92,066	4,744	8,614	7,881	10,872	114,640	7.68	3.337
Tuolumne	56,392	51,494	4,898	29,036	22,249	652	1,172	1,074	3,889	21,526	25.86	2.392
Ventura	792,361	779,648	12,713	261,899	168,682	27,434	16,520	37,032	12,231	253,226	3.31	3.079
Yolo	181,849	173,555	8,294	65,523	37,067	4,953	4,473	15,409	3,621	63,309	3.38	2.741
Yuba	63,730	62,361	1,369	23,061	14,361	1,289	1,608	2,250	3,553	20,907	9.34	2.983
California	35,652,700	34,809,466	843,234	12,598,945	7,159,531	937,811	1,034,653	2,892,107	574,843	11,867,069	5.81	2.933

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

	POPULATION			HOUSING UNITS	SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Alameda County												
Alameda	73,288	72,472	816	31,930	12,931	3,964	5,056	9,679	300	30,403	4.78	2.384
Albany	16,731	16,698	33	7,287	3,779	181	823	2,498	6	7,048	3.28	2.369
Berkeley	104,228	98,409	5,819	47,027	20,131	1,756	9,301	15,780	59	45,101	4.10	2.182
Dublin	36,194	30,971	5,223	12,016	7,081	1,304	412	3,192	27	11,568	3.73	2.677
Emeryville	7,514	7,447	67	4,615	270	329	484	3,495	37	4,292	7.00	1.735
Fremont	209,358	207,599	1,759	70,645	42,072	7,136	2,968	17,713	756	69,409	1.75	2.991
Hayward	144,248	142,097	2,151	46,757	23,237	3,396	3,383	14,442	2,299	45,619	2.43	3.115
Livermore	77,777	77,480	297	27,857	20,412	2,271	1,213	3,530	431	27,347	1.83	2.833
Newark	43,811	43,722	89	13,404	9,197	1,238	764	2,146	59	13,243	1.20	3.302
Oakland	409,621	402,364	7,257	159,614	71,940	6,645	28,984	51,589	456	152,806	4.27	2.633
Piedmont	11,091	11,089	2	3,861	3,784	0	35	34	8	3,806	1.42	2.914
Pleasanton	66,809	66,574	235	24,860	16,181	2,704	1,163	4,356	456	24,179	2.74	2.753
San Leandro	81,101	80,274	827	31,609	19,182	2,028	2,246	7,249	904	30,911	2.21	2.597
Union City	70,106	69,764	342	19,559	12,481	2,367	1,106	2,682	923	19,315	1.25	3.612
Balance Of County	138,596	135,920	2,676	50,031	34,098	3,469	3,334	8,201	929	48,961	2.14	2.776
Incorporated	1,351,877	1,326,960	24,917	501,041	262,678	35,319	57,938	138,385	6,721	485,047	3.19	2.736
County Total	1,490,473	1,462,880	27,593	551,072	296,776	38,788	61,272	146,586	7,650	534,008	3.10	2.739
Alpine County												
County Total	1,252	1,251	1	1,615	935	38	35	545	62	514	68.17	2.434
Amador County												
Amador	209	209	0	97	78	12	5	2	0	91	6.19	2.297
Ione	7,470	3,321	4,149	1,320	1,030	54	64	87	85	1,235	6.44	2.689
Jackson	4,086	3,818	268	1,902	1,168	112	148	247	227	1,787	6.05	2.137
Plymouth	1,079	1,079	0	502	281	23	24	26	148	430	14.34	2.509
Sutter Creek	2,454	2,453	1	1,175	772	105	55	162	81	1,088	7.40	2.255
Balance Of County	21,414	21,357	57	10,810	9,582	84	88	47	1,009	8,789	18.70	2.430
Incorporated	15,298	10,880	4,418	4,996	3,329	306	296	524	541	4,631	7.31	2.349
County Total	36,712	32,237	4,475	15,806	12,911	390	384	571	1,550	13,420	15.10	2.402
Butte County												
Biggs	1,807	1,807	0	619	511	28	28	5	47	577	6.79	3.132
Chico	68,547	64,571	3,976	27,734	13,427	959	4,198	8,020	1,130	26,699	3.73	2.418
Gridley	5,766	5,644	122	2,111	1,713	45	137	141	75	1,980	6.21	2.851
Oroville	13,263	12,431	832	5,540	2,917	162	765	1,308	388	4,990	9.93	2.491
Paradise	26,678	26,058	620	12,529	8,662	338	770	290	2,469	11,736	6.33	2.220
Balance Of County	94,174	93,517	657	40,041	27,030	855	1,783	139	10,234	36,541	8.74	2.559
Incorporated	116,061	110,511	5,550	48,533	27,230	1,532	5,898	9,764	4,109	45,982	5.26	2.403

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
County Total	210,235	204,028	6,207	88,574	54,260	2,387	7,681	9,903	14,343	82,523	6.83	2.472
Calaveras County												
Angels City	3,376	3,376	0	1,617	1,101	67	122	113	214	1,462	9.59	2.309
Balance Of County	39,425	38,996	429	22,877	19,629	398	381	242	2,227	16,138	29.46	2.416
Incorporated	3,376	3,376	0	1,617	1,101	67	122	113	214	1,462	9.59	2.309
County Total	42,801	42,372	429	24,494	20,730	465	503	355	2,441	17,600	28.15	2.408
Colusa County												
Colusa	5,607	5,534	73	2,031	1,523	84	189	183	52	1,912	5.86	2.894
Williams	4,050	3,800	250	1,043	757	33	95	91	67	995	4.60	3.819
Balance Of County	10,148	10,051	97	3,847	2,846	112	123	115	651	3,325	13.57	3.023
Incorporated	9,657	9,334	323	3,074	2,280	117	284	274	119	2,907	5.43	3.211
County Total	19,805	19,385	420	6,921	5,126	229	407	389	770	6,232	9.96	3.111
Contra Costa County												
Antioch	99,001	98,585	416	32,623	24,591	2,203	1,765	3,795	269	31,780	2.58	3.102
Brentwood	34,040	34,003	37	11,293	9,902	367	267	405	352	10,873	3.72	3.127
Clayton	10,947	10,921	26	3,953	3,221	681	19	27	5	3,912	1.04	2.792
Concord	124,383	122,961	1,422	45,581	27,265	2,851	2,871	11,217	1,377	44,507	2.36	2.763
Danville	43,088	42,624	464	15,480	11,961	2,558	279	682	0	15,159	2.07	2.812
El Cerrito	23,460	23,284	176	10,490	7,318	343	1,309	1,488	32	10,236	2.42	2.275
Hercules	20,429	20,390	39	6,795	4,280	1,617	294	604	0	6,667	1.88	3.058
Lafayette	24,329	24,193	136	9,406	7,464	294	425	1,223	0	9,222	1.96	2.623
Martinez	36,786	35,470	1,316	14,853	9,531	2,213	984	2,101	24	14,550	2.04	2.438
Moraga	16,469	14,838	1,631	5,773	4,010	968	243	545	7	5,675	1.70	2.615
Oakley	27,664	27,597	67	8,498	7,757	84	66	170	421	8,376	1.44	3.295
Orinda	17,777	17,710	67	6,746	6,245	188	87	219	7	6,598	2.19	2.684
Pinole	19,472	19,254	218	6,917	5,105	498	366	933	15	6,832	1.23	2.818
Pittsburg	60,888	60,382	506	19,447	12,887	1,296	1,330	3,264	670	18,854	3.05	3.203
Pleasant Hill	33,577	33,117	460	14,214	8,436	1,573	688	3,465	52	13,929	2.01	2.378
Richmond	101,089	99,461	1,628	36,375	20,751	2,929	5,275	7,299	121	34,943	3.94	2.846
San Pablo	30,712	30,247	465	9,404	4,139	774	1,301	2,383	807	9,113	3.09	3.319
San Ramon	46,920	46,835	85	18,236	11,221	2,076	1,039	3,889	11	17,604	3.47	2.660
Walnut Creek	65,803	64,839	964	31,857	12,178	4,791	4,316	10,524	48	30,717	3.58	2.111
Balance Of County	156,834	155,676	1,158	59,045	43,679	2,769	2,360	6,864	3,373	56,606	4.13	2.750
Incorporated	836,834	826,711	10,123	307,941	198,262	28,304	22,924	54,233	4,218	299,547	2.73	2.760
County Total	993,668	982,387	11,281	366,986	241,941	31,073	25,284	61,097	7,591	356,153	2.95	2.758

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Del Norte County												
Crescent City	7,365	3,827	3,538	1,760	861	50	393	424	32	1,583	10.06	2.418
Balance Of County	20,681	20,398	283	8,858	5,370	132	410	160	2,786	7,747	12.54	2.633
Incorporated	7,365	3,827	3,538	1,760	861	50	393	424	32	1,583	10.06	2.418
County Total	28,046	24,225	3,821	10,618	6,231	182	803	584	2,818	9,330	12.13	2.596
El Dorado County												
Placerville	10,272	10,010	262	4,508	2,744	256	620	728	160	4,252	5.68	2.354
South Lake Tahoe	23,977	23,849	128	14,116	8,864	363	1,981	2,240	668	9,485	32.81	2.514
Balance Of County	132,585	131,922	663	56,712	49,208	1,075	907	1,976	3,546	48,688	14.15	2.710
Incorporated	34,249	33,859	390	18,624	11,608	619	2,601	2,968	828	13,737	26.24	2.465
County Total	166,834	165,781	1,053	75,336	60,816	1,694	3,508	4,944	4,374	62,425	17.14	2.656
Fresno County												
Clovis	76,624	76,144	480	27,606	18,680	549	3,084	4,377	916	26,619	3.58	2.861
Coalinga	16,050	10,793	5,257	3,746	2,472	127	283	546	318	3,410	8.97	3.165
Firebaugh	6,207	6,146	61	1,670	1,094	156	193	141	86	1,498	10.30	4.103
Fowler	4,366	4,292	74	1,368	948	50	160	163	47	1,331	2.70	3.225
Fresno	451,071	442,342	8,729	153,428	90,699	6,028	16,406	36,372	3,923	144,218	6.00	3.067
Huron	6,938	6,766	172	1,523	493	204	231	525	70	1,485	2.50	4.556
Kerman	10,048	10,017	31	2,826	1,969	153	248	340	116	2,742	2.97	3.653
Kingsburg	10,582	10,491	91	3,784	2,836	102	243	439	164	3,637	3.88	2.885
Mendota	8,211	8,203	8	1,908	1,153	139	230	313	73	1,855	2.78	4.422
Orange Cove	8,791	8,791	0	1,964	1,187	206	224	321	26	1,883	4.12	4.669
Parlier	12,239	12,137	102	2,837	2,001	234	184	404	14	2,625	7.47	4.624
Reedley	21,459	21,064	395	6,032	4,180	216	594	851	191	5,819	3.53	3.620
Sanger	20,012	19,872	140	5,596	3,984	194	567	688	163	5,389	3.70	3.688
San Joaquin	3,513	3,513	0	771	453	80	115	63	60	737	4.41	4.767
Selma	21,026	20,896	130	6,142	4,487	148	333	752	422	5,911	3.76	3.535
Balance Of County	169,348	166,827	2,521	58,732	47,303	1,475	1,305	1,893	6,756	52,477	10.65	3.179
Incorporated	677,137	661,467	15,670	221,201	136,636	8,586	23,095	46,295	6,589	209,159	5.44	3.163
County Total	846,485	828,294	18,191	279,933	183,939	10,061	24,400	48,188	13,345	261,636	6.54	3.166
Glenn County												
Orland	6,454	6,430	24	2,330	1,736	44	318	197	35	2,211	5.11	2.908
Willows	6,352	6,171	181	2,376	1,552	54	305	458	7	2,142	9.85	2.881
Balance Of County	14,569	14,385	184	5,444	3,777	109	95	45	1,418	4,975	8.61	2.891
Incorporated	12,806	12,601	205	4,706	3,288	98	623	655	42	4,353	7.50	2.895

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	27,375	26,986	389	10,150	7,065	207	718	700	1,460	9,328	8.10	2.893
Humboldt County												
Arcata	17,048	15,356	1,692	7,342	3,378	269	1,169	1,843	683	7,118	3.05	2.157
Blue Lake	1,173	1,173	0	575	379	21	68	36	71	522	9.22	2.247
Eureka	26,291	24,922	1,369	11,714	7,249	381	2,209	1,701	174	11,029	5.85	2.260
Ferndale	1,403	1,403	0	673	544	27	83	10	9	621	7.73	2.259
Fortuna	10,969	10,734	235	4,619	3,077	229	520	351	442	4,379	5.20	2.451
Rio Dell	3,203	3,193	10	1,448	1,005	26	150	36	231	1,233	14.85	2.590
Trinidad	314	314	0	230	181	7	11	0	31	170	26.09	1.847
Balance Of County	68,934	67,909	1,025	30,498	23,322	602	1,488	706	4,380	27,246	10.66	2.492
Incorporated	60,401	57,095	3,306	26,601	15,813	960	4,210	3,977	1,641	25,072	5.75	2.277
County Total	129,335	125,004	4,331	57,099	39,135	1,562	5,698	4,683	6,021	52,318	8.37	2.389
Imperial County												
Brawley	22,731	22,419	312	7,143	4,581	362	639	1,105	456	6,730	5.78	3.331
Calexico	32,014	31,911	103	8,121	5,396	439	898	1,183	205	7,925	2.41	4.027
Calipatria	7,651	3,556	4,095	1,053	720	38	75	158	62	985	6.46	3.610
El Centro	39,359	38,472	887	12,564	6,615	563	1,087	2,981	1,318	11,724	6.69	3.281
Holtville	5,710	5,580	130	1,620	1,037	111	117	162	193	1,567	3.27	3.561
Imperial	8,524	8,492	32	2,648	2,132	91	227	164	34	2,563	3.21	3.313
Westmorland	2,201	2,201	0	678	431	16	90	102	39	636	6.19	3.461
Balance Of County	33,625	28,038	5,587	12,117	5,802	273	419	209	5,414	9,220	23.91	3.041
Incorporated	118,190	112,631	5,559	33,827	20,912	1,620	3,133	5,855	2,307	32,130	5.02	3.505
County Total	151,815	140,669	11,146	45,944	26,714	1,893	3,552	6,064	7,721	41,350	10.00	3.402
Inyo County												
Bishop	3,632	3,555	77	1,875	845	78	262	323	367	1,692	9.76	2.101
Balance Of County	14,799	14,591	208	7,239	4,644	134	145	145	2,171	6,073	16.11	2.403
Incorporated	3,632	3,555	77	1,875	845	78	262	323	367	1,692	9.76	2.101
County Total	18,431	18,146	285	9,114	5,489	212	407	468	2,538	7,765	14.80	2.337
Kern County												
Arvin	14,141	14,070	71	3,362	2,302	218	264	322	256	3,218	4.28	4.372
Bakersfield	268,728	265,062	3,666	94,175	63,058	3,223	10,122	15,198	2,574	89,036	5.46	2.977
California City	11,165	8,551	2,614	3,579	2,675	68	310	226	300	3,084	13.83	2.773
Delano	42,294	36,627	5,667	9,375	6,590	547	597	1,192	449	8,928	4.77	4.102
Maricopa	1,135	1,135	0	460	247	7	5	9	192	404	12.17	2.809
Mcfarland	10,706	9,423	1,283	2,191	1,697	153	252	60	29	2,147	2.01	4.389

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Ridgecrest	26,834	26,548	286	11,342	7,473	412	1,697	765	995	10,355	8.70	2.564
Shafter	13,435	12,764	671	3,746	2,887	177	234	237	211	3,404	9.13	3.750
Taft	9,023	6,053	2,970	2,514	1,829	52	315	222	96	2,266	9.86	2.671
Tehachapi	11,440	6,822	4,618	2,967	1,867	150	385	281	284	2,580	13.04	2.644
Wasco	22,388	16,234	6,154	4,496	3,306	326	415	318	131	4,196	6.67	3.869
Balance Of County	277,464	273,181	4,283	104,024	71,583	3,248	5,968	4,894	18,331	89,339	14.12	3.058
Incorporated	431,289	403,289	28,000	138,207	93,931	5,333	14,596	18,830	5,517	129,618	6.21	3.111
County Total	708,753	676,470	32,283	242,231	165,514	8,581	20,564	23,724	23,848	218,957	9.61	3.090
Kings County												
Avenal	15,373	8,214	7,159	2,098	1,398	81	303	224	92	1,963	6.43	4.184
Corcoran	21,186	9,747	11,439	3,049	2,173	180	270	303	123	2,799	8.20	3.482
Hanford	44,536	43,688	848	15,561	11,234	552	1,393	2,041	341	14,726	5.37	2.967
Lemoore	21,093	21,091	2	7,214	4,731	152	459	1,543	329	6,820	5.46	3.093
Balance Of County	35,223	33,488	1,735	10,096	7,030	1,392	303	115	1,256	9,504	5.86	3.524
Incorporated	102,188	82,740	19,448	27,922	19,536	965	2,425	4,111	885	26,308	5.78	3.145
County Total	137,411	116,228	21,183	38,018	26,566	2,357	2,728	4,226	2,141	35,812	5.80	3.246
Lake County												
Clearlake	13,569	13,450	119	7,568	3,606	99	247	246	3,370	5,506	27.25	2.443
Lakeport	5,022	4,848	174	2,407	1,451	119	158	223	456	1,978	17.82	2.451
Balance Of County	42,874	41,967	907	23,040	15,499	315	497	361	6,368	16,849	26.87	2.491
Incorporated	18,591	18,298	293	9,975	5,057	218	405	469	3,826	7,484	24.97	2.445
County Total	61,465	60,265	1,200	33,015	20,556	533	902	830	10,194	24,333	26.30	2.477
Lassen County												
Susanville	17,506	8,756	8,750	3,978	2,810	131	377	450	210	3,604	9.40	2.430
Balance Of County	16,570	16,405	165	8,321	5,663	165	138	59	2,296	6,331	23.92	2.591
Incorporated	17,506	8,756	8,750	3,978	2,810	131	377	450	210	3,604	9.40	2.430
County Total	34,076	25,161	8,915	12,299	8,473	296	515	509	2,506	9,935	19.22	2.533
Los Angeles County												
Agoura Hills	21,894	21,871	23	7,203	5,270	979	176	778	0	7,081	1.69	3.089
Alhambra	88,746	86,823	1,923	30,062	12,749	3,265	3,963	10,068	17	29,103	3.19	2.983
Arcadia	55,441	54,860	581	20,171	11,911	1,698	1,379	5,157	26	19,341	4.11	2.836
Artesia	16,980	16,408	572	4,611	3,192	327	323	673	96	4,483	2.78	3.660
Avalon	3,471	3,409	62	1,926	502	487	545	383	9	1,229	36.19	2.774

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Azusa	47,089	45,140	1,949	13,271	5,991	1,766	1,465	3,460	589	12,798	3.56	3.527
Baldwin Park	79,444	78,838	606	17,647	11,886	1,861	604	2,953	343	17,172	2.69	4.591
Bell	38,170	37,632	538	9,274	3,553	1,517	1,453	2,291	460	8,975	3.22	4.193
Bellflower	76,304	75,681	623	24,536	11,332	2,085	1,433	8,084	1,602	23,646	3.63	3.201
Bell Gardens	45,694	45,238	456	9,812	3,970	2,469	1,451	1,526	396	9,489	3.29	4.767
Beverly Hills	35,293	35,254	39	16,003	5,707	236	1,805	8,227	28	15,174	5.18	2.323
Bradbury	919	919	0	323	321	0	2	0	0	294	8.98	3.126
Burbank	104,326	103,500	826	43,064	19,930	1,728	4,680	16,614	112	41,819	2.89	2.475
Calabasas	22,555	22,495	60	8,273	5,678	804	204	1,334	253	8,005	3.24	2.810
Carson	94,673	93,382	1,291	25,823	18,085	2,280	716	2,237	2,505	25,121	2.72	3.717
Cerritos	54,139	54,046	93	15,856	13,363	1,220	600	641	32	15,636	1.39	3.457
Claremont	36,047	30,673	5,374	11,855	8,255	843	635	2,109	13	11,570	2.40	2.651
Commerce	13,154	13,051	103	3,416	1,943	588	330	551	4	3,323	2.72	3.927
Compton	96,838	96,188	650	23,817	15,858	2,140	2,266	2,915	638	22,348	6.17	4.304
Covina	48,641	48,039	602	16,427	9,396	1,297	977	4,169	588	16,032	2.40	2.996
Cudahy	25,414	25,402	12	5,621	1,679	1,291	344	1,893	414	5,497	2.21	4.621
Culver City	40,191	39,667	524	17,144	6,619	1,903	2,301	6,140	181	16,625	3.03	2.386
Diamond Bar	58,866	58,748	118	18,147	12,794	2,501	823	1,696	333	17,836	1.71	3.294
Downey	111,505	109,740	1,765	34,912	20,442	1,662	1,644	10,971	193	34,139	2.21	3.215
Duarte	22,343	21,853	490	6,843	4,317	876	224	1,197	229	6,672	2.50	3.275
El Monte	121,724	120,454	1,270	28,164	15,043	3,396	2,021	6,298	1,406	27,429	2.61	4.391
El Segundo	16,670	16,647	23	7,294	3,116	416	817	2,934	11	7,093	2.76	2.347
Gardena	60,370	59,566	804	21,265	9,127	1,711	2,688	6,636	1,103	20,540	3.41	2.900
Glendale	202,420	199,556	2,864	73,976	26,093	3,814	6,911	37,061	97	72,061	2.59	2.769
Glendora	51,388	50,381	1,007	17,239	12,538	1,094	695	2,029	883	16,911	1.90	2.979
Hawaiian Gardens	15,549	15,545	4	3,684	1,519	490	450	950	275	3,565	3.23	4.360
Hawthorne	87,281	86,781	500	29,710	8,236	2,429	3,323	15,549	173	28,615	3.69	3.033
Hermosa Beach	19,333	19,220	113	9,902	4,153	986	2,122	2,559	82	9,535	3.71	2.016
Hidden Hills	1,996	1,996	0	609	607	2	0	0	0	585	3.94	3.412
Huntington Park	63,865	63,684	181	15,425	5,276	2,370	2,209	5,556	14	14,947	3.10	4.261
Industry	795	531	264	124	101	23	0	0	0	121	2.42	4.388
Inglewood	116,789	115,419	1,370	38,752	13,955	3,224	4,753	16,582	238	36,903	4.77	3.128
Irwindale	1,488	1,486	2	376	316	15	13	24	8	363	3.46	4.094
La Canada Flintridge	21,178	20,989	189	7,041	6,534	200	132	175	0	6,874	2.37	3.053
La Habra Heights	6,060	6,060	0	2,000	1,968	24	8	0	0	1,934	3.30	3.133
Lakewood	82,199	82,005	194	27,336	22,216	741	715	3,566	98	26,879	1.67	3.051
La Mirada	48,843	47,204	1,639	14,962	11,779	800	480	1,737	166	14,729	1.56	3.205
Lancaster	125,857	118,906	6,951	42,931	27,978	1,200	2,670	7,585	3,498	39,310	8.43	3.025
La Puente	42,571	42,539	32	9,676	6,339	642	340	2,246	109	9,477	2.06	4.489
La Verne	32,870	32,162	708	11,338	7,535	599	734	707	1,763	11,122	1.91	2.892
Lawndale	32,796	32,710	86	9,862	4,918	1,606	905	2,305	128	9,548	3.18	3.426
Lomita	20,802	20,669	133	8,318	4,026	766	581	2,447	498	8,037	3.38	2.572
Long Beach	480,200	469,807	10,393	172,601	69,222	10,091	23,274	67,485	2,529	164,009	4.98	2.865
Los Angeles	3,856,688	3,773,520	83,168	1,349,910	528,163	87,965	129,257	595,439	9,086	1,287,189	4.65	2.932
Lynwood	72,489	70,289	2,200	15,045	8,206	1,677	1,713	3,337	112	14,450	3.95	4.864
Malibu	13,295	12,995	300	6,266	3,937	475	404	840	610	5,254	16.15	2.473
Manhattan Beach	36,212	36,198	14	15,544	10,623	1,342	2,659	887	33	14,966	3.72	2.419
Maywood	29,129	29,035	94	6,716	2,814	1,110	1,445	1,339	8	6,484	3.45	4.478
Monrovia	38,387	38,094	293	14,021	7,717	1,549	1,324	3,316	115	13,564	3.26	2.808

California Department of Finance
Demographic Research Unit

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COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Montebello	64,590	64,281	309	19,498	9,357	1,580	2,863	5,465	233	18,924	2.94	3.397
Monterey Park	63,301	63,024	277	20,586	11,628	2,205	2,026	4,647	80	19,929	3.19	3.162
Norwalk	108,525	106,412	2,113	27,786	20,187	1,412	829	4,900	458	27,114	2.42	3.925
Palmdale	127,017	126,923	94	39,020	29,978	905	940	5,415	1,782	36,063	7.58	3.519
Palos Verdes Estates	13,905	13,900	5	5,239	4,817	40	44	338	0	5,029	4.01	2.764
Paramount	57,220	56,900	320	14,598	6,049	2,167	1,088	3,922	1,372	13,979	4.24	4.070
Pasadena	141,974	138,456	3,518	55,521	24,840	4,171	4,650	21,787	73	53,174	4.23	2.604
Pico Rivera	66,079	65,729	350	16,920	12,677	934	337	2,382	590	16,578	2.02	3.965
Pomona	156,255	150,940	5,315	39,980	24,316	3,339	3,233	7,387	1,705	38,220	4.40	3.949
Rancho Palos Verdes	42,740	42,231	509	15,772	12,189	1,287	245	2,051	0	15,318	2.88	2.757
Redondo Beach	66,436	66,249	187	29,979	11,857	4,238	4,063	9,441	380	28,987	3.31	2.285
Rolling Hills	1,933	1,933	0	681	674	7	0	0	0	644	5.43	3.002
Rolling Hills Estates	8,037	8,025	12	2,914	2,297	565	41	7	4	2,840	2.54	2.826
Rosemead	56,143	55,531	612	14,550	9,850	2,030	911	1,355	404	14,112	3.01	3.935
San Dimas	36,376	35,167	1,209	12,579	7,557	2,100	361	1,618	943	12,237	2.72	2.874
San Fernando	24,467	24,421	46	5,951	4,006	634	476	762	73	5,793	2.66	4.216
San Gabriel	41,500	40,745	755	13,013	7,060	1,156	1,081	3,672	44	12,688	2.50	3.211
San Marino	13,413	13,406	7	4,442	4,406	19	8	9	0	4,271	3.85	3.139
Santa Clarita	162,655	161,262	1,393	54,579	32,857	6,314	2,622	10,546	2,240	52,853	3.16	3.051
Santa Fe Springs	17,079	16,861	218	4,961	3,099	286	158	1,291	127	4,861	2.02	3.469
Santa Monica	89,190	86,674	2,516	49,136	9,361	1,928	5,579	31,979	289	45,680	7.03	1.897
Sierra Madre	10,956	10,829	127	4,928	3,405	205	377	914	27	4,761	3.39	2.275
Signal Hill	10,267	10,213	54	4,038	1,214	461	680	1,675	8	3,852	4.61	2.651
South El Monte	21,922	21,904	18	4,732	2,942	458	233	595	504	4,628	2.20	4.733
South Gate	100,132	99,991	141	24,362	12,353	3,262	3,695	4,774	278	23,302	4.35	4.291
South Pasadena	25,233	25,046	187	10,895	5,071	624	1,108	4,078	14	10,521	3.43	2.381
Temple City	34,643	34,132	511	11,713	9,449	802	421	983	58	11,376	2.88	3.000
Torrance	144,179	142,930	1,249	56,536	30,375	3,693	3,296	17,989	1,183	55,096	2.55	2.594
Vernon	94	94	0	26	19	0	0	7	0	25	3.85	3.760
Walnut	31,369	31,329	40	8,480	8,123	119	46	192	0	8,344	1.60	3.755
West Covina	110,335	109,527	808	32,533	21,164	2,812	1,570	6,639	348	31,876	2.02	3.436
West Hollywood	37,230	36,994	236	24,282	1,808	681	1,840	19,953	0	23,288	4.09	1.589
Westlake Village	8,749	8,740	9	3,381	2,239	608	158	201	175	3,303	2.31	2.646
Whittier	86,269	84,244	2,025	28,993	19,069	1,480	2,056	6,174	214	28,286	2.44	2.978
Balance Of County	1,043,813	1,026,765	17,048	300,173	206,586	22,882	18,044	41,750	10,911	286,334	4.61	3.586
Incorporated	8,917,594	8,758,348	159,246	3,008,728	1,405,091	219,102	270,021	1,068,804	45,710	2,883,854	4.15	3.037
County Total	9,961,407	9,785,113	176,294	3,308,901	1,611,677	241,984	288,065	1,110,554	56,621	3,170,188	4.19	3.087
Madera County												
Chowchilla	14,394	8,209	6,185	2,874	2,251	31	252	304	36	2,716	5.50	3.022
Madera	47,239	46,801	438	13,342	8,810	742	1,410	2,079	301	12,764	4.33	3.667
Balance Of County	70,188	69,402	786	26,277	21,610	563	601	417	3,086	22,579	14.07	3.074
Incorporated	61,633	55,010	6,623	16,216	11,061	773	1,662	2,383	337	15,480	4.54	3.554
County Total	131,821	124,412	7,409	42,493	32,671	1,336	2,263	2,800	3,423	38,059	10.43	3.269

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Marin County												
Belvedere	2,138	2,138	0	1,065	874	54	94	43	0	962	9.67	2.222
Corte Madera	9,392	9,384	8	3,972	2,616	416	369	561	10	3,896	1.91	2.409
Fairfax	7,326	7,296	30	3,420	2,331	193	492	393	11	3,308	3.27	2.206
Larkspur	12,033	11,878	155	6,420	2,444	360	544	2,833	239	6,149	4.22	1.932
Mill Valley	13,659	13,568	91	6,310	4,112	536	535	1,127	0	6,171	2.20	2.199
Novato	48,769	47,787	982	19,449	11,397	2,607	1,162	3,565	718	18,967	2.48	2.519
Ross	2,351	2,257	94	813	793	0	12	0	8	769	5.41	2.935
San Anselmo	12,379	12,123	256	5,406	3,988	185	458	757	18	5,265	2.61	2.303
San Rafael	57,146	55,126	2,020	23,396	10,598	2,020	2,468	7,821	489	22,808	2.51	2.417
Sausalito	7,360	7,348	12	4,527	1,722	423	1,353	805	224	4,270	5.68	1.721
Tiburon	8,792	8,686	106	3,949	2,411	237	464	837	0	3,765	4.66	2.307
Balance Of County	69,119	61,580	7,539	27,621	21,276	1,480	1,569	2,882	414	25,669	7.07	2.399
Incorporated	181,345	177,591	3,754	78,727	43,286	7,031	7,951	18,742	1,717	76,330	3.04	2.327
County Total	250,464	239,171	11,293	106,348	64,562	8,511	9,520	21,624	2,131	101,999	4.09	2.345
Mariposa County												
County Total	17,535	16,132	1,403	9,340	6,083	270	214	383	2,390	6,999	25.06	2.305
Mendocino County												
Fort Bragg	6,890	6,764	126	3,091	2,010	158	312	459	152	2,877	6.92	2.351
Point Arena	479	479	0	221	137	7	45	13	19	194	12.22	2.469
Ukiah	15,891	15,157	734	6,312	3,484	379	762	1,225	462	6,155	2.49	2.463
Willits	5,036	4,910	126	2,001	1,189	84	293	291	144	1,924	3.85	2.552
Balance Of County	60,072	58,824	1,248	26,266	19,668	535	705	778	4,580	22,968	12.56	2.561
Incorporated	28,296	27,310	986	11,625	6,820	628	1,412	1,988	777	11,150	4.09	2.449
County Total	88,368	86,134	2,234	37,891	26,488	1,163	2,117	2,766	5,357	34,118	9.96	2.525
Merced County												
Atwater	26,235	24,458	1,777	8,516	5,601	584	834	990	507	7,606	10.69	3.216
Dos Palos	4,628	4,604	24	1,487	1,272	55	44	78	38	1,418	4.64	3.247
Gustine	5,175	5,175	0	1,904	1,543	30	98	105	128	1,818	4.52	2.847
Livingston	11,134	11,097	37	2,553	1,926	80	206	305	36	2,491	2.43	4.455
Los Banos	29,401	29,226	175	8,976	7,245	263	534	658	276	8,610	4.08	3.394
Merced	68,208	66,838	1,370	22,568	13,505	942	2,710	4,703	708	21,419	5.09	3.121
Balance Of County	82,351	81,367	984	25,884	20,183	581	786	628	3,706	23,754	8.23	3.425
Incorporated	144,781	141,398	3,383	46,004	31,092	1,954	4,426	6,839	1,693	43,362	5.74	3.261
	227,132	222,765	4,367	71,888	51,275	2,535	5,212	7,467	5,399	67,116		
County Total	227,132	222,765	4,367	71,888	51,275	2,535	5,212	7,467	5,399	67,116	6.64	3.319

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Modoc County												
Alturas	2,860	2,780	80	1,366	1,020	54	47	144	101	1,180	13.62	2.356
Balance Of County	6,631	6,302	329	3,520	2,298	33	50	15	1,124	2,664	24.32	2.366
Incorporated	2,860	2,780	80	1,366	1,020	54	47	144	101	1,180	13.62	2.356
County Total	9,491	9,082	409	4,886	3,318	87	97	159	1,225	3,844	21.33	2.363
Mono County												
Mammoth Lakes	7,391	7,173	218	8,418	2,204	1,003	1,712	3,306	193	2,975	64.66	2.411
Balance Of County	5,821	5,741	80	3,928	2,512	256	307	74	779	2,405	38.77	2.387
Incorporated	7,391	7,173	218	8,418	2,204	1,003	1,712	3,306	193	2,975	64.66	2.411
County Total	13,212	12,914	298	12,346	4,716	1,259	2,019	3,380	972	5,380	56.42	2.400
Monterey County												
Carmel-By-The-Sea	4,135	4,135	0	3,345	2,750	111	214	270	0	2,293	31.45	1.803
Del Rey Oaks	1,667	1,667	0	727	567	25	23	109	3	704	3.16	2.368
Gonzales	8,409	8,336	73	1,899	1,391	128	169	169	42	1,867	1.69	4.465
Greenfield	13,144	13,048	96	2,805	1,917	282	274	247	85	2,720	3.03	4.797
King City	11,498	11,314	184	2,868	1,598	278	288	415	289	2,780	3.07	4.070
Marina	19,178	19,047	131	8,564	3,409	1,537	1,455	1,743	420	6,766	20.99	2.815
Monterey	30,452	27,271	3,181	13,483	5,912	913	2,260	4,377	21	12,714	5.70	2.145
Pacific Grove	15,700	15,525	175	8,043	5,013	448	981	1,510	91	7,326	8.91	2.119
Salinas	148,117	145,665	2,452	40,772	21,739	3,463	3,456	10,828	1,286	39,372	3.43	3.700
Sand City	285	221	64	96	55	5	22	9	5	89	7.29	2.483
Seaside	33,896	31,494	2,402	10,911	6,009	2,279	927	1,264	432	9,648	11.58	3.264
Soledad	24,711	12,918	11,793	2,890	2,035	205	317	210	123	2,819	2.46	4.582
Balance Of County	106,227	104,573	1,654	38,434	29,503	2,695	1,548	1,741	2,947	35,098	8.68	2.979
Incorporated	311,192	290,641	20,551	96,403	52,395	9,674	10,386	21,151	2,797	89,098	7.58	3.262
County Total	417,419	395,214	22,205	134,837	81,898	12,369	11,934	22,892	5,744	124,196	7.89	3.182
Napa County												
American Canyon	12,330	12,196	134	4,125	3,190	23	70	61	781	4,043	1.99	3.017
Calistoga	5,236	5,169	67	2,260	1,054	97	186	361	562	2,053	9.16	2.518
Napa	74,718	73,259	1,459	28,489	17,762	2,064	2,783	4,491	1,389	27,671	2.87	2.648
St Helena	6,040	5,988	52	2,737	1,669	215	214	478	161	2,407	12.06	2.488
Yountville	3,280	2,102	1,178	1,163	609	172	39	35	308	1,071	7.91	1.963
Balance Of County	28,176	25,805	2,371	11,629	9,863	650	361	23	732	9,932	14.59	2.598
Incorporated	101,604	98,714	2,890	38,774	24,284	2,571	3,292	5,426	3,201	37,245	3.94	2.650

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
County Total	129,780	124,519	5,261	50,403	34,147	3,221	3,653	5,449	3,933	47,177	6.40	2.639
Nevada County												
Grass Valley	12,042	11,692	350	5,790	2,660	256	743	1,439	692	5,515	4.75	2.120
Nevada City	3,036	2,849	187	1,438	1,116	53	117	78	74	1,334	7.23	2.136
Truckee	14,883	14,842	41	10,503	8,914	242	571	478	298	5,542	47.23	2.678
Balance Of County	66,146	65,785	361	28,753	25,440	320	243	193	2,557	26,246	8.72	2.506
Incorporated	29,961	29,383	578	17,731	12,690	551	1,431	1,995	1,064	12,391	30.12	2.371
County Total	96,107	95,168	939	46,484	38,130	871	1,674	2,188	3,621	38,637	16.88	2.463
Orange County												
Aliso Viejo	43,787	43,627	160	17,676	6,411	4,935	739	5,576	15	17,186	2.77	2.539
Anaheim	337,404	333,608	3,796	100,216	43,177	8,923	10,405	33,327	4,384	97,453	2.76	3.423
Brea	37,925	37,797	128	13,965	7,996	1,077	526	3,496	870	13,694	1.94	2.760
Buena Park	80,333	79,399	934	23,850	14,040	1,900	1,420	6,199	291	23,355	2.08	3.400
Costa Mesa	111,568	108,358	3,210	40,551	15,485	4,127	5,855	13,871	1,213	39,347	2.97	2.754
Cypress	47,943	47,622	321	16,271	10,060	2,485	520	2,842	364	15,892	2.33	2.997
Dana Point	36,265	36,023	242	15,824	7,788	2,266	2,794	2,607	369	14,588	7.81	2.469
Fountain Valley	56,297	55,785	512	18,479	12,367	2,194	644	2,876	398	18,168	1.68	3.071
Fullerton	131,537	128,331	3,206	45,537	23,055	3,728	3,643	14,190	921	44,355	2.60	2.893
Garden Grove	169,995	167,761	2,234	46,958	26,654	4,486	3,410	10,591	1,817	46,041	1.95	3.644
Huntington Beach	197,087	196,295	792	76,835	38,052	9,457	9,694	16,491	3,141	74,799	2.65	2.624
Irvine	165,002	157,129	7,873	60,627	24,161	13,398	4,384	17,662	1,022	57,791	4.68	2.719
Laguna Beach	24,586	24,464	122	13,124	8,190	759	1,760	2,091	324	11,652	11.22	2.100
Laguna Hills	32,847	32,423	424	11,095	5,820	2,183	608	2,267	217	10,750	3.11	3.016
Laguna Niguel	65,124	64,821	303	24,553	13,479	5,007	1,441	4,610	16	23,866	2.80	2.716
Laguna Woods	18,216	18,142	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.441
La Habra	61,217	60,622	595	19,718	10,460	1,659	1,352	5,508	739	19,216	2.55	3.155
Lake Forest	77,371	76,527	844	26,385	14,166	3,923	1,276	5,734	1,286	25,712	2.55	2.976
La Palma	15,962	15,931	31	5,126	3,632	376	102	989	27	5,038	1.72	3.162
Los Alamitos	11,823	11,417	406	4,337	1,918	243	1,033	1,014	129	4,254	1.91	2.684
Mission Viejo	97,381	96,316	1,065	33,714	24,475	4,021	1,201	3,928	89	33,166	1.63	2.904
Newport Beach	81,361	80,421	940	41,590	18,540	7,156	5,459	9,572	863	37,052	10.91	2.170
Orange	134,636	129,304	5,332	42,855	24,266	5,149	4,697	7,404	1,339	41,860	2.32	3.089
Placentia	49,120	48,817	303	15,822	9,450	2,050	1,104	2,641	577	15,524	1.88	3.145
Rancho Santa Margarita	48,835	48,821	14	16,684	9,118	3,889	598	3,079	0	16,419	1.59	2.973
San Clemente	60,731	60,439	292	24,558	13,809	2,414	3,998	3,934	403	23,061	6.10	2.621
San Juan Capistrano	35,232	34,806	426	11,522	5,926	2,395	944	781	1,476	11,125	3.45	3.129
Santa Ana	347,378	341,731	5,647	74,913	33,538	6,427	7,520	23,519	3,909	73,319	2.13	4.661
Seal Beach	25,106	24,820	286	14,370	4,642	2,121	1,169	6,275	163	13,233	7.91	1.876
Stanton	38,431	37,913	518	11,054	2,977	1,873	988	3,954	1,262	10,809	2.22	3.508
Tustin	69,790	69,372	418	25,745	8,290	3,488	3,836	9,223	908	24,068	6.51	2.882
Villa Park	6,161	6,140	21	2,014	1,985	18	0	6	5	1,956	2.88	3.139
Westminster	90,689	90,137	552	27,057	14,849	2,445	2,077	4,618	3,068	26,521	1.98	3.399

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Yorba Linda	62,711	62,576	135	20,344	16,146	2,081	534	1,272	311	20,016	1.61	3.126
Balance Of County	110,958	109,437	1,521	37,027	29,272	2,721	1,806	2,700	528	34,982	5.52	3.128
Incorporated	2,869,851	2,827,695	42,156	956,998	475,649	122,665	88,205	238,537	31,942	923,877	3.46	3.061
County Total	2,980,809	2,937,132	43,677	994,025	504,921	125,386	90,011	241,237	32,470	958,859	3.54	3.063
Placer County												
Auburn	12,611	12,405	206	5,592	3,781	211	655	945	0	5,433	2.84	2.283
Colfax	1,790	1,789	1	771	496	15	164	63	33	745	3.37	2.401
Lincoln	19,977	19,863	114	8,189	7,008	196	176	713	96	7,828	4.41	2.537
Loomis	6,355	6,321	34	2,336	1,959	199	58	9	111	2,268	2.91	2.787
Rocklin	46,085	46,001	84	17,700	12,962	518	709	3,072	439	17,041	3.72	2.699
Roseville	93,540	92,486	1,054	37,844	27,771	1,082	1,627	6,821	543	36,490	3.58	2.535
Balance Of County	103,699	102,119	1,580	50,522	40,279	1,916	2,513	2,331	3,483	38,944	22.92	2.622
Incorporated	180,358	178,865	1,493	72,432	53,977	2,221	3,389	11,623	1,222	69,805	3.63	2.562
County Total	284,057	280,984	3,073	122,954	94,256	4,137	5,902	13,954	4,705	108,749	11.55	2.584
Plumas County												
Portola	2,170	2,149	21	1,021	773	11	72	110	55	911	10.77	2.359
Balance Of County	18,710	18,543	167	12,953	9,873	433	303	286	2,058	8,477	34.56	2.187
Incorporated	2,170	2,149	21	1,021	773	11	72	110	55	911	10.77	2.359
County Total	20,880	20,692	188	13,974	10,646	444	375	396	2,113	9,388	32.82	2.204
Riverside County												
Banning	25,637	25,299	338	10,404	7,499	728	426	595	1,156	9,531	8.39	2.654
Beaumont	13,930	13,775	155	5,083	3,518	172	340	706	347	4,633	8.85	2.973
Blythe	21,350	12,928	8,422	5,148	2,878	151	502	801	816	4,319	16.10	2.993
Calimesa	7,412	7,316	96	3,283	1,796	111	57	64	1,255	3,015	8.16	2.427
Canyon Lake	10,625	10,609	16	4,205	3,896	78	6	84	141	3,786	9.96	2.802
Cathedral City	47,799	47,615	184	19,507	10,235	2,587	2,337	1,644	2,704	15,292	21.61	3.114
Coachella	27,061	27,017	44	5,824	3,347	319	700	1,003	455	5,572	4.33	4.849
Corona	138,478	137,846	632	42,369	29,089	2,186	2,225	7,587	1,282	40,824	3.65	3.377
Desert Hot Springs	17,364	17,190	174	7,171	3,906	180	1,193	1,313	579	5,973	16.71	2.878
Hemet	64,001	62,322	1,679	30,646	13,024	1,748	2,133	4,497	9,244	26,805	12.53	2.325
Indian Wells	4,443	4,443	0	4,354	2,881	884	112	469	8	2,246	48.42	1.978
Indio	55,030	54,174	856	18,471	9,224	878	1,419	3,780	3,170	15,152	17.97	3.575
Lake Elsinore	33,391	33,318	73	10,681	7,379	707	735	1,099	761	9,908	7.24	3.363
La Quinta	30,781	30,741	40	14,938	12,368	1,358	268	685	259	10,680	28.50	2.878
Moreno Valley	151,539	150,842	697	43,002	36,139	891	1,389	3,540	1,043	40,721	5.30	3.704
Murrieta	68,396	67,736	660	23,088	17,656	211	463	3,084	1,674	22,020	4.63	3.076
Norco	25,466	20,812	4,654	6,577	6,163	137	9	177	91	6,429	2.25	3.237

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Palm Desert	44,388	44,161	227	29,422	11,973	9,534	2,462	4,255	1,198	20,144	31.53	2.192
Palm Springs	44,462	43,766	696	31,174	10,446	6,160	2,506	9,827	2,235	20,750	33.44	2.109
Perris	38,610	38,378	232	10,961	7,302	321	371	1,264	1,703	10,025	8.54	3.828
Rancho Mirage	15,122	14,685	437	12,878	5,403	3,680	615	1,196	1,984	7,425	42.34	1.978
Riverside	276,910	267,594	9,316	90,511	57,323	4,185	5,824	20,770	2,409	86,332	4.62	3.100
San Jacinto	26,321	26,131	190	10,215	5,782	596	651	567	2,619	8,963	12.26	2.915
Temecula	75,821	75,799	22	24,215	19,048	386	598	3,862	321	23,199	4.20	3.267
Balance Of County	459,639	453,515	6,124	170,070	111,396	4,178	3,293	5,615	45,588	146,235	14.01	3.101
Incorporated	1,264,337	1,234,497	29,840	464,127	288,275	38,188	27,341	72,869	37,454	403,744	13.01	3.058
County Total	1,723,976	1,688,012	35,964	634,197	399,671	42,366	30,634	78,484	83,042	549,979	13.28	3.069
Sacramento County												
Citrus Heights	87,729	86,852	877	35,363	19,577	3,531	3,021	7,355	1,879	33,926	4.06	2.560
Elk Grove	86,348	85,773	575	28,323	25,462	919	525	1,144	273	27,692	2.23	3.097
Folsom	64,143	57,609	6,534	22,632	15,636	635	627	4,864	870	21,660	4.29	2.660
Galt	21,997	21,809	188	6,902	5,505	203	340	482	372	6,639	3.81	3.285
Isleton	843	843	0	384	222	2	77	36	47	343	10.68	2.458
Sacramento	435,231	425,994	9,237	172,487	102,026	11,366	15,914	39,503	3,678	162,723	5.66	2.618
Balance Of County	621,701	613,718	7,983	236,068	149,644	15,612	15,861	46,490	8,461	227,520	3.62	2.697
Incorporated	696,291	678,880	17,411	266,091	168,428	16,656	20,504	53,384	7,119	252,983	4.93	2.684
County Total	1,317,992	1,292,598	25,394	502,159	318,072	32,268	36,365	99,874	15,580	480,503	4.31	2.690
San Benito County												
Hollister	36,614	36,443	171	10,585	7,975	531	992	781	306	10,363	2.10	3.517
San Juan Bautista	1,607	1,607	0	639	417	70	73	62	17	589	7.82	2.728
Balance Of County	18,096	17,760	336	6,263	5,172	427	70	42	552	5,886	6.02	3.017
Incorporated	38,221	38,050	171	11,224	8,392	601	1,065	843	323	10,952	2.42	3.474
County Total	56,317	55,810	507	17,487	13,564	1,028	1,135	885	875	16,838	3.71	3.315
San Bernardino County												
Adelanto	19,458	18,109	1,349	5,808	4,020	149	382	750	507	4,936	15.01	3.669
Apple Valley	59,083	58,720	363	21,140	15,889	726	2,074	1,417	1,034	19,456	7.97	3.018
Barstow	23,093	22,638	455	9,634	5,371	356	1,292	1,500	1,115	8,037	16.58	2.817
Big Bear Lake	5,893	5,868	25	9,077	7,594	326	360	410	387	2,443	73.09	2.402
Chino	70,877	63,377	7,500	18,385	12,953	952	782	3,170	528	17,775	3.32	3.566
Chino Hills	73,241	73,090	151	21,540	17,634	1,378	284	1,558	686	21,144	1.84	3.457
Colton	50,381	50,117	264	15,949	9,363	602	1,059	4,110	815	14,769	7.40	3.393
Fontana	146,263	145,764	499	39,204	29,836	1,198	1,579	5,709	882	37,136	5.27	3.925
Grand Terrace	12,130	11,921	209	4,478	2,883	175	265	905	250	4,240	5.31	2.812
Hesperia	68,082	67,751	331	22,352	17,599	893	1,028	1,624	1,208	20,906	6.47	3.241

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Highland	47,611	47,371	240	15,259	11,210	512	598	2,129	810	13,842	9.29	3.422
Loma Linda	20,749	19,789	960	8,459	3,492	673	1,307	2,425	562	7,885	6.79	2.510
Montclair	34,421	33,809	612	9,090	5,245	758	1,002	1,331	754	8,824	2.93	3.831
Needles	5,243	5,232	11	2,664	1,414	86	254	367	543	2,026	23.95	2.582
Ontario	166,239	165,138	1,101	45,756	27,154	3,649	3,960	8,833	2,160	44,078	3.67	3.746
Rancho Cucamonga	147,153	143,527	3,626	46,870	32,156	2,569	1,794	8,979	1,372	45,456	3.02	3.157
Redlands	67,829	65,863	1,966	25,487	16,289	900	2,422	4,967	909	24,256	4.83	2.715
Rialto	96,897	96,093	804	26,437	18,768	586	1,810	3,479	1,794	25,030	5.32	3.839
San Bernardino	194,739	188,237	6,502	63,863	37,710	2,716	5,711	13,246	4,480	56,811	11.04	3.313
Twentynine Palms	22,548	17,158	5,390	8,528	4,629	1,262	1,661	445	531	6,702	21.41	2.560
Upland	72,063	71,478	585	25,824	14,902	1,766	2,675	5,636	845	24,895	3.60	2.871
Victorville	72,725	70,323	2,402	24,021	17,532	389	1,333	3,009	1,758	22,307	7.14	3.153
Yucaipa	45,564	44,992	572	17,161	11,040	394	726	774	4,227	16,181	5.71	2.781
Yucca Valley	18,026	17,715	311	8,186	6,322	140	639	378	707	7,153	12.62	2.477
Balance Of County	299,577	288,828	10,749	126,792	102,078	4,208	4,250	3,034	13,222	92,204	27.28	3.132
Incorporated	1,540,308	1,504,080	36,228	495,172	331,005	23,155	34,997	77,151	28,864	456,288	7.85	3.296
County Total	1,839,885	1,792,908	46,977	621,964	433,083	27,363	39,247	80,185	42,086	548,492	11.81	3.269
San Diego County												
Carlsbad	90,663	89,776	887	38,406	20,882	5,762	2,496	7,975	1,291	35,820	6.73	2.506
Chula Vista	200,427	199,096	1,331	67,360	35,515	5,454	4,401	18,144	3,846	65,334	3.01	3.047
Coronado	26,441	18,076	8,365	9,579	4,477	874	822	3,383	23	7,797	18.60	2.318
Del Mar	4,521	4,519	2	2,583	1,347	366	198	672	0	2,201	14.79	2.053
El Cajon	97,020	94,537	2,483	35,318	13,535	1,548	2,244	15,957	2,034	34,323	2.82	2.754
Encinitas	61,321	60,762	559	24,742	13,896	4,535	2,107	3,435	769	23,691	4.25	2.565
Escondido	138,638	136,873	1,765	45,894	22,274	2,922	3,100	13,782	3,816	44,639	2.73	3.066
Imperial Beach	27,717	27,020	697	9,804	4,028	687	1,059	3,690	340	9,333	4.80	2.895
La Mesa	55,895	54,849	1,046	24,986	11,112	1,922	2,003	9,590	359	24,228	3.03	2.264
Lemon Grove	25,468	24,877	591	8,748	5,773	714	694	1,470	97	8,514	2.67	2.922
National City	59,971	52,011	7,960	15,451	6,612	1,336	1,686	5,380	437	15,046	2.62	3.457
Oceanside	170,455	169,175	1,280	61,883	32,200	8,222	4,369	13,671	3,421	58,670	5.19	2.884
Poway	50,020	49,594	426	16,052	12,001	877	318	2,165	691	15,800	1.57	3.139
San Diego	1,279,790	1,233,168	46,622	482,429	224,514	45,766	42,684	163,033	6,432	462,886	4.05	2.664
San Marcos	63,769	63,700	69	21,493	11,521	1,083	708	4,521	3,660	20,638	3.98	3.087
Santee	53,781	52,738	1,043	18,759	10,598	1,615	1,194	2,849	2,503	18,397	1.93	2.867
Solana Beach	13,380	13,346	34	6,528	2,971	1,265	622	1,631	39	5,819	10.86	2.294
Vista	93,112	90,846	2,266	30,328	15,159	2,029	2,171	8,840	2,129	29,375	3.14	3.093
Balance Of County	462,693	434,722	27,971	156,824	105,596	11,326	6,488	18,225	15,189	146,867	6.35	2.960
Incorporated	2,512,389	2,434,963	77,426	920,343	448,415	86,977	72,876	280,188	31,887	882,511	4.11	2.759
County Total	2,975,082	2,869,685	105,397	1,077,167	554,011	98,303	79,364	298,413	47,076	1,029,378	4.44	2.788
San Francisco County												
City and County Total	793,064	773,311	19,753	352,502	62,816	48,696	81,401	159,029	560	335,553	4.81	2.305

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
San Joaquin County												
Escalon	6,611	6,585	26	2,297	1,891	20	153	98	135	2,216	3.53	2.972
Lathrop	12,116	12,106	10	3,377	2,859	63	92	12	351	3,282	2.81	3.689
Lodi	60,851	59,827	1,024	22,192	14,019	1,453	1,756	4,500	464	21,480	3.21	2.785
Manteca	57,500	57,023	477	19,231	14,171	739	1,106	2,346	869	18,585	3.36	3.068
Ripon	11,645	11,534	111	3,845	3,267	101	151	316	10	3,758	2.26	3.069
Stockton	262,506	257,306	5,200	85,988	52,996	6,592	8,410	16,702	1,288	82,334	4.25	3.125
Tracy	70,006	69,661	345	21,628	17,384	1,015	941	1,813	475	21,070	2.58	3.306
Balance Of County	135,242	124,060	11,182	42,817	34,453	1,240	772	592	5,760	40,698	4.95	3.048
Incorporated	481,235	474,042	7,193	158,558	106,587	9,983	12,609	25,787	3,592	152,725	3.68	3.104
County Total	616,477	598,102	18,375	201,375	141,040	11,223	13,381	26,379	9,352	193,423	3.95	3.092
San Luis Obispo County												
Arroyo Grande	16,504	16,294	210	7,101	4,830	585	489	649	548	6,814	4.04	2.391
Atascadero	27,353	25,691	1,662	10,242	7,164	441	862	1,220	555	9,912	3.22	2.592
El Paso De Robles	26,825	26,194	631	9,950	6,473	842	1,023	1,200	412	9,684	2.67	2.705
Grover Beach	13,077	12,951	126	5,439	3,111	786	706	589	247	5,076	6.67	2.551
Morro Bay	10,506	10,308	198	6,410	4,159	394	634	464	759	5,113	20.23	2.016
Pismo Beach	8,699	8,672	27	5,647	3,048	576	457	479	1,087	4,346	23.04	1.995
San Luis Obispo	44,313	42,451	1,862	19,560	9,271	1,272	2,217	5,298	1,502	18,884	3.46	2.248
Balance Of County	108,665	98,020	10,645	42,950	32,121	1,278	1,926	1,208	6,417	37,477	12.74	2.615
Incorporated	147,277	142,561	4,716	64,349	38,056	4,896	6,388	9,899	5,110	59,829	7.02	2.383
County Total	255,942	240,581	15,361	107,299	70,177	6,174	8,314	11,107	11,527	97,306	9.31	2.472
San Mateo County												
Atherton	7,196	6,878	318	2,515	2,476	32	0	7	0	2,423	3.66	2.839
Belmont	25,336	24,709	627	10,706	6,279	581	275	3,571	0	10,545	1.50	2.343
Brisbane	3,638	3,598	40	1,858	1,018	260	179	358	43	1,644	11.52	2.189
Burlingame	28,189	27,703	486	12,928	6,141	423	987	5,377	0	12,568	2.78	2.204
Colma	1,193	1,144	49	344	207	39	71	21	6	330	4.07	3.467
Daly City	104,043	103,253	790	31,550	16,052	4,469	2,825	7,596	608	31,010	1.71	3.330
East Palo Alto	31,633	31,444	189	7,632	3,851	376	360	2,886	159	7,507	1.64	4.189
Foster City	29,753	29,666	87	12,449	4,809	2,464	767	4,402	7	12,039	3.29	2.464
Half Moon Bay	12,260	11,412	848	4,285	2,701	536	302	319	427	4,170	2.68	2.737
Hillsborough	10,935	10,933	2	3,856	3,839	8	9	0	0	3,740	3.01	2.923
Menlo Park	30,724	29,863	861	12,771	6,896	930	1,574	3,366	5	12,442	2.58	2.400
Millbrae	20,663	20,331	332	8,119	5,320	269	426	2,093	11	7,962	1.93	2.554
Pacifica	38,514	38,333	181	14,341	10,344	778	719	2,402	98	14,089	1.76	2.721
Portola Valley	4,483	4,413	70	1,787	1,494	33	0	260	0	1,715	4.03	2.573
Redwood City	75,798	73,871	1,927	29,178	13,535	3,653	2,605	8,552	833	28,310	2.97	2.609
San Bruno	40,865	40,644	221	15,296	9,074	566	1,188	4,446	22	14,987	2.02	2.712

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

	POPULATION			HOUSING UNITS								PERSONS
					SINGLE		MULTIPLE					PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
San Carlos	27,698	27,515	183	11,723	8,247	608	474	2,378	16	11,487	2.01	2.395
San Mateo	93,448	92,132	1,316	38,805	17,740	3,492	3,014	14,514	45	37,883	2.38	2.432
South San Francisco	60,713	60,270	443	20,262	11,874	2,485	1,672	3,822	409	19,799	2.29	3.044
Woodside	5,347	5,341	6	2,035	1,973	28	28	5	1	1,954	3.98	2.733
Balance Of County	63,636	62,253	1,383	22,185	18,314	690	910	1,424	847	21,447	3.33	2.903
Incorporated	652,429	643,453	8,976	242,440	133,870	22,030	17,475	66,375	2,690	236,604	2.41	2.720
County Total	716,065	705,706	10,359	264,625	152,184	22,720	18,385	67,799	3,537	258,051	2.48	2.735
Santa Barbara County												
Buellton	4,211	4,205	6	1,624	1,015	63	30	98	418	1,569	3.39	2.680
Carpinteria	14,383	14,258	125	5,511	2,153	422	529	1,467	940	5,033	8.67	2.833
Goleta	30,764	30,422	342	11,481	5,856	1,588	753	2,663	621	11,196	2.48	2.717
Guadalupe	6,271	6,271	0	1,599	1,156	161	177	99	6	1,560	2.44	4.020
Lompoc	41,839	38,321	3,518	13,792	7,208	1,044	1,927	2,673	940	13,223	4.13	2.898
Santa Barbara	90,412	88,620	1,792	37,238	17,162	2,874	5,521	11,163	518	35,761	3.97	2.478
Santa Maria	82,097	79,899	2,198	24,138	15,090	1,324	1,671	4,481	1,572	23,397	3.07	3.415
Solvang	5,580	5,420	160	2,322	1,330	151	169	453	219	2,277	1.94	2.380
Balance Of County	136,086	127,365	8,721	48,500	34,039	2,736	2,695	5,695	3,335	46,181	4.78	2.758
Incorporated	275,557	267,416	8,141	97,705	50,970	7,627	10,777	23,097	5,234	94,016	3.78	2.844
County Total	411,643	394,781	16,862	146,205	85,009	10,363	13,472	28,792	8,569	140,197	4.11	2.816
Santa Clara County												
Campbell	38,231	37,941	290	16,384	6,949	1,981	2,442	4,755	257	16,017	2.24	2.369
Cupertino	52,129	51,648	481	19,237	11,918	2,028	1,674	3,608	9	18,748	2.54	2.755
Gilroy	44,894	44,464	430	13,215	8,701	751	1,298	2,034	431	12,908	2.32	3.445
Los Altos	27,671	27,252	419	10,757	9,205	364	269	903	16	10,491	2.47	2.598
Los Altos Hills	8,332	8,267	65	2,993	2,929	32	17	9	6	2,914	2.64	2.837
Los Gatos	28,858	28,156	702	12,530	7,084	1,837	931	2,555	123	12,147	3.06	2.318
Milpitas	64,934	61,760	3,174	18,081	10,929	2,225	1,631	2,724	572	17,839	1.34	3.462
Monte Sereno	3,496	3,496	0	1,246	1,142	13	18	73	0	1,220	2.09	2.866
Morgan Hill	34,885	34,372	513	11,577	7,197	1,610	649	1,195	926	11,321	2.21	3.036
Mountain View	71,874	71,370	504	33,089	9,199	3,888	2,670	16,101	1,231	31,875	3.67	2.239
Palo Alto	60,355	59,687	668	26,934	15,583	974	1,736	8,477	164	26,074	3.19	2.289
San Jose	923,446	912,438	11,008	291,960	164,596	27,583	23,270	65,483	11,028	286,531	1.86	3.184
Santa Clara	105,642	102,855	2,787	41,082	18,047	3,588	3,892	15,446	109	39,938	2.78	2.575
Saratoga	30,432	30,071	361	10,861	9,630	560	197	467	7	10,658	1.87	2.821
Sunnyvale	132,342	131,467	875	54,185	21,117	3,940	4,911	20,121	4,096	52,962	2.26	2.482
Balance Of County	99,636	91,656	7,980	31,748	24,965	1,683	1,153	3,264	683	30,676	3.38	2.988
Incorporated	1,627,521	1,605,244	22,277	564,131	304,226	51,374	45,605	143,951	18,975	551,643	2.21	2.910
County Total	1,727,157	1,696,900	30,257	595,879	329,191	53,057	46,758	147,215	19,658	582,319	2.28	2.914

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Cruz County												
Capitola	10,082	9,926	156	5,383	1,973	514	1,139	1,107	650	4,757	11.63	2.087
Santa Cruz	55,347	50,048	5,299	21,737	12,221	1,905	2,593	4,578	440	20,663	4.94	2.422
Scotts Valley	11,561	11,109	452	4,535	2,461	415	397	458	804	4,381	3.40	2.536
Watsonville	47,417	46,864	553	12,650	6,453	1,594	1,671	2,032	900	12,310	2.69	3.807
Balance Of County	134,019	130,802	3,217	55,893	40,681	4,333	2,605	3,816	4,458	50,308	9.99	2.600
Incorporated	124,407	117,947	6,460	44,305	23,108	4,428	5,800	8,175	2,794	42,111	4.95	2.801
County Total	258,426	248,749	9,677	100,198	63,789	8,761	8,405	11,991	7,252	92,419	7.76	2.692
Shasta County												
Anderson	9,603	9,485	118	3,745	2,431	209	372	560	173	3,529	5.77	2.688
Redding	86,156	83,761	2,395	35,434	22,942	949	4,522	4,437	2,584	33,652	5.03	2.489
Shasta Lake	9,869	9,817	52	4,018	3,146	27	237	114	494	3,655	9.03	2.686
Balance Of County	67,359	66,568	791	28,501	20,105	272	369	198	7,557	25,270	11.34	2.634
Incorporated	105,628	103,063	2,565	43,197	28,519	1,185	5,131	5,111	3,251	40,836	5.47	2.524
County Total	172,987	169,631	3,356	71,698	48,624	1,457	5,500	5,309	10,808	66,106	7.80	2.566
Sierra County												
Loyalton	871	841	30	354	307	13	3	0	31	330	6.78	2.548
Balance Of County	2,711	2,705	6	1,882	1,537	36	44	63	202	1,214	35.49	2.228
Incorporated	871	841	30	354	307	13	3	0	31	330	6.78	2.548
County Total	3,582	3,546	36	2,236	1,844	49	47	63	233	1,544	30.95	2.297
Siskiyou County												
Dorris	887	887	0	401	317	3	16	0	65	347	13.47	2.556
Dunsmuir	1,902	1,902	0	1,170	791	23	126	184	46	867	25.90	2.194
Etna	776	776	0	364	267	10	19	13	55	331	9.07	2.344
Fort Jones	663	663	0	333	236	11	34	2	50	303	9.01	2.188
Montague	1,461	1,442	19	618	472	6	10	43	87	569	7.93	2.534
Mount Shasta	3,664	3,616	48	1,839	1,169	89	251	256	74	1,706	7.23	2.120
Tulelake	1,013	1,013	0	461	317	2	44	19	79	360	21.91	2.814
Weed	3,012	2,840	172	1,300	895	19	136	190	60	1,190	8.46	2.387
Yreka	7,361	7,141	220	3,372	2,207	140	285	511	229	3,180	5.69	2.246
Balance Of County	24,096	23,811	285	12,575	9,136	184	178	96	2,981	10,113	19.58	2.354
Incorporated	20,739	20,280	459	9,858	6,671	303	921	1,218	745	8,853	10.19	2.291
County Total	44,835	44,091	744	22,433	15,807	487	1,099	1,314	3,726	18,966	15.45	2.325

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Solano County												
Benicia	27,093	27,039	54	10,608	6,865	1,047	921	1,449	326	10,388	2.07	2.603
Dixon	16,208	16,167	41	5,192	4,280	213	364	249	86	5,093	1.91	3.174
Fairfield	103,079	98,847	4,232	34,660	23,248	2,413	2,233	5,874	892	33,519	3.29	2.949
Rio Vista	5,654	5,654	0	2,467	2,049	34	103	171	110	2,351	4.70	2.405
Suisun City	26,925	26,831	94	8,376	7,040	189	327	754	66	8,212	1.96	3.267
Vacaville	94,122	84,706	9,416	30,529	21,335	1,035	2,141	4,710	1,308	29,900	2.06	2.833
Vallejo	120,355	118,199	2,156	42,247	29,330	1,776	3,919	5,876	1,346	40,588	3.93	2.912
Balance Of County	19,717	19,120	597	7,074	5,973	220	293	119	469	6,648	6.02	2.876
Incorporated	393,436	377,443	15,993	134,079	94,147	6,707	10,008	19,083	4,134	130,051	3.00	2.902
County Total	413,153	396,563	16,590	141,153	100,120	6,927	10,301	19,202	4,603	136,699	3.16	2.901
Sonoma County												
Cloverdale	7,481	7,404	77	2,893	2,159	121	112	293	208	2,756	4.74	2.687
Cotati	6,850	6,832	18	2,757	1,598	372	341	325	121	2,700	2.07	2.530
Healdsburg	11,616	11,493	123	4,497	3,224	252	443	479	99	4,314	4.07	2.664
Petaluma	55,804	55,064	740	20,934	15,172	1,652	1,305	1,874	931	20,550	1.83	2.680
Rohnert Park	42,412	41,311	1,101	15,995	7,660	1,698	929	4,295	1,413	15,687	1.93	2.633
Santa Rosa	153,879	150,109	3,770	60,558	36,383	5,669	4,835	10,989	2,682	58,937	2.68	2.547
Sebastopol	7,783	7,572	211	3,350	2,006	253	535	497	59	3,279	2.12	2.309
Sonoma	9,569	9,478	91	4,929	2,763	684	452	593	437	4,619	6.29	2.052
Windsor	24,403	24,312	91	8,356	6,513	460	209	352	822	8,205	1.81	2.963
Balance Of County	151,032	145,321	5,711	64,776	52,396	2,890	2,876	2,021	4,593	57,026	11.96	2.548
Incorporated	319,797	313,575	6,222	124,269	77,478	11,161	9,161	19,697	6,772	121,047	2.59	2.591
County Total	470,829	458,896	11,933	189,045	129,874	14,051	12,037	21,718	11,365	178,073	5.80	2.577
Stanislaus County												
Ceres	36,504	36,405	99	11,109	8,465	343	603	986	712	10,761	3.13	3.383
Hughson	4,932	4,926	6	1,517	1,162	65	66	135	89	1,481	2.37	3.326
Modesto	203,813	200,642	3,171	70,970	49,524	4,006	6,223	9,254	1,963	68,625	3.30	2.924
Newman	7,783	7,717	66	2,335	1,923	76	193	117	26	2,231	4.45	3.459
Oakdale	16,771	16,592	179	6,144	4,555	208	487	683	211	5,938	3.35	2.794
Patterson	13,704	13,475	229	3,777	3,245	190	151	63	128	3,642	3.57	3.700
Riverbank	17,304	17,169	135	5,025	4,189	185	180	182	289	4,861	3.26	3.532
Turlock	62,347	60,257	2,090	20,934	14,094	963	1,750	3,523	604	20,181	3.60	2.986
Waterford	7,691	7,674	17	2,259	1,843	47	172	168	29	2,161	4.34	3.551
Balance Of County	112,856	111,386	1,470	35,654	28,321	1,058	941	416	4,918	33,861	5.03	3.290
Incorporated	370,849	364,857	5,992	124,070	89,000	6,083	9,825	15,111	4,051	119,881	3.38	3.043
County Total	483,705	476,243	7,462	159,724	117,321	7,141	10,766	15,527	8,969	153,742	3.75	3.098

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Sutter County												
Live Oak	6,506	6,210	296	1,848	1,386	75	141	104	142	1,757	4.92	3.534
Yuba City	48,829	47,879	950	17,332	10,830	839	1,540	3,600	523	16,598	4.23	2.885
Balance Of County	28,700	28,542	158	10,354	8,750	272	227	76	1,029	9,841	4.95	2.900
Incorporated	55,335	54,089	1,246	19,180	12,216	914	1,681	3,704	665	18,355	4.30	2.947
County Total	84,035	82,631	1,404	29,534	20,966	1,186	1,908	3,780	1,694	28,196	4.53	2.931
Tehama County												
Corning	6,844	6,787	57	2,651	1,574	70	278	495	234	2,456	7.36	2.763
Red Bluff	13,484	12,949	535	5,708	3,339	218	697	1,090	364	5,238	8.23	2.472
Tehama	435	435	0	197	167	4	10	0	16	180	8.63	2.417
Balance Of County	37,072	36,650	422	15,726	9,543	194	239	78	5,672	13,790	12.31	2.658
Incorporated	20,763	20,171	592	8,556	5,080	292	985	1,585	614	7,874	7.97	2.562
County Total	57,835	56,821	1,014	24,282	14,623	486	1,224	1,663	6,286	21,664	10.78	2.623
Trinity County												
County Total	13,319	13,078	241	8,092	5,355	112	106	117	2,402	5,665	29.99	2.309
Tulare County												
Dinuba	18,387	18,273	114	5,006	3,788	280	268	465	205	4,817	3.78	3.793
Exeter	9,663	9,571	92	3,279	2,597	107	203	184	188	3,106	5.28	3.081
Farmersville	9,298	9,279	19	2,370	1,918	90	155	109	98	2,247	5.19	4.130
Lindsay	10,591	10,442	149	2,893	1,972	135	243	358	185	2,744	5.15	3.805
Porterville	42,188	40,557	1,631	13,299	9,198	483	1,528	1,448	642	12,453	6.36	3.257
Tulare	46,545	46,098	447	14,808	11,175	511	1,214	1,134	774	14,071	4.98	3.276
Visalia	99,474	97,852	1,622	34,924	25,390	1,572	3,523	2,969	1,470	33,012	5.47	2.964
Woodlake	6,971	6,962	9	1,928	1,266	126	152	324	60	1,828	5.19	3.809
Balance Of County	145,491	143,530	1,961	45,670	34,762	1,440	1,328	890	7,250	40,362	11.62	3.556
Incorporated	243,117	239,034	4,083	78,507	57,304	3,304	7,286	6,991	3,622	74,278	5.39	3.218
County Total	388,608	382,564	6,044	124,177	92,066	4,744	8,614	7,881	10,872	114,640	7.68	3.337
Tuolumne County												
Sonora	4,598	4,399	199	2,261	1,315	86	385	447	28	2,111	6.63	2.084
Balance Of County	51,794	47,095	4,699	26,775	20,934	566	787	627	3,861	19,415	27.49	2.426
Incorporated	4,598	4,399	199	2,261	1,315	86	385	447	28	2,111	6.63	2.084
County Total	56,392	51,494	4,898	29,036	22,249	652	1,172	1,074	3,889	21,526	25.86	2.392

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2003

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Ventura County												
Camarillo	60,605	59,524	1,081	23,002	13,701	4,493	860	2,890	1,058	22,493	2.21	2.646
Fillmore	14,685	14,439	246	4,111	2,954	277	232	322	326	4,015	2.34	3.596
Moorpark	34,522	34,510	12	9,895	7,107	1,234	223	999	332	9,786	1.10	3.526
Ojai	7,989	7,799	190	3,250	2,235	266	289	452	8	3,109	4.34	2.509
Oxnard	181,720	179,123	2,597	47,751	26,601	4,576	4,384	9,250	2,940	46,070	3.52	3.888
Port Hueneme	22,214	21,534	680	7,969	2,352	2,204	1,201	2,171	41	7,403	7.10	2.909
San Buenaventura	104,236	101,866	2,370	40,739	22,984	3,428	4,148	7,556	2,623	39,430	3.21	2.583
Santa Paula	28,955	28,712	243	8,363	5,003	723	774	1,076	787	8,158	2.45	3.519
Simi Valley	117,645	116,845	800	39,006	29,289	2,733	1,655	4,437	892	38,115	2.28	3.066
Thousand Oaks	123,960	122,009	1,951	45,106	30,426	5,152	1,745	6,711	1,072	43,883	2.71	2.780
Balance Of County	95,830	93,287	2,543	32,707	26,030	2,348	1,009	1,168	2,152	30,764	5.94	3.032
Incorporated	696,531	686,361	10,170	229,192	142,652	25,086	15,511	35,864	10,079	222,462	2.94	3.085
County Total	792,361	779,648	12,713	261,899	168,682	27,434	16,520	37,032	12,231	253,226	3.31	3.079
Yolo County												
Davis	64,027	60,918	3,109	24,670	11,299	2,351	2,153	8,482	385	24,140	2.15	2.524
West Sacramento	36,597	36,391	206	13,919	8,355	879	936	2,218	1,531	13,082	6.01	2.782
Winters	6,591	6,585	6	2,082	1,650	105	67	182	78	2,032	2.40	3.241
Woodland	51,782	50,992	790	17,874	11,032	1,313	1,125	3,723	681	17,488	2.16	2.916
Balance Of County	22,852	18,669	4,183	6,978	4,731	305	192	804	946	6,567	5.89	2.843
Incorporated	158,997	154,886	4,111	58,545	32,336	4,648	4,281	14,605	2,675	56,742	3.08	2.730
County Total	181,849	173,555	8,294	65,523	37,067	4,953	4,473	15,409	3,621	63,309	3.38	2.741
Yuba County												
Marysville	12,868	12,261	607	5,005	2,772	339	767	1,119	8	4,693	6.23	2.613
Wheatland	2,764	2,764	0	944	660	35	155	55	39	908	3.81	3.044
Balance Of County	48,098	47,336	762	17,112	10,929	915	686	1,076	3,506	15,306	10.55	3.093
Incorporated	15,632	15,025	607	5,949	3,432	374	922	1,174	47	5,601	5.85	2.683
County Total	63,730	62,361	1,369	23,061	14,361	1,289	1,608	2,250	3,553	20,907	9.34	2.983
California												
Incorporated Total	29,214,822	28,551,415	663,407	10,229,285	5,441,124	827,308	936,526	2,714,036	310,291	9,749,354	4.69	2.929
Balance Of State Total	6,437,878	6,258,051	179,827	2,369,660	1,718,407	110,503	98,127	178,071	264,552	2,117,715	10.63	2.955
State Total	35,652,700	34,809,466	843,234	12,598,945	7,159,531	937,811	1,034,653	2,892,107	574,843	11,867,069	5.81	2.933

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2004

	POPULATION			HOUSING UNITS								PERSONS
					SINGLE		MULTIPLE					PER
COUNTY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Alameda	1,495,162	1,467,632	27,530	554,614	298,452	38,903	61,454	148,175	7,630	538,053	2.99	2.728
Alpine	1,260	1,259	1	1,638	950	38	35	553	62	521	68.19	2.417
Amador	37,006	32,511	4,495	16,020	13,118	390	384	571	1,557	13,603	15.09	2.390
Butte	212,393	206,184	6,209	89,898	55,493	2,388	7,727	9,908	14,382	83,797	6.79	2.461
Calaveras	43,707	43,284	423	25,066	21,210	465	507	355	2,529	18,013	28.14	2.403
Colusa	20,345	19,925	420	7,029	5,210	229	410	389	791	6,331	9.93	3.147
Contra Costa	1,005,590	994,289	11,301	372,411	246,354	31,241	25,321	61,906	7,589	361,419	2.95	2.751
Del Norte	28,421	24,676	3,745	10,735	6,307	182	804	584	2,858	9,434	12.12	2.616
El Dorado	169,830	168,776	1,054	77,181	62,466	1,761	3,532	5,048	4,374	64,005	17.07	2.637
Fresno	864,893	846,122	18,771	284,392	188,004	10,060	24,521	48,329	13,478	265,865	6.51	3.183
Glenn	27,721	27,325	396	10,242	7,124	207	718	700	1,493	9,413	8.09	2.903
Humboldt	130,452	126,077	4,375	57,540	39,471	1,566	5,744	4,699	6,060	52,718	8.38	2.392
Imperial	156,398	144,984	11,414	47,086	27,635	1,913	3,570	6,234	7,734	42,443	9.86	3.416
Inyo	18,452	18,170	282	9,147	5,496	212	407	468	2,564	7,792	14.81	2.332
Kern	730,493	698,156	32,337	247,918	170,628	8,582	20,741	23,730	24,237	224,234	9.55	3.114
Kings	141,818	118,893	22,925	38,884	27,291	2,389	2,731	4,307	2,166	36,628	5.80	3.246
Lake	62,255	61,052	1,203	33,347	20,827	534	904	910	10,172	24,577	26.30	2.484
Lassen	34,632	25,385	9,247	12,457	8,577	296	519	509	2,556	10,057	19.27	2.524
Los Angeles	10,077,865	9,900,639	177,226	3,323,841	1,618,064	242,246	288,457	1,118,440	56,634	3,184,314	4.20	3.109
Madera	136,434	128,075	8,359	43,598	33,593	1,336	2,320	2,881	3,468	39,052	10.43	3.280
Marin	250,793	239,939	10,854	106,831	64,863	8,572	9,526	21,739	2,131	102,463	4.09	2.342
Mariposa	17,711	16,341	1,370	9,466	6,093	330	214	383	2,446	7,093	25.07	2.304
Mendocino	88,945	86,674	2,271	38,274	26,845	1,163	2,123	2,766	5,377	34,456	9.98	2.515
Merced	233,393	229,027	4,366	74,075	53,342	2,537	5,269	7,475	5,452	69,174	6.62	3.311
Modoc	9,580	9,173	407	5,010	3,417	87	97	159	1,250	3,938	21.40	2.329
Mono	13,352	12,930	422	12,859	5,001	1,259	2,065	3,562	972	5,630	56.22	2.297
Monterey	420,802	398,877	21,925	136,046	82,857	12,440	11,964	22,995	5,790	125,341	7.87	3.182
Napa	131,228	125,887	5,341	51,538	34,633	3,255	3,673	6,042	3,935	48,276	6.33	2.608
Nevada	97,334	96,415	919	47,394	38,788	871	1,762	2,248	3,725	39,360	16.95	2.450
Orange	3,017,390	2,973,761	43,629	1,003,112	509,421	126,001	90,371	244,847	32,472	967,611	3.54	3.073
Placer	296,557	293,475	3,082	129,311	99,154	4,141	6,027	15,272	4,717	114,799	11.22	2.556
Plumas	20,967	20,779	188	14,252	10,874	445	375	396	2,162	9,574	32.82	2.170
Riverside	1,803,742	1,767,206	36,536	659,966	423,522	42,511	30,890	79,859	83,184	572,582	13.24	3.086

California Department of Finance
Demographic Research Unit

Table 1: E-5 County/State Population and Housing Estimates, Revised 1/1/2004

COUNTY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Sacramento	1,345,634	1,320,427	25,207	512,864	327,481	32,278	36,407	101,114	15,584	490,806	4.30	2.690
San Benito	56,730	56,223	507	17,567	13,648	1,028	1,135	885	871	16,913	3.72	3.324
San Bernardino	1,893,154	1,844,556	48,598	632,267	441,342	27,440	39,270	81,792	42,423	557,874	11.77	3.306
San Diego	3,011,770	2,912,597	99,173	1,091,266	562,937	97,958	80,448	302,762	47,161	1,042,879	4.43	2.793
San Francisco	795,042	775,337	19,705	353,717	62,870	48,696	81,571	160,020	560	336,710	4.81	2.303
San Joaquin	634,971	618,016	16,955	207,449	146,632	11,241	13,424	26,757	9,395	199,275	3.94	3.101
San Luis Obispo	258,616	242,552	16,064	108,608	71,233	6,212	8,348	11,175	11,640	98,500	9.31	2.462
San Mateo	717,921	707,552	10,369	265,533	152,666	22,757	18,432	68,124	3,554	258,935	2.48	2.733
Santa Barbara	415,253	398,332	16,921	147,694	85,857	10,564	13,541	29,154	8,578	141,637	4.10	2.812
Santa Clara	1,739,939	1,710,566	29,373	600,707	330,773	53,413	46,864	150,013	19,644	587,040	2.28	2.914
Santa Cruz	258,985	249,232	9,753	101,133	64,214	8,838	8,447	12,382	7,252	93,305	7.74	2.671
Shasta	175,686	172,264	3,422	73,081	49,623	1,457	5,573	5,404	11,024	67,382	7.80	2.557
Sierra	3,540	3,504	36	2,258	1,865	49	47	63	234	1,562	30.82	2.243
Siskiyou	45,141	44,409	732	22,739	16,014	488	1,118	1,314	3,805	19,220	15.48	2.311
Solano	416,379	400,376	16,003	143,189	101,657	6,938	10,365	19,604	4,625	138,673	3.15	2.887
Sonoma	473,521	461,510	12,011	190,591	130,814	14,138	12,196	22,060	11,383	179,547	5.79	2.570
Stanislaus	493,515	485,997	7,518	162,925	120,232	7,142	10,884	15,633	9,034	156,830	3.74	3.099
Sutter	86,416	84,988	1,428	30,131	21,555	1,186	1,912	3,780	1,698	28,768	4.52	2.954
Tehama	58,797	57,773	1,024	24,634	14,874	488	1,228	1,663	6,381	21,974	10.80	2.629
Trinity	13,506	13,258	248	8,138	5,384	112	108	117	2,417	5,697	30.00	2.327
Tulare	398,679	392,670	6,009	126,241	93,947	4,744	8,723	7,955	10,872	116,573	7.66	3.368
Tuolumne	56,628	51,759	4,869	29,384	22,475	652	1,178	1,074	4,005	21,784	25.86	2.376
Ventura	802,215	789,095	13,120	264,556	170,941	27,456	16,613	37,308	12,238	255,782	3.32	3.085
Yolo	185,291	176,788	8,503	67,027	38,197	4,958	4,598	15,622	3,652	64,751	3.40	2.730
Yuba	65,092	63,757	1,335	23,364	14,584	1,291	1,610	2,250	3,629	21,189	9.31	3.009
California	36,199,342	35,357,436	841,906	12,758,241	7,276,895	940,074	1,039,202	2,924,464	577,606	12,016,172	5.82	2.942

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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	------------POPULATION------------			----- HOUSING UNITS -----	-------- SINGLE --------		----- MULTIPLE -----					PERSONS PER HOUSE-HOLD
	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Alameda County												
Alameda	74,382	73,599	783	32,003	12,997	3,964	5,063	9,679	300	31,093	2.84	2.367
Albany	16,693	16,660	33	7,299	3,779	181	823	2,510	6	7,060	3.27	2.360
Berkeley	104,113	98,236	5,877	47,127	20,142	1,756	9,311	15,859	59	45,197	4.10	2.174
Dublin	38,236	33,115	5,121	12,898	7,348	1,304	444	3,774	28	12,419	3.71	2.666
Emeryville	7,653	7,586	67	4,720	270	329	488	3,596	37	4,390	6.99	1.728
Fremont	208,726	206,967	1,759	70,704	42,126	7,141	2,968	17,713	756	69,467	1.75	2.979
Hayward	144,392	142,237	2,155	46,985	23,364	3,396	3,383	14,543	2,299	45,841	2.43	3.103
Livermore	78,437	78,130	307	28,200	20,654	2,365	1,220	3,530	431	27,684	1.83	2.822
Newark	43,677	43,588	89	13,415	9,206	1,238	766	2,146	59	13,254	1.20	3.289
Oakland	410,507	403,250	7,257	160,588	72,107	6,645	29,090	52,290	456	153,738	4.27	2.623
Piedmont	11,048	11,046	2	3,861	3,784	0	35	34	8	3,806	1.42	2.902
Pleasanton	67,036	66,801	235	25,042	16,349	2,718	1,163	4,356	456	24,356	2.74	2.743
San Leandro	81,352	80,525	827	31,831	19,404	2,028	2,246	7,249	904	31,128	2.21	2.587
Union City	70,070	69,728	342	19,625	12,571	2,369	1,106	2,676	903	19,380	1.25	3.598
Balance Of County	138,840	136,164	2,676	50,316	34,351	3,469	3,348	8,220	928	49,240	2.14	2.765
Incorporated	1,356,322	1,331,468	24,854	504,298	264,101	35,434	58,106	139,955	6,702	488,813	3.07	2.724
County Total	1,495,162	1,467,632	27,530	554,614	298,452	38,903	61,454	148,175	7,630	538,053	2.99	2.728
Alpine County												
County Total	1,260	1,259	1	1,638	950	38	35	553	62	521	68.19	2.417
Amador County												
Amador	210	210	0	98	79	12	5	2	0	92	6.12	2.283
Ione	7,540	3,379	4,161	1,350	1,060	54	64	87	85	1,263	6.44	2.675
Jackson	4,118	3,850	268	1,928	1,185	112	148	247	236	1,811	6.07	2.126
Plymouth	1,069	1,069	0	500	281	23	24	26	146	428	14.40	2.498
Sutter Creek	2,491	2,490	1	1,199	796	105	55	162	81	1,110	7.42	2.243
Balance Of County	21,578	21,513	65	10,945	9,717	84	88	47	1,009	8,899	18.69	2.417
Incorporated	15,428	10,998	4,430	5,075	3,401	306	296	524	548	4,704	7.31	2.338
County Total	37,006	32,511	4,495	16,020	13,118	390	384	571	1,557	13,603	15.09	2.390
Butte County												
Biggs	1,802	1,802	0	620	513	28	28	5	46	578	6.77	3.118
Chico	71,207	67,229	3,978	29,003	14,356	989	4,286	8,053	1,319	27,921	3.73	2.408
Gridley	5,760	5,638	122	2,118	1,720	45	137	141	75	1,987	6.19	2.837
Oroville	13,322	12,490	832	5,591	2,964	162	769	1,308	388	5,036	9.93	2.480
Paradise	26,677	26,057	620	12,584	8,717	338	770	290	2,469	11,788	6.33	2.210
Balance Of County	93,625	92,968	657	39,982	27,223	826	1,737	111	10,085	36,487	8.74	2.548
Incorporated	118,768	113,216	5,552	49,916	28,270	1,562	5,990	9,797	4,297	47,310	5.22	2.393

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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
County Total	212,393	206,184	6,209	89,898	55,493	2,388	7,727	9,908	14,382	83,797	6.79	2.461
Calaveras County												
Angels City	3,470	3,470	0	1,665	1,149	67	122	113	214	1,505	9.61	2.306
Balance Of County	40,237	39,814	423	23,401	20,061	398	385	242	2,315	16,508	29.46	2.412
Incorporated	3,470	3,470	0	1,665	1,149	67	122	113	214	1,505	9.61	2.306
County Total	43,707	43,284	423	25,066	21,210	465	507	355	2,529	18,013	28.14	2.403
Colusa County												
Colusa	5,686	5,613	73	2,039	1,531	84	189	183	52	1,920	5.84	2.923
Williams	4,280	4,030	250	1,095	806	33	98	91	67	1,045	4.57	3.856
Balance Of County	10,379	10,282	97	3,895	2,873	112	123	115	672	3,366	13.58	3.055
Incorporated	9,966	9,643	323	3,134	2,337	117	287	274	119	2,965	5.39	3.252
County Total	20,345	19,925	420	7,029	5,210	229	410	389	791	6,331	9.93	3.147
Contra Costa County												
Antioch	100,549	100,133	416	33,248	24,917	2,205	1,779	4,078	269	32,389	2.58	3.092
Brentwood	38,309	38,272	37	12,828	11,434	370	267	405	352	12,359	3.66	3.097
Clayton	10,985	10,959	26	3,980	3,248	681	19	27	5	3,939	1.03	2.782
Concord	124,783	123,361	1,422	45,885	27,457	2,851	2,871	11,329	1,377	44,804	2.36	2.753
Danville	43,226	42,762	464	15,583	11,987	2,561	279	756	0	15,260	2.07	2.802
El Cerrito	23,388	23,212	176	10,493	7,321	343	1,309	1,488	32	10,239	2.42	2.267
Hercules	21,696	21,657	39	7,242	4,727	1,617	294	604	0	7,106	1.88	3.048
Lafayette	24,288	24,152	136	9,422	7,480	294	425	1,223	0	9,238	1.95	2.614
Martinez	36,790	35,454	1,336	14,897	9,551	2,237	984	2,101	24	14,593	2.04	2.430
Moraga	16,437	14,806	1,631	5,780	4,017	968	243	545	7	5,682	1.70	2.606
Oakley	28,357	28,290	67	8,741	7,992	84	74	170	421	8,616	1.43	3.283
Orinda	17,751	17,684	67	6,759	6,258	188	87	219	7	6,611	2.19	2.675
Pinole	19,531	19,313	218	6,962	5,126	498	366	957	15	6,876	1.24	2.809
Pittsburg	61,456	60,950	506	19,697	13,143	1,298	1,330	3,256	670	19,096	3.05	3.192
Pleasant Hill	33,604	33,144	460	14,274	8,438	1,631	688	3,465	52	13,988	2.00	2.369
Richmond	101,618	99,990	1,628	36,693	20,894	2,929	5,282	7,467	121	35,248	3.94	2.837
San Pablo	31,020	30,555	465	9,532	4,213	824	1,305	2,383	807	9,237	3.09	3.308
San Ramon	48,589	48,504	85	18,950	11,887	2,077	1,039	3,936	11	18,293	3.47	2.652
Walnut Creek	66,111	64,960	1,151	32,025	12,204	4,817	4,316	10,640	48	30,879	3.58	2.104
Balance Of County	157,102	156,131	971	59,420	44,060	2,768	2,364	6,857	3,371	56,966	4.13	2.741
Incorporated	848,488	838,158	10,330	312,991	202,294	28,473	22,957	55,049	4,218	304,453	2.73	2.753
County Total	1,005,590	994,289	11,301	372,411	246,354	31,241	25,321	61,906	7,589	361,419	2.95	2.751

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	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Del Norte County												
Crescent City	7,568	4,015	3,553	1,832	930	50	394	424	34	1,648	10.04	2.436
Balance Of County	20,853	20,661	192	8,903	5,377	132	410	160	2,824	7,786	12.55	2.654
Incorporated	7,568	4,015	3,553	1,832	930	50	394	424	34	1,648	10.04	2.436
County Total	28,421	24,676	3,745	10,735	6,307	182	804	584	2,858	9,434	12.12	2.616
El Dorado County												
Placerville	10,244	9,982	262	4,529	2,763	256	622	728	160	4,272	5.67	2.337
South Lake Tahoe	23,847	23,719	128	14,145	8,907	361	1,983	2,226	668	9,504	32.81	2.496
Balance Of County	135,739	135,075	664	58,507	50,796	1,144	927	2,094	3,546	50,229	14.15	2.689
Incorporated	34,091	33,701	390	18,674	11,670	617	2,605	2,954	828	13,776	26.23	2.446
County Total	169,830	168,776	1,054	77,181	62,466	1,761	3,532	5,048	4,374	64,005	17.07	2.637
Fresno County												
Clovis	81,099	80,619	480	29,104	20,180	549	3,082	4,377	916	28,067	3.56	2.872
Coalinga	16,713	11,025	5,688	3,806	2,532	127	283	546	318	3,465	8.96	3.182
Firebaugh	6,603	6,542	61	1,768	1,167	155	193	141	112	1,586	10.29	4.125
Fowler	4,612	4,523	89	1,434	1,014	50	160	163	47	1,395	2.72	3.242
Fresno	457,339	448,479	8,860	154,722	91,953	6,028	16,432	36,386	3,923	145,434	6.00	3.084
Huron	6,988	6,816	172	1,526	496	204	231	525	70	1,488	2.49	4.581
Kerman	10,693	10,662	31	2,992	2,135	153	248	340	116	2,903	2.97	3.673
Kingsburg	11,188	11,097	91	3,981	3,021	102	255	439	164	3,826	3.89	2.900
Mendota	8,679	8,671	8	2,006	1,170	139	311	313	73	1,950	2.79	4.447
Orange Cove	9,280	9,280	0	2,062	1,207	206	224	399	26	1,977	4.12	4.694
Parlier	12,295	12,193	102	2,835	1,999	234	184	404	14	2,623	7.48	4.648
Reedley	21,808	21,413	395	6,099	4,243	216	598	851	191	5,884	3.53	3.639
Sanger	20,573	20,433	140	5,723	4,111	194	567	688	163	5,511	3.70	3.708
San Joaquin	3,578	3,578	0	781	463	80	115	63	60	747	4.35	4.790
Selma	21,840	21,710	130	6,347	4,643	148	333	801	422	6,108	3.77	3.554
Balance Of County	171,605	169,081	2,524	59,206	47,670	1,475	1,305	1,893	6,863	52,901	10.65	3.196
Incorporated	693,288	677,041	16,247	225,186	140,334	8,585	23,216	46,436	6,615	212,964	5.43	3.179
County Total	864,893	846,122	18,771	284,392	188,004	10,060	24,521	48,329	13,478	265,865	6.51	3.183
Glenn County												
Orland	6,520	6,496	24	2,346	1,752	44	318	197	35	2,226	5.12	2.918
Willows	6,378	6,197	181	2,378	1,554	54	305	458	7	2,144	9.84	2.890
Balance Of County	14,823	14,632	191	5,518	3,818	109	95	45	1,451	5,043	8.61	2.901
Incorporated	12,898	12,693	205	4,724	3,306	98	623	655	42	4,370	7.49	2.905

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	HOUSE-HOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	27,721	27,325	396	10,242	7,124	207	718	700	1,493	9,413	8.09	2.903
Humboldt County												
Arcata	17,163	15,439	1,724	7,376	3,408	269	1,173	1,843	683	7,151	3.05	2.159
Blue Lake	1,176	1,176	0	576	380	21	68	36	71	523	9.20	2.249
Eureka	26,353	24,998	1,355	11,741	7,262	381	2,223	1,701	174	11,054	5.85	2.261
Ferndale	1,441	1,419	22	680	551	27	83	10	9	627	7.79	2.263
Fortuna	11,114	10,879	235	4,678	3,127	232	524	351	444	4,435	5.19	2.453
Rio Dell	3,218	3,208	10	1,454	1,010	26	150	36	232	1,238	14.86	2.591
Trinidad	318	318	0	233	183	8	11	0	31	172	26.18	1.849
Balance Of County	69,669	68,640	1,029	30,802	23,550	602	1,512	722	4,416	27,518	10.66	2.494
Incorporated	60,783	57,437	3,346	26,738	15,921	964	4,232	3,977	1,644	25,200	5.75	2.279
County Total	130,452	126,077	4,375	57,540	39,471	1,566	5,744	4,699	6,060	52,718	8.38	2.392
Imperial County												
Brawley	23,402	23,090	312	7,336	4,682	362	651	1,185	456	6,912	5.78	3.341
Calexico	34,256	34,153	103	8,667	5,862	439	898	1,263	205	8,458	2.41	4.038
Calipatria	7,791	3,603	4,188	1,064	730	38	75	158	63	995	6.48	3.621
El Centro	39,862	38,975	887	12,692	6,727	563	1,093	2,991	1,318	11,843	6.69	3.291
Holtville	5,726	5,596	130	1,620	1,037	111	117	162	193	1,567	3.27	3.571
Imperial	9,281	9,249	32	2,876	2,340	111	227	164	34	2,784	3.20	3.322
Westmorland	2,210	2,210	0	679	432	16	90	102	39	637	6.19	3.469
Balance Of County	33,870	28,108	5,762	12,152	5,825	273	419	209	5,426	9,247	23.91	3.040
Incorporated	122,528	116,876	5,652	34,934	21,810	1,640	3,151	6,025	2,308	33,196	4.98	3.521
County Total	156,398	144,984	11,414	47,086	27,635	1,913	3,570	6,234	7,734	42,443	9.86	3.416
Inyo County												
Bishop	3,620	3,543	77	1,873	843	78	262	323	367	1,690	9.77	2.096
Balance Of County	14,832	14,627	205	7,274	4,653	134	145	145	2,197	6,102	16.11	2.397
Incorporated	3,620	3,543	77	1,873	843	78	262	323	367	1,690	9.77	2.096
County Total	18,452	18,170	282	9,147	5,496	212	407	468	2,564	7,792	14.81	2.332
Kern County												
Arvin	14,591	14,520	71	3,443	2,382	218	264	322	257	3,296	4.27	4.405
Bakersfield	281,427	278,072	3,355	98,043	66,653	3,223	10,256	15,310	2,601	92,693	5.46	3.000
California City	11,366	8,696	2,670	3,612	2,689	68	310	226	319	3,112	13.84	2.794
Delano	43,420	37,838	5,582	9,611	6,823	547	600	1,192	449	9,153	4.77	4.134
Maricopa	1,146	1,146	0	461	248	7	5	9	192	405	12.15	2.830
Mcfarland	11,211	10,145	1,066	2,341	1,831	153	268	60	29	2,294	2.01	4.422

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Ridgecrest	27,182	26,785	397	11,382	7,510	412	1,697	765	998	10,392	8.70	2.577
Shafter	13,776	13,113	663	3,819	2,960	177	234	237	211	3,470	9.14	3.779
Taft	9,001	6,093	2,908	2,511	1,826	52	315	222	96	2,263	9.88	2.692
Tehachapi	11,752	7,004	4,748	3,023	1,886	150	385	281	321	2,629	13.03	2.664
Wasco	22,963	16,607	6,356	4,564	3,372	326	417	318	131	4,259	6.68	3.899
Balance Of County	282,658	278,137	4,521	105,108	72,448	3,249	5,990	4,788	18,633	90,268	14.12	3.081
Incorporated	447,835	420,019	27,816	142,810	98,180	5,333	14,751	18,942	5,604	133,966	6.19	3.135
County Total	730,493	698,156	32,337	247,918	170,628	8,582	20,741	23,730	24,237	224,234	9.55	3.114
Kings County												
Avenal	16,126	8,663	7,463	2,206	1,392	113	303	305	93	2,064	6.44	4.197
Corcoran	22,058	9,876	12,182	3,080	2,204	180	270	303	123	2,827	8.21	3.493
Hanford	45,904	45,056	848	15,999	11,668	552	1,396	2,041	342	15,140	5.37	2.976
Lemoore	21,717	21,715	2	7,405	4,922	152	459	1,543	329	7,001	5.46	3.102
Balance Of County	36,013	33,583	2,430	10,194	7,105	1,392	303	115	1,279	9,596	5.87	3.500
Incorporated	105,805	85,310	20,495	28,690	20,186	997	2,428	4,192	887	27,032	5.78	3.156
County Total	141,818	118,893	22,925	38,884	27,291	2,389	2,731	4,307	2,166	36,628	5.80	3.246
Lake County												
Clearlake	13,722	13,603	119	7,631	3,610	100	247	326	3,348	5,552	27.24	2.450
Lakeport	5,051	4,877	174	2,414	1,458	119	158	223	456	1,984	17.81	2.458
Balance Of County	43,482	42,572	910	23,302	15,759	315	499	361	6,368	17,041	26.87	2.498
Incorporated	18,773	18,480	293	10,045	5,068	219	405	549	3,804	7,536	24.98	2.452
County Total	62,255	61,052	1,203	33,347	20,827	534	904	910	10,172	24,577	26.30	2.484
Lassen County												
Susanville	17,908	8,826	9,082	4,022	2,850	131	381	450	210	3,644	9.40	2.422
Balance Of County	16,724	16,559	165	8,435	5,727	165	138	59	2,346	6,413	23.97	2.582
Incorporated	17,908	8,826	9,082	4,022	2,850	131	381	450	210	3,644	9.40	2.422
County Total	34,632	25,385	9,247	12,457	8,577	296	519	509	2,556	10,057	19.27	2.524
Los Angeles County												
Agoura Hills	22,071	22,048	23	7,209	5,276	979	176	778	0	7,087	1.69	3.111
Alhambra	89,488	87,565	1,923	30,100	12,745	3,275	3,963	10,100	17	29,140	3.19	3.005
Arcadia	55,730	55,149	581	20,131	11,871	1,698	1,379	5,157	26	19,303	4.11	2.857
Artesia	17,157	16,585	572	4,627	3,208	327	323	673	96	4,499	2.77	3.686
Avalon	3,489	3,427	62	1,922	502	487	547	377	9	1,226	36.21	2.795

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Azusa	48,051	46,102	1,949	13,456	6,176	1,766	1,465	3,460	589	12,976	3.57	3.553
Baldwin Park	80,134	79,528	606	17,673	11,912	1,861	604	2,953	343	17,197	2.69	4.625
Bell	38,562	38,024	538	9,303	3,581	1,517	1,453	2,291	461	9,003	3.22	4.223
Bellflower	76,814	76,191	623	24,523	11,319	2,085	1,433	8,084	1,602	23,633	3.63	3.224
Bell Gardens	45,818	45,362	456	9,768	3,957	2,469	1,440	1,506	396	9,446	3.30	4.802
Beverly Hills	35,614	35,575	39	16,032	5,715	236	1,805	8,248	28	15,201	5.18	2.340
Bradbury	935	935	0	326	324	0	2	0	0	297	8.90	3.148
Burbank	105,178	104,352	826	43,105	19,944	1,728	4,689	16,632	112	41,859	2.89	2.493
Calabasas	22,833	22,773	60	8,315	5,720	804	204	1,334	253	8,046	3.24	2.830
Carson	96,062	94,818	1,244	26,031	18,265	2,280	716	2,265	2,505	25,323	2.72	3.744
Cerritos	54,532	54,439	93	15,856	13,363	1,220	600	641	32	15,636	1.39	3.482
Claremont	36,260	30,914	5,346	11,862	8,262	843	635	2,109	13	11,577	2.40	2.670
Commerce	13,341	13,138	203	3,414	1,944	585	330	551	4	3,321	2.72	3.956
Compton	97,691	97,041	650	23,855	15,900	2,140	2,274	2,903	638	22,384	6.17	4.335
Covina	49,002	48,400	602	16,431	9,400	1,297	977	4,169	588	16,036	2.40	3.018
Cudahy	25,599	25,587	12	5,621	1,679	1,291	344	1,893	414	5,497	2.21	4.655
Culver City	40,472	39,948	524	17,141	6,613	1,903	2,304	6,140	181	16,622	3.03	2.403
Diamond Bar	59,342	59,224	118	18,162	12,809	2,501	823	1,696	333	17,851	1.71	3.318
Downey	112,544	110,779	1,765	34,988	20,463	1,662	1,644	11,026	193	34,213	2.22	3.238
Duarte	22,524	22,034	490	6,850	4,324	876	224	1,197	229	6,679	2.50	3.299
El Monte	123,156	121,886	1,270	28,293	15,170	3,396	2,023	6,298	1,406	27,555	2.61	4.423
El Segundo	16,821	16,798	23	7,307	3,129	416	817	2,934	11	7,106	2.75	2.364
Gardena	60,851	60,047	804	21,282	9,121	1,711	2,695	6,652	1,103	20,556	3.41	2.921
Glendale	204,844	201,980	2,864	74,334	26,114	3,814	6,914	37,395	97	72,410	2.59	2.789
Glendora	51,851	50,844	1,007	17,272	12,571	1,094	695	2,029	883	16,943	1.90	3.001
Hawaiian Gardens	15,666	15,662	4	3,685	1,518	492	450	950	275	3,566	3.23	4.392
Hawthorne	87,965	87,465	500	29,728	8,254	2,429	3,323	15,549	173	28,632	3.69	3.055
Hermosa Beach	19,500	19,387	113	9,916	4,163	1,008	2,104	2,559	82	9,548	3.71	2.030
Hidden Hills	2,011	2,011	0	609	607	2	0	0	0	585	3.94	3.438
Huntington Park	64,307	64,126	181	15,420	5,271	2,370	2,209	5,556	14	14,942	3.10	4.292
Industry	799	535	264	124	101	23	0	0	0	121	2.42	4.421
Inglewood	117,307	115,937	1,370	38,645	13,955	3,227	4,737	16,488	238	36,801	4.77	3.150
Irwindale	1,487	1,485	2	373	313	15	13	24	8	360	3.49	4.125
La Canada Flintridge	21,367	21,178	189	7,053	6,546	200	132	175	0	6,886	2.37	3.076
La Habra Heights	6,134	6,134	0	2,010	1,978	24	8	0	0	1,944	3.28	3.155
Lakewood	82,907	82,713	194	27,373	22,238	741	730	3,566	98	26,915	1.67	3.073
La Mirada	50,019	47,900	2,119	15,073	11,890	800	480	1,737	166	14,838	1.56	3.228
Lancaster	128,891	121,593	7,298	43,584	28,496	1,195	2,616	7,779	3,498	39,908	8.43	3.047
La Puente	42,951	42,919	32	9,692	6,355	642	340	2,246	109	9,493	2.05	4.521
La Verne	33,152	32,444	708	11,355	7,552	599	734	707	1,763	11,139	1.90	2.913
Lawndale	33,127	33,041	86	9,890	4,914	1,606	919	2,323	128	9,575	3.19	3.451
Lomita	20,972	20,839	133	8,326	4,026	774	581	2,447	498	8,045	3.37	2.590
Long Beach	485,941	475,578	10,363	173,460	69,259	10,091	23,285	68,296	2,529	164,825	4.98	2.885
Los Angeles	3,901,614	3,818,092	83,522	1,356,107	528,631	88,016	129,477	600,897	9,086	1,292,995	4.65	2.953
Lynwood	72,783	70,583	2,200	14,999	8,164	1,690	1,696	3,337	112	14,406	3.95	4.900
Malibu	13,521	13,221	300	6,329	4,000	475	404	840	610	5,307	16.15	2.491
Manhattan Beach	36,487	36,473	14	15,549	10,598	1,384	2,663	871	33	14,971	3.72	2.436
Maywood	29,314	29,220	94	6,710	2,812	1,109	1,442	1,339	8	6,478	3.46	4.511
Monrovia	38,705	38,412	293	14,036	7,732	1,549	1,324	3,316	115	13,579	3.26	2.829

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Montebello	65,064	64,755	309	19,500	9,362	1,577	2,863	5,465	233	18,926	2.94	3.421
Monterey Park	63,771	63,494	277	20,590	11,639	2,204	2,009	4,658	80	19,933	3.19	3.185
Norwalk	109,211	107,194	2,017	27,788	20,187	1,412	829	4,900	460	27,116	2.42	3.953
Palmdale	130,974	130,880	94	39,946	30,919	905	938	5,402	1,782	36,919	7.58	3.545
Palos Verdes Estates	14,051	14,046	5	5,256	4,834	40	44	338	0	5,045	4.01	2.784
Paramount	57,594	57,274	320	14,588	6,041	2,165	1,088	3,922	1,372	13,969	4.24	4.100
Pasadena	143,658	140,140	3,518	55,791	24,845	4,292	4,654	21,927	73	53,433	4.23	2.623
Pico Rivera	66,619	66,269	350	16,936	12,693	934	337	2,382	590	16,594	2.02	3.994
Pomona	157,985	152,384	5,601	40,071	24,407	3,339	3,233	7,387	1,705	38,307	4.40	3.978
Rancho Palos Verdes	43,071	42,562	509	15,781	12,198	1,287	245	2,051	0	15,327	2.88	2.777
Redondo Beach	66,762	66,575	187	29,909	11,773	4,238	4,077	9,441	380	28,919	3.31	2.302
Rolling Hills	1,956	1,956	0	684	677	7	0	0	0	647	5.41	3.023
Rolling Hills Estates	8,103	8,091	12	2,917	2,300	565	41	7	4	2,843	2.54	2.846
Rosemead	56,574	55,962	612	14,557	9,861	2,030	907	1,355	404	14,119	3.01	3.964
San Dimas	36,640	35,431	1,209	12,582	7,564	2,100	357	1,618	943	12,240	2.72	2.895
San Fernando	24,698	24,652	46	5,964	4,017	634	478	762	73	5,806	2.65	4.246
San Gabriel	41,812	41,057	755	13,018	7,060	1,156	1,081	3,677	44	12,693	2.50	3.235
San Marino	13,544	13,537	7	4,453	4,417	19	8	9	0	4,282	3.84	3.161
Santa Clarita	164,515	163,122	1,393	54,810	33,085	6,314	2,625	10,546	2,240	53,077	3.16	3.073
Santa Fe Springs	17,701	17,483	218	5,107	3,101	286	158	1,435	127	5,004	2.02	3.494
Santa Monica	90,324	87,718	2,606	49,369	9,367	1,928	5,582	32,203	289	45,897	7.03	1.911
Sierra Madre	11,039	10,912	127	4,930	3,407	205	377	914	27	4,763	3.39	2.291
Signal Hill	10,604	10,550	54	4,141	1,311	467	680	1,675	8	3,950	4.61	2.671
South El Monte	22,044	22,026	18	4,724	2,934	458	233	595	504	4,620	2.20	4.768
South Gate	101,144	101,003	141	24,431	12,356	3,261	3,697	4,837	280	23,368	4.35	4.322
South Pasadena	25,456	25,269	187	10,913	5,072	624	1,108	4,095	14	10,538	3.44	2.398
Temple City	35,226	34,715	511	11,827	9,563	802	421	983	58	11,487	2.87	3.022
Torrance	145,850	144,601	1,249	56,784	30,447	3,693	3,318	18,143	1,183	55,338	2.55	2.613
Vernon	95	95	0	26	19	0	0	7	0	25	3.85	3.800
Walnut	31,601	31,561	40	8,481	8,124	119	46	192	0	8,345	1.60	3.782
West Covina	111,131	110,323	808	32,533	21,164	2,812	1,570	6,639	348	31,876	2.02	3.461
West Hollywood	37,661	37,425	236	24,388	1,808	681	1,847	20,052	0	23,390	4.09	1.600
Westlake Village	8,813	8,804	9	3,381	2,239	608	158	201	175	3,303	2.31	2.665
Whittier	86,836	84,856	1,980	28,993	19,069	1,480	2,056	6,174	214	28,286	2.44	3.000
Balance Of County	1,062,045	1,045,476	16,569	303,437	209,454	22,882	18,227	41,955	10,919	289,448	4.61	3.612
Incorporated	9,015,820	8,855,163	160,657	3,020,404	1,408,610	219,364	270,230	1,076,485	45,715	2,894,866	4.16	3.059
County Total	10,077,865	9,900,639	177,226	3,323,841	1,618,064	242,246	288,457	1,118,440	56,634	3,184,314	4.20	3.109
Madera County												
Chowchilla	15,520	8,385	7,135	2,927	2,302	31	254	304	36	2,766	5.50	3.031
Madera	48,807	48,369	438	13,748	9,080	742	1,465	2,160	301	13,152	4.34	3.678
Balance Of County	72,107	71,321	786	26,923	22,211	563	601	417	3,131	23,134	14.07	3.083
Incorporated	64,327	56,754	7,573	16,675	11,382	773	1,719	2,464	337	15,918	4.54	3.565
County Total	136,434	128,075	8,359	43,598	33,593	1,336	2,320	2,881	3,468	39,052	10.43	3.280

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COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Marin County												
Belvedere	2,135	2,135	0	1,065	874	54	94	43	0	962	9.67	2.219
Corte Madera	9,383	9,375	8	3,974	2,618	416	369	561	10	3,898	1.91	2.405
Fairfax	7,317	7,287	30	3,421	2,332	193	492	393	11	3,309	3.27	2.202
Larkspur	12,022	11,867	155	6,424	2,448	360	544	2,833	239	6,153	4.22	1.929
Mill Valley	13,655	13,564	91	6,318	4,120	536	535	1,127	0	6,179	2.20	2.195
Novato	49,532	48,662	870	19,852	11,624	2,668	1,162	3,680	718	19,362	2.47	2.513
Ross	2,351	2,257	94	814	794	0	12	0	8	770	5.41	2.931
San Anselmo	12,374	12,118	256	5,412	3,994	185	458	757	18	5,271	2.61	2.299
San Rafael	57,067	55,047	2,020	23,398	10,592	2,020	2,476	7,821	489	22,810	2.51	2.413
Sausalito	7,352	7,340	12	4,529	1,724	423	1,353	805	224	4,272	5.67	1.718
Tiburon	8,786	8,680	106	3,952	2,416	237	462	837	0	3,768	4.66	2.304
Balance Of County	68,819	61,607	7,212	27,672	21,327	1,480	1,569	2,882	414	25,709	7.09	2.396
Incorporated	181,974	178,332	3,642	79,159	43,536	7,092	7,957	18,857	1,717	76,754	3.04	2.323
County Total	250,793	239,939	10,854	106,831	64,863	8,572	9,526	21,739	2,131	102,463	4.09	2.342
Mariposa County												
County Total	17,711	16,341	1,370	9,466	6,093	330	214	383	2,446	7,093	25.07	2.304
Mendocino County												
Fort Bragg	6,878	6,752	126	3,097	2,011	158	314	459	155	2,883	6.91	2.342
Point Arena	481	481	0	223	139	7	45	13	19	196	12.11	2.454
Ukiah	15,866	15,132	734	6,325	3,497	379	762	1,225	462	6,168	2.48	2.453
Willits	5,020	4,894	126	2,002	1,188	84	293	291	146	1,925	3.85	2.542
Balance Of County	60,700	59,415	1,285	26,627	20,010	535	709	778	4,595	23,284	12.55	2.552
Incorporated	28,245	27,259	986	11,647	6,835	628	1,414	1,988	782	11,172	4.08	2.440
County Total	88,945	86,674	2,271	38,274	26,845	1,163	2,123	2,766	5,377	34,456	9.98	2.515
Merced County												
Atwater	26,511	24,735	1,776	8,637	5,724	584	832	990	507	7,714	10.69	3.207
Dos Palos	4,821	4,797	24	1,554	1,335	55	48	78	38	1,482	4.63	3.237
Gustine	5,255	5,255	0	1,939	1,578	30	98	105	128	1,851	4.54	2.839
Livingston	11,756	11,719	37	2,704	2,077	80	206	305	36	2,638	2.44	4.442
Los Banos	30,794	30,619	175	9,431	7,695	263	538	658	277	9,046	4.08	3.385
Merced	70,180	68,810	1,370	23,301	14,231	944	2,707	4,711	708	22,115	5.09	3.111
Balance Of County	84,076	83,092	984	26,509	20,702	581	840	628	3,758	24,328	8.23	3.415
Incorporated	149,317	145,935	3,382	47,566	32,640	1,956	4,429	6,847	1,694	44,846	5.72	3.254
	233,393	229,027	4,366	74,075	53,342	2,537	5,269	7,475	5,452	69,174		
County Total	233,393	229,027	4,366	74,075	53,342	2,537	5,269	7,475	5,452	69,174	6.62	3.311

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Modoc County												
Alturas	2,823	2,743	80	1,367	1,020	54	47	144	102	1,181	13.61	2.323
Balance Of County	6,757	6,430	327	3,643	2,397	33	50	15	1,148	2,757	24.32	2.332
Incorporated	2,823	2,743	80	1,367	1,020	54	47	144	102	1,181	13.61	2.323
County Total	9,580	9,173	407	5,010	3,417	87	97	159	1,250	3,938	21.40	2.329
Mono County												
Mammoth Lakes	7,298	7,080	218	8,683	2,241	1,003	1,758	3,488	193	3,069	64.66	2.307
Balance Of County	6,054	5,850	204	4,176	2,760	256	307	74	779	2,561	38.67	2.284
Incorporated	7,298	7,080	218	8,683	2,241	1,003	1,758	3,488	193	3,069	64.66	2.307
County Total	13,352	12,930	422	12,859	5,001	1,259	2,065	3,562	972	5,630	56.22	2.297
Monterey County												
Carmel-By-The-Sea	4,134	4,134	0	3,345	2,750	111	214	270	0	2,293	31.45	1.803
Del Rey Oaks	1,667	1,667	0	727	567	25	23	109	3	704	3.16	2.368
Gonzales	8,490	8,417	73	1,918	1,411	127	169	169	42	1,886	1.67	4.463
Greenfield	13,270	13,174	96	2,833	1,944	282	274	247	86	2,747	3.04	4.796
King City	11,566	11,382	184	2,886	1,615	278	288	415	290	2,797	3.08	4.069
Marina	19,266	19,135	131	8,606	3,444	1,537	1,457	1,748	420	6,799	21.00	2.814
Monterey	29,779	27,121	2,658	13,495	5,918	913	2,266	4,377	21	12,725	5.71	2.131
Pacific Grove	15,698	15,523	175	8,044	5,014	448	981	1,510	91	7,327	8.91	2.119
Salinas	149,906	147,454	2,452	41,285	22,137	3,463	3,479	10,920	1,286	39,867	3.43	3.699
Sand City	310	246	64	107	59	6	28	9	5	99	7.48	2.485
Seaside	33,674	31,280	2,394	10,972	5,999	2,351	920	1,270	432	9,702	11.57	3.224
Soledad	26,315	14,264	12,051	3,192	2,338	204	317	210	123	3,114	2.44	4.581
Balance Of County	106,727	105,080	1,647	38,636	29,661	2,695	1,548	1,741	2,991	35,281	8.68	2.978
Incorporated	314,075	293,797	20,278	97,410	53,196	9,745	10,416	21,254	2,799	90,060	7.55	3.262
County Total	420,802	398,877	21,925	136,046	82,857	12,440	11,964	22,995	5,790	125,341	7.87	3.182
Napa County												
American Canyon	13,114	12,980	134	4,448	3,515	23	68	61	781	4,360	1.98	2.977
Calistoga	5,176	5,109	67	2,263	1,055	97	186	361	564	2,056	9.15	2.485
Napa	75,688	74,229	1,459	29,246	17,849	2,098	2,811	5,099	1,389	28,406	2.87	2.613
St Helena	5,975	5,923	52	2,743	1,675	215	214	478	161	2,412	12.07	2.456
Yountville	3,258	2,077	1,181	1,164	610	172	39	35	308	1,072	7.90	1.938
Balance Of County	28,017	25,569	2,448	11,674	9,929	650	355	8	732	9,970	14.60	2.565
Incorporated	103,211	100,318	2,893	39,864	24,704	2,605	3,318	6,034	3,203	38,306	3.91	2.619

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	131,228	125,887	5,341	51,538	34,633	3,255	3,673	6,042	3,935	48,276	6.33	2.608
Nevada County												
Grass Valley	12,215	11,865	350	5,909	2,779	256	743	1,439	692	5,628	4.76	2.108
Nevada City	3,032	2,845	187	1,444	1,122	53	117	78	74	1,340	7.20	2.123
Truckee	15,211	15,170	41	10,796	9,071	242	659	526	298	5,697	47.23	2.663
Balance Of County	66,876	66,535	341	29,245	25,816	320	243	205	2,661	26,695	8.72	2.492
Incorporated	30,458	29,880	578	18,149	12,972	551	1,519	2,043	1,064	12,665	30.22	2.359
County Total	97,334	96,415	919	47,394	38,788	871	1,762	2,248	3,725	39,360	16.95	2.450
Orange County												
Aliso Viejo	44,678	44,518	160	17,968	6,455	4,935	739	5,824	15	17,470	2.77	2.548
Anaheim	340,490	336,694	3,796	100,764	43,452	8,923	10,408	33,597	4,384	97,987	2.76	3.436
Brea	38,959	38,831	128	14,292	8,273	1,095	553	3,501	870	14,015	1.94	2.771
Buena Park	80,631	79,697	934	23,848	14,038	1,900	1,420	6,199	291	23,353	2.08	3.413
Costa Mesa	113,010	109,836	3,174	40,947	15,623	4,156	5,934	14,021	1,213	39,731	2.97	2.764
Cypress	48,449	48,128	321	16,381	10,118	2,540	517	2,842	364	15,999	2.33	3.008
Dana Point	36,531	36,289	242	15,880	7,839	2,266	2,798	2,607	370	14,640	7.81	2.479
Fountain Valley	56,520	56,008	512	18,482	12,370	2,194	644	2,876	398	18,171	1.68	3.082
Fullerton	134,182	130,971	3,211	46,296	23,683	3,728	3,711	14,253	921	45,094	2.60	2.904
Garden Grove	171,038	168,804	2,234	47,069	26,681	4,486	3,410	10,674	1,818	46,150	1.95	3.658
Huntington Beach	198,831	198,039	792	77,221	38,138	9,457	9,708	16,777	3,141	75,175	2.65	2.634
Irvine	171,825	163,942	7,883	63,014	25,001	13,733	4,408	18,850	1,022	60,066	4.68	2.729
Laguna Beach	24,773	24,651	122	13,174	8,224	759	1,762	2,105	324	11,696	11.22	2.108
Laguna Hills	33,010	32,586	424	11,108	5,833	2,183	608	2,267	217	10,763	3.11	3.028
Laguna Niguel	65,667	65,364	303	24,664	13,590	5,007	1,441	4,610	16	23,974	2.80	2.726
Laguna Woods	18,286	18,212	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.446
La Habra	61,453	60,858	595	19,719	10,461	1,659	1,352	5,508	739	19,217	2.55	3.167
Lake Forest	77,665	76,821	844	26,385	14,166	3,923	1,276	5,734	1,286	25,712	2.55	2.988
La Palma	16,039	16,008	31	5,131	3,637	376	102	989	27	5,043	1.72	3.174
Los Alamitos	11,933	11,527	406	4,362	1,941	245	1,033	1,014	129	4,279	1.90	2.694
Mission Viejo	97,751	96,686	1,065	33,714	24,475	4,021	1,201	3,928	89	33,166	1.63	2.915
Newport Beach	82,177	81,237	940	41,851	18,729	7,162	5,467	9,630	863	37,285	10.91	2.179
Orange	136,699	131,367	5,332	43,372	24,762	5,149	4,698	7,424	1,339	42,365	2.32	3.101
Placentia	49,890	49,587	303	16,010	9,614	2,050	1,104	2,665	577	15,708	1.89	3.157
Rancho Santa Margarita	49,023	49,009	14	16,684	9,118	3,889	598	3,079	0	16,419	1.59	2.985
San Clemente	63,016	62,724	292	25,389	14,208	2,414	4,010	4,354	403	23,841	6.10	2.631
San Juan Capistrano	35,833	35,407	426	11,676	5,996	2,395	944	865	1,476	11,274	3.44	3.141
Santa Ana	349,189	343,542	5,647	75,022	33,582	6,493	7,519	23,519	3,909	73,426	2.13	4.679
Seal Beach	25,134	24,875	259	14,347	4,633	2,121	1,167	6,263	163	13,212	7.91	1.883
Stanton	38,615	38,097	518	11,065	2,988	1,873	988	3,954	1,262	10,820	2.21	3.521
Tustin	70,341	69,923	418	25,850	8,340	3,489	3,836	9,277	908	24,166	6.51	2.893
Villa Park	6,203	6,182	21	2,020	1,991	18	0	6	5	1,962	2.87	3.151
Westminster	91,463	90,911	552	27,185	14,871	2,449	2,081	4,716	3,068	26,646	1.98	3.412

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Yorba Linda	63,992	63,857	135	20,681	16,357	2,207	534	1,272	311	20,348	1.61	3.138
Balance Of County	114,094	112,573	1,521	37,912	29,507	2,694	1,926	3,257	528	35,847	5.45	3.140
Incorporated	2,903,296	2,861,188	42,108	965,200	479,914	123,307	88,445	241,590	31,944	931,764	3.46	3.071
County Total	3,017,390	2,973,761	43,629	1,003,112	509,421	126,001	90,371	244,847	32,472	967,611	3.54	3.073
Placer County												
Auburn	12,826	12,620	206	5,732	3,841	211	655	1,025	0	5,569	2.84	2.266
Colfax	1,806	1,805	1	784	503	21	164	63	33	758	3.32	2.381
Lincoln	23,410	23,296	114	9,964	8,783	196	176	713	96	9,587	3.78	2.430
Loomis	6,323	6,289	34	2,342	1,963	199	58	9	113	2,274	2.90	2.766
Rocklin	49,667	49,457	210	19,175	13,624	516	820	3,776	439	18,461	3.72	2.679
Roseville	98,399	97,345	1,054	40,136	29,529	1,082	1,627	7,355	543	38,700	3.58	2.515
Balance Of County	104,126	102,663	1,463	51,178	40,911	1,916	2,527	2,331	3,493	39,450	22.92	2.602
Incorporated	192,431	190,812	1,619	78,133	58,243	2,225	3,500	12,941	1,224	75,349	3.56	2.532
County Total	296,557	293,475	3,082	129,311	99,154	4,141	6,027	15,272	4,717	114,799	11.22	2.556
Plumas County												
Portola	2,173	2,152	21	1,038	783	12	72	110	61	926	10.79	2.324
Balance Of County	18,794	18,627	167	13,214	10,091	433	303	286	2,101	8,648	34.55	2.154
Incorporated	2,173	2,152	21	1,038	783	12	72	110	61	926	10.79	2.324
County Total	20,967	20,779	188	14,252	10,874	445	375	396	2,162	9,574	32.82	2.170
Riverside County												
Banning	27,582	27,244	338	11,153	8,248	728	426	595	1,156	10,217	8.39	2.667
Beaumont	16,580	16,425	155	6,033	4,468	172	340	706	347	5,499	8.85	2.987
Blythe	22,156	13,045	9,111	5,171	2,882	151	502	801	835	4,338	16.11	3.007
Calimesa	7,454	7,358	96	3,287	1,800	111	57	64	1,255	3,019	8.15	2.437
Canyon Lake	10,813	10,797	16	4,260	3,896	133	6	84	141	3,836	9.95	2.815
Cathedral City	49,294	49,098	196	20,023	10,677	2,587	2,369	1,644	2,746	15,697	21.61	3.128
Coachella	28,055	28,011	44	6,011	3,495	319	700	1,042	455	5,751	4.33	4.871
Corona	143,806	143,174	632	43,807	30,196	2,186	2,225	7,587	1,613	42,210	3.65	3.392
Desert Hot Springs	19,311	19,137	174	7,947	4,682	180	1,193	1,313	579	6,619	16.71	2.891
Hemet	66,021	64,342	1,679	31,408	13,775	1,748	2,133	4,497	9,255	27,471	12.54	2.342
Indian Wells	4,498	4,498	0	4,388	2,915	884	112	469	8	2,264	48.40	1.987
Indio	59,983	59,127	856	20,068	10,794	878	1,431	3,795	3,170	16,462	17.97	3.592
Lake Elsinore	35,872	35,799	73	11,424	8,109	707	735	1,099	774	10,597	7.24	3.378
La Quinta	32,997	32,957	40	15,942	13,164	1,448	386	685	259	11,398	28.50	2.891
Moreno Valley	157,355	156,658	697	44,457	37,594	891	1,389	3,540	1,043	42,099	5.30	3.721
Murrieta	78,788	78,128	660	26,509	20,175	211	463	3,971	1,689	25,283	4.62	3.090
Norco	25,790	21,164	4,626	6,658	6,244	137	9	177	91	6,508	2.25	3.252

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Palm Desert	45,463	45,236	227	30,001	12,207	9,534	2,486	4,576	1,198	20,540	31.54	2.202
Palm Springs	44,895	44,199	696	31,339	10,585	6,160	2,508	9,851	2,235	20,860	33.44	2.119
Perris	41,912	41,680	232	11,850	8,175	321	371	1,264	1,719	10,838	8.54	3.846
Rancho Mirage	15,738	15,271	467	13,331	5,853	3,680	615	1,196	1,987	7,686	42.34	1.987
Riverside	280,928	271,305	9,623	91,349	58,106	4,185	5,826	20,801	2,431	87,131	4.62	3.114
San Jacinto	27,111	26,921	190	10,476	6,042	596	651	567	2,620	9,192	12.26	2.929
Temecula	78,585	78,563	22	24,984	19,817	386	598	3,862	321	23,936	4.19	3.282
Balance Of County	482,755	477,069	5,686	178,090	119,623	4,178	3,359	5,673	45,257	153,131	14.01	3.115
Incorporated	1,320,987	1,290,137	30,850	481,876	303,899	38,333	27,531	74,186	37,927	419,451	12.95	3.076
County Total	1,803,742	1,767,206	36,536	659,966	423,522	42,511	30,890	79,859	83,184	572,582	13.24	3.086
Sacramento County												
Citrus Heights	87,686	86,809	877	35,374	19,588	3,531	3,021	7,355	1,879	33,937	4.06	2.558
Elk Grove	109,948	109,453	495	36,812	33,903	919	525	1,192	273	35,962	2.31	3.044
Folsom	66,025	59,544	6,481	23,411	16,331	635	629	4,944	872	22,406	4.29	2.658
Galt	22,165	21,977	188	6,961	5,559	208	340	482	372	6,696	3.81	3.282
Isleton	838	838	0	382	221	1	77	36	47	341	10.73	2.457
Rancho Cordova	54,667	54,317	350	21,296	10,247	2,024	1,983	5,653	1,389	20,344	4.47	2.670
Sacramento	444,041	434,858	9,183	176,219	104,930	11,372	15,950	40,287	3,680	166,244	5.66	2.616
Balance Of County	560,264	552,631	7,633	212,409	136,702	13,588	13,882	41,165	7,072	204,876	3.55	2.697
Incorporated	785,370	767,796	17,574	300,455	190,779	18,690	22,525	59,949	8,512	285,930	4.83	2.685
County Total	1,345,634	1,320,427	25,207	512,864	327,481	32,278	36,407	101,114	15,584	490,806	4.30	2.690
San Benito County												
Hollister	36,746	36,575	171	10,586	7,976	531	992	781	306	10,364	2.10	3.529
San Juan Bautista	1,709	1,709	0	677	455	70	73	62	17	624	7.83	2.739
Balance Of County	18,275	17,939	336	6,304	5,217	427	70	42	548	5,925	6.01	3.028
Incorporated	38,455	38,284	171	11,263	8,431	601	1,065	843	323	10,988	2.44	3.484
County Total	56,730	56,223	507	17,567	13,648	1,028	1,135	885	871	16,913	3.72	3.324
San Bernardino County												
Adelanto	21,322	19,757	1,565	6,269	4,400	149	382	831	507	5,328	15.01	3.708
Apple Valley	61,494	61,131	363	21,773	16,516	726	2,077	1,417	1,037	20,039	7.96	3.051
Barstow	23,282	22,934	348	9,636	5,373	356	1,292	1,500	1,115	8,039	16.57	2.853
Big Bear Lake	6,043	6,018	25	9,210	7,724	326	360	410	390	2,479	73.08	2.428
Chino	75,621	64,654	10,967	18,555	13,115	952	790	3,170	528	17,939	3.32	3.604
Chino Hills	76,603	76,452	151	22,290	17,926	1,378	300	2,000	686	21,880	1.84	3.494
Colton	50,922	50,658	264	15,949	9,363	602	1,059	4,110	815	14,769	7.40	3.430
Fontana	155,199	154,700	499	41,163	31,793	1,198	1,581	5,709	882	38,992	5.27	3.967
Grand Terrace	12,259	12,050	209	4,478	2,883	175	265	905	250	4,240	5.31	2.842

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Hesperia	70,492	70,161	331	22,900	18,147	893	1,028	1,624	1,208	21,419	6.47	3.276
Highland	49,378	49,138	240	15,659	11,610	512	598	2,129	810	14,205	9.29	3.459
Loma Linda	21,004	20,040	964	8,475	3,508	673	1,307	2,425	562	7,900	6.78	2.537
Montclair	34,819	34,207	612	9,099	5,254	758	1,002	1,331	754	8,833	2.92	3.873
Needles	5,401	5,390	11	2,715	1,426	86	254	367	582	2,065	23.94	2.610
Ontario	168,365	167,264	1,101	45,850	27,209	3,649	3,964	8,893	2,135	44,169	3.67	3.787
Rancho Cucamonga	155,184	151,558	3,626	48,964	33,340	2,601	1,798	9,853	1,372	47,487	3.02	3.192
Redlands	69,010	67,044	1,966	25,667	16,464	900	2,422	4,967	914	24,427	4.83	2.745
Rialto	98,375	97,571	804	26,557	18,888	586	1,810	3,479	1,794	25,144	5.32	3.880
San Bernardino	196,777	190,251	6,526	63,857	37,708	2,716	5,712	13,251	4,470	56,806	11.04	3.349
Twentynine Palms	23,861	17,729	6,132	8,581	4,638	1,301	1,661	445	536	6,604	23.04	2.685
Upland	72,901	72,316	585	25,848	14,926	1,766	2,675	5,636	845	24,918	3.60	2.902
Victorville	77,881	75,344	2,537	25,461	18,872	389	1,333	3,109	1,758	23,644	7.14	3.187
Yucaipa	47,553	46,981	572	17,728	11,562	394	726	819	4,227	16,716	5.71	2.811
Yucca Valley	18,771	18,460	311	8,439	6,571	140	643	378	707	7,374	12.62	2.503
Balance Of County	300,637	292,748	7,889	127,144	102,126	4,214	4,231	3,034	13,539	92,458	27.28	3.166
Incorporated	1,592,517	1,551,808	40,709	505,123	339,216	23,226	35,039	78,758	28,884	465,416	7.86	3.334
County Total	1,893,154	1,844,556	48,598	632,267	441,342	27,440	39,270	81,792	42,423	557,874	11.77	3.306
San Diego County												
Carlsbad	92,830	91,917	913	39,269	21,361	5,763	2,531	8,323	1,291	36,625	6.73	2.510
Chula Vista	208,785	207,377	1,408	70,067	37,532	5,454	4,708	18,527	3,846	67,960	3.01	3.051
Coronado	23,066	18,059	5,007	9,558	4,460	870	822	3,383	23	7,779	18.61	2.322
Del Mar	4,548	4,546	2	2,595	1,357	366	200	672	0	2,211	14.80	2.056
El Cajon	97,472	94,989	2,483	35,439	13,656	1,548	2,244	15,957	2,034	34,441	2.82	2.758
Encinitas	62,475	61,916	559	25,178	14,194	4,535	2,125	3,555	769	24,108	4.25	2.568
Escondido	140,257	138,492	1,765	46,374	22,651	2,922	3,121	13,782	3,898	45,106	2.73	3.070
Imperial Beach	27,731	27,085	646	9,814	4,038	687	1,059	3,690	340	9,343	4.80	2.899
La Mesa	55,984	54,938	1,046	24,993	11,119	1,922	2,003	9,590	359	24,235	3.03	2.267
Lemon Grove	25,547	24,956	591	8,764	5,789	714	694	1,470	97	8,530	2.67	2.926
National City	57,657	52,128	5,529	15,465	6,624	1,336	1,688	5,380	437	15,060	2.62	3.461
Oceanside	173,008	171,728	1,280	62,732	32,739	8,222	4,389	13,961	3,421	59,475	5.19	2.887
Poway	50,551	50,125	426	16,202	12,080	877	345	2,209	691	15,948	1.57	3.143
San Diego	1,287,703	1,247,174	40,529	487,254	226,280	45,771	43,093	165,678	6,432	467,520	4.05	2.668
San Marcos	67,307	66,769	538	22,498	12,042	1,083	897	4,816	3,660	21,603	3.98	3.091
Santee	53,928	52,885	1,043	18,786	10,607	1,615	1,198	2,863	2,503	18,423	1.93	2.871
Solana Beach	13,408	13,374	34	6,533	2,976	1,265	622	1,631	39	5,823	10.87	2.297
Vista	93,883	91,617	2,266	30,544	15,345	2,029	2,201	8,840	2,129	29,584	3.14	3.097
Balance Of County	475,630	442,522	33,108	159,201	108,087	10,979	6,508	18,435	15,192	149,105	6.34	2.968
Incorporated	2,536,140	2,470,075	66,065	932,065	454,850	86,979	73,940	284,327	31,969	893,774	4.11	2.764
County Total	3,011,770	2,912,597	99,173	1,091,266	562,937	97,958	80,448	302,762	47,161	1,042,879	4.43	2.793
San Francisco County												

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
City and County Total	795,042	775,337	19,705	353,717	62,870	48,696	81,571	160,020	560	336,710	4.81	2.303
San Joaquin County												
Escalon	6,690	6,664	26	2,319	1,913	20	153	98	135	2,237	3.54	2.979
Lathrop	12,508	12,498	10	3,476	2,958	63	92	12	351	3,378	2.82	3.700
Lodi	61,737	60,713	1,024	22,466	14,287	1,453	1,762	4,500	464	21,745	3.21	2.792
Manteca	60,148	59,671	477	20,075	14,965	739	1,106	2,396	869	19,401	3.36	3.076
Ripon	12,365	12,254	111	4,075	3,479	119	151	316	10	3,983	2.26	3.077
Stockton	271,005	266,445	4,560	88,826	55,538	6,592	8,411	16,997	1,288	85,051	4.25	3.133
Tracy	74,621	74,276	345	23,005	18,726	1,015	943	1,846	475	22,411	2.58	3.314
Balance Of County	135,897	125,495	10,402	43,207	34,766	1,240	806	592	5,803	41,069	4.95	3.056
Incorporated	499,074	492,521	6,553	164,242	111,866	10,001	12,618	26,165	3,592	158,206	3.68	3.113
County Total	634,971	618,016	16,955	207,449	146,632	11,241	13,424	26,757	9,395	199,275	3.94	3.101
San Luis Obispo County												
Arroyo Grande	16,610	16,400	210	7,179	4,892	601	489	649	548	6,889	4.04	2.381
Atascadero	27,736	25,914	1,822	10,377	7,297	441	862	1,220	557	10,043	3.22	2.580
El Paso De Robles	27,262	26,811	451	10,230	6,726	864	1,023	1,200	417	9,957	2.67	2.693
Grover Beach	13,275	13,149	126	5,547	3,217	786	708	589	247	5,177	6.67	2.540
Morro Bay	10,539	10,341	198	6,459	4,196	394	646	464	759	5,152	20.24	2.007
Pismo Beach	8,731	8,704	27	5,693	3,082	576	463	485	1,087	4,381	23.05	1.987
San Luis Obispo	44,248	42,386	1,862	19,617	9,266	1,272	2,217	5,360	1,502	18,939	3.46	2.238
Balance Of County	110,215	98,847	11,368	43,506	32,557	1,278	1,940	1,208	6,523	37,962	12.74	2.604
Incorporated	148,401	143,705	4,696	65,102	38,676	4,934	6,408	9,967	5,117	60,538	7.01	2.374
County Total	258,616	242,552	16,064	108,608	71,233	6,212	8,348	11,175	11,640	98,500	9.31	2.462
San Mateo County												
Atherton	7,236	6,918	318	2,532	2,493	32	0	7	0	2,439	3.67	2.836
Belmont	25,327	24,700	627	10,712	6,285	581	275	3,571	0	10,551	1.50	2.341
Brisbane	3,670	3,630	40	1,876	1,036	260	179	358	43	1,660	11.51	2.187
Burlingame	28,177	27,691	486	12,934	6,147	423	987	5,377	0	12,574	2.78	2.202
Colma	1,295	1,246	49	375	211	66	71	21	6	360	4.00	3.461
Daly City	104,186	103,396	790	31,623	16,104	4,469	2,829	7,596	625	31,082	1.71	3.327
East Palo Alto	31,798	31,609	189	7,679	3,901	376	360	2,883	159	7,553	1.64	4.185
Foster City	29,726	29,639	87	12,449	4,809	2,464	767	4,402	7	12,039	3.29	2.462
Half Moon Bay	12,356	11,508	848	4,325	2,733	536	310	319	427	4,209	2.68	2.734
Hillsborough	10,948	10,946	2	3,864	3,844	11	9	0	0	3,748	3.00	2.920
Menlo Park	30,658	29,787	871	12,750	6,875	930	1,574	3,366	5	12,422	2.57	2.398
Millbrae	20,647	20,315	332	8,120	5,319	269	428	2,093	11	7,963	1.93	2.551
Pacifica	38,527	38,346	181	14,359	10,354	782	723	2,402	98	14,107	1.75	2.718
Portola Valley	4,521	4,451	70	1,804	1,496	33	8	267	0	1,731	4.05	2.571
Redwood City	75,763	73,836	1,927	29,191	13,543	3,656	2,607	8,552	833	28,323	2.97	2.607

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
San Bruno	40,868	40,647	221	15,311	9,089	566	1,188	4,446	22	15,002	2.02	2.709
San Carlos	27,912	27,729	183	11,825	8,252	608	482	2,467	16	11,587	2.01	2.393
San Mateo	93,871	92,555	1,316	39,019	17,724	3,492	3,017	14,741	45	38,092	2.38	2.430
South San Francisco	60,925	60,482	443	20,352	11,964	2,485	1,672	3,822	409	19,887	2.28	3.041
Woodside	5,452	5,446	6	2,077	2,015	28	28	5	1	1,994	4.00	2.731
Balance Of County	64,058	62,675	1,383	22,356	18,472	690	918	1,429	847	21,612	3.33	2.900
Incorporated	653,863	644,877	8,986	243,177	134,194	22,067	17,514	66,695	2,707	237,323	2.41	2.717
County Total	717,921	707,552	10,369	265,533	152,666	22,757	18,432	68,124	3,554	258,935	2.48	2.733
Santa Barbara County												
Buellton	4,454	4,448	6	1,722	1,073	100	33	98	418	1,664	3.37	2.673
Carpinteria	14,353	14,228	125	5,513	2,155	422	529	1,467	940	5,035	8.67	2.826
Goleta	30,695	30,353	342	11,483	5,858	1,588	753	2,663	621	11,198	2.48	2.711
Guadalupe	6,307	6,307	0	1,612	1,158	168	181	99	6	1,573	2.42	4.010
Lompoc	42,224	38,524	3,700	13,899	7,299	1,044	1,931	2,685	940	13,326	4.12	2.891
Santa Barbara	90,418	88,626	1,792	37,331	17,185	2,884	5,533	11,211	518	35,850	3.97	2.472
Santa Maria	85,275	83,077	2,198	25,159	15,735	1,471	1,705	4,673	1,575	24,387	3.07	3.407
Solvang	5,576	5,416	160	2,326	1,332	151	171	453	219	2,281	1.93	2.374
Balance Of County	135,951	127,353	8,598	48,649	34,062	2,736	2,705	5,805	3,341	46,323	4.78	2.749
Incorporated	279,302	270,979	8,323	99,045	51,795	7,828	10,836	23,349	5,237	95,314	3.77	2.843
County Total	415,253	398,332	16,921	147,694	85,857	10,564	13,541	29,154	8,578	141,637	4.10	2.812
Santa Clara County												
Campbell	38,366	38,076	290	16,444	6,996	1,994	2,442	4,755	257	16,076	2.24	2.368
Cupertino	52,883	52,402	481	19,520	11,976	2,028	1,674	3,833	9	19,024	2.54	2.755
Gilroy	46,420	45,990	430	13,670	9,013	755	1,310	2,161	431	13,352	2.33	3.444
Los Altos	27,645	27,226	419	10,748	9,184	364	273	911	16	10,482	2.47	2.597
Los Altos Hills	8,395	8,330	65	3,016	2,952	32	17	9	6	2,936	2.65	2.837
Los Gatos	28,886	28,184	702	12,544	7,095	1,837	934	2,555	123	12,161	3.05	2.318
Milpitas	64,931	61,757	3,174	18,082	10,930	2,225	1,631	2,724	572	17,840	1.34	3.462
Monte Sereno	3,518	3,518	0	1,254	1,150	13	18	73	0	1,228	2.07	2.865
Morgan Hill	35,659	35,146	513	11,839	7,368	1,662	702	1,195	912	11,577	2.21	3.036
Mountain View	71,964	71,448	516	33,129	9,197	3,889	2,670	16,142	1,231	31,914	3.67	2.239
Palo Alto	60,537	59,869	668	27,019	15,592	976	1,736	8,551	164	26,156	3.19	2.289
San Jose	930,734	920,374	10,360	294,530	165,157	27,743	23,282	67,320	11,028	289,053	1.86	3.184
Santa Clara	107,717	104,930	2,787	41,915	18,254	3,712	3,908	15,932	109	40,748	2.78	2.575
Saratoga	30,457	30,096	361	10,871	9,640	560	197	467	7	10,668	1.87	2.821
Sunnyvale	132,350	131,475	875	54,194	21,126	3,940	4,911	20,121	4,096	52,971	2.26	2.482
Balance Of County	99,477	91,745	7,732	31,932	25,143	1,683	1,159	3,264	683	30,854	3.38	2.974
Incorporated	1,640,462	1,618,821	21,641	568,775	305,630	51,730	45,705	146,749	18,961	556,186	2.21	2.911
County Total	1,739,939	1,710,566	29,373	600,707	330,773	53,413	46,864	150,013	19,644	587,040	2.28	2.914

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Cruz County												
Capitola	10,009	9,853	156	5,388	1,978	514	1,139	1,107	650	4,761	11.64	2.070
Santa Cruz	56,037	50,656	5,381	22,184	12,250	1,947	2,595	4,952	440	21,088	4.94	2.402
Scotts Valley	11,542	11,090	452	4,565	2,463	415	415	468	804	4,410	3.40	2.515
Watsonville	48,059	47,506	553	12,930	6,706	1,594	1,698	2,032	900	12,582	2.69	3.776
Balance Of County	133,338	130,127	3,211	56,066	40,817	4,368	2,600	3,823	4,458	50,464	9.99	2.579
Incorporated	125,647	119,105	6,542	45,067	23,397	4,470	5,847	8,559	2,794	42,841	4.94	2.780
County Total	258,985	249,232	9,753	101,133	64,214	8,838	8,447	12,382	7,252	93,305	7.74	2.671
Shasta County												
Anderson	10,072	9,954	118	3,945	2,528	209	374	655	179	3,717	5.78	2.678
Redding	87,269	84,812	2,457	36,017	23,448	949	4,587	4,437	2,596	34,206	5.03	2.479
Shasta Lake	10,031	9,979	52	4,100	3,220	27	245	114	494	3,730	9.02	2.675
Balance Of County	68,314	67,519	795	29,019	20,427	272	367	198	7,755	25,729	11.34	2.624
Incorporated	107,372	104,745	2,627	44,062	29,196	1,185	5,206	5,206	3,269	41,653	5.47	2.515
County Total	175,686	172,264	3,422	73,081	49,623	1,457	5,573	5,404	11,024	67,382	7.80	2.557
Sierra County												
Loyalton	881	851	30	367	318	13	3	0	33	342	6.81	2.488
Balance Of County	2,659	2,653	6	1,891	1,547	36	44	63	201	1,220	35.48	2.175
Incorporated	881	851	30	367	318	13	3	0	33	342	6.81	2.488
County Total	3,540	3,504	36	2,258	1,865	49	47	63	234	1,562	30.82	2.243
Siskiyou County												
Dorris	886	886	0	403	318	2	16	0	67	349	13.40	2.539
Dunsmuir	1,892	1,892	0	1,171	792	23	126	184	46	868	25.88	2.180
Etna	773	773	0	365	268	10	19	13	55	332	9.04	2.328
Fort Jones	665	665	0	336	238	11	34	2	51	306	8.93	2.173
Montague	1,475	1,456	19	628	477	8	10	43	90	578	7.96	2.519
Mount Shasta	3,675	3,627	48	1,856	1,177	89	260	256	74	1,722	7.22	2.106
Tulelake	1,007	1,007	0	461	317	2	44	19	79	360	21.91	2.797
Weed	2,983	2,823	160	1,300	895	19	136	190	60	1,190	8.46	2.372
Yreka	7,359	7,139	220	3,392	2,214	140	288	511	239	3,199	5.69	2.232
Balance Of County	24,426	24,141	285	12,827	9,318	184	185	96	3,044	10,316	19.58	2.340
Incorporated	20,715	20,268	447	9,912	6,696	304	933	1,218	761	8,904	10.17	2.276
County Total	45,141	44,409	732	22,739	16,014	488	1,118	1,314	3,805	19,220	15.48	2.311

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Solano County												
Benicia	27,003	26,949	54	10,617	6,872	1,049	921	1,449	326	10,397	2.07	2.592
Dixon	16,332	16,291	41	5,254	4,338	213	368	249	86	5,154	1.90	3.161
Fairfield	103,347	99,889	3,458	35,205	23,630	2,413	2,289	5,981	892	34,048	3.29	2.934
Rio Vista	6,261	6,261	0	2,743	2,325	34	103	171	110	2,614	4.70	2.395
Suisun City	27,428	27,334	94	8,569	7,233	189	327	754	66	8,401	1.96	3.254
Vacaville	95,113	85,557	9,556	30,987	21,620	1,036	2,143	4,880	1,308	30,350	2.06	2.819
Vallejo	121,136	118,943	2,193	42,692	29,644	1,782	3,919	6,001	1,346	41,016	3.93	2.900
Balance Of County	19,759	19,152	607	7,122	5,995	222	295	119	491	6,693	6.02	2.861
Incorporated	396,620	381,224	15,396	136,067	95,662	6,716	10,070	19,485	4,134	131,980	3.00	2.888
County Total	416,379	400,376	16,003	143,189	101,657	6,938	10,365	19,604	4,625	138,673	3.15	2.887
Sonoma County												
Cloverdale	7,959	7,882	77	3,088	2,344	131	112	293	208	2,942	4.73	2.679
Cotati	7,042	7,024	18	2,842	1,613	402	373	333	121	2,783	2.08	2.524
Healdsburg	11,631	11,508	123	4,515	3,234	252	451	479	99	4,331	4.08	2.657
Petaluma	56,057	55,317	740	21,087	15,219	1,652	1,305	1,980	931	20,700	1.84	2.672
Rohnert Park	42,256	41,155	1,101	15,977	7,660	1,698	929	4,277	1,413	15,669	1.93	2.627
Santa Rosa	154,855	151,121	3,734	61,130	36,713	5,704	4,853	11,175	2,685	59,494	2.68	2.540
Sebastopol	7,765	7,554	211	3,351	2,007	253	535	497	59	3,280	2.12	2.303
Sonoma	9,714	9,623	91	5,018	2,828	690	470	593	437	4,702	6.30	2.047
Windsor	24,855	24,764	91	8,534	6,624	460	250	378	822	8,380	1.80	2.955
Balance Of County	151,387	145,562	5,825	65,049	52,572	2,896	2,918	2,055	4,608	57,266	11.96	2.542
Incorporated	322,134	315,948	6,186	125,542	78,242	11,242	9,278	20,005	6,775	122,281	2.60	2.584
County Total	473,521	461,510	12,011	190,591	130,814	14,138	12,196	22,060	11,383	179,547	5.79	2.570
Stanislaus County												
Ceres	37,458	37,359	99	11,399	8,696	343	617	1,031	712	11,042	3.13	3.383
Hughson	5,248	5,242	6	1,614	1,259	65	66	135	89	1,576	2.35	3.326
Modesto	206,861	203,630	3,231	72,018	50,524	4,010	6,239	9,254	1,991	69,638	3.30	2.924
Newman	8,339	8,273	66	2,503	2,091	76	193	117	26	2,392	4.43	3.459
Oakdale	17,173	16,994	179	6,292	4,684	207	499	691	211	6,081	3.35	2.795
Patterson	14,209	13,980	229	3,918	3,386	190	151	63	128	3,778	3.57	3.700
Riverbank	18,256	18,121	135	5,303	4,467	185	180	182	289	5,130	3.26	3.532
Turlock	64,417	62,331	2,086	21,652	14,694	961	1,822	3,571	604	20,873	3.60	2.986
Waterford	7,882	7,865	17	2,315	1,899	47	172	168	29	2,215	4.32	3.551
Balance Of County	113,672	112,202	1,470	35,911	28,532	1,058	945	421	4,955	34,105	5.03	3.290
Incorporated	379,843	373,795	6,048	127,014	91,700	6,084	9,939	15,212	4,079	122,725	3.38	3.046
County Total	493,515	485,997	7,518	162,925	120,232	7,142	10,884	15,633	9,034	156,830	3.74	3.099

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Sutter County												
Live Oak	6,622	6,316	306	1,864	1,402	75	141	104	142	1,772	4.94	3.564
Yuba City	51,320	50,356	964	18,079	11,565	839	1,552	3,600	523	17,313	4.24	2.909
Balance Of County	28,474	28,316	158	10,188	8,588	272	219	76	1,033	9,683	4.96	2.924
Incorporated	57,942	56,672	1,270	19,943	12,967	914	1,693	3,704	665	19,085	4.30	2.969
County Total	86,416	84,988	1,428	30,131	21,555	1,186	1,912	3,780	1,698	28,768	4.52	2.954
Tehama County												
Corning	6,892	6,835	57	2,664	1,583	70	282	495	234	2,468	7.36	2.769
Red Bluff	13,568	13,033	535	5,732	3,361	220	697	1,090	364	5,260	8.23	2.478
Tehama	436	436	0	197	167	4	10	0	16	180	8.63	2.422
Balance Of County	37,901	37,469	432	16,041	9,763	194	239	78	5,767	14,066	12.31	2.664
Incorporated	20,896	20,304	592	8,593	5,111	294	989	1,585	614	7,908	7.97	2.568
County Total	58,797	57,773	1,024	24,634	14,874	488	1,228	1,663	6,381	21,974	10.80	2.629
Trinity County												
County Total	13,506	13,258	248	8,138	5,384	112	108	117	2,417	5,697	30.00	2.327
Tulare County												
Dinuba	18,688	18,574	114	5,038	3,820	280	268	465	205	4,848	3.77	3.831
Exeter	9,950	9,858	92	3,344	2,652	107	205	192	188	3,168	5.26	3.112
Farmersville	9,822	9,803	19	2,479	2,027	90	155	109	98	2,350	5.20	4.171
Lindsay	10,775	10,626	149	2,915	1,994	135	243	358	185	2,765	5.15	3.843
Porterville	43,348	41,751	1,597	13,555	9,452	483	1,528	1,448	644	12,693	6.36	3.289
Tulare	47,920	47,473	447	15,099	11,444	511	1,236	1,134	774	14,348	4.97	3.309
Visalia	103,162	101,540	1,622	35,882	26,266	1,572	3,539	3,035	1,470	33,918	5.47	2.994
Woodlake	7,041	7,032	9	1,928	1,266	126	152	324	60	1,828	5.19	3.847
Balance Of County	147,973	146,013	1,960	46,001	35,026	1,440	1,397	890	7,248	40,655	11.62	3.592
Incorporated	250,706	246,657	4,049	80,240	58,921	3,304	7,326	7,065	3,624	75,918	5.39	3.249
County Total	398,679	392,670	6,009	126,241	93,947	4,744	8,723	7,955	10,872	116,573	7.66	3.368
Tuolumne County												
Sonora	4,624	4,425	199	2,290	1,336	86	391	447	30	2,138	6.64	2.070
Balance Of County	52,004	47,334	4,670	27,094	21,139	566	787	627	3,975	19,646	27.49	2.409
Incorporated	4,624	4,425	199	2,290	1,336	86	391	447	30	2,138	6.64	2.070

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2004

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
County Total	56,628	51,759	4,869	29,384	22,475	652	1,178	1,074	4,005	21,784	25.86	2.376
Ventura County												
Camarillo	61,733	60,652	1,081	23,397	13,907	4,493	884	3,055	1,058	22,880	2.21	2.651
Fillmore	15,102	14,856	246	4,222	3,057	281	236	322	326	4,123	2.34	3.603
Moorpark	34,735	34,723	12	9,938	7,180	1,234	223	999	302	9,829	1.10	3.533
Ojai	8,082	7,892	190	3,283	2,268	266	289	452	8	3,141	4.33	2.513
Oxnard	185,802	183,205	2,597	48,750	27,594	4,576	4,384	9,250	2,946	47,034	3.52	3.895
Port Hueneme	22,388	21,280	1,108	7,981	2,364	2,204	1,201	2,171	41	7,391	7.39	2.879
San Buenaventura	104,851	102,405	2,446	40,880	23,048	3,428	4,201	7,580	2,623	39,566	3.21	2.588
Santa Paula	29,072	28,829	243	8,382	5,012	729	778	1,076	787	8,177	2.45	3.526
Simi Valley	118,590	117,790	800	39,250	29,489	2,741	1,655	4,473	892	38,353	2.29	3.071
Thousand Oaks	125,868	123,917	1,951	45,728	30,993	5,156	1,745	6,762	1,072	44,488	2.71	2.785
Balance Of County	95,992	93,546	2,446	32,745	26,029	2,348	1,017	1,168	2,183	30,800	5.94	3.037
Incorporated	706,223	695,549	10,674	231,811	144,912	25,108	15,596	36,140	10,055	224,982	2.95	3.092
County Total	802,215	789,095	13,120	264,556	170,941	27,456	16,613	37,308	12,238	255,782	3.32	3.085
Yolo County												
Davis	64,755	61,646	3,109	25,072	11,386	2,356	2,266	8,679	385	24,533	2.15	2.513
West Sacramento	38,187	37,981	206	14,590	9,004	879	938	2,234	1,535	13,713	6.01	2.770
Winters	6,899	6,893	6	2,189	1,757	105	67	182	78	2,136	2.42	3.227
Woodland	52,752	51,463	1,289	18,117	11,265	1,313	1,135	3,723	681	17,726	2.16	2.903
Balance Of County	22,698	18,805	3,893	7,059	4,785	305	192	804	973	6,643	5.89	2.831
Incorporated	162,593	157,983	4,610	59,968	33,412	4,653	4,406	14,818	2,679	58,108	3.10	2.719
County Total	185,291	176,788	8,503	67,027	38,197	4,958	4,598	15,622	3,652	64,751	3.40	2.730
Yuba County												
Marysville	13,027	12,420	607	5,023	2,790	339	767	1,119	8	4,710	6.23	2.637
Wheatland	3,233	3,233	0	1,094	808	37	155	55	39	1,052	3.84	3.073
Balance Of County	48,832	48,104	728	17,247	10,986	915	688	1,076	3,582	15,427	10.55	3.118
Incorporated	16,260	15,653	607	6,117	3,598	376	922	1,174	47	5,762	5.80	2.717
County Total	65,092	63,757	1,335	23,364	14,584	1,291	1,610	2,250	3,629	21,189	9.31	3.009
California												
Incorporated Total	29,735,056	29,073,826	661,230	10,383,735	5,546,400	831,820	942,381	2,750,510	312,624	9,896,111	4.70	2.938
Balance Of State Total	6,464,286	6,283,610	180,676	2,374,506	1,730,495	108,254	96,821	173,954	264,982	2,120,061	10.72	2.964
State Total	36,199,342	35,357,436	841,906	12,758,241	7,276,895	940,074	1,039,202	2,924,464	577,606	12,016,172	5.82	2.942

Table 1: E-5 County/State Population and Housing Estimates, 1/1/2005

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Alameda	1,499,356	1,471,855	27,501	558,836	300,014	39,146	61,595	150,451	7,630	542,101	2.99	2.715
Alpine	1,236	1,235	1	1,659	970	39	35	553	62	528	68.17	2.339
Amador	37,437	32,940	4,497	16,423	13,343	400	434	682	1,564	13,961	14.99	2.359
Butte	214,280	208,020	6,260	91,668	56,412	2,392	7,771	10,210	14,883	85,480	6.75	2.434
Calaveras	44,561	44,108	453	25,848	21,881	474	511	355	2,627	18,573	28.15	2.375
Colusa	20,921	20,501	420	7,342	5,428	229	412	463	810	6,617	9.87	3.098
Contra Costa	1,016,304	1,005,003	11,301	379,058	251,175	31,556	25,624	63,103	7,600	367,843	2.96	2.732
Del Norte	28,786	24,870	3,916	10,828	6,382	182	804	584	2,876	9,515	12.13	2.614
El Dorado	172,945	171,894	1,051	79,448	64,274	1,804	3,558	5,438	4,374	65,962	16.97	2.606
Fresno	881,258	862,397	18,861	290,752	193,020	10,060	24,718	49,346	13,608	271,888	6.49	3.172
Glenn	28,026	27,626	400	10,343	7,201	207	722	700	1,513	9,506	8.09	2.906
Humboldt	131,191	126,821	4,370	58,015	39,860	1,584	5,769	4,707	6,095	53,155	8.38	2.386
Imperial	161,089	149,320	11,769	48,495	28,557	2,032	3,611	6,519	7,776	43,737	9.81	3.414
Inyo	18,359	18,075	284	9,166	5,505	211	407	468	2,575	7,808	14.82	2.315
Kern	753,395	720,589	32,806	254,417	176,242	8,538	21,025	23,992	24,620	230,281	9.49	3.129
Kings	145,365	122,659	22,706	39,631	27,952	2,391	2,783	4,319	2,186	37,373	5.70	3.282
Lake	62,837	61,636	1,201	33,637	21,140	538	912	917	10,130	24,790	26.30	2.486
Lassen	34,998	25,725	9,273	12,652	8,715	352	523	509	2,553	10,214	19.27	2.519
Los Angeles	10,163,097	9,986,158	176,939	3,341,518	1,625,536	242,941	289,571	1,126,807	56,663	3,201,093	4.20	3.120
Madera	140,578	131,949	8,629	44,986	34,843	1,336	2,393	2,881	3,533	40,308	10.40	3.274
Marin	251,510	240,221	11,289	107,482	65,278	8,593	9,664	21,816	2,131	103,095	4.08	2.330
Mariposa	17,841	16,429	1,412	9,710	6,123	450	214	383	2,540	7,276	25.07	2.258
Mendocino	89,277	87,002	2,275	38,659	27,170	1,163	2,151	2,766	5,409	34,798	9.99	2.500
Merced	239,343	234,915	4,428	77,138	55,780	2,538	5,338	7,907	5,575	72,065	6.58	3.260
Modoc	9,610	9,200	410	5,063	3,455	86	97	159	1,266	3,978	21.43	2.313
Mono	13,441	13,064	377	13,210	5,084	1,259	2,093	3,776	998	5,774	56.29	2.263
Monterey	421,374	398,801	22,573	137,338	84,029	12,440	11,981	23,050	5,838	126,559	7.85	3.151
Napa	132,328	127,061	5,267	52,209	35,201	3,318	3,673	6,072	3,945	48,923	6.29	2.597
Nevada	98,172	97,260	912	48,393	39,503	871	1,888	2,379	3,752	40,157	17.02	2.422
Orange	3,045,218	3,001,324	43,894	1,013,036	513,034	126,864	90,821	249,964	32,353	977,224	3.54	3.071
Placer	307,485	304,252	3,233	134,846	104,033	4,141	6,067	15,867	4,738	119,990	11.02	2.536
Plumas	21,025	20,837	188	14,557	11,121	450	375	396	2,215	9,775	32.85	2.132
Riverside	1,882,812	1,846,735	36,077	690,037	448,803	42,659	31,332	83,714	83,529	598,689	13.24	3.085

California Department of Finance
Demographic Research Unit

Table 1: E-5 County/State Population and Housing Estimates, 1/1/2005

	POPULATION			HOUSING UNITS								PERSONS PER HOUSEHOLD
					SINGLE		MULTIPLE					
COUNTY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Sacramento	1,368,390	1,342,830	25,560	524,600	337,040	32,277	36,371	103,244	15,668	502,095	4.29	2.674
San Benito	56,989	56,482	507	17,638	13,719	1,028	1,135	885	871	16,980	3.73	3.326
San Bernardino	1,945,242	1,894,805	50,437	645,627	452,455	27,592	39,521	83,148	42,911	569,973	11.72	3.324
San Diego	3,038,074	2,936,106	101,968	1,104,990	568,814	97,989	81,853	309,097	47,237	1,056,119	4.42	2.780
San Francisco	798,038	777,689	20,349	355,101	62,925	48,696	81,704	161,216	560	338,024	4.81	2.301
San Joaquin	652,060	634,942	17,118	213,767	152,514	11,283	13,469	27,023	9,478	205,346	3.94	3.092
San Luis Obispo	261,345	245,505	15,840	110,793	72,728	6,289	8,542	11,438	11,796	100,494	9.30	2.443
San Mateo	720,530	710,191	10,339	266,551	152,942	22,880	18,494	68,664	3,571	259,930	2.48	2.732
Santa Barbara	417,789	400,382	17,407	149,448	86,941	10,640	13,658	29,593	8,616	143,340	4.09	2.793
Santa Clara	1,755,453	1,725,991	29,462	607,035	332,346	53,575	46,758	154,698	19,658	593,061	2.30	2.910
Santa Cruz	259,933	250,652	9,281	102,872	64,802	8,847	8,466	13,504	7,253	94,693	7.95	2.647
Shasta	177,717	174,303	3,414	73,985	50,393	1,460	5,587	5,497	11,048	68,220	7.79	2.555
Sierra	3,489	3,453	36	2,265	1,872	49	47	63	234	1,568	30.77	2.202
Siskiyou	45,459	44,745	714	23,047	16,225	499	1,122	1,314	3,887	19,472	15.51	2.298
Solano	418,592	402,688	15,904	146,251	103,707	7,046	10,517	20,355	4,626	141,187	3.46	2.852
Sonoma	475,461	463,355	12,106	191,949	131,783	14,336	12,302	22,140	11,388	180,852	5.78	2.562
Stanislaus	503,003	495,279	7,724	167,048	124,093	7,159	11,015	15,681	9,100	160,806	3.74	3.080
Sutter	88,766	87,334	1,432	31,175	22,425	1,192	1,912	3,945	1,701	29,772	4.50	2.933
Tehama	59,698	58,687	1,011	25,127	15,355	488	1,241	1,663	6,380	22,410	10.81	2.619
Trinity	13,773	13,543	230	8,198	5,425	112	108	117	2,436	5,739	30.00	2.360
Tulare	408,764	402,799	5,965	128,889	95,947	4,791	8,993	8,098	11,060	119,057	7.63	3.383
Tuolumne	56,710	51,885	4,825	29,752	22,746	652	1,178	1,074	4,102	22,056	25.87	2.352
Ventura	809,230	795,616	13,614	267,337	172,281	27,667	16,682	38,433	12,274	258,483	3.31	3.078
Yolo	188,261	179,898	8,363	68,537	39,237	4,989	4,657	15,999	3,655	66,027	3.66	2.725
Yuba	67,125	65,778	1,347	24,550	15,646	1,291	1,611	2,250	3,752	22,021	10.30	2.987
California	36,675,346	35,825,420	849,926	12,942,932	7,401,425	944,071	1,045,815	2,970,392	581,229	12,186,761	5.84	2.940

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Alameda County												
Alameda	74,338	73,514	824	32,112	13,057	3,964	5,065	9,726	300	31,199	2.84	2.356
Albany	16,654	16,621	33	7,315	3,779	197	823	2,510	6	7,075	3.28	2.349
Berkeley	104,010	98,150	5,860	47,368	20,148	1,756	9,317	16,088	59	45,385	4.19	2.163
Dublin	39,737	34,669	5,068	13,564	7,600	1,304	444	4,188	28	13,061	3.71	2.654
Emeryville	8,217	8,150	67	5,094	270	329	493	3,965	37	4,738	6.99	1.720
Fremont	209,336	207,577	1,759	71,237	42,182	7,181	2,983	18,135	756	69,991	1.75	2.966
Hayward	145,263	143,108	2,155	47,489	23,666	3,548	3,391	14,585	2,299	46,333	2.43	3.089
Livermore	80,293	79,986	307	29,002	21,023	2,365	1,238	3,945	431	28,471	1.83	2.809
Newark	43,476	43,387	89	13,414	9,205	1,238	766	2,146	59	13,253	1.20	3.274
Oakland	409,756	402,499	7,257	161,022	72,236	6,646	29,152	52,532	456	154,153	4.27	2.611
Piedmont	10,998	10,996	2	3,861	3,784	0	35	34	8	3,806	1.42	2.889
Pleasanton	67,292	67,057	235	25,253	16,536	2,742	1,163	4,356	456	24,561	2.74	2.730
San Leandro	81,013	80,186	827	31,842	19,415	2,028	2,246	7,249	904	31,139	2.21	2.575
Union City	70,311	69,969	342	19,783	12,678	2,379	1,106	2,717	903	19,536	1.25	3.582
Balance Of County	138,662	135,986	2,676	50,480	34,435	3,469	3,373	8,275	928	49,400	2.14	2.753
Incorporated	1,360,694	1,335,869	24,825	508,356	265,579	35,677	58,222	142,176	6,702	492,701	3.08	2.711
County Total	1,499,356	1,471,855	27,501	558,836	300,014	39,146	61,595	150,451	7,630	542,101	2.99	2.715
Alpine County												
County Total	1,236	1,235	1	1,659	970	39	35	553	62	528	68.17	2.339
Amador County												
Amador	216	216	0	102	83	12	5	2	0	96	5.88	2.250
Ione	7,577	3,396	4,181	1,373	1,081	54	66	87	85	1,285	6.41	2.643
Jackson	4,245	3,977	268	2,015	1,252	112	168	247	236	1,893	6.05	2.101
Plymouth	1,062	1,062	0	503	281	28	24	26	144	431	14.31	2.464
Sutter Creek	2,714	2,713	1	1,322	801	105	61	273	82	1,224	7.41	2.217
Balance Of County	21,623	21,576	47	11,108	9,845	89	110	47	1,017	9,032	18.69	2.389
Incorporated	15,814	11,364	4,450	5,315	3,498	311	324	635	547	4,929	7.26	2.306
County Total	37,437	32,940	4,497	16,423	13,343	400	434	682	1,564	13,961	14.99	2.359
Butte County												
Biggs	1,789	1,789	0	622	516	28	28	5	45	580	6.75	3.084
Chico	73,614	69,585	4,029	30,344	15,291	993	4,374	8,375	1,311	29,212	3.73	2.382
Gridley	5,705	5,583	122	2,120	1,720	45	139	141	75	1,989	6.18	2.807
Oroville	13,378	12,546	832	5,677	3,048	162	769	1,308	390	5,113	9.93	2.454
Paradise	26,519	25,899	620	12,643	8,776	338	770	290	2,469	11,843	6.33	2.187
Balance Of County	93,275	92,618	657	40,262	27,061	826	1,691	91	10,593	36,743	8.74	2.521
Incorporated	121,005	115,402	5,603	51,406	29,351	1,566	6,080	10,119	4,290	48,737	5.19	2.368

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
County Total	214,280	208,020	6,260	91,668	56,412	2,392	7,771	10,210	14,883	85,480	6.75	2.434
Calaveras County												
Angels City	3,518	3,518	0	1,708	1,191	67	122	113	215	1,544	9.60	2.278
Balance Of County	41,043	40,590	453	24,140	20,690	407	389	242	2,412	17,029	29.46	2.384
Incorporated	3,518	3,518	0	1,708	1,191	67	122	113	215	1,544	9.60	2.278
County Total	44,561	44,108	453	25,848	21,881	474	511	355	2,627	18,573	28.15	2.375
Colusa County												
Colusa	5,593	5,520	73	2,047	1,537	84	191	183	52	1,928	5.81	2.863
Williams	4,803	4,553	250	1,263	900	33	98	165	67	1,205	4.59	3.778
Balance Of County	10,525	10,428	97	4,032	2,991	112	123	115	691	3,484	13.59	2.993
Incorporated	10,396	10,073	323	3,310	2,437	117	289	348	119	3,133	5.35	3.215
County Total	20,921	20,501	420	7,342	5,428	229	412	463	810	6,617	9.87	3.098
Contra Costa County												
Antioch	100,308	99,892	416	33,424	25,089	2,205	1,783	4,078	269	32,560	2.58	3.068
Brentwood	41,936	41,899	37	14,152	12,759	370	267	405	351	13,635	3.65	3.073
Clayton	10,901	10,875	26	3,980	3,248	681	19	27	5	3,939	1.03	2.761
Concord	124,527	123,105	1,422	46,143	27,575	2,911	2,911	11,369	1,377	45,056	2.36	2.732
Danville	42,958	42,494	464	15,605	12,009	2,561	279	756	0	15,282	2.07	2.781
El Cerrito	23,234	23,058	176	10,504	7,332	343	1,309	1,488	32	10,250	2.42	2.250
Hercules	23,189	23,150	39	7,801	5,148	1,631	294	728	0	7,655	1.87	3.024
Lafayette	24,139	24,003	136	9,436	7,485	294	434	1,223	0	9,252	1.95	2.594
Martinez	36,556	35,220	1,336	14,913	9,557	2,237	988	2,107	24	14,609	2.04	2.411
Moraga	16,329	14,698	1,631	5,782	4,019	968	243	545	7	5,684	1.69	2.586
Oakley	28,950	28,883	67	8,993	8,244	84	74	170	421	8,864	1.43	3.258
Orinda	17,665	17,598	67	6,778	6,277	188	87	219	7	6,630	2.18	2.654
Pinole	19,461	19,243	218	6,990	5,130	498	366	981	15	6,904	1.23	2.787
Pittsburg	62,147	61,641	506	20,074	13,506	1,298	1,330	3,266	674	19,461	3.05	3.167
Pleasant Hill	33,394	32,934	460	14,293	8,436	1,631	709	3,465	52	14,007	2.00	2.351
Richmond	102,269	100,641	1,628	37,217	21,069	2,931	5,292	7,804	121	35,751	3.94	2.815
San Pablo	31,116	30,651	465	9,636	4,217	853	1,362	2,397	807	9,338	3.09	3.282
San Ramon	50,651	50,566	85	19,908	12,550	2,284	1,047	4,016	11	19,218	3.47	2.631
Walnut Creek	66,020	64,869	1,151	32,227	12,233	4,820	4,318	10,808	48	31,074	3.58	2.088
Balance Of County	160,554	159,583	971	61,202	45,292	2,768	2,512	7,251	3,379	58,674	4.13	2.720
Incorporated	855,750	845,420	10,330	317,856	205,883	28,788	23,112	55,852	4,221	309,169	2.73	2.734
County Total	1,016,304	1,005,003	11,301	379,058	251,175	31,556	25,624	63,103	7,600	367,843	2.96	2.732

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Del Norte County												
Crescent City	7,648	4,011	3,637	1,832	930	50	394	424	34	1,648	10.04	2.434
Balance Of County	21,138	20,859	279	8,996	5,452	132	410	160	2,842	7,867	12.55	2.651
Incorporated	7,648	4,011	3,637	1,832	930	50	394	424	34	1,648	10.04	2.434
County Total	28,786	24,870	3,916	10,828	6,382	182	804	584	2,876	9,515	12.13	2.614
El Dorado County												
Placerville	10,197	9,935	262	4,560	2,788	256	628	728	160	4,301	5.68	2.310
South Lake Tahoe	23,700	23,572	128	14,220	8,970	361	1,995	2,226	668	9,554	32.81	2.467
Balance Of County	139,048	138,387	661	60,668	52,516	1,187	935	2,484	3,546	52,107	14.11	2.656
Incorporated	33,897	33,507	390	18,780	11,758	617	2,623	2,954	828	13,855	26.22	2.418
County Total	172,945	171,894	1,051	79,448	64,274	1,804	3,558	5,438	4,374	65,962	16.97	2.606
Fresno County												
Clovis	85,789	85,309	480	30,897	21,730	549	3,082	4,620	916	29,796	3.56	2.863
Coalinga	17,050	11,186	5,864	3,874	2,599	127	283	546	319	3,527	8.96	3.172
Firebaugh	6,722	6,661	61	1,806	1,206	155	192	141	112	1,620	10.30	4.112
Fowler	4,717	4,628	89	1,472	1,052	50	160	163	47	1,432	2.72	3.232
Fresno	463,523	454,741	8,782	157,393	93,837	6,028	16,609	36,996	3,923	147,945	6.00	3.074
Huron	6,997	6,825	172	1,533	501	204	231	525	72	1,495	2.48	4.565
Kerman	11,426	11,395	31	3,208	2,351	153	248	340	116	3,113	2.96	3.660
Kingsburg	11,208	11,117	91	4,001	3,032	102	264	439	164	3,845	3.90	2.891
Mendota	8,716	8,708	8	2,021	1,185	139	311	313	73	1,965	2.77	4.432
Orange Cove	9,273	9,273	0	2,067	1,212	206	224	399	26	1,982	4.11	4.679
Parlier	12,675	12,573	102	2,933	2,016	234	184	485	14	2,714	7.47	4.633
Reedley	22,540	22,145	395	6,328	4,451	216	606	864	191	6,105	3.52	3.627
Sanger	22,048	21,908	140	6,156	4,470	194	571	758	163	5,928	3.70	3.696
San Joaquin	3,612	3,612	0	791	473	80	115	63	60	757	4.30	4.771
Selma	22,353	22,223	130	6,518	4,810	148	333	801	426	6,273	3.76	3.543
Balance Of County	172,609	170,093	2,516	59,754	48,095	1,475	1,305	1,893	6,986	53,391	10.65	3.186
Incorporated	708,649	692,304	16,345	230,998	144,925	8,585	23,413	47,453	6,622	218,497	5.41	3.168
County Total	881,258	862,397	18,861	290,752	193,020	10,060	24,718	49,346	13,608	271,888	6.49	3.172
Glenn County												
Orland	6,635	6,597	38	2,380	1,782	44	322	197	35	2,258	5.13	2.922
Willows	6,401	6,220	181	2,384	1,560	54	305	458	7	2,149	9.86	2.894
Balance Of County	14,990	14,809	181	5,579	3,859	109	95	45	1,471	5,099	8.60	2.904
Incorporated	13,036	12,817	219	4,764	3,342	98	627	655	42	4,407	7.49	2.908

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	28,026	27,626	400	10,343	7,201	207	722	700	1,513	9,506	8.09	2.906
Humboldt County												
Arcata	17,271	15,568	1,703	7,455	3,454	284	1,183	1,851	683	7,228	3.04	2.154
Blue Lake	1,177	1,177	0	578	382	21	68	36	71	525	9.17	2.242
Eureka	26,346	24,991	1,355	11,765	7,273	381	2,236	1,701	174	11,077	5.85	2.256
Ferndale	1,448	1,426	22	685	556	27	83	10	9	632	7.74	2.256
Fortuna	11,238	10,972	266	4,729	3,175	235	524	351	444	4,483	5.20	2.447
Rio Dell	3,236	3,226	10	1,466	1,018	26	150	36	236	1,248	14.87	2.585
Trinidad	317	317	0	233	183	8	11	0	31	172	26.18	1.843
Balance Of County	70,158	69,144	1,014	31,104	23,819	602	1,514	722	4,447	27,790	10.65	2.488
Incorporated	61,033	57,677	3,356	26,911	16,041	982	4,255	3,985	1,648	25,365	5.74	2.274
County Total	131,191	126,821	4,370	58,015	39,860	1,584	5,769	4,707	6,095	53,155	8.38	2.386
Imperial County												
Brawley	23,915	23,603	312	7,514	4,841	362	664	1,191	456	7,080	5.78	3.334
Calexico	36,079	35,976	103	9,148	6,298	439	898	1,308	205	8,927	2.42	4.030
Calipatria	7,884	3,626	4,258	1,073	739	38	75	158	63	1,003	6.52	3.615
El Centro	40,817	39,930	887	13,029	6,972	563	1,097	3,079	1,318	12,157	6.69	3.285
Holtville	5,715	5,585	130	1,620	1,037	111	117	162	193	1,567	3.27	3.564
Imperial	9,516	9,484	32	2,955	2,413	117	227	164	34	2,860	3.21	3.316
Westmorland	2,430	2,430	0	748	435	16	90	167	40	702	6.15	3.462
Balance Of County	34,733	28,686	6,047	12,408	5,822	386	443	290	5,467	9,441	23.91	3.038
Incorporated	126,356	120,634	5,722	36,087	22,735	1,646	3,168	6,229	2,309	34,296	4.96	3.517
County Total	161,089	149,320	11,769	48,495	28,557	2,032	3,611	6,519	7,776	43,737	9.81	3.414
Inyo County												
Bishop	3,598	3,521	77	1,875	845	78	262	323	367	1,692	9.76	2.081
Balance Of County	14,761	14,554	207	7,291	4,660	133	145	145	2,208	6,116	16.12	2.380
Incorporated	3,598	3,521	77	1,875	845	78	262	323	367	1,692	9.76	2.081
County Total	18,359	18,075	284	9,166	5,505	211	407	468	2,575	7,808	14.82	2.315
Kern County												
Arvin	14,971	14,900	71	3,513	2,406	218	264	368	257	3,363	4.27	4.431
Bakersfield	295,985	292,617	3,368	102,584	70,848	3,223	10,414	15,462	2,637	96,986	5.46	3.017
California City	11,505	8,854	2,651	3,657	2,732	68	312	226	319	3,151	13.84	2.810
Delano	45,071	39,065	6,006	9,866	7,063	549	612	1,192	450	9,396	4.76	4.158
Maricopa	1,148	1,148	0	459	247	7	5	9	191	403	12.20	2.849
Mcfarland	12,181	11,083	1,098	2,543	1,886	236	268	124	29	2,492	2.01	4.447

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Ridgecrest	27,413	27,054	359	11,419	7,541	414	1,697	765	1,002	10,426	8.70	2.595
Shafter	14,125	13,468	657	3,900	3,041	177	234	237	211	3,544	9.13	3.800
Taft	9,055	6,138	2,917	2,515	1,829	52	315	222	97	2,267	9.86	2.708
Tehachapi	11,909	7,128	4,781	3,059	1,922	150	385	281	321	2,660	13.04	2.680
Wasco	23,714	17,273	6,441	4,720	3,485	360	425	318	132	4,405	6.67	3.921
Balance Of County	286,318	281,861	4,457	106,182	73,242	3,084	6,094	4,788	18,974	91,188	14.12	3.091
Incorporated	467,077	438,728	28,349	148,235	103,000	5,454	14,931	19,204	5,646	139,093	6.17	3.154
County Total	753,395	720,589	32,806	254,417	176,242	8,538	21,025	23,992	24,620	230,281	9.49	3.129
Kings County												
Avenal	16,155	8,844	7,311	2,216	1,395	113	309	305	94	2,073	6.45	4.266
Corcoran	22,491	10,389	12,102	3,188	2,311	180	270	303	124	2,926	8.22	3.551
Hanford	47,900	47,052	848	16,440	12,051	552	1,442	2,053	342	15,557	5.37	3.024
Lemoore	22,429	22,427	2	7,525	5,040	154	459	1,543	329	7,114	5.46	3.153
Balance Of County	36,390	33,947	2,443	10,262	7,155	1,392	303	115	1,297	9,703	5.45	3.499
Incorporated	108,975	88,712	20,263	29,369	20,797	999	2,480	4,204	889	27,670	5.79	3.206
County Total	145,365	122,659	22,706	39,631	27,952	2,391	2,783	4,319	2,186	37,373	5.70	3.282
Lake County												
Clearlake	13,719	13,600	119	7,623	3,640	104	247	326	3,306	5,546	27.25	2.452
Lakeport	5,077	4,903	174	2,425	1,463	119	164	223	456	1,993	17.81	2.460
Balance Of County	44,041	43,133	908	23,589	16,037	315	501	368	6,368	17,251	26.87	2.500
Incorporated	18,796	18,503	293	10,048	5,103	223	411	549	3,762	7,539	24.97	2.454
County Total	62,837	61,636	1,201	33,637	21,140	538	912	917	10,130	24,790	26.30	2.486
Lassen County												
Susanville	18,049	8,935	9,114	4,084	2,908	131	385	450	210	3,700	9.40	2.415
Balance Of County	16,949	16,790	159	8,568	5,807	221	138	59	2,343	6,514	23.97	2.578
Incorporated	18,049	8,935	9,114	4,084	2,908	131	385	450	210	3,700	9.40	2.415
County Total	34,998	25,725	9,273	12,652	8,715	352	523	509	2,553	10,214	19.27	2.519
Los Angeles County												
Agoura Hills	23,186	23,163	23	7,549	5,280	979	176	1,114	0	7,421	1.70	3.121
Alhambra	90,014	88,091	1,923	30,182	12,740	3,282	3,963	10,180	17	29,219	3.19	3.015
Arcadia	55,976	55,395	581	20,155	11,879	1,698	1,411	5,141	26	19,326	4.11	2.866
Artesia	17,207	16,635	572	4,626	3,207	327	323	673	96	4,498	2.77	3.698
Avalon	3,488	3,426	62	1,915	498	487	550	371	9	1,222	36.19	2.804

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Azusa	48,233	46,284	1,949	13,465	6,183	1,766	1,467	3,460	589	12,985	3.56	3.564
Baldwin Park	80,728	80,122	606	17,747	11,980	1,861	610	2,953	343	17,269	2.69	4.640
Bell	38,723	38,185	538	9,312	3,590	1,517	1,453	2,291	461	9,012	3.22	4.237
Bellflower	77,038	76,415	623	24,515	11,311	2,085	1,433	8,084	1,602	23,625	3.63	3.234
Bell Gardens	46,026	45,570	456	9,781	3,966	2,469	1,444	1,506	396	9,459	3.29	4.818
Beverly Hills	35,748	35,709	39	16,040	5,723	236	1,803	8,250	28	15,209	5.18	2.348
Bradbury	944	944	0	328	326	0	2	0	0	299	8.84	3.157
Burbank	106,084	105,258	826	43,338	19,935	1,731	4,686	16,874	112	42,085	2.89	2.501
Calabasas	22,981	22,921	60	8,350	5,755	804	204	1,334	253	8,081	3.22	2.836
Carson	97,726	96,421	1,305	26,385	18,619	2,280	716	2,265	2,505	25,667	2.72	3.757
Cerritos	54,734	54,641	93	15,863	13,370	1,220	600	641	32	15,643	1.39	3.493
Claremont	36,442	31,096	5,346	11,893	8,284	852	635	2,109	13	11,607	2.40	2.679
Commerce	13,422	13,219	203	3,424	1,944	593	332	551	4	3,331	2.72	3.968
Compton	98,195	97,545	650	23,901	15,926	2,150	2,274	2,903	648	22,427	6.17	4.349
Covina	49,260	48,658	602	16,465	9,431	1,298	979	4,169	588	16,069	2.41	3.028
Cudahy	25,688	25,676	12	5,622	1,680	1,291	344	1,893	414	5,498	2.21	4.670
Culver City	40,621	40,097	524	17,149	6,621	1,903	2,304	6,140	181	16,630	3.03	2.411
Diamond Bar	59,584	59,466	118	18,177	12,824	2,501	823	1,696	333	17,866	1.71	3.328
Downey	112,915	111,150	1,765	34,991	20,461	1,667	1,644	11,026	193	34,216	2.21	3.248
Duarte	22,696	22,206	490	6,881	4,350	881	224	1,197	229	6,709	2.50	3.310
El Monte	125,062	123,792	1,270	28,642	15,319	3,396	2,023	6,498	1,406	27,895	2.61	4.438
El Segundo	16,920	16,897	23	7,326	3,124	416	820	2,955	11	7,124	2.76	2.372
Gardena	61,050	60,246	804	21,283	9,122	1,711	2,695	6,652	1,103	20,557	3.41	2.931
Glendale	205,746	202,882	2,864	74,423	26,118	3,814	6,914	37,480	97	72,497	2.59	2.798
Glendora	52,055	51,042	1,013	17,283	12,582	1,094	695	2,029	883	16,954	1.90	3.011
Hawaiian Gardens	15,772	15,768	4	3,698	1,516	492	455	960	275	3,579	3.22	4.406
Hawthorne	88,245	87,745	500	29,726	8,250	2,429	3,325	15,549	173	28,630	3.69	3.065
Hermosa Beach	19,487	19,374	113	9,877	4,139	1,013	2,084	2,559	82	9,510	3.72	2.037
Hidden Hills	2,025	2,025	0	611	609	2	0	0	0	587	3.93	3.450
Huntington Park	64,528	64,347	181	15,423	5,271	2,371	2,211	5,556	14	14,945	3.10	4.306
Industry	801	537	264	124	101	23	0	0	0	121	2.42	4.438
Inglewood	117,442	116,072	1,370	38,564	13,958	3,228	4,720	16,420	238	36,724	4.77	3.161
Irwindale	1,492	1,490	2	373	313	15	13	24	8	360	3.49	4.139
La Canada Flintridge	21,475	21,286	189	7,066	6,559	200	132	175	0	6,899	2.36	3.085
La Habra Heights	6,154	6,154	0	2,010	1,978	24	8	0	0	1,944	3.28	3.166
Lakewood	83,159	82,965	194	27,367	22,232	741	730	3,566	98	26,909	1.67	3.083
La Mirada	50,178	48,059	2,119	15,074	11,891	800	480	1,737	166	14,839	1.56	3.239
Lancaster	132,925	125,340	7,585	44,781	29,693	1,197	2,614	7,779	3,498	41,004	8.43	3.057
La Puente	43,091	43,059	32	9,692	6,355	642	340	2,246	109	9,493	2.05	4.536
La Verne	33,278	32,570	708	11,362	7,557	599	736	707	1,763	11,146	1.90	2.922
Lawndale	33,252	33,166	86	9,895	4,919	1,606	919	2,323	128	9,580	3.18	3.462
Lomita	21,060	20,927	133	8,334	4,034	774	581	2,447	498	8,053	3.37	2.599
Long Beach	488,591	478,198	10,393	173,848	69,299	10,091	23,294	68,635	2,529	165,194	4.98	2.895
Los Angeles	3,932,740	3,849,730	83,010	1,363,250	529,103	88,122	130,130	606,809	9,086	1,299,749	4.66	2.962
Lynwood	72,773	70,573	2,200	14,948	8,135	1,691	1,673	3,337	112	14,357	3.95	4.916
Malibu	13,620	13,320	300	6,356	4,027	475	404	840	610	5,330	16.14	2.499
Manhattan Beach	36,615	36,601	14	15,553	10,603	1,405	2,641	871	33	14,975	3.72	2.444
Maywood	29,413	29,319	94	6,711	2,813	1,109	1,442	1,339	8	6,479	3.46	4.525
Monrovia	38,908	38,615	293	14,064	7,760	1,549	1,324	3,316	115	13,606	3.26	2.838

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

	------------POPULATION------------			------------ HOUSING UNITS ------------								PERSONS PER HOUSE-HOLD
					-------- SINGLE --------		----- MULTIPLE -----					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Montebello	65,268	64,959	309	19,498	9,361	1,576	2,863	5,465	233	18,924	2.94	3.433
Monterey Park	64,216	63,939	277	20,667	11,684	2,204	2,005	4,694	80	20,008	3.19	3.196
Norwalk	109,511	107,552	1,959	27,790	20,184	1,410	830	4,900	466	27,118	2.42	3.966
Palmdale	135,808	135,714	94	41,312	32,285	905	938	5,402	1,782	38,186	7.57	3.554
Palos Verdes Estates	14,121	14,116	5	5,265	4,843	40	44	338	0	5,054	4.01	2.793
Paramount	57,750	57,430	320	14,580	6,033	2,165	1,088	3,922	1,372	13,961	4.25	4.114
Pasadena	145,285	141,767	3,518	56,255	24,853	4,748	4,654	21,927	73	53,877	4.23	2.631
Pico Rivera	66,874	66,524	350	16,946	12,692	945	337	2,382	590	16,604	2.02	4.007
Pomona	159,825	154,346	5,479	40,455	24,621	3,339	3,233	7,557	1,705	38,674	4.40	3.991
Rancho Palos Verdes	43,259	42,750	509	15,799	12,216	1,287	245	2,051	0	15,344	2.88	2.786
Redondo Beach	66,910	66,723	187	29,878	11,766	4,238	4,053	9,441	380	28,889	3.31	2.310
Rolling Hills	1,971	1,971	0	687	680	7	0	0	0	650	5.39	3.032
Rolling Hills Estates	8,140	8,128	12	2,921	2,304	565	41	7	4	2,847	2.53	2.855
Rosemead	56,842	56,230	612	14,579	9,879	2,030	911	1,355	404	14,140	3.01	3.977
San Dimas	36,784	35,575	1,209	12,592	7,574	2,100	357	1,618	943	12,250	2.72	2.904
San Fernando	24,804	24,758	46	5,970	4,021	634	480	762	73	5,812	2.65	4.260
San Gabriel	42,117	41,362	755	13,072	7,070	1,189	1,092	3,677	44	12,746	2.49	3.245
San Marino	13,588	13,581	7	4,453	4,417	19	8	9	0	4,282	3.84	3.172
Santa Clarita	166,926	165,533	1,393	55,439	33,519	6,314	2,820	10,546	2,240	53,686	3.16	3.083
Santa Fe Springs	17,758	17,540	218	5,107	3,101	286	158	1,435	127	5,004	2.02	3.505
Santa Monica	90,661	88,055	2,606	49,397	9,360	1,928	5,584	32,236	289	45,923	7.03	1.917
Sierra Madre	11,079	10,952	127	4,932	3,409	205	377	914	27	4,765	3.39	2.298
Signal Hill	10,881	10,827	54	4,236	1,376	467	710	1,675	8	4,041	4.60	2.679
South El Monte	22,279	22,261	18	4,759	2,969	458	233	595	504	4,654	2.21	4.783
South Gate	101,536	101,395	141	24,446	12,363	3,265	3,701	4,837	280	23,382	4.35	4.336
South Pasadena	25,629	25,442	187	10,952	5,084	633	1,114	4,107	14	10,576	3.43	2.406
Temple City	35,431	34,920	511	11,858	9,594	802	421	983	58	11,517	2.88	3.032
Torrance	146,504	145,255	1,249	56,855	30,503	3,693	3,327	18,149	1,183	55,407	2.55	2.622
Vernon	95	95	0	26	19	0	0	7	0	25	3.85	3.800
Walnut	31,704	31,664	40	8,481	8,124	119	46	192	0	8,345	1.60	3.794
West Covina	111,726	110,918	808	32,602	21,233	2,812	1,570	6,639	348	31,944	2.02	3.472
West Hollywood	37,801	37,565	236	24,400	1,807	681	1,850	20,062	0	23,402	4.09	1.605
Westlake Village	8,850	8,841	9	3,384	2,242	608	158	201	175	3,306	2.30	2.674
Whittier	86,720	85,130	1,590	28,992	19,068	1,480	2,056	6,174	214	28,285	2.44	3.010
Balance Of County	1,078,928	1,061,948	16,980	307,215	212,019	22,882	18,464	42,918	10,932	293,052	4.61	3.624
Incorporated	9,084,169	8,924,210	159,959	3,034,303	1,413,517	220,059	271,107	1,083,889	45,731	2,908,041	4.16	3.069
County Total	10,163,097	9,986,158	176,939	3,341,518	1,625,536	242,941	289,571	1,126,807	56,663	3,201,093	4.20	3.120
Madera County												
Chowchilla	16,038	8,633	7,405	3,021	2,384	31	266	304	36	2,855	5.49	3.024
Madera	50,678	50,240	438	14,314	9,589	742	1,522	2,160	301	13,693	4.34	3.669
Balance Of County	73,862	73,076	786	27,651	22,870	563	605	417	3,196	23,760	14.07	3.076
Incorporated	66,716	58,873	7,843	17,335	11,973	773	1,788	2,464	337	16,548	4.54	3.558
County Total	140,578	131,949	8,629	44,986	34,843	1,336	2,393	2,881	3,533	40,308	10.40	3.274

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Marin County												
Belvedere	2,124	2,124	0	1,065	874	54	94	43	0	962	9.67	2.208
Corte Madera	9,341	9,333	8	3,977	2,621	416	369	561	10	3,901	1.91	2.392
Fairfax	7,279	7,249	30	3,421	2,334	193	490	393	11	3,309	3.27	2.191
Larkspur	11,966	11,811	155	6,427	2,451	360	544	2,833	239	6,156	4.22	1.919
Mill Valley	13,633	13,542	91	6,341	4,129	550	535	1,127	0	6,201	2.21	2.184
Novato	50,447	49,544	903	20,317	11,941	2,668	1,310	3,680	718	19,816	2.47	2.500
Ross	2,339	2,245	94	814	794	0	12	0	8	770	5.41	2.916
San Anselmo	12,338	12,082	256	5,424	3,995	186	468	757	18	5,283	2.60	2.287
San Rafael	57,005	54,935	2,070	23,472	10,624	2,024	2,459	7,876	489	22,882	2.51	2.401
Sausalito	7,346	7,334	12	4,549	1,725	423	1,350	827	224	4,291	5.67	1.709
Tiburon	8,737	8,631	106	3,950	2,412	237	464	837	0	3,766	4.66	2.292
Balance Of County	68,955	61,391	7,564	27,725	21,378	1,482	1,569	2,882	414	25,758	7.09	2.383
Incorporated	182,555	178,830	3,725	79,757	43,900	7,111	8,095	18,934	1,717	77,337	3.03	2.312
County Total	251,510	240,221	11,289	107,482	65,278	8,593	9,664	21,816	2,131	103,095	4.08	2.330
Mariposa County												
County Total	17,841	16,429	1,412	9,710	6,123	450	214	383	2,540	7,276	25.07	2.258
Mendocino County												
Fort Bragg	6,908	6,782	126	3,130	2,026	158	324	459	163	2,914	6.90	2.327
Point Arena	491	491	0	229	145	7	45	13	19	201	12.23	2.443
Ukiah	15,835	15,101	734	6,351	3,523	379	762	1,225	462	6,193	2.49	2.438
Willits	5,032	4,906	126	2,019	1,191	84	307	291	146	1,941	3.86	2.528
Balance Of County	61,011	59,722	1,289	26,930	20,285	535	713	778	4,619	23,549	12.55	2.536
Incorporated	28,266	27,280	986	11,729	6,885	628	1,438	1,988	790	11,249	4.09	2.425
County Total	89,277	87,002	2,275	38,659	27,170	1,163	2,151	2,766	5,409	34,798	9.99	2.500
Merced County												
Atwater	26,608	24,770	1,838	8,784	5,871	584	832	990	507	7,845	10.69	3.157
Dos Palos	4,839	4,815	24	1,584	1,364	55	48	78	39	1,511	4.61	3.187
Gustine	5,292	5,292	0	1,983	1,622	30	98	105	128	1,893	4.54	2.796
Livingston	12,302	12,265	37	2,874	2,247	80	206	305	36	2,804	2.44	4.374
Los Banos	32,268	32,093	175	10,039	8,271	263	570	658	277	9,629	4.08	3.333
Merced	73,358	71,988	1,370	24,757	15,218	944	2,744	5,143	708	23,497	5.09	3.064
Balance Of County	84,676	83,692	984	27,117	21,187	582	840	628	3,880	24,886	8.23	3.363
Incorporated	154,667	151,223	3,444	50,021	34,593	1,956	4,498	7,279	1,695	47,179	5.68	3.205
	239,343	234,915	4,428	77,138	55,780	2,538	5,338	7,907	5,575	72,065		
County Total	239,343	234,915	4,428	77,138	55,780	2,538	5,338	7,907	5,575	72,065	6.58	3.260

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Modoc County												
Alturas	2,811	2,731	80	1,371	1,021	53	47	144	106	1,184	13.64	2.307
Balance Of County	6,799	6,469	330	3,692	2,434	33	50	15	1,160	2,794	24.32	2.315
Incorporated	2,811	2,731	80	1,371	1,021	53	47	144	106	1,184	13.64	2.307
County Total	9,610	9,200	410	5,063	3,455	86	97	159	1,266	3,978	21.43	2.313
Mono County												
Mammoth Lakes	7,416	7,198	218	8,962	2,278	1,003	1,786	3,702	193	3,168	64.65	2.272
Balance Of County	6,025	5,866	159	4,248	2,806	256	307	74	805	2,606	38.65	2.251
Incorporated	7,416	7,198	218	8,962	2,278	1,003	1,786	3,702	193	3,168	64.65	2.272
County Total	13,441	13,064	377	13,210	5,084	1,259	2,093	3,776	998	5,774	56.29	2.263
Monterey County												
Carmel-By-The-Sea	4,089	4,089	0	3,349	2,752	111	216	270	0	2,296	31.44	1.781
Del Rey Oaks	1,647	1,647	0	727	567	25	23	109	3	704	3.16	2.339
Gonzales	8,397	8,324	73	1,920	1,413	127	169	169	42	1,888	1.67	4.409
Greenfield	13,354	13,258	96	2,886	1,997	282	274	247	86	2,798	3.05	4.738
King City	11,428	11,244	184	2,886	1,615	278	288	415	290	2,797	3.08	4.020
Marina	19,047	18,916	131	8,612	3,450	1,537	1,457	1,748	420	6,804	20.99	2.780
Monterey	30,462	27,367	3,095	13,537	5,920	913	2,268	4,415	21	12,765	5.70	2.144
Pacific Grove	15,525	15,350	175	8,052	5,014	448	989	1,510	91	7,334	8.92	2.093
Salinas	149,675	147,223	2,452	41,725	22,560	3,463	3,479	10,937	1,286	40,292	3.43	3.654
Sand City	302	238	64	105	57	6	28	9	5	97	7.62	2.454
Seaside	33,991	31,479	2,512	11,223	6,250	2,351	920	1,270	432	9,925	11.57	3.172
Soledad	27,362	15,218	12,144	3,447	2,593	204	317	210	123	3,363	2.44	4.525
Balance Of County	106,095	104,448	1,647	38,869	29,841	2,695	1,553	1,741	3,039	35,496	8.68	2.943
Incorporated	315,279	294,353	20,926	98,469	54,188	9,745	10,428	21,309	2,799	91,063	7.52	3.232
County Total	421,374	398,801	22,573	137,338	84,029	12,440	11,981	23,050	5,838	126,559	7.85	3.151
Napa County												
American Canyon	14,198	14,064	134	4,844	3,911	23	68	61	781	4,748	1.98	2.962
Calistoga	5,184	5,117	67	2,278	1,061	97	186	361	573	2,070	9.13	2.472
Napa	75,783	74,324	1,459	29,433	17,943	2,161	2,811	5,129	1,389	28,588	2.87	2.600
St Helena	5,960	5,908	52	2,750	1,681	215	214	478	162	2,418	12.07	2.443
Yountville	3,240	2,068	1,172	1,165	611	172	39	35	308	1,073	7.90	1.927
Balance Of County	27,963	25,580	2,383	11,739	9,994	650	355	8	732	10,026	14.59	2.551
Incorporated	104,365	101,481	2,884	40,470	25,207	2,668	3,318	6,064	3,213	38,897	3.89	2.609

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
County Total	132,328	127,061	5,267	52,209	35,201	3,318	3,673	6,072	3,945	48,923	6.29	2.597
Nevada County												
Grass Valley	12,905	12,555	350	6,318	2,963	256	759	1,645	695	6,018	4.75	2.086
Nevada City	3,028	2,841	187	1,457	1,135	53	117	78	74	1,352	7.21	2.101
Truckee	15,532	15,491	41	11,140	9,293	242	741	566	298	5,879	47.23	2.635
Balance Of County	66,707	66,373	334	29,478	26,112	320	271	90	2,685	26,908	8.72	2.467
Incorporated	31,465	30,887	578	18,915	13,391	551	1,617	2,289	1,067	13,249	29.96	2.331
County Total	98,172	97,260	912	48,393	39,503	871	1,888	2,379	3,752	40,157	17.02	2.422
Orange County												
Aliso Viejo	44,694	44,534	160	17,968	6,455	4,935	739	5,824	15	17,470	2.77	2.549
Anaheim	341,318	337,522	3,796	100,975	43,561	8,923	10,439	33,668	4,384	98,192	2.76	3.437
Brea	39,416	39,288	128	14,455	8,426	1,095	563	3,501	870	14,175	1.94	2.772
Buena Park	80,727	79,793	934	23,868	14,033	1,911	1,424	6,209	291	23,373	2.07	3.414
Costa Mesa	112,972	109,844	3,128	40,935	15,699	4,161	5,932	14,047	1,096	39,719	2.97	2.766
Cypress	48,658	48,337	321	16,446	10,159	2,562	519	2,842	364	16,062	2.33	3.009
Dana Point	36,610	36,368	242	15,909	7,868	2,266	2,798	2,607	370	14,667	7.81	2.480
Fountain Valley	57,114	56,602	512	18,671	12,385	2,194	648	3,046	398	18,357	1.68	3.083
Fullerton	135,107	131,896	3,211	46,606	23,928	3,775	3,729	14,253	921	45,396	2.60	2.905
Garden Grove	171,322	169,088	2,234	47,131	26,739	4,486	3,410	10,674	1,822	46,211	1.95	3.659
Huntington Beach	199,896	199,104	792	77,608	38,348	9,457	9,780	16,882	3,141	75,552	2.65	2.635
Irvine	183,344	175,354	7,990	68,916	25,998	14,591	4,579	22,726	1,022	64,626	6.22	2.713
Laguna Beach	24,862	24,740	122	13,217	8,263	759	1,766	2,105	324	11,734	11.22	2.108
Laguna Hills	33,113	32,689	424	11,139	5,864	2,183	608	2,267	217	10,793	3.11	3.029
Laguna Niguel	65,847	65,544	303	24,723	13,649	5,007	1,441	4,610	16	24,031	2.80	2.727
Laguna Woods	18,293	18,219	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.447
La Habra	61,512	60,917	595	19,731	10,461	1,667	1,360	5,508	735	19,229	2.54	3.168
Lake Forest	77,693	76,849	844	26,385	14,166	3,923	1,276	5,734	1,286	25,712	2.55	2.989
La Palma	16,045	16,014	31	5,131	3,637	376	102	989	27	5,043	1.72	3.175
Los Alamitos	11,953	11,547	406	4,368	1,941	251	1,033	1,014	129	4,285	1.90	2.695
Mission Viejo	97,786	96,721	1,065	33,714	24,475	4,021	1,201	3,928	89	33,166	1.63	2.916
Newport Beach	82,774	81,834	940	42,143	18,918	7,166	5,475	9,721	863	37,545	10.91	2.180
Orange	137,243	131,775	5,468	43,491	24,872	5,149	4,709	7,422	1,339	42,481	2.32	3.102
Placentia	50,109	49,806	303	16,075	9,675	2,050	1,108	2,665	577	15,772	1.88	3.158
Rancho Santa Margarita	49,041	49,027	14	16,684	9,118	3,889	598	3,079	0	16,419	1.59	2.986
San Clemente	65,061	64,769	292	26,207	14,664	2,645	4,010	4,485	403	24,609	6.10	2.632
San Juan Capistrano	35,927	35,469	458	11,692	6,014	2,395	944	865	1,474	11,289	3.45	3.142
Santa Ana	350,400	344,753	5,647	75,259	33,671	6,578	7,493	23,608	3,909	73,658	2.13	4.680
Seal Beach	25,404	25,109	295	14,476	4,635	2,121	1,167	6,390	163	13,331	7.91	1.884
Stanton	38,650	38,132	518	11,071	2,994	1,873	988	3,954	1,262	10,826	2.21	3.522
Tustin	70,575	70,157	418	25,927	8,375	3,531	3,836	9,277	908	24,238	6.51	2.895
Villa Park	6,205	6,184	21	2,020	1,991	18	0	6	5	1,962	2.87	3.152
Westminster	91,881	91,329	552	27,300	14,891	2,449	2,084	4,808	3,068	26,759	1.98	3.413

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Yorba Linda	65,344	65,209	135	21,111	16,701	2,213	570	1,316	311	20,771	1.61	3.139
Balance Of County	118,322	116,801	1,521	38,055	29,733	2,232	2,018	3,544	528	37,180	2.30	3.142
Incorporated	2,926,896	2,884,523	42,373	974,981	483,301	124,632	88,803	246,420	31,825	940,044	3.58	3.068
County Total	3,045,218	3,001,324	43,894	1,013,036	513,034	126,864	90,821	249,964	32,353	977,224	3.54	3.071
Placer County												
Auburn	12,934	12,728	206	5,814	3,923	211	655	1,025	0	5,649	2.84	2.253
Colfax	1,834	1,833	1	801	512	21	172	63	33	774	3.37	2.368
Lincoln	27,323	27,209	114	11,880	10,699	196	176	713	96	11,467	3.48	2.373
Loomis	6,317	6,283	34	2,353	1,980	199	58	2	114	2,285	2.89	2.750
Rocklin	50,829	50,468	361	19,679	14,128	516	820	3,776	439	18,946	3.72	2.664
Roseville	102,867	101,813	1,054	42,219	31,010	1,082	1,627	7,957	543	40,708	3.58	2.501
Balance Of County	105,381	103,918	1,463	52,100	41,781	1,916	2,559	2,331	3,513	40,161	22.92	2.588
Incorporated	202,104	200,334	1,770	82,746	62,252	2,225	3,508	13,536	1,225	79,829	3.53	2.510
County Total	307,485	304,252	3,233	134,846	104,033	4,141	6,067	15,867	4,738	119,990	11.02	2.536
Plumas County												
Portola	2,149	2,128	21	1,045	783	17	72	110	63	932	10.81	2.283
Balance Of County	18,876	18,709	167	13,512	10,338	433	303	286	2,152	8,843	34.55	2.116
Incorporated	2,149	2,128	21	1,045	783	17	72	110	63	932	10.81	2.283
County Total	21,025	20,837	188	14,557	11,121	450	375	396	2,215	9,775	32.85	2.132
Riverside County												
Banning	28,022	27,684	338	11,359	8,459	728	421	595	1,156	10,406	8.39	2.660
Beaumont	19,031	18,876	155	6,949	5,384	172	340	706	347	6,334	8.85	2.980
Blythe	22,037	13,308	8,729	5,287	2,911	152	498	881	845	4,435	16.11	3.001
Calimesa	7,453	7,357	96	3,294	1,807	111	57	64	1,255	3,025	8.17	2.432
Canyon Lake	10,938	10,922	16	4,319	3,955	133	6	84	141	3,889	9.96	2.808
Cathedral City	50,759	50,568	191	20,670	10,947	2,587	2,417	1,938	2,781	16,204	21.61	3.121
Coachella	30,842	30,798	44	6,624	4,108	319	700	1,042	455	6,337	4.33	4.860
Corona	144,428	143,796	632	44,098	30,487	2,186	2,225	7,587	1,613	42,490	3.65	3.384
Desert Hot Springs	20,796	20,622	174	8,583	5,282	180	1,199	1,313	609	7,149	16.71	2.885
Hemet	68,030	66,351	1,679	32,452	14,583	1,766	2,133	4,497	9,473	28,406	12.47	2.336
Indian Wells	4,791	4,791	0	4,685	3,085	884	239	469	8	2,417	48.41	1.982
Indio	66,284	65,428	856	22,257	12,979	878	1,431	3,795	3,174	18,258	17.97	3.584
Lake Elsinore	38,141	38,068	73	12,190	8,872	712	731	1,099	776	11,310	7.22	3.366
La Quinta	36,236	36,196	40	17,549	14,393	1,545	403	949	259	12,547	28.50	2.885
Moreno Valley	165,742	165,045	697	46,944	39,763	891	1,389	3,858	1,043	44,454	5.30	3.713
Murrieta	85,312	84,652	660	28,788	21,552	211	645	4,667	1,713	27,457	4.62	3.083
Norco	26,756	22,111	4,645	6,972	6,558	137	9	177	91	6,815	2.25	3.244

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Palm Desert	49,402	49,018	384	32,711	12,785	9,601	2,497	4,576	3,252	22,577	30.98	2.171
Palm Springs	45,824	45,128	696	32,068	11,310	6,160	2,512	9,851	2,235	21,348	33.43	2.114
Perris	44,705	44,473	232	12,673	8,977	321	371	1,264	1,740	11,591	8.54	3.837
Rancho Mirage	16,457	15,944	513	13,950	6,471	3,680	615	1,196	1,988	8,043	42.34	1.982
Riverside	286,239	276,753	9,486	93,451	58,673	4,139	5,826	22,382	2,431	89,166	4.59	3.104
San Jacinto	28,508	28,318	190	11,045	6,611	596	651	567	2,620	9,691	12.26	2.922
Temecula	81,602	81,580	22	26,007	20,763	397	598	3,928	321	24,917	4.19	3.274
Balance Of County	504,477	498,948	5,529	185,112	128,088	4,173	3,419	6,229	43,203	159,423	13.88	3.130
Incorporated	1,378,335	1,347,787	30,548	504,925	320,715	38,486	27,913	77,485	40,326	439,266	13.00	3.068
County Total	1,882,812	1,846,735	36,077	690,037	448,803	42,659	31,332	83,714	83,529	598,689	13.24	3.085
Sacramento County												
Citrus Heights	87,464	86,587	877	35,514	19,728	3,531	3,021	7,355	1,879	34,071	4.06	2.541
Elk Grove	121,489	120,912	577	40,932	37,687	919	525	1,528	273	39,987	2.31	3.024
Folsom	67,972	61,030	6,942	24,152	17,072	635	629	4,944	872	23,115	4.29	2.640
Galt	22,781	22,593	188	7,203	5,801	208	340	482	372	6,929	3.80	3.261
Isleton	820	820	0	376	221	0	72	36	47	336	10.64	2.440
Rancho Cordova	55,100	54,750	350	21,606	10,553	2,024	1,987	5,653	1,389	20,640	4.47	2.653
Sacramento	452,310	443,317	8,993	180,946	107,987	11,372	15,903	41,998	3,686	170,731	5.65	2.597
Balance Of County	560,454	552,821	7,633	213,871	137,991	13,588	13,894	41,248	7,150	206,286	3.55	2.680
Incorporated	807,936	790,009	17,927	310,729	199,049	18,689	22,477	61,996	8,518	295,809	4.80	2.671
County Total	1,368,390	1,342,830	25,560	524,600	337,040	32,277	36,371	103,244	15,668	502,095	4.29	2.674
San Benito County												
Hollister	36,786	36,615	171	10,587	7,977	531	992	781	306	10,365	2.10	3.533
San Juan Bautista	1,714	1,714	0	678	456	70	73	62	17	625	7.82	2.742
Balance Of County	18,489	18,153	336	6,373	5,286	427	70	42	548	5,990	6.01	3.031
Incorporated	38,500	38,329	171	11,265	8,433	601	1,065	843	323	10,990	2.44	3.488
County Total	56,989	56,482	507	17,638	13,719	1,028	1,135	885	871	16,980	3.73	3.326
San Bernardino County												
Adelanto	23,345	21,765	1,580	6,867	4,998	149	382	831	507	5,836	15.01	3.729
Apple Valley	63,761	63,398	363	22,453	17,181	726	2,077	1,430	1,039	20,665	7.96	3.068
Barstow	23,652	23,293	359	9,756	5,412	356	1,292	1,581	1,115	8,119	16.78	2.869
Big Bear Lake	6,140	6,115	25	9,305	7,813	326	366	410	390	2,505	73.08	2.441
Chino	77,670	66,359	11,311	18,937	13,454	952	803	3,200	528	18,308	3.32	3.625
Chino Hills	77,706	77,555	151	22,484	18,120	1,378	300	2,000	686	22,070	1.84	3.514
Colton	51,554	51,290	264	16,057	9,471	602	1,059	4,110	815	14,869	7.40	3.449
Fontana	159,785	159,286	499	42,144	32,784	1,198	1,571	5,709	882	39,921	5.27	3.990
Grand Terrace	12,374	12,165	209	4,495	2,900	175	265	905	250	4,256	5.32	2.858

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Hesperia	76,002	75,671	331	24,559	19,612	893	1,079	1,693	1,282	22,971	6.47	3.294
Highland	50,786	50,546	240	16,017	11,968	512	598	2,129	810	14,530	9.28	3.479
Loma Linda	21,560	20,596	964	8,661	3,694	673	1,307	2,425	562	8,073	6.79	2.551
Montclair	35,478	34,866	612	9,222	5,337	758	1,042	1,331	754	8,952	2.93	3.895
Needles	5,545	5,534	11	2,772	1,449	110	254	367	592	2,108	23.95	2.625
Ontario	170,129	169,021	1,108	46,070	27,295	3,649	4,027	8,935	2,164	44,381	3.67	3.808
Rancho Cucamonga	161,601	157,975	3,626	50,749	34,244	2,727	1,912	10,494	1,372	49,218	3.02	3.210
Redlands	70,223	68,257	1,966	25,984	16,772	900	2,428	4,967	917	24,729	4.83	2.760
Rialto	99,099	98,295	804	26,603	18,917	586	1,822	3,479	1,799	25,188	5.32	3.902
San Bernardino	199,521	193,417	6,104	64,553	37,947	2,716	5,684	13,731	4,475	57,425	11.04	3.368
Twentynine Palms	25,000	17,954	7,046	8,623	4,685	1,303	1,646	445	544	6,637	23.03	2.705
Upland	73,590	73,005	585	25,947	15,021	1,770	2,675	5,636	845	25,013	3.60	2.919
Victorville	86,355	83,066	3,289	27,912	21,323	389	1,333	3,109	1,758	25,920	7.14	3.205
Yucaipa	49,317	48,745	572	18,290	12,107	394	743	819	4,227	17,246	5.71	2.826
Yucca Valley	19,698	19,387	311	8,813	6,939	140	649	378	707	7,701	12.62	2.517
Balance Of County	305,351	297,244	8,107	128,354	103,012	4,210	4,207	3,034	13,891	93,332	27.29	3.185
Incorporated	1,639,891	1,597,561	42,330	517,273	349,443	23,382	35,314	80,114	29,020	476,641	7.86	3.352
County Total	1,945,242	1,894,805	50,437	645,627	452,455	27,592	39,521	83,148	42,911	569,973	11.72	3.324
San Diego County												
Carlsbad	94,880	93,967	913	40,307	21,794	5,766	2,604	8,852	1,291	37,593	6.73	2.500
Chula Vista	216,961	215,527	1,434	73,115	39,709	5,454	5,167	18,899	3,886	70,916	3.01	3.039
Coronado	23,563	18,015	5,548	9,573	4,471	870	826	3,383	23	7,792	18.60	2.312
Del Mar	4,530	4,528	2	2,595	1,357	366	200	672	0	2,211	14.80	2.048
El Cajon	97,435	94,702	2,733	35,475	13,692	1,548	2,244	15,957	2,034	34,476	2.82	2.747
Encinitas	62,598	62,039	559	25,330	14,334	4,545	2,127	3,555	769	24,254	4.25	2.558
Escondido	140,958	139,193	1,765	46,797	22,953	2,923	3,121	13,807	3,993	45,517	2.74	3.058
Imperial Beach	27,634	26,970	664	9,812	4,036	687	1,059	3,690	340	9,341	4.80	2.887
La Mesa	55,862	54,816	1,046	25,038	11,145	1,923	2,003	9,608	359	24,279	3.03	2.258
Lemon Grove	25,461	24,870	591	8,769	5,792	716	694	1,470	97	8,535	2.67	2.914
National City	61,194	51,835	9,359	15,440	6,609	1,336	1,690	5,368	437	15,036	2.62	3.447
Oceanside	174,597	173,317	1,280	63,568	33,260	8,222	4,463	14,170	3,453	60,268	5.19	2.876
Poway	50,541	50,115	426	16,264	12,142	877	345	2,209	691	16,009	1.57	3.130
San Diego	1,296,869	1,256,291	40,578	492,969	227,431	45,784	43,491	169,922	6,341	473,068	4.04	2.656
San Marcos	72,850	72,315	535	24,465	12,881	1,083	1,251	5,590	3,660	23,492	3.98	3.078
Santee	54,327	53,284	1,043	19,004	10,662	1,616	1,225	2,998	2,503	18,637	1.93	2.859
Solana Beach	13,362	13,328	34	6,537	2,980	1,265	622	1,631	39	5,827	10.86	2.287
Vista	93,849	91,583	2,266	30,656	15,404	2,029	2,213	8,881	2,129	29,692	3.14	3.084
Balance Of County	470,603	439,411	31,192	159,276	108,162	10,979	6,508	18,435	15,192	149,176	6.34	2.946
Incorporated	2,567,471	2,496,695	70,776	945,714	460,652	87,010	75,345	290,662	32,045	906,943	4.10	2.753
County Total	3,038,074	2,936,106	101,968	1,104,990	568,814	97,989	81,853	309,097	47,237	1,056,119	4.42	2.780
San Francisco County												

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
City and County Total	798,038	777,689	20,349	355,101	62,925	48,696	81,704	161,216	560	338,024	4.81	2.301
San Joaquin County												
Escalon	6,897	6,871	26	2,399	1,993	20	153	98	135	2,314	3.54	2.969
Lathrop	12,810	12,800	10	3,577	3,059	63	92	12	351	3,467	3.08	3.692
Lodi	62,330	61,306	1,024	22,762	14,572	1,464	1,762	4,500	464	22,032	3.21	2.783
Manteca	61,790	61,313	477	20,697	15,569	739	1,124	2,396	869	20,002	3.36	3.065
Ripon	13,211	13,100	111	4,371	3,759	136	151	316	9	4,272	2.26	3.066
Stockton	278,776	274,216	4,560	91,725	58,146	6,592	8,436	17,263	1,288	87,827	4.25	3.122
Tracy	78,133	77,788	345	24,174	19,892	1,015	945	1,846	476	23,550	2.58	3.303
Balance Of County	138,113	127,548	10,565	44,062	35,524	1,254	806	592	5,886	41,882	4.95	3.045
Incorporated	513,947	507,394	6,553	169,705	116,990	10,029	12,663	26,431	3,592	163,464	3.68	3.104
County Total	652,060	634,942	17,118	213,767	152,514	11,283	13,469	27,023	9,478	205,346	3.94	3.092
San Luis Obispo County												
Arroyo Grande	16,579	16,369	210	7,227	4,936	605	489	649	548	6,935	4.04	2.360
Atascadero	27,662	26,010	1,652	10,505	7,423	441	864	1,220	557	10,167	3.22	2.558
El Paso De Robles	28,035	27,648	387	10,640	7,069	920	1,034	1,200	417	10,356	2.67	2.670
Grover Beach	13,262	13,136	126	5,589	3,227	790	726	599	247	5,216	6.67	2.518
Morro Bay	10,536	10,338	198	6,513	4,244	396	650	464	759	5,195	20.24	1.990
Pismo Beach	8,663	8,636	27	5,697	3,082	576	467	485	1,087	4,384	23.05	1.970
San Luis Obispo	44,625	42,763	1,862	19,962	9,344	1,283	2,225	5,608	1,502	19,272	3.46	2.219
Balance Of County	111,983	100,605	11,378	44,660	33,403	1,278	2,087	1,213	6,679	38,969	12.74	2.582
Incorporated	149,362	144,900	4,462	66,133	39,325	5,011	6,455	10,225	5,117	61,525	6.97	2.355
County Total	261,345	245,505	15,840	110,793	72,728	6,289	8,542	11,438	11,796	100,494	9.30	2.443
San Mateo County												
Atherton	7,234	6,916	318	2,532	2,493	32	0	7	0	2,439	3.67	2.836
Belmont	25,395	24,768	627	10,745	6,290	609	275	3,571	0	10,584	1.50	2.340
Brisbane	3,715	3,675	40	1,900	1,060	260	179	358	43	1,681	11.53	2.186
Burlingame	28,196	27,710	486	12,947	6,156	423	991	5,377	0	12,587	2.78	2.201
Colma	1,564	1,515	49	456	216	66	98	70	6	438	3.95	3.459
Daly City	104,347	103,557	790	31,682	16,104	4,507	2,833	7,596	642	31,140	1.71	3.326
East Palo Alto	32,097	31,908	189	7,754	3,945	376	360	2,914	159	7,627	1.64	4.184
Foster City	29,786	29,699	87	12,478	4,809	2,464	767	4,431	7	12,067	3.29	2.461
Half Moon Bay	12,653	11,805	848	4,438	2,782	536	314	379	427	4,319	2.68	2.733
Hillsborough	10,951	10,949	2	3,866	3,846	11	9	0	0	3,750	3.00	2.920
Menlo Park	30,558	29,717	841	12,724	6,849	930	1,574	3,366	5	12,397	2.57	2.397
Millbrae	20,646	20,314	332	8,122	5,319	269	430	2,093	11	7,965	1.93	2.550
Pacifica	38,563	38,382	181	14,377	10,358	786	723	2,412	98	14,125	1.75	2.717
Portola Valley	4,525	4,455	70	1,806	1,498	33	8	267	0	1,733	4.04	2.571
Redwood City	75,763	73,836	1,927	29,200	13,552	3,656	2,607	8,552	833	28,332	2.97	2.606

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
San Bruno	41,322	41,101	221	15,487	9,138	566	1,188	4,573	22	15,174	2.02	2.709
San Carlos	28,105	27,922	183	11,911	8,256	609	482	2,548	16	11,671	2.01	2.392
San Mateo	93,931	92,615	1,316	39,072	17,725	3,492	3,028	14,782	45	38,145	2.37	2.428
South San Francisco	61,477	61,034	443	20,544	12,001	2,524	1,676	3,934	409	20,075	2.28	3.040
Woodside	5,479	5,473	6	2,088	2,026	28	28	5	1	2,005	3.98	2.730
Balance Of County	64,223	62,840	1,383	22,422	18,519	703	924	1,429	847	21,676	3.33	2.899
Incorporated	656,307	647,351	8,956	244,129	134,423	22,177	17,570	67,235	2,724	238,254	2.41	2.717
County Total	720,530	710,191	10,339	266,551	152,942	22,880	18,494	68,664	3,571	259,930	2.48	2.732
Santa Barbara County												
Buellton	4,527	4,521	6	1,763	1,114	100	33	98	418	1,704	3.35	2.653
Carpinteria	14,259	14,134	125	5,517	2,155	422	533	1,467	940	5,039	8.66	2.805
Goleta	30,482	30,140	342	11,486	5,861	1,588	753	2,663	621	11,201	2.48	2.691
Guadalupe	6,261	6,261	0	1,612	1,158	168	181	99	6	1,573	2.42	3.980
Lompoc	42,099	38,524	3,575	14,001	7,384	1,044	1,940	2,693	940	13,424	4.12	2.870
Santa Barbara	90,017	88,225	1,792	37,435	17,199	2,892	5,604	11,222	518	35,950	3.97	2.454
Santa Maria	88,305	86,107	2,198	26,268	16,423	1,536	1,733	5,001	1,575	25,462	3.07	3.382
Solvang	5,543	5,383	160	2,329	1,335	151	171	453	219	2,284	1.93	2.357
Balance Of County	136,296	127,087	9,209	49,037	34,312	2,739	2,710	5,897	3,379	46,703	4.76	2.721
Incorporated	281,493	273,295	8,198	100,411	52,629	7,901	10,948	23,696	5,237	96,637	3.76	2.828
County Total	417,789	400,382	17,407	149,448	86,941	10,640	13,658	29,593	8,616	143,340	4.09	2.793
Santa Clara County												
Campbell	38,340	38,050	290	16,459	6,999	2,006	2,442	4,755	257	16,091	2.24	2.365
Cupertino	53,346	52,865	481	19,724	12,148	2,028	1,696	3,843	9	19,223	2.54	2.750
Gilroy	47,578	47,148	430	14,054	9,384	756	1,310	2,173	431	13,728	2.32	3.434
Los Altos	27,558	27,139	419	10,731	9,151	364	273	927	16	10,465	2.48	2.593
Los Altos Hills	8,433	8,368	65	3,035	2,971	32	17	9	6	2,954	2.67	2.833
Los Gatos	28,919	28,217	702	12,579	7,126	1,837	938	2,555	123	12,195	3.05	2.314
Milpitas	64,875	61,701	3,174	18,095	10,929	2,225	1,631	2,724	586	17,853	1.34	3.456
Monte Sereno	3,498	3,498	0	1,249	1,145	13	18	73	0	1,223	2.08	2.860
Morgan Hill	36,352	35,839	513	12,092	7,572	1,713	700	1,195	912	11,824	2.22	3.031
Mountain View	71,890	71,374	516	33,148	9,211	3,889	2,668	16,149	1,231	31,932	3.67	2.235
Palo Alto	61,554	60,886	668	27,522	15,592	976	1,733	9,057	164	26,643	3.19	2.285
San Jose	942,993	932,525	10,468	298,901	165,818	27,822	23,340	70,893	11,028	293,343	1.86	3.179
Santa Clara	108,895	106,108	2,787	42,454	18,422	3,712	3,921	16,290	109	41,272	2.78	2.571
Saratoga	30,790	30,429	361	11,009	9,644	560	241	557	7	10,803	1.87	2.817
Sunnyvale	132,821	131,946	875	54,476	21,178	4,047	4,911	20,244	4,096	53,247	2.26	2.478
Balance Of County	97,611	89,898	7,713	31,507	25,056	1,595	919	3,254	683	30,265	3.94	2.970
Incorporated	1,657,842	1,636,093	21,749	575,528	307,290	51,980	45,839	151,444	18,975	562,796	2.21	2.907
County Total	1,755,453	1,725,991	29,462	607,035	332,346	53,575	46,758	154,698	19,658	593,061	2.30	2.910

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Cruz County												
Capitola	9,912	9,756	156	5,387	1,977	514	1,139	1,107	650	4,760	11.64	2.050
Santa Cruz	56,387	51,458	4,929	23,133	12,289	1,954	2,601	5,849	440	21,723	6.10	2.369
Scotts Valley	11,558	11,106	452	4,616	2,482	415	417	497	805	4,459	3.40	2.491
Watsonville	49,539	48,986	553	13,463	7,100	1,594	1,705	2,164	900	13,101	2.69	3.739
Balance Of County	132,537	129,346	3,191	56,273	40,954	4,370	2,604	3,887	4,458	50,650	9.99	2.554
Incorporated	127,396	121,306	6,090	46,599	23,848	4,477	5,862	9,617	2,795	44,043	5.49	2.754
County Total	259,933	250,652	9,281	102,872	64,802	8,847	8,466	13,504	7,253	94,693	7.95	2.647
Shasta County												
Anderson	10,414	10,296	118	4,083	2,609	209	378	708	179	3,847	5.78	2.676
Redding	88,219	85,762	2,457	36,444	23,828	949	4,589	4,477	2,601	34,612	5.03	2.478
Shasta Lake	10,176	10,124	52	4,162	3,280	27	249	114	492	3,786	9.03	2.674
Balance Of County	68,908	68,121	787	29,296	20,676	275	371	198	7,776	25,975	11.34	2.623
Incorporated	108,809	106,182	2,627	44,689	29,717	1,185	5,216	5,299	3,272	42,245	5.47	2.513
County Total	177,717	174,303	3,414	73,985	50,393	1,460	5,587	5,497	11,048	68,220	7.79	2.555
Sierra County												
Loyalton	874	844	30	371	322	13	3	0	33	346	6.74	2.439
Balance Of County	2,615	2,609	6	1,894	1,550	36	44	63	201	1,222	35.48	2.135
Incorporated	874	844	30	371	322	13	3	0	33	346	6.74	2.439
County Total	3,489	3,453	36	2,265	1,872	49	47	63	234	1,568	30.77	2.202
Siskiyou County												
Dorris	883	883	0	404	318	2	16	0	68	350	13.37	2.523
Dunsmuir	1,881	1,881	0	1,171	792	23	126	184	46	868	25.88	2.167
Etna	771	771	0	366	269	10	19	13	55	333	9.02	2.315
Fort Jones	667	667	0	339	241	11	34	2	51	309	8.85	2.159
Montague	1,495	1,476	19	640	481	15	10	43	91	589	7.97	2.506
Mount Shasta	3,676	3,628	48	1,867	1,184	89	264	256	74	1,732	7.23	2.095
Tulelake	1,001	1,001	0	461	317	2	44	19	79	360	21.91	2.781
Weed	2,969	2,811	158	1,302	897	19	136	190	60	1,192	8.45	2.358
Yreka	7,327	7,107	220	3,396	2,217	140	288	511	240	3,203	5.68	2.219
Balance Of County	24,789	24,520	269	13,101	9,509	188	185	96	3,123	10,536	19.58	2.327
Incorporated	20,670	20,225	445	9,946	6,716	311	937	1,218	764	8,936	10.15	2.263
County Total	45,459	44,745	714	23,047	16,225	499	1,122	1,314	3,887	19,472	15.51	2.298

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

	POPULATION			HOUSING UNITS	SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Solano County												
Benicia	27,136	27,082	54	10,810	6,938	1,049	942	1,555	326	10,586	2.07	2.558
Dixon	17,060	17,019	41	5,561	4,628	213	378	256	86	5,455	1.91	3.120
Fairfield	104,024	100,594	3,430	36,248	24,250	2,519	2,406	6,181	892	34,597	4.55	2.908
Rio Vista	6,775	6,775	0	3,007	2,588	34	103	171	111	2,866	4.69	2.364
Suisun City	27,525	27,431	94	8,713	7,377	189	327	754	66	8,542	1.96	3.211
Vacaville	96,134	86,673	9,461	31,805	22,000	1,036	2,143	5,318	1,308	31,151	2.06	2.782
Vallejo	120,400	118,167	2,233	42,973	29,921	1,784	3,921	6,001	1,346	41,286	3.93	2.862
Balance Of County	19,538	18,947	591	7,134	6,005	222	297	119	491	6,704	6.03	2.826
Incorporated	399,054	383,741	15,313	139,117	97,702	6,824	10,220	20,236	4,135	134,483	3.33	2.853
County Total	418,592	402,688	15,904	146,251	103,707	7,046	10,517	20,355	4,626	141,187	3.46	2.852
Sonoma County												
Cloverdale	8,197	8,120	77	3,192	2,416	155	120	293	208	3,041	4.73	2.670
Cotati	7,300	7,282	18	2,956	1,623	506	373	333	121	2,895	2.06	2.515
Healdsburg	11,651	11,528	123	4,538	3,255	254	451	479	99	4,353	4.08	2.648
Petaluma	56,337	55,597	740	21,265	15,334	1,652	1,368	1,980	931	20,875	1.83	2.663
Rohnert Park	42,229	41,128	1,101	16,020	7,660	1,699	929	4,319	1,413	15,711	1.93	2.618
Santa Rosa	155,471	151,737	3,734	61,586	37,030	5,760	4,892	11,210	2,694	59,938	2.68	2.532
Sebastopol	7,756	7,545	211	3,358	2,013	254	535	497	59	3,287	2.11	2.295
Sonoma	9,783	9,692	91	5,071	2,876	698	473	587	437	4,752	6.29	2.040
Windsor	25,342	25,251	91	8,731	6,803	460	252	394	822	8,573	1.81	2.945
Balance Of County	151,395	145,475	5,920	65,232	52,773	2,898	2,909	2,048	4,604	57,427	11.96	2.533
Incorporated	324,066	317,880	6,186	126,717	79,010	11,438	9,393	20,092	6,784	123,425	2.60	2.575
County Total	475,461	463,355	12,106	191,949	131,783	14,336	12,302	22,140	11,388	180,852	5.78	2.562
Stanislaus County												
Ceres	38,697	38,598	99	11,865	9,142	343	631	1,037	712	11,493	3.14	3.358
Hughson	5,925	5,919	6	1,836	1,481	65	66	135	89	1,793	2.34	3.301
Modesto	207,029	203,798	3,231	72,615	51,090	4,010	6,260	9,264	1,991	70,215	3.31	2.902
Newman	9,108	9,042	66	2,756	2,292	76	245	117	26	2,634	4.43	3.433
Oakdale	17,388	17,209	179	6,419	4,803	207	507	691	211	6,204	3.35	2.774
Patterson	16,110	15,881	229	4,484	3,952	190	151	63	128	4,324	3.57	3.673
Riverbank	19,926	19,791	135	5,835	4,999	185	180	182	289	5,645	3.26	3.506
Turlock	66,815	64,523	2,292	22,581	15,566	961	1,847	3,603	604	21,769	3.60	2.964
Waterford	7,874	7,857	17	2,330	1,894	64	175	168	29	2,229	4.33	3.525
Balance Of County	114,131	112,661	1,470	36,327	28,874	1,058	953	421	5,021	34,500	5.03	3.266
Incorporated	388,872	382,618	6,254	130,721	95,219	6,101	10,062	15,260	4,079	126,306	3.38	3.029
County Total	503,003	495,279	7,724	167,048	124,093	7,159	11,015	15,681	9,100	160,806	3.74	3.080

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Sutter County												
Live Oak	6,772	6,456	316	1,918	1,450	81	141	104	142	1,823	4.95	3.541
Yuba City	58,253	57,295	958	20,670	13,526	851	1,587	3,773	933	19,816	4.13	2.891
Balance Of County	23,741	23,583	158	8,587	7,449	260	184	68	626	8,133	5.29	2.900
Incorporated	65,025	63,751	1,274	22,588	14,976	932	1,728	3,877	1,075	21,639	4.20	2.946
County Total	88,766	87,334	1,432	31,175	22,425	1,192	1,912	3,945	1,701	29,772	4.50	2.933
Tehama County												
Corning	6,989	6,932	57	2,713	1,626	70	288	495	234	2,513	7.37	2.758
Red Bluff	13,638	13,103	535	5,787	3,416	220	697	1,090	364	5,310	8.24	2.468
Tehama	434	434	0	197	168	4	10	0	15	180	8.63	2.411
Balance Of County	38,637	38,218	419	16,430	10,145	194	246	78	5,767	14,407	12.31	2.653
Incorporated	21,061	20,469	592	8,697	5,210	294	995	1,585	613	8,003	7.98	2.558
County Total	59,698	58,687	1,011	25,127	15,355	488	1,241	1,663	6,380	22,410	10.81	2.619
Trinity County												
County Total	13,773	13,543	230	8,198	5,425	112	108	117	2,436	5,739	30.00	2.360
Tulare County												
Dinuba	19,214	19,100	114	5,154	3,856	280	268	545	205	4,960	3.76	3.851
Exeter	10,329	10,237	92	3,455	2,763	107	205	192	188	3,273	5.27	3.128
Farmersville	10,214	10,195	19	2,565	2,062	90	155	157	101	2,432	5.19	4.192
Lindsay	11,002	10,853	149	2,962	1,991	182	246	358	185	2,810	5.13	3.862
Porterville	44,384	42,832	1,552	13,835	9,695	483	1,556	1,456	645	12,955	6.36	3.306
Tulare	49,346	48,899	447	15,473	11,778	511	1,275	1,134	775	14,703	4.98	3.326
Visalia	107,268	105,646	1,622	37,142	27,406	1,572	3,659	3,035	1,470	35,109	5.47	3.009
Woodlake	7,169	7,160	9	1,953	1,282	126	154	331	60	1,852	5.17	3.866
Balance Of County	149,838	147,877	1,961	46,350	35,114	1,440	1,475	890	7,431	40,963	11.62	3.610
Incorporated	258,926	254,922	4,004	82,539	60,833	3,351	7,518	7,208	3,629	78,094	5.39	3.264
County Total	408,764	402,799	5,965	128,889	95,947	4,791	8,993	8,098	11,060	119,057	7.63	3.383
Tuolumne County												
Sonora	4,623	4,424	199	2,312	1,358	86	391	447	30	2,159	6.62	2.049
Balance Of County	52,087	47,461	4,626	27,440	21,388	566	787	627	4,072	19,897	27.49	2.385
Incorporated	4,623	4,424	199	2,312	1,358	86	391	447	30	2,159	6.62	2.049

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2005

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	56,710	51,885	4,825	29,752	22,746	652	1,178	1,074	4,102	22,056	25.87	2.352
Ventura County												
Camarillo	62,449	61,061	1,388	23,617	14,127	4,493	884	3,055	1,058	23,096	2.21	2.644
Fillmore	15,130	14,884	246	4,241	3,076	281	236	322	326	4,142	2.33	3.593
Moorpark	35,595	35,583	12	10,211	7,263	1,234	223	1,189	302	10,099	1.10	3.523
Ojai	8,104	7,914	190	3,301	2,271	266	304	452	8	3,158	4.33	2.506
Oxnard	187,691	185,094	2,597	49,382	28,001	4,576	4,427	9,432	2,946	47,644	3.52	3.885
Port Hueneme	22,566	21,371	1,195	8,037	2,420	2,204	1,201	2,171	41	7,443	7.39	2.871
San Buenaventura	105,454	102,793	2,661	41,143	23,110	3,428	4,212	7,770	2,623	39,821	3.21	2.581
Santa Paula	29,099	28,856	243	8,412	5,027	729	778	1,091	787	8,206	2.45	3.516
Simi Valley	120,678	119,878	800	40,051	29,686	2,881	1,655	4,937	892	39,136	2.28	3.063
Thousand Oaks	126,337	124,386	1,951	46,022	31,132	5,227	1,745	6,846	1,072	44,774	2.71	2.778
Balance Of County	96,127	93,796	2,331	32,920	26,168	2,348	1,017	1,168	2,219	30,964	5.94	3.029
Incorporated	713,103	701,820	11,283	234,417	146,113	25,319	15,665	37,265	10,055	227,519	2.94	3.085
County Total	809,230	795,616	13,614	267,337	172,281	27,667	16,682	38,433	12,274	258,483	3.31	3.078
Yolo County												
Davis	64,574	61,541	3,033	25,248	11,442	2,387	2,306	8,728	385	24,541	2.80	2.508
West Sacramento	40,316	40,110	206	15,455	9,630	879	945	2,463	1,538	14,526	6.01	2.761
Winters	7,000	6,994	6	2,228	1,796	105	67	182	78	2,174	2.42	3.217
Woodland	53,542	52,237	1,305	18,446	11,483	1,313	1,147	3,822	681	18,048	2.16	2.894
Balance Of County	22,829	19,016	3,813	7,160	4,886	305	192	804	973	6,738	5.89	2.822
Incorporated	165,432	160,882	4,550	61,377	34,351	4,684	4,465	15,195	2,682	59,289	3.40	2.714
County Total	188,261	179,898	8,363	68,537	39,237	4,989	4,657	15,999	3,655	66,027	3.66	2.725
Yuba County												
Marysville	12,849	12,242	607	5,016	2,786	339	764	1,119	8	4,703	6.24	2.603
Wheatland	3,494	3,494	0	1,198	912	37	155	55	39	1,152	3.84	3.033
Balance Of County	50,782	50,042	740	18,336	11,948	915	692	1,076	3,705	16,166	11.83	3.096
Incorporated	16,343	15,736	607	6,214	3,698	376	919	1,174	47	5,855	5.78	2.688
County Total	67,125	65,778	1,347	24,550	15,646	1,291	1,611	2,250	3,752	22,021	10.30	2.987
California												
Incorporated Total	30,146,525	29,476,949	669,576	10,538,255	5,644,559	836,163	948,270	2,793,621	315,642	10,039,386	4.73	2.936
Balance Of State Total	6,528,821	6,348,471	180,350	2,404,677	1,756,866	107,908	97,545	176,771	265,587	2,147,375	10.70	2.956
State Total	36,675,346	35,825,420	849,926	12,942,932	7,401,425	944,071	1,045,815	2,970,392	581,229	12,186,761	5.84	2.940

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	------------POPULATION------------			------------ HOUSING UNITS ------------								
					-------- SINGLE --------		----- MULTIPLE -----					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Alameda County												
Alameda	74,419	73,616	803	32,212	13,139	3,983	5,064	9,726	300	31,296	2.84	2.352
Albany	16,648	16,615	33	7,325	3,784	197	828	2,510	6	7,085	3.28	2.345
Berkeley	105,206	98,533	6,673	47,648	20,153	1,756	9,330	16,350	59	45,683	4.12	2.157
Dublin	41,827	36,547	5,280	14,322	7,851	1,304	444	4,695	28	13,792	3.70	2.650
Emeryville	8,520	8,453	67	5,293	270	329	507	4,150	37	4,923	6.99	1.717
Fremont	209,779	208,020	1,759	71,512	42,289	7,181	3,057	18,229	756	70,261	1.75	2.961
Hayward	146,136	143,981	2,155	47,861	23,910	3,552	3,448	14,652	2,299	46,696	2.43	3.083
Livermore	81,295	80,988	307	29,416	21,308	2,446	1,246	3,985	431	28,877	1.83	2.805
Newark	43,407	43,318	89	13,416	9,207	1,238	766	2,146	59	13,255	1.20	3.268
Oakland	410,613	403,356	7,257	161,642	72,390	6,646	29,176	52,974	456	154,747	4.27	2.607
Piedmont	10,979	10,977	2	3,861	3,784	0	35	34	8	3,806	1.42	2.884
Pleasanton	67,728	67,493	235	25,461	16,707	2,747	1,163	4,388	456	24,763	2.74	2.726
San Leandro	80,928	80,101	827	31,863	19,434	2,028	2,248	7,249	904	31,160	2.21	2.571
Union City	71,024	70,682	342	20,019	12,777	2,381	1,106	2,836	919	19,769	1.25	3.575
Balance Of County	138,801	136,125	2,676	50,619	34,515	3,469	3,390	8,317	928	49,536	2.14	2.748
Incorporated	1,368,509	1,342,680	25,829	511,851	267,003	35,788	58,418	143,924	6,718	496,113	3.07	2.706
County Total	1,507,310	1,478,805	28,505	562,470	301,518	39,257	61,808	152,241	7,646	545,649	2.99	2.710
Alpine County												
County Total	1,225	1,224	1	1,725	992	50	35	586	62	549	68.17	2.230
Amador County												
Amador	212	212	0	102	83	12	5	2	0	96	5.88	2.208
Ione	7,582	3,427	4,155	1,411	1,119	54	66	87	85	1,321	6.38	2.594
Jackson	4,315	4,047	268	2,088	1,325	112	168	247	236	1,962	6.03	2.063
Plymouth	1,049	1,049	0	506	281	31	24	26	144	434	14.23	2.417
Sutter Creek	2,918	2,917	1	1,447	809	111	61	384	82	1,340	7.39	2.177
Balance Of County	21,761	21,695	66	11,374	10,090	89	122	47	1,026	9,248	18.69	2.346
Incorporated	16,076	11,652	4,424	5,554	3,617	320	324	746	547	5,153	7.22	2.261
County Total	37,837	33,347	4,490	16,928	13,707	409	446	793	1,573	14,401	14.93	2.316
Butte County												
Biggs	1,773	1,773	0	622	516	28	30	5	43	580	6.75	3.057
Chico	78,787	74,670	4,117	32,864	16,907	993	4,939	8,624	1,401	31,638	3.73	2.360
Gridley	5,925	5,803	122	2,224	1,818	45	144	141	76	2,087	6.16	2.781
Oroville	13,499	12,667	832	5,785	3,124	162	773	1,333	393	5,210	9.94	2.431
Paradise	26,410	25,790	620	12,707	8,800	338	812	290	2,467	11,903	6.33	2.167
Balance Of County	89,957	89,300	657	39,181	26,226	826	1,151	0	10,978	35,756	8.74	2.497
Incorporated	126,394	120,703	5,691	54,202	31,165	1,566	6,698	10,393	4,380	51,418	5.14	2.347

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
County Total	216,351	210,003	6,348	93,383	57,391	2,392	7,849	10,393	15,358	87,174	6.65	2.409
Calaveras County												
Angels City	3,549	3,549	0	1,747	1,229	67	122	113	216	1,579	9.62	2.248
Balance Of County	41,823	41,367	456	24,938	21,389	429	401	242	2,477	17,592	29.46	2.351
Incorporated	3,549	3,549	0	1,747	1,229	67	122	113	216	1,579	9.62	2.248
County Total	45,372	44,916	456	26,685	22,618	496	523	355	2,693	19,171	28.16	2.343
Colusa County												
Colusa	5,648	5,575	73	2,099	1,589	84	191	183	52	1,977	5.81	2.820
Williams	5,044	4,794	250	1,350	987	33	98	165	67	1,288	4.59	3.722
Balance Of County	10,638	10,541	97	4,138	3,078	112	123	115	710	3,576	13.58	2.948
Incorporated	10,692	10,369	323	3,449	2,576	117	289	348	119	3,265	5.33	3.176
County Total	21,330	20,910	420	7,587	5,654	229	412	463	829	6,841	9.83	3.057
Contra Costa County												
Antioch	99,723	99,307	416	33,633	25,298	2,205	1,783	4,078	269	32,764	2.58	3.031
Brentwood	45,770	45,733	37	15,635	13,969	417	347	551	351	15,064	3.65	3.036
Clayton	10,792	10,766	26	3,988	3,256	681	19	27	5	3,947	1.03	2.728
Concord	123,430	122,008	1,422	46,289	27,683	2,911	2,929	11,389	1,377	45,199	2.35	2.699
Danville	42,532	42,068	464	15,637	12,038	2,564	279	756	0	15,313	2.07	2.747
El Cerrito	23,187	23,011	176	10,610	7,338	355	1,315	1,570	32	10,353	2.42	2.223
Hercules	23,544	23,505	39	8,017	5,312	1,631	294	780	0	7,867	1.87	2.988
Lafayette	23,897	23,761	136	9,455	7,504	294	434	1,223	0	9,271	1.95	2.563
Martinez	36,153	34,817	1,336	14,922	9,566	2,237	988	2,107	24	14,618	2.04	2.382
Moraga	16,160	14,529	1,631	5,785	4,022	968	243	545	7	5,687	1.69	2.555
Oakley	29,354	29,287	67	9,230	8,481	84	74	170	421	9,098	1.43	3.219
Orinda	17,479	17,412	67	6,788	6,287	188	87	219	7	6,640	2.18	2.622
Pinole	19,229	19,011	218	6,990	5,130	498	366	981	15	6,904	1.23	2.754
Pittsburg	62,218	61,712	506	20,342	13,782	1,298	1,320	3,266	676	19,721	3.05	3.129
Pleasant Hill	33,059	32,599	460	14,320	8,434	1,631	718	3,485	52	14,033	2.00	2.323
Richmond	102,230	100,602	1,628	37,656	21,326	2,931	5,367	7,911	121	36,173	3.94	2.781
San Pablo	30,841	30,376	465	9,666	4,224	853	1,362	2,420	807	9,367	3.09	3.243
San Ramon	56,257	56,172	85	22,404	13,675	2,389	1,047	5,282	11	21,630	3.45	2.597
Walnut Creek	65,319	64,168	1,151	32,267	12,227	4,852	4,308	10,832	48	31,113	3.58	2.062
Balance Of County	165,060	164,089	971	63,697	46,751	2,768	2,568	8,221	3,389	61,066	4.13	2.687
Incorporated	861,174	850,844	10,330	323,634	209,552	28,987	23,280	57,592	4,223	314,762	2.74	2.703
County Total	1,026,234	1,014,933	11,301	387,331	256,303	31,755	25,848	65,813	7,612	375,828	2.97	2.701

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Del Norte County												
Crescent City	7,675	4,006	3,669	1,839	931	56	394	424	34	1,654	10.06	2.422
Balance Of County	21,310	21,033	277	9,115	5,533	132	410	160	2,880	7,971	12.55	2.639
Incorporated	7,675	4,006	3,669	1,839	931	56	394	424	34	1,654	10.06	2.422
County Total	28,985	25,039	3,946	10,954	6,464	188	804	584	2,914	9,625	12.13	2.601
El Dorado County												
Placerville	10,146	9,884	262	4,582	2,809	256	628	728	161	4,322	5.67	2.287
South Lake Tahoe	23,530	23,402	128	14,259	8,985	361	2,024	2,221	668	9,580	32.81	2.443
Balance Of County	142,053	141,393	660	62,637	54,081	1,207	965	2,838	3,546	53,819	14.08	2.627
Incorporated	33,676	33,286	390	18,841	11,794	617	2,652	2,949	829	13,902	26.21	2.394
County Total	175,729	174,679	1,050	81,478	65,875	1,824	3,617	5,787	4,375	67,721	16.88	2.579
Fresno County												
Clovis	89,740	89,260	480	32,458	22,885	549	3,082	5,025	917	31,301	3.56	2.852
Coalinga	17,250	11,469	5,781	3,988	2,713	127	283	546	319	3,631	8.95	3.159
Firebaugh	6,695	6,634	61	1,806	1,204	155	194	141	112	1,620	10.30	4.095
Fowler	4,846	4,757	89	1,519	1,097	50	162	163	47	1,478	2.70	3.219
Fresno	470,530	461,709	8,821	160,446	95,857	6,028	16,799	37,839	3,923	150,815	6.00	3.061
Huron	7,329	7,157	172	1,614	502	204	231	586	91	1,574	2.48	4.547
Kerman	12,608	12,577	31	3,555	2,609	153	256	421	116	3,450	2.95	3.646
Kingsburg	11,224	11,133	91	4,023	3,052	102	266	439	164	3,866	3.90	2.880
Mendota	8,759	8,751	8	2,039	1,203	139	311	313	73	1,983	2.75	4.413
Orange Cove	9,620	9,620	0	2,153	1,217	206	224	480	26	2,064	4.13	4.661
Parlier	12,868	12,766	102	2,990	2,073	234	184	485	14	2,767	7.46	4.614
Reedley	23,295	22,900	395	6,570	4,687	216	612	864	191	6,338	3.53	3.613
Sanger	23,275	23,135	140	6,527	4,837	194	575	758	163	6,285	3.71	3.681
San Joaquin	3,739	3,739	0	822	504	80	115	63	60	787	4.26	4.751
Selma	22,886	22,756	130	6,701	4,993	148	333	801	426	6,449	3.76	3.529
Balance Of County	173,171	170,668	2,503	60,197	48,329	1,475	1,314	1,948	7,131	53,787	10.65	3.173
Incorporated	724,664	708,363	16,301	237,211	149,433	8,585	23,627	48,924	6,642	224,408	5.40	3.157
County Total	897,835	879,031	18,804	297,408	197,762	10,060	24,941	50,872	13,773	278,195	6.46	3.160
Glenn County												
Orland	6,937	6,899	38	2,497	1,837	44	382	197	37	2,369	5.13	2.912
Willows	6,382	6,201	181	2,384	1,560	54	305	458	7	2,149	9.86	2.886
Balance Of County	15,103	14,927	176	5,641	3,909	109	93	45	1,485	5,156	8.60	2.895
Incorporated	13,319	13,100	219	4,881	3,397	98	687	655	44	4,518	7.44	2.900

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	28,422	28,027	395	10,522	7,306	207	780	700	1,529	9,674	8.06	2.897
Humboldt County												
Arcata	17,282	15,582	1,700	7,507	3,492	297	1,183	1,851	684	7,278	3.05	2.141
Blue Lake	1,170	1,170	0	578	382	21	68	36	71	525	9.17	2.229
Eureka	26,205	24,856	1,349	11,773	7,268	381	2,246	1,704	174	11,085	5.84	2.242
Ferndale	1,427	1,427	0	690	561	27	83	10	9	637	7.68	2.240
Fortuna	11,305	11,039	266	4,787	3,204	235	536	368	444	4,538	5.20	2.433
Rio Dell	3,249	3,239	10	1,481	1,030	26	150	36	239	1,261	14.85	2.569
Trinidad	315	315	0	233	183	8	11	0	31	172	26.18	1.831
Balance Of County	70,622	69,602	1,020	31,501	24,145	602	1,540	722	4,492	28,145	10.65	2.473
Incorporated	60,953	57,628	3,325	27,049	16,120	995	4,277	4,005	1,652	25,496	5.74	2.260
County Total	131,575	127,230	4,345	58,550	40,265	1,597	5,817	4,727	6,144	53,641	8.38	2.372
Imperial County												
Brawley	25,426	25,114	312	8,237	5,313	362	694	1,413	455	7,761	5.78	3.236
Calexico	36,651	36,548	103	9,575	6,619	439	939	1,373	205	9,344	2.41	3.911
Calipatria	7,819	3,546	4,273	1,081	747	38	75	158	63	1,010	6.57	3.511
El Centro	41,904	41,017	887	13,789	7,601	563	1,102	3,205	1,318	12,866	6.69	3.188
Holtville	5,832	5,702	130	1,704	1,038	111	198	162	195	1,648	3.29	3.460
Imperial	10,116	10,084	32	3,237	2,679	117	243	164	34	3,133	3.21	3.219
Westmorland	2,368	2,368	0	751	438	16	90	167	40	705	6.13	3.359
Balance Of County	36,116	30,006	6,110	13,418	6,818	357	443	314	5,486	10,206	23.94	2.940
Incorporated	130,116	124,379	5,737	38,374	24,435	1,646	3,341	6,642	2,310	36,467	4.97	3.411
County Total	166,232	154,385	11,847	51,792	31,253	2,003	3,784	6,956	7,796	46,673	9.88	3.308
Inyo County												
Bishop	3,561	3,484	77	1,879	847	78	262	323	369	1,696	9.74	2.054
Balance Of County	14,671	14,467	204	7,340	4,670	133	145	145	2,247	6,157	16.12	2.350
Incorporated	3,561	3,484	77	1,879	847	78	262	323	369	1,696	9.74	2.054
County Total	18,232	17,951	281	9,219	5,517	211	407	468	2,616	7,853	14.82	2.286
Kern County												
Arvin	15,005	14,934	71	3,530	2,423	218	264	368	257	3,379	4.28	4.420
Bakersfield	311,353	307,981	3,372	108,242	76,115	3,224	10,644	15,590	2,669	102,335	5.46	3.010
California City	12,031	9,387	2,644	3,887	2,946	68	322	226	325	3,349	13.84	2.803
Delano	49,299	40,100	9,199	10,153	7,321	549	641	1,192	450	9,669	4.77	4.147
Maricopa	1,135	1,135	0	459	247	7	5	9	191	403	12.20	2.816
Mcfarland	12,519	11,212	1,307	2,579	1,910	246	270	124	29	2,527	2.02	4.437

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Ridgecrest	27,465	27,063	402	11,529	7,651	414	1,697	765	1,002	10,527	8.69	2.571
Shafter	14,481	13,803	678	4,007	3,149	177	234	237	210	3,641	9.13	3.791
Taft	9,138	6,147	2,991	2,525	1,836	52	315	222	100	2,276	9.86	2.701
Tehachapi	12,599	7,612	4,987	3,275	2,106	150	391	281	347	2,848	13.04	2.673
Wasco	24,260	17,861	6,399	4,893	3,655	360	428	318	132	4,566	6.68	3.912
Balance Of County	288,434	284,101	4,333	107,855	74,261	3,084	6,255	4,874	19,381	91,971	14.73	3.089
Incorporated	489,285	457,235	32,050	155,079	109,359	5,465	15,211	19,332	5,712	145,520	6.16	3.142
County Total	777,719	741,336	36,383	262,934	183,620	8,549	21,466	24,206	25,093	237,491	9.68	3.122
Kings County												
Avenal	16,308	8,929	7,379	2,251	1,395	147	309	305	95	2,106	6.44	4.240
Corcoran	23,397	10,905	12,492	3,367	2,405	180	348	308	126	3,090	8.23	3.529
Hanford	48,828	47,980	848	16,867	12,474	552	1,446	2,053	342	15,961	5.37	3.006
Lemoore	23,281	23,279	2	7,859	5,226	154	487	1,663	329	7,430	5.46	3.133
Balance Of County	36,476	33,981	2,495	10,252	7,197	1,392	225	110	1,328	9,694	5.44	3.505
Incorporated	111,814	91,093	20,721	30,344	21,500	1,033	2,590	4,329	892	28,587	5.79	3.187
County Total	148,290	125,074	23,216	40,596	28,697	2,425	2,815	4,439	2,220	38,281	5.70	3.267
Lake County												
Clearlake	13,760	13,641	119	7,665	3,686	104	247	326	3,302	5,577	27.24	2.446
Lakeport	5,069	4,895	174	2,427	1,463	119	166	223	456	1,995	17.80	2.454
Balance Of County	44,539	43,635	904	23,922	16,355	315	509	375	6,368	17,495	26.87	2.494
Incorporated	18,829	18,536	293	10,092	5,149	223	413	549	3,758	7,572	24.97	2.448
County Total	63,368	62,171	1,197	34,014	21,504	538	922	924	10,126	25,067	26.30	2.480
Lassen County												
Susanville	18,113	8,947	9,166	4,131	2,961	131	379	450	210	3,743	9.39	2.390
Balance Of County	17,133	16,868	265	8,696	5,882	221	138	59	2,396	6,611	23.98	2.552
Incorporated	18,113	8,947	9,166	4,131	2,961	131	379	450	210	3,743	9.39	2.390
County Total	35,246	25,815	9,431	12,827	8,843	352	517	509	2,606	10,354	19.28	2.493
Los Angeles County												
Agoura Hills	23,182	23,159	23	7,554	5,285	979	176	1,114	0	7,426	1.69	3.119
Alhambra	89,139	87,216	1,923	30,188	12,744	3,284	3,963	10,180	17	29,225	3.19	2.984
Arcadia	56,026	55,445	581	20,190	11,856	1,699	1,468	5,141	26	19,360	4.11	2.864
Artesia	17,459	16,887	572	4,700	3,219	327	323	735	96	4,570	2.77	3.695
Avalon	3,481	3,419	62	1,913	498	487	548	371	9	1,221	36.17	2.800

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COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Azusa	48,204	46,255	1,949	13,468	6,185	1,767	1,467	3,460	589	12,988	3.56	3.561
Baldwin Park	80,814	80,208	606	17,781	11,997	1,878	610	2,953	343	17,302	2.69	4.636
Bell	38,740	38,202	538	9,324	3,598	1,517	1,457	2,291	461	9,024	3.22	4.233
Bellflower	76,877	76,254	623	24,484	11,282	2,085	1,431	8,084	1,602	23,595	3.63	3.232
Bell Gardens	45,946	45,490	456	9,772	3,958	2,470	1,442	1,506	396	9,450	3.30	4.814
Beverly Hills	35,738	35,699	39	16,049	5,736	236	1,802	8,247	28	15,218	5.18	2.346
Bradbury	940	940	0	330	328	0	2	0	0	301	8.79	3.123
Burbank	106,652	105,826	826	43,608	19,927	1,731	4,677	17,161	112	42,347	2.89	2.499
Calabasas	23,338	23,278	60	8,487	5,892	804	204	1,334	253	8,214	3.22	2.834
Carson	97,773	96,475	1,298	26,422	18,656	2,280	716	2,265	2,505	25,703	2.72	3.753
Cerritos	54,716	54,623	93	15,871	13,378	1,220	600	641	32	15,651	1.39	3.490
Claremont	36,624	31,182	5,442	11,936	8,324	855	635	2,109	13	11,649	2.40	2.677
Commerce	13,411	13,208	203	3,424	1,944	593	332	551	4	3,331	2.72	3.965
Compton	98,737	98,087	650	24,054	16,049	2,150	2,304	2,903	648	22,571	6.17	4.346
Covina	49,272	48,670	602	16,483	9,441	1,298	987	4,169	588	16,087	2.40	3.025
Cudahy	25,603	25,591	12	5,608	1,674	1,283	344	1,893	414	5,484	2.21	4.666
Culver City	40,583	40,059	524	17,147	6,621	1,903	2,302	6,140	181	16,628	3.03	2.409
Diamond Bar	59,596	59,478	118	18,196	12,843	2,501	823	1,696	333	17,885	1.71	3.326
Downey	112,825	111,060	1,765	34,992	20,446	1,667	1,660	11,026	193	34,217	2.21	3.246
Duarte	22,951	22,461	490	6,966	4,353	882	224	1,278	229	6,792	2.50	3.307
El Monte	125,088	123,818	1,270	28,672	15,349	3,396	2,023	6,498	1,406	27,924	2.61	4.434
El Segundo	16,929	16,906	23	7,336	3,124	426	820	2,955	11	7,134	2.75	2.370
Gardena	61,384	60,580	804	21,419	9,248	1,711	2,699	6,658	1,103	20,688	3.41	2.928
Glendale	205,876	203,012	2,864	74,533	26,119	3,814	6,912	37,591	97	72,604	2.59	2.796
Glendora	52,089	51,076	1,013	17,309	12,604	1,094	699	2,029	883	16,980	1.90	3.008
Hawaiian Gardens	15,814	15,810	4	3,711	1,519	502	455	960	275	3,592	3.21	4.401
Hawthorne	88,272	87,772	500	29,760	8,242	2,471	3,325	15,549	173	28,663	3.69	3.062
Hermosa Beach	19,395	19,282	113	9,838	4,132	1,022	2,043	2,559	82	9,472	3.72	2.036
Hidden Hills	2,030	2,030	0	613	611	2	0	0	0	589	3.92	3.447
Huntington Park	64,470	64,289	181	15,422	5,274	2,380	2,211	5,542	15	14,944	3.10	4.302
Industry	801	537	264	124	101	23	0	0	0	121	2.42	4.438
Inglewood	117,863	116,493	1,370	38,736	14,130	3,230	4,718	16,420	238	36,888	4.77	3.158
Irwindale	1,555	1,553	2	389	328	16	13	24	8	375	3.60	4.141
La Canada Flintridge	21,266	21,077	189	7,068	6,561	200	132	175	0	6,901	2.36	3.054
La Habra Heights	6,095	6,095	0	2,011	1,979	24	8	0	0	1,945	3.28	3.134
Lakewood	83,111	82,917	194	27,374	22,239	741	730	3,566	98	26,916	1.67	3.081
La Mirada	49,691	47,572	2,119	15,074	11,891	800	480	1,737	166	14,839	1.56	3.206
Lancaster	138,112	130,854	7,258	46,790	31,626	1,197	2,614	7,855	3,498	42,844	8.43	3.054
La Puente	43,073	43,041	32	9,696	6,359	642	340	2,246	109	9,497	2.05	4.532
La Verne	33,240	32,532	708	11,358	7,553	599	736	707	1,763	11,142	1.90	2.920
Lawndale	33,271	33,185	86	9,909	4,933	1,606	919	2,323	128	9,594	3.18	3.459
Lomita	21,020	20,887	133	8,325	4,025	774	581	2,447	498	8,044	3.38	2.597
Long Beach	489,143	478,752	10,391	174,195	69,305	10,091	23,310	68,960	2,529	165,524	4.98	2.892
Los Angeles	3,966,959	3,882,507	84,452	1,375,930	529,744	88,262	130,805	618,030	9,089	1,311,887	4.65	2.959
Lynwood	72,893	70,693	2,200	14,986	8,164	1,691	1,682	3,337	112	14,393	3.96	4.912
Malibu	13,632	13,332	300	6,367	4,038	475	404	840	610	5,339	16.15	2.497
Manhattan Beach	36,425	36,411	14	15,485	10,568	1,417	2,596	871	33	14,910	3.71	2.442
Maywood	29,480	29,386	94	6,732	2,813	1,114	1,444	1,353	8	6,499	3.46	4.522
Monrovia	38,925	38,632	293	14,082	7,784	1,549	1,318	3,316	115	13,623	3.26	2.836

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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSE-HOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	SINGLE: DETACHED	SINGLE: ATTACHED	MULTIPLE: 2 TO 4	MULTIPLE: 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Montebello	65,284	64,975	309	19,519	9,382	1,576	2,863	5,465	233	18,944	2.95	3.430
Monterey Park	64,250	63,973	277	20,695	11,712	2,204	2,005	4,694	80	20,035	3.19	3.193
Norwalk	109,452	107,532	1,920	27,808	20,186	1,422	830	4,900	470	27,136	2.42	3.963
Palmdale	140,713	140,619	94	42,841	33,814	905	938	5,402	1,782	39,599	7.57	3.551
Palos Verdes Estates	14,010	14,005	5	5,277	4,855	40	44	338	0	5,066	4.00	2.765
Paramount	57,682	57,362	320	14,575	6,032	2,165	1,084	3,922	1,372	13,956	4.25	4.110
Pasadena	145,834	142,316	3,518	56,520	24,869	4,997	4,654	21,927	73	54,131	4.23	2.629
Pico Rivera	66,838	66,488	350	16,951	12,697	945	337	2,382	590	16,609	2.02	4.003
Pomona	161,519	155,475	6,044	40,785	24,715	3,339	3,289	7,737	1,705	38,989	4.40	3.988
Rancho Palos Verdes	42,899	42,390	509	15,826	12,239	1,287	249	2,051	0	15,370	2.88	2.758
Redondo Beach	66,968	66,781	187	29,929	11,840	4,238	4,030	9,441	380	28,938	3.31	2.308
Rolling Hills	1,960	1,960	0	690	683	7	0	0	0	653	5.36	3.002
Rolling Hills Estates	8,072	8,060	12	2,926	2,309	565	41	7	4	2,852	2.53	2.826
Rosemead	57,026	56,414	612	14,639	9,931	2,030	919	1,355	404	14,198	3.01	3.973
San Dimas	36,788	35,579	1,209	12,604	7,586	2,100	357	1,618	943	12,262	2.71	2.902
San Fernando	24,982	24,936	46	6,018	4,036	634	473	802	73	5,859	2.64	4.256
San Gabriel	42,231	41,476	755	13,119	7,080	1,189	1,105	3,701	44	12,792	2.49	3.242
San Marino	13,451	13,444	7	4,453	4,417	19	8	9	0	4,282	3.84	3.140
Santa Clarita	167,059	165,666	1,393	55,530	33,606	6,314	2,824	10,546	2,240	53,774	3.16	3.081
Santa Fe Springs	17,743	17,525	218	5,107	3,101	286	158	1,435	127	5,004	2.02	3.502
Santa Monica	90,562	87,956	2,606	49,383	9,361	1,929	5,563	32,241	289	45,910	7.03	1.916
Sierra Madre	10,988	10,861	127	4,941	3,412	205	377	920	27	4,774	3.38	2.275
Signal Hill	11,066	11,012	54	4,312	1,405	467	757	1,675	8	4,114	4.59	2.677
South El Monte	22,260	22,242	18	4,759	2,969	458	233	595	504	4,654	2.21	4.779
South Gate	101,430	101,289	141	24,441	12,354	3,267	3,703	4,837	280	23,377	4.35	4.333
South Pasadena	25,620	25,433	187	10,957	5,085	633	1,118	4,107	14	10,581	3.43	2.404
Temple City	35,396	34,885	511	11,856	9,592	802	421	983	58	11,515	2.88	3.030
Torrance	146,798	145,549	1,249	57,051	30,600	3,693	3,358	18,217	1,183	55,601	2.54	2.618
Vernon	95	95	0	26	19	0	0	7	0	25	3.85	3.800
Walnut	32,080	32,040	40	8,589	8,124	119	46	300	0	8,451	1.61	3.791
West Covina	112,222	111,414	808	32,775	21,320	2,812	1,570	6,725	348	32,114	2.02	3.469
West Hollywood	37,463	37,227	236	24,427	1,807	682	1,860	20,078	0	23,428	4.09	1.589
Westlake Village	8,843	8,834	9	3,384	2,242	608	158	201	175	3,306	2.30	2.672
Whittier	86,661	85,071	1,590	28,996	19,072	1,480	2,056	6,174	214	28,289	2.44	3.007
Balance Of County	1,090,489	1,073,636	16,853	310,856	214,005	22,882	18,628	44,389	10,952	296,525	4.61	3.621
Incorporated	9,132,774	8,971,087	161,687	3,053,900	1,419,049	220,582	271,942	1,096,588	45,739	2,926,698	4.17	3.065
County Total	10,223,263	10,044,723	178,540	3,364,756	1,633,054	243,464	290,570	1,140,977	56,691	3,223,223	4.21	3.116
Madera County												
Chowchilla	17,080	9,467	7,613	3,353	2,710	31	272	304	36	3,169	5.49	2.987
Madera	52,531	52,003	528	14,997	10,237	742	1,557	2,160	301	14,346	4.34	3.625
Balance Of County	74,646	73,860	786	28,289	23,422	563	605	417	3,282	24,308	14.07	3.039
Incorporated	69,611	61,470	8,141	18,350	12,947	773	1,829	2,464	337	17,515	4.55	3.510
County Total	144,257	135,330	8,927	46,639	36,369	1,336	2,434	2,881	3,619	41,823	10.33	3.236

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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Marin County												
Belvedere	2,136	2,136	0	1,065	874	54	94	43	0	962	9.67	2.220
Corte Madera	9,394	9,386	8	3,977	2,621	416	369	561	10	3,901	1.91	2.406
Fairfax	7,322	7,292	30	3,422	2,335	193	490	393	11	3,310	3.27	2.203
Larkspur	12,034	11,879	155	6,428	2,452	360	544	2,833	239	6,157	4.22	1.929
Mill Valley	13,728	13,637	91	6,350	4,138	550	535	1,127	0	6,210	2.20	2.196
Novato	51,066	50,196	870	20,469	12,089	2,669	1,313	3,680	718	19,964	2.47	2.514
Ross	2,355	2,261	94	815	795	0	12	0	8	771	5.40	2.933
San Anselmo	12,413	12,157	256	5,427	3,998	186	468	757	18	5,286	2.60	2.300
San Rafael	57,323	55,253	2,070	23,476	10,641	2,009	2,459	7,878	489	22,886	2.51	2.414
Sausalito	7,390	7,378	12	4,551	1,728	423	1,349	827	224	4,293	5.67	1.719
Tiburon	8,812	8,706	106	3,962	2,421	237	467	837	0	3,777	4.67	2.305
Balance Of County	69,102	61,882	7,220	27,798	21,424	1,489	1,589	2,882	414	25,816	7.13	2.397
Incorporated	183,973	180,281	3,692	79,942	44,092	7,097	8,100	18,936	1,717	77,517	3.03	2.326
County Total	253,075	242,163	10,912	107,740	65,516	8,586	9,689	21,818	2,131	103,333	4.09	2.344
Mariposa County												
County Total	18,065	16,620	1,445	9,959	6,281	450	214	383	2,631	7,463	25.06	2.227
Mendocino County												
Fort Bragg	6,877	6,751	126	3,140	2,036	158	324	459	163	2,923	6.91	2.310
Point Arena	493	493	0	232	148	7	45	13	19	204	12.07	2.417
Ukiah	15,759	15,025	734	6,369	3,528	379	767	1,233	462	6,211	2.48	2.419
Willits	5,015	4,889	126	2,028	1,191	84	315	291	147	1,950	3.85	2.507
Balance Of County	61,176	59,898	1,278	27,222	20,545	535	725	778	4,639	23,804	12.56	2.516
Incorporated	28,144	27,158	986	11,769	6,903	628	1,451	1,996	791	11,288	4.09	2.406
County Total	89,320	87,056	2,264	38,991	27,448	1,163	2,176	2,774	5,430	35,092	10.00	2.481
Merced County												
Atwater	27,080	25,510	1,570	9,181	6,268	584	832	990	507	8,200	10.69	3.111
Dos Palos	4,912	4,888	24	1,632	1,411	55	48	78	40	1,557	4.60	3.139
Gustine	5,214	5,214	0	1,983	1,622	30	98	105	128	1,893	4.54	2.754
Livingston	12,504	12,467	37	2,965	2,338	80	206	305	36	2,893	2.43	4.309
Los Banos	33,923	33,748	175	10,714	8,946	263	570	658	277	10,276	4.09	3.284
Merced	75,564	74,194	1,370	25,896	16,236	944	2,771	5,237	708	24,578	5.09	3.019
Balance Of County	85,989	84,434	1,555	27,765	21,787	582	840	628	3,928	25,481	8.23	3.314
Incorporated	159,197	156,021	3,176	52,371	36,821	1,956	4,525	7,373	1,696	49,397	5.68	3.159
	245,186	240,455	4,731	80,136	58,608	2,538	5,365	8,001	5,624	74,878		
County Total	245,186	240,455	4,731	80,136	58,608	2,538	5,365	8,001	5,624	74,878	6.56	3.211

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Modoc County												
Alturas	2,810	2,730	80	1,376	1,021	57	47	144	107	1,188	13.66	2.298
Balance Of County	6,836	6,507	329	3,729	2,449	33	50	15	1,182	2,822	24.32	2.306
Incorporated	2,810	2,730	80	1,376	1,021	57	47	144	107	1,188	13.66	2.298
County Total	9,646	9,237	409	5,105	3,470	90	97	159	1,289	4,010	21.45	2.303
Mono County												
Mammoth Lakes	7,355	7,137	218	9,223	2,306	1,003	1,880	3,841	193	3,260	64.65	2.189
Balance Of County	6,231	5,908	323	4,328	2,849	256	307	74	842	2,724	37.06	2.169
Incorporated	7,355	7,137	218	9,223	2,306	1,003	1,880	3,841	193	3,260	64.65	2.189
County Total	13,586	13,045	541	13,551	5,155	1,259	2,187	3,915	1,035	5,984	55.84	2.180
Monterey County												
Carmel-By-The-Sea	4,051	4,051	0	3,355	2,752	114	219	270	0	2,300	31.45	1.761
Del Rey Oaks	1,629	1,629	0	727	567	25	23	109	3	704	3.16	2.314
Gonzales	8,486	8,413	73	1,962	1,413	133	205	169	42	1,929	1.68	4.361
Greenfield	15,390	15,294	96	3,366	2,467	282	284	247	86	3,263	3.06	4.687
King City	11,370	11,186	184	2,903	1,624	278	296	415	290	2,813	3.10	3.977
Marina	18,891	18,760	131	8,635	3,460	1,537	1,457	1,748	433	6,822	21.00	2.750
Monterey	30,101	27,068	3,033	13,537	5,920	913	2,268	4,415	21	12,765	5.70	2.120
Pacific Grove	15,359	15,184	175	8,053	5,015	448	989	1,510	91	7,335	8.92	2.070
Salinas	148,870	146,418	2,452	41,955	22,785	3,468	3,479	10,937	1,286	40,514	3.43	3.614
Sand City	301	237	64	106	58	6	28	9	5	98	7.55	2.418
Seaside	33,509	31,207	2,302	11,266	6,293	2,351	920	1,270	432	9,963	11.57	3.132
Soledad	28,134	16,205	11,929	3,711	2,792	204	382	210	123	3,621	2.43	4.475
Balance Of County	105,326	103,679	1,647	39,041	30,016	2,695	1,567	1,663	3,100	35,616	8.77	2.911
Incorporated	316,091	295,652	20,439	99,576	55,146	9,759	10,550	21,309	2,812	92,127	7.48	3.209
County Total	421,417	399,331	22,086	138,617	85,162	12,454	12,117	22,972	5,912	127,743	7.84	3.126
Napa County												
American Canyon	14,884	14,750	134	5,109	4,178	23	68	61	779	5,008	1.98	2.945
Calistoga	5,220	5,153	67	2,307	1,072	97	186	361	591	2,096	9.15	2.458
Napa	76,123	74,664	1,459	29,735	18,006	2,338	2,856	5,146	1,389	28,881	2.87	2.585
St Helena	5,944	5,892	52	2,758	1,687	215	216	478	162	2,425	12.07	2.430
Yountville	3,247	2,077	1,170	1,177	623	172	39	35	308	1,084	7.90	1.916
Balance Of County	28,075	25,688	2,387	11,855	10,112	650	353	8	732	10,125	14.59	2.537
Incorporated	105,418	102,536	2,882	41,086	25,566	2,845	3,365	6,081	3,229	39,494	3.87	2.596

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	------------POPULATION------------			---------------------------------- HOUSING UNITS ----------------------------------								
					-------- SINGLE --------		----- MULTIPLE -----					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
County Total	133,493	128,224	5,269	52,941	35,678	3,495	3,718	6,089	3,961	49,619	6.27	2.584
Nevada County												
Grass Valley	12,868	12,518	350	6,339	2,980	260	759	1,645	695	6,038	4.75	2.073
Nevada City	3,049	2,862	187	1,477	1,137	53	123	90	74	1,371	7.18	2.088
Truckee	15,710	15,669	41	11,339	9,459	242	766	574	298	5,984	47.23	2.618
Balance Of County	67,171	66,782	389	29,846	26,431	320	271	90	2,734	27,244	8.72	2.451
Incorporated	31,627	31,049	578	19,155	13,576	555	1,648	2,309	1,067	13,393	30.08	2.318
County Total	98,798	97,831	967	49,001	40,007	875	1,919	2,399	3,801	40,637	17.07	2.407
Orange County												
Aliso Viejo	44,705	44,545	160	17,968	6,455	4,935	739	5,824	15	17,470	2.77	2.550
Anaheim	341,472	337,676	3,796	100,996	43,623	8,923	10,370	33,695	4,385	98,212	2.76	3.438
Brea	39,483	39,355	128	14,476	8,447	1,095	563	3,501	870	14,196	1.93	2.772
Buena Park	81,192	80,258	934	24,001	14,166	1,911	1,424	6,209	291	23,503	2.07	3.415
Costa Mesa	112,918	109,852	3,066	40,928	15,694	4,161	5,930	14,047	1,096	39,712	2.97	2.766
Cypress	48,761	48,440	321	16,477	10,186	2,562	523	2,842	364	16,092	2.34	3.010
Dana Point	36,598	36,356	242	15,900	7,900	2,266	2,819	2,622	293	14,659	7.81	2.480
Fountain Valley	57,295	56,783	512	18,726	12,386	2,194	668	3,080	398	18,411	1.68	3.084
Fullerton	136,164	132,945	3,219	46,965	23,934	3,845	3,729	14,536	921	45,746	2.60	2.906
Garden Grove	171,432	169,198	2,234	47,150	26,748	4,486	3,414	10,674	1,828	46,230	1.95	3.660
Huntington Beach	200,608	199,816	792	77,866	38,484	9,457	9,866	16,918	3,141	75,803	2.65	2.636
Irvine	193,419	185,436	7,983	71,652	26,794	14,591	4,682	24,563	1,022	68,426	4.50	2.710
Laguna Beach	24,913	24,791	122	13,241	8,285	759	1,768	2,105	324	11,755	11.22	2.109
Laguna Hills	33,159	32,735	424	11,152	5,872	2,183	608	2,272	217	10,806	3.10	3.029
Laguna Niguel	66,049	65,746	303	24,793	13,719	5,007	1,441	4,610	16	24,099	2.80	2.728
Laguna Woods	18,298	18,224	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.447
La Habra	61,669	61,074	595	19,777	10,480	1,695	1,360	5,508	734	19,274	2.54	3.169
Lake Forest	77,709	76,865	844	26,384	14,165	3,923	1,276	5,734	1,286	25,711	2.55	2.990
La Palma	16,049	16,018	31	5,131	3,637	376	102	989	27	5,043	1.72	3.176
Los Alamitos	11,982	11,576	406	4,378	1,933	269	1,033	1,014	129	4,295	1.90	2.695
Mission Viejo	97,807	96,742	1,065	33,713	24,474	4,021	1,201	3,928	89	33,165	1.63	2.917
Newport Beach	83,200	82,260	940	42,352	19,083	7,166	5,515	9,725	863	37,731	10.91	2.180
Orange	137,540	132,072	5,468	43,578	24,933	5,149	4,715	7,442	1,339	42,566	2.32	3.103
Placentia	51,135	50,832	303	16,402	9,713	2,050	1,108	2,954	577	16,093	1.88	3.159
Rancho Santa Margarita	49,035	49,021	14	16,678	9,118	3,883	598	3,079	0	16,413	1.59	2.987
San Clemente	66,150	65,858	292	26,641	15,031	2,663	4,059	4,485	403	25,017	6.10	2.633
San Juan Capistrano	36,003	35,545	458	11,714	6,025	2,395	944	865	1,485	11,310	3.45	3.143
Santa Ana	350,811	345,164	5,647	75,330	33,736	6,578	7,499	23,608	3,909	73,727	2.13	4.682
Seal Beach	25,421	25,137	284	14,490	4,647	2,121	1,169	6,390	163	13,344	7.91	1.884
Stanton	38,688	38,170	518	11,079	3,002	1,873	988	3,954	1,262	10,834	2.21	3.523
Tustin	71,631	71,213	418	25,281	8,498	3,746	3,174	8,955	908	24,596	2.71	2.895
Villa Park	6,207	6,186	21	2,020	1,991	18	0	6	5	1,962	2.87	3.153
Westminster	92,229	91,677	552	27,397	14,884	2,553	2,084	4,808	3,068	26,854	1.98	3.414

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Yorba Linda	66,668	66,533	135	21,534	16,986	2,307	570	1,360	311	21,187	1.61	3.140
Balance Of County	120,083	118,562	1,521	38,619	30,026	2,234	2,127	3,704	528	37,731	2.30	3.142
Incorporated	2,946,400	2,904,099	42,301	979,799	485,756	125,173	88,413	248,692	31,765	946,833	3.36	3.067
County Total	3,066,483	3,022,661	43,822	1,018,418	515,782	127,407	90,540	252,396	32,293	984,564	3.32	3.070
Placer County												
Auburn	13,026	12,820	206	5,898	4,007	211	655	1,025	0	5,731	2.83	2.237
Colfax	1,832	1,831	1	806	516	22	172	63	33	779	3.35	2.350
Lincoln	33,716	33,602	114	14,807	13,515	196	287	713	96	14,298	3.44	2.350
Loomis	6,506	6,472	34	2,441	2,068	199	58	2	114	2,370	2.91	2.731
Rocklin	51,110	50,732	378	19,924	14,321	516	820	3,828	439	19,182	3.72	2.645
Roseville	105,049	103,995	1,054	43,433	31,837	1,082	1,627	8,344	543	41,879	3.58	2.483
Balance Of County	106,463	105,000	1,463	53,021	42,692	1,916	2,569	2,331	3,513	40,871	22.92	2.569
Incorporated	211,239	209,452	1,787	87,309	66,264	2,226	3,619	13,975	1,225	84,239	3.52	2.486
County Total	317,702	314,452	3,250	140,330	108,956	4,142	6,188	16,306	4,738	125,110	10.85	2.513
Plumas County												
Portola	2,107	2,086	21	1,055	789	17	72	110	67	941	10.81	2.217
Balance Of County	18,904	18,737	167	13,934	10,706	433	303	286	2,206	9,119	34.56	2.055
Incorporated	2,107	2,086	21	1,055	789	17	72	110	67	941	10.81	2.217
County Total	21,011	20,823	188	14,989	11,495	450	375	396	2,273	10,060	32.88	2.070
Riverside County												
Banning	28,240	27,902	338	11,521	8,621	728	421	595	1,156	10,554	8.39	2.644
Beaumont	23,237	23,082	155	8,563	6,976	172	340	728	347	7,810	8.79	2.955
Blythe	22,232	13,272	8,960	5,306	2,920	152	498	881	855	4,451	16.11	2.982
Calimesa	7,444	7,348	96	3,311	1,822	113	57	64	1,255	3,041	8.15	2.416
Canyon Lake	10,982	10,966	16	4,364	4,000	133	6	84	141	3,930	9.95	2.790
Cathedral City	51,284	51,090	194	21,016	11,216	2,607	2,436	1,938	2,819	16,475	21.61	3.101
Coachella	35,346	35,302	44	7,641	5,115	319	700	1,050	457	7,310	4.33	4.829
Corona	145,235	144,603	632	44,627	31,016	2,186	2,225	7,587	1,613	43,000	3.65	3.363
Desert Hot Springs	23,454	23,280	174	9,751	6,320	180	1,279	1,313	659	8,122	16.71	2.866
Hemet	71,315	69,636	1,679	34,141	16,008	1,766	2,182	4,497	9,688	29,884	12.47	2.330
Indian Wells	4,885	4,885	0	4,807	3,207	884	239	469	8	2,480	48.41	1.970
Indio	71,939	71,083	856	24,334	14,980	878	1,500	3,795	3,181	19,962	17.97	3.561
Lake Elsinore	41,150	41,077	73	13,237	9,878	716	728	1,135	780	12,281	7.22	3.345
La Quinta	38,494	38,454	40	18,762	15,504	1,563	475	963	257	13,414	28.50	2.867
Moreno Valley	175,262	174,565	697	49,967	41,250	891	1,389	5,394	1,043	47,317	5.30	3.689
Murrieta	93,296	92,636	660	31,703	23,682	232	696	5,380	1,713	30,237	4.62	3.064
Norco	27,350	22,643	4,707	7,185	6,770	137	9	177	92	7,023	2.25	3.224

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Palm Desert	49,735	49,351	384	33,142	13,057	9,625	2,493	4,701	3,266	22,874	30.98	2.158
Palm Springs	46,621	45,925	696	32,841	11,747	6,424	2,530	9,907	2,233	21,863	33.43	2.101
Perris	47,326	47,094	232	13,505	9,759	321	371	1,264	1,790	12,352	8.54	3.813
Rancho Mirage	16,737	16,254	483	14,311	6,831	3,680	615	1,196	1,989	8,251	42.35	1.970
Riverside	288,933	279,644	9,289	95,020	59,933	4,139	5,832	22,639	2,477	90,662	4.59	3.084
San Jacinto	31,190	31,000	190	12,168	7,723	596	653	567	2,629	10,676	12.26	2.904
Temecula	94,300	94,278	22	30,113	24,434	448	598	4,312	321	28,890	4.06	3.263
Balance Of County	516,814	511,282	5,532	191,196	132,917	4,213	3,659	6,229	44,178	164,493	13.97	3.108
Incorporated	1,445,987	1,415,370	30,617	531,336	342,769	38,890	28,272	80,636	40,769	462,859	12.89	3.058
County Total	1,962,801	1,926,652	36,149	722,532	475,686	43,103	31,931	86,865	84,947	627,352	13.17	3.071
Sacramento County												
Citrus Heights	86,988	86,111	877	35,589	19,799	3,531	3,025	7,355	1,879	34,143	4.06	2.522
Elk Grove	131,033	130,506	527	44,518	40,958	919	525	1,843	273	43,490	2.31	3.001
Folsom	69,521	62,575	6,946	24,953	17,721	635	647	5,078	872	23,882	4.29	2.620
Galt	23,007	22,819	188	7,331	5,911	226	340	482	372	7,052	3.81	3.236
Isleton	814	814	0	376	221	0	72	36	47	336	10.64	2.423
Rancho Cordova	56,432	56,082	350	22,301	11,248	2,024	1,987	5,653	1,389	21,304	4.47	2.632
Sacramento	457,837	448,855	8,982	184,756	110,459	11,372	15,998	43,241	3,686	174,358	5.63	2.574
Balance Of County	561,625	553,992	7,633	215,964	139,127	13,590	13,902	42,154	7,191	208,305	3.55	2.660
Incorporated	825,632	807,762	17,870	319,824	206,317	18,707	22,594	63,688	8,518	304,565	4.77	2.652
County Total	1,387,257	1,361,754	25,503	535,788	345,444	32,297	36,496	105,842	15,709	512,870	4.28	2.655
San Benito County												
Hollister	36,764	36,593	171	10,586	7,976	531	992	781	306	10,364	2.10	3.531
San Juan Bautista	1,713	1,713	0	678	456	70	73	62	17	625	7.82	2.741
Balance Of County	18,657	18,321	336	6,435	5,338	427	70	42	558	6,048	6.01	3.029
Incorporated	38,477	38,306	171	11,264	8,432	601	1,065	843	323	10,989	2.44	3.486
County Total	57,134	56,627	507	17,699	13,770	1,028	1,135	885	881	17,037	3.74	3.324
San Bernardino County												
Adelanto	24,826	23,730	1,096	7,504	5,642	149	382	823	508	6,377	15.02	3.721
Apple Valley	67,362	66,999	363	23,782	18,371	726	2,085	1,558	1,042	21,888	7.96	3.061
Barstow	23,670	23,343	327	9,823	5,479	356	1,292	1,581	1,115	8,156	16.97	2.862
Big Bear Lake	6,169	6,144	25	9,370	7,878	326	366	410	390	2,522	73.08	2.436
Chino	79,603	68,012	11,591	19,453	13,912	952	809	3,252	528	18,807	3.32	3.616
Chino Hills	77,798	77,647	151	22,562	18,198	1,378	300	2,000	686	22,147	1.84	3.506
Colton	51,667	51,403	264	16,129	9,543	602	1,059	4,110	815	14,936	7.40	3.442
Fontana	165,102	164,603	499	43,650	34,163	1,208	1,573	5,757	949	41,348	5.27	3.981
Grand Terrace	12,354	12,145	209	4,498	2,903	175	265	905	250	4,259	5.31	2.852

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	------------POPULATION------------			---------------------------------- HOUSING UNITS ----------------------------------								
					-------- SINGLE --------		----- MULTIPLE -----					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Hesperia	80,094	79,763	331	25,946	20,870	893	1,139	1,762	1,282	24,268	6.47	3.287
Highland	51,377	51,137	240	16,241	12,120	533	598	2,129	861	14,733	9.29	3.471
Loma Linda	21,864	20,893	971	8,806	3,836	673	1,310	2,425	562	8,208	6.79	2.545
Montclair	35,568	34,956	612	9,267	5,382	758	1,042	1,331	754	8,996	2.92	3.886
Needles	5,670	5,659	11	2,841	1,518	110	254	367	592	2,160	23.97	2.620
Ontario	170,743	169,666	1,077	46,351	27,437	3,649	4,033	9,021	2,211	44,652	3.67	3.800
Rancho Cucamonga	170,115	166,489	3,626	53,606	34,711	3,027	1,942	12,554	1,372	51,989	3.02	3.202
Redlands	70,935	68,969	1,966	26,315	16,981	900	2,432	5,083	919	25,044	4.83	2.754
Rialto	98,976	98,172	804	26,630	18,916	586	1,826	3,500	1,802	25,214	5.32	3.894
San Bernardino	201,396	194,844	6,552	65,177	38,490	2,716	5,684	13,806	4,481	57,980	11.04	3.361
Twentynine Palms	27,401	19,210	8,191	8,850	4,898	1,303	1,660	445	544	6,817	22.97	2.818
Upland	73,938	73,353	585	26,130	15,202	1,770	2,677	5,636	845	25,189	3.60	2.912
Victorville	94,947	90,487	4,460	30,475	23,701	389	1,333	3,286	1,766	28,300	7.14	3.197
Yucaipa	50,445	49,873	572	18,756	12,573	394	743	819	4,227	17,685	5.71	2.820
Yucca Valley	20,492	20,181	311	9,195	7,321	140	649	378	707	8,035	12.62	2.512
Balance Of County	308,455	300,681	7,774	130,311	104,561	4,200	4,205	2,998	14,347	94,366	27.58	3.186
Incorporated	1,682,512	1,637,678	44,834	531,357	360,045	23,713	35,453	82,938	29,208	489,710	7.84	3.344
County Total	1,990,967	1,938,359	52,608	661,668	464,606	27,913	39,658	85,936	43,555	584,076	11.73	3.319
San Diego County												
Carlsbad	98,673	97,760	913	42,086	22,889	5,767	2,699	9,440	1,291	39,252	6.73	2.491
Chula Vista	223,604	222,165	1,439	75,640	40,956	5,490	5,515	19,793	3,886	73,365	3.01	3.028
Coronado	22,903	17,981	4,922	9,589	4,487	870	826	3,383	23	7,806	18.59	2.303
Del Mar	4,528	4,526	2	2,603	1,361	366	204	672	0	2,218	14.79	2.041
El Cajon	96,930	94,357	2,573	35,474	13,691	1,548	2,244	15,957	2,034	34,475	2.82	2.737
Encinitas	62,857	62,298	559	25,528	14,454	4,555	2,119	3,631	769	24,444	4.25	2.549
Escondido	140,861	139,096	1,765	46,934	23,067	2,929	3,123	13,885	3,930	45,650	2.74	3.047
Imperial Beach	27,581	26,976	605	9,850	4,074	687	1,059	3,690	340	9,377	4.80	2.877
La Mesa	55,798	54,752	1,046	25,099	11,206	1,923	2,003	9,608	359	24,338	3.03	2.250
Lemon Grove	25,380	24,789	591	8,772	5,795	716	694	1,470	97	8,538	2.67	2.903
National City	61,139	52,156	8,983	15,592	6,692	1,405	1,690	5,368	437	15,184	2.62	3.435
Oceanside	175,045	173,765	1,280	63,963	33,464	8,334	4,499	14,170	3,496	60,642	5.19	2.865
Poway	50,584	50,158	426	16,337	12,215	877	345	2,209	691	16,081	1.57	3.119
San Diego	1,306,028	1,264,374	41,654	498,125	228,064	45,797	43,485	174,438	6,341	478,024	4.04	2.645
San Marcos	76,779	76,245	534	25,888	13,569	1,083	1,348	6,228	3,660	24,858	3.98	3.067
Santee	54,746	53,703	1,043	19,223	10,709	1,788	1,225	2,998	2,503	18,852	1.93	2.849
Solana Beach	13,336	13,302	34	6,548	2,992	1,265	621	1,631	39	5,837	10.86	2.279
Vista	94,504	92,238	2,266	30,987	15,461	2,029	2,217	9,151	2,129	30,013	3.14	3.073
Balance Of County	473,801	442,355	31,446	160,986	109,506	10,977	6,545	18,560	15,398	150,786	6.34	2.934
Incorporated	2,591,276	2,520,641	70,635	958,238	465,146	87,429	75,916	297,722	32,025	918,954	4.10	2.743
County Total	3,065,077	2,962,996	102,081	1,119,224	574,652	98,406	82,461	316,282	47,423	1,069,740	4.42	2.770
San Francisco County												

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
City and County Total	802,994	782,666	20,328	356,985	62,974	48,700	81,809	162,942	560	339,472	4.91	2.306
San Joaquin County												
Escalon	7,012	6,986	26	2,458	2,052	20	153	98	135	2,371	3.54	2.946
Lathrop	14,558	14,548	10	4,092	3,574	63	92	12	351	3,969	3.01	3.665
Lodi	62,534	61,470	1,064	23,000	14,797	1,476	1,762	4,500	465	22,262	3.21	2.761
Manteca	63,413	62,936	477	21,410	16,107	739	1,134	2,561	869	20,691	3.36	3.042
Ripon	13,844	13,733	111	4,618	4,001	140	151	316	10	4,513	2.27	3.043
Stockton	284,626	280,066	4,560	94,409	60,697	6,592	8,456	17,376	1,288	90,397	4.25	3.098
Tracy	80,095	79,750	345	24,976	20,672	1,015	961	1,852	476	24,331	2.58	3.278
Balance Of County	139,075	128,553	10,522	44,754	36,053	1,254	816	652	5,979	42,540	4.95	3.022
Incorporated	526,082	519,489	6,593	174,963	121,900	10,045	12,709	26,715	3,594	168,534	3.67	3.082
County Total	665,157	648,042	17,115	219,717	157,953	11,299	13,525	27,367	9,573	211,074	3.93	3.070
San Luis Obispo County												
Arroyo Grande	16,636	16,426	210	7,304	4,962	656	489	649	548	7,009	4.04	2.344
Atascadero	27,717	26,084	1,633	10,610	7,497	449	883	1,220	561	10,269	3.21	2.540
El Paso De Robles	29,034	28,664	370	11,110	7,501	920	1,072	1,200	417	10,813	2.67	2.651
Grover Beach	13,243	13,117	126	5,621	3,254	791	730	599	247	5,246	6.67	2.500
Morro Bay	10,513	10,315	198	6,545	4,271	396	655	464	759	5,221	20.23	1.976
Pismo Beach	8,637	8,610	27	5,720	3,105	576	467	485	1,087	4,402	23.04	1.956
San Luis Obispo	44,535	42,673	1,862	20,062	9,363	1,307	2,242	5,648	1,502	19,369	3.45	2.203
Balance Of County	113,486	102,040	11,446	45,620	34,157	1,276	2,167	1,213	6,807	39,807	12.74	2.563
Incorporated	150,315	145,889	4,426	66,972	39,953	5,095	6,538	10,265	5,121	62,329	6.93	2.341
County Total	263,801	247,929	15,872	112,592	74,110	6,371	8,705	11,478	11,928	102,136	9.29	2.427
San Mateo County												
Atherton	7,261	6,943	318	2,532	2,493	32	0	7	0	2,439	3.67	2.847
Belmont	25,648	25,021	627	10,813	6,293	649	275	3,596	0	10,651	1.50	2.349
Brisbane	3,744	3,704	40	1,908	1,068	260	179	358	43	1,688	11.53	2.194
Burlingame	28,321	27,835	486	12,956	6,163	423	993	5,377	0	12,596	2.78	2.210
Colma	1,577	1,528	49	458	218	66	98	70	6	440	3.93	3.473
Daly City	104,816	104,026	790	31,704	16,124	4,507	2,835	7,596	642	31,162	1.71	3.338
East Palo Alto	32,083	31,894	189	7,721	3,952	342	360	2,908	159	7,595	1.63	4.199
Foster City	29,900	29,813	87	12,478	4,809	2,464	767	4,431	7	12,067	3.29	2.471
Half Moon Bay	12,738	11,890	848	4,453	2,797	536	314	379	427	4,334	2.67	2.743
Hillsborough	10,965	10,963	2	3,856	3,836	11	9	0	0	3,740	3.01	2.931
Menlo Park	30,751	29,791	960	12,707	6,832	930	1,574	3,366	5	12,380	2.57	2.406
Millbrae	20,734	20,402	332	8,126	5,321	269	432	2,093	11	7,969	1.93	2.560
Pacifica	38,739	38,558	181	14,388	10,366	787	725	2,412	98	14,136	1.75	2.728
Portola Valley	4,552	4,482	70	1,810	1,502	33	8	267	0	1,737	4.03	2.580
Redwood City	76,086	74,159	1,927	29,216	13,556	3,656	2,619	8,552	833	28,348	2.97	2.616

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
San Bruno	41,515	41,294	221	15,500	9,151	566	1,188	4,573	22	15,187	2.02	2.719
San Carlos	28,264	28,081	183	11,933	8,265	609	490	2,553	16	11,693	2.01	2.402
San Mateo	94,312	92,996	1,316	39,083	17,730	3,492	3,034	14,782	45	38,156	2.37	2.437
South San Francisco	61,824	61,381	443	20,582	12,009	2,544	1,686	3,934	409	20,112	2.28	3.052
Woodside	5,505	5,499	6	2,090	2,028	28	28	5	1	2,007	3.97	2.740
Balance Of County	64,756	63,373	1,383	22,526	18,613	708	929	1,429	847	21,777	3.33	2.910
Incorporated	659,335	650,260	9,075	244,314	134,513	22,204	17,614	67,259	2,724	238,437	2.41	2.727
County Total	724,091	713,633	10,458	266,840	153,126	22,912	18,543	68,688	3,571	260,214	2.48	2.742
Santa Barbara County												
Buellton	4,527	4,521	6	1,784	1,113	102	48	103	418	1,724	3.36	2.622
Carpinteria	14,107	13,982	125	5,523	2,158	425	533	1,467	940	5,044	8.67	2.772
Goleta	30,130	29,788	342	11,488	5,861	1,588	755	2,663	621	11,203	2.48	2.659
Guadalupe	6,394	6,394	0	1,666	1,159	168	187	146	6	1,626	2.40	3.932
Lompoc	41,737	38,283	3,454	14,080	7,451	1,044	1,944	2,701	940	13,500	4.12	2.836
Santa Barbara	89,148	87,356	1,792	37,510	17,238	2,892	5,612	11,250	518	36,022	3.97	2.425
Santa Maria	89,800	87,602	2,198	27,044	16,860	1,608	1,752	5,249	1,575	26,214	3.07	3.342
Solvang	5,486	5,326	160	2,332	1,338	151	171	453	219	2,287	1.93	2.329
Balance Of County	138,709	129,714	8,995	51,030	35,457	3,521	2,730	5,897	3,425	48,561	4.84	2.671
Incorporated	281,329	273,252	8,077	101,427	53,178	7,978	11,002	24,032	5,237	97,620	3.75	2.799
County Total	420,038	402,966	17,072	152,457	88,635	11,499	13,732	29,929	8,662	146,181	4.12	2.757
Santa Clara County												
Campbell	38,497	38,207	290	16,475	6,999	2,022	2,442	4,755	257	16,107	2.23	2.372
Cupertino	53,964	53,483	481	19,892	12,209	2,135	1,696	3,843	9	19,387	2.54	2.759
Gilroy	48,638	48,208	430	14,328	9,653	757	1,314	2,173	431	13,996	2.32	3.444
Los Altos	27,668	27,249	419	10,741	9,159	364	275	927	16	10,475	2.48	2.601
Los Altos Hills	8,500	8,435	65	3,050	2,986	32	17	9	6	2,969	2.66	2.841
Los Gatos	29,053	28,351	702	12,599	7,141	1,839	936	2,560	123	12,214	3.06	2.321
Milpitas	65,418	62,244	3,174	18,197	10,942	2,225	1,643	2,801	586	17,954	1.34	3.467
Monte Sereno	3,520	3,520	0	1,253	1,149	13	18	73	0	1,227	2.08	2.869
Morgan Hill	37,175	36,662	513	12,331	7,672	1,752	728	1,267	912	12,058	2.21	3.040
Mountain View	72,157	71,641	516	33,168	9,222	3,907	2,659	16,149	1,231	31,951	3.67	2.242
Palo Alto	62,289	61,621	668	27,767	15,607	980	1,729	9,287	164	26,880	3.19	2.292
San Jose	955,829	944,678	11,151	301,848	166,652	27,918	23,413	72,837	11,028	296,235	1.86	3.189
Santa Clara	111,019	108,232	2,787	43,168	18,571	3,723	3,923	16,842	109	41,966	2.78	2.579
Saratoga	30,905	30,544	361	11,016	9,651	560	241	557	7	10,810	1.87	2.826
Sunnyvale	133,848	132,973	875	54,728	21,195	4,329	4,908	20,200	4,096	53,493	2.26	2.486
Balance Of County	98,106	90,382	7,724	31,568	25,115	1,597	919	3,254	683	30,339	3.89	2.979
Incorporated	1,678,480	1,656,048	22,432	580,561	308,808	52,556	45,942	154,280	18,975	567,722	2.21	2.917
County Total	1,776,586	1,746,430	30,156	612,129	333,923	54,153	46,861	157,534	19,658	598,061	2.30	2.920

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Santa Cruz County												
Capitola	9,904	9,748	156	5,389	1,984	514	1,134	1,107	650	4,762	11.63	2.047
Santa Cruz	56,709	51,541	5,168	23,070	12,323	1,984	2,603	5,719	441	21,775	5.61	2.367
Scotts Valley	11,559	11,107	452	4,622	2,488	415	417	497	805	4,465	3.40	2.488
Watsonville	50,003	49,450	553	13,644	7,265	1,594	1,711	2,174	900	13,279	2.68	3.724
Balance Of County	133,119	129,864	3,255	56,565	41,194	4,370	2,656	3,887	4,458	50,913	9.99	2.551
Incorporated	128,175	121,846	6,329	46,725	24,060	4,507	5,865	9,497	2,796	44,281	5.23	2.752
County Total	261,294	251,710	9,584	103,290	65,254	8,877	8,521	13,384	7,254	95,194	7.84	2.644
Shasta County												
Anderson	10,547	10,429	118	4,169	2,674	209	378	729	179	3,928	5.78	2.655
Redding	88,878	86,421	2,457	37,020	24,307	985	4,637	4,477	2,614	35,159	5.03	2.458
Shasta Lake	10,196	10,144	52	4,204	3,322	27	249	114	492	3,824	9.04	2.653
Balance Of County	69,638	68,847	791	29,847	20,980	275	401	198	7,993	26,464	11.33	2.602
Incorporated	109,621	106,994	2,627	45,393	30,303	1,221	5,264	5,320	3,285	42,911	5.47	2.493
County Total	179,259	175,841	3,418	75,240	51,283	1,496	5,665	5,518	11,278	69,375	7.80	2.535
Sierra County												
Loyalton	875	845	30	375	326	13	3	0	33	350	6.67	2.414
Balance Of County	2,595	2,589	6	1,897	1,553	36	44	63	201	1,224	35.48	2.115
Incorporated	875	845	30	375	326	13	3	0	33	350	6.67	2.414
County Total	3,470	3,434	36	2,272	1,879	49	47	63	234	1,574	30.72	2.182
Siskiyou County												
Dorris	878	878	0	405	318	2	16	0	69	351	13.33	2.501
Dunsmuir	1,865	1,865	0	1,171	792	23	126	184	46	868	25.88	2.149
Etna	766	766	0	367	270	10	19	13	55	334	8.99	2.293
Fort Jones	667	667	0	342	242	11	34	2	53	312	8.77	2.138
Montague	1,505	1,486	19	650	485	15	10	43	97	598	8.00	2.485
Mount Shasta	3,655	3,607	48	1,872	1,187	89	266	256	74	1,737	7.21	2.077
Tulelake	993	993	0	461	316	2	44	19	80	360	21.91	2.758
Weed	2,922	2,791	131	1,304	899	19	136	190	60	1,194	8.44	2.338
Yreka	7,257	7,037	220	3,391	2,225	140	294	491	241	3,198	5.69	2.200
Balance Of County	25,107	24,845	262	13,387	9,721	188	187	96	3,195	10,766	19.58	2.308
Incorporated	20,508	20,090	418	9,963	6,734	311	945	1,198	775	8,952	10.15	2.244
County Total	45,615	44,935	680	23,350	16,455	499	1,132	1,294	3,970	19,718	15.55	2.279

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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Solano County												
Benicia	27,135	27,081	54	10,945	7,068	1,049	942	1,560	326	10,718	2.07	2.527
Dixon	17,454	17,413	41	5,761	4,646	213	378	438	86	5,651	1.91	3.081
Fairfield	104,874	101,794	3,080	37,449	25,323	2,519	2,504	6,211	892	35,544	5.09	2.864
Rio Vista	7,308	7,308	0	3,314	2,895	34	103	171	111	3,165	4.50	2.309
Suisun City	27,559	27,465	94	8,833	7,497	189	327	754	66	8,660	1.96	3.171
Vacaville	95,803	86,251	9,552	32,047	22,231	1,040	2,150	5,318	1,308	31,388	2.06	2.748
Vallejo	120,288	118,038	2,250	43,464	30,380	1,792	3,921	6,025	1,346	41,758	3.93	2.827
Balance Of County	19,932	19,330	602	7,380	6,009	450	299	119	503	6,935	6.03	2.787
Incorporated	400,421	385,350	15,071	141,813	100,040	6,836	10,325	20,477	4,135	136,884	3.48	2.815
County Total	420,353	404,680	15,673	149,193	106,049	7,286	10,624	20,596	4,638	143,819	3.60	2.814
Sonoma County												
Cloverdale	8,412	8,335	77	3,297	2,498	162	120	308	209	3,141	4.73	2.654
Cotati	7,348	7,330	18	2,994	1,641	526	373	333	121	2,932	2.07	2.500
Healdsburg	11,648	11,525	123	4,565	3,276	254	450	485	100	4,379	4.07	2.632
Petaluma	56,455	55,715	740	21,443	15,406	1,677	1,368	2,061	931	21,050	1.83	2.647
Rohnert Park	42,824	41,723	1,101	16,353	7,660	1,699	929	4,652	1,413	16,038	1.93	2.602
Santa Rosa	156,407	152,673	3,734	62,398	37,558	5,835	4,918	11,386	2,701	60,733	2.67	2.514
Sebastopol	7,718	7,507	211	3,362	2,017	254	535	497	59	3,291	2.11	2.281
Sonoma	9,844	9,753	91	5,135	2,913	720	478	587	437	4,812	6.29	2.027
Windsor	25,887	25,796	91	8,975	7,004	460	254	435	822	8,813	1.81	2.927
Balance Of County	150,413	144,819	5,594	65,338	52,834	2,902	2,945	2,053	4,604	57,520	11.97	2.518
Incorporated	326,543	320,357	6,186	128,522	79,973	11,587	9,425	20,744	6,793	125,189	2.59	2.559
County Total	476,956	465,176	11,780	193,860	132,807	14,489	12,370	22,797	11,397	182,709	5.75	2.546
Stanislaus County												
Ceres	40,739	40,640	99	12,641	9,857	343	638	1,091	712	12,245	3.13	3.319
Hughson	6,095	6,089	6	1,911	1,556	65	66	135	89	1,866	2.35	3.263
Modesto	207,096	203,865	3,231	73,501	51,938	4,010	6,268	9,264	2,021	71,072	3.30	2.868
Newman	10,091	10,025	66	3,092	2,628	76	245	117	26	2,955	4.43	3.393
Oakdale	17,769	17,590	179	6,639	5,023	207	507	691	211	6,417	3.34	2.741
Patterson	19,172	18,943	229	5,412	4,880	190	151	63	128	5,219	3.57	3.630
Riverbank	21,108	20,973	135	6,257	5,421	185	180	182	289	6,053	3.26	3.465
Turlock	67,547	65,186	2,361	23,084	15,889	961	1,927	3,703	604	22,254	3.60	2.929
Waterford	8,175	8,158	17	2,448	2,008	64	179	168	29	2,342	4.33	3.483
Balance Of County	114,056	112,586	1,470	36,734	28,840	1,419	956	436	5,083	34,887	5.03	3.227
Incorporated	397,792	391,469	6,323	134,985	99,200	6,101	10,161	15,414	4,109	130,423	3.38	3.002
County Total	511,848	504,055	7,793	171,719	128,040	7,520	11,117	15,850	9,192	165,310	3.73	3.049

Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Sutter County												
Live Oak	7,466	7,152	314	2,152	1,680	85	141	104	142	2,045	4.97	3.497
Yuba City	60,434	59,479	955	21,734	14,528	851	1,628	3,773	954	20,836	4.13	2.855
Balance Of County	23,438	23,280	158	8,586	7,495	260	149	68	614	8,132	5.29	2.863
Incorporated	67,900	66,631	1,269	23,886	16,208	936	1,769	3,877	1,096	22,881	4.21	2.912
County Total	91,338	89,911	1,427	32,472	23,703	1,196	1,918	3,945	1,710	31,013	4.49	2.899
Tehama County												
Corning	7,132	7,075	57	2,801	1,703	70	294	495	239	2,595	7.35	2.726
Red Bluff	13,488	12,953	535	5,787	3,416	220	697	1,090	364	5,310	8.24	2.439
Tehama	433	433	0	199	170	4	10	0	15	182	8.54	2.379
Balance Of County	39,737	39,307	430	17,094	10,533	214	252	78	6,017	14,989	12.31	2.622
Incorporated	21,053	20,461	592	8,787	5,289	294	1,001	1,585	618	8,087	7.97	2.530
County Total	60,790	59,768	1,022	25,881	15,822	508	1,253	1,663	6,635	23,076	10.84	2.590
Trinity County												
County Total	13,966	13,747	219	8,346	5,523	112	108	133	2,470	5,843	29.99	2.353
Tulare County												
Dinuba	19,460	19,346	114	5,242	3,942	280	268	545	207	5,045	3.76	3.835
Exeter	10,567	10,475	92	3,550	2,858	107	205	192	188	3,363	5.27	3.115
Farmersville	10,354	10,335	19	2,611	2,105	90	155	157	104	2,476	5.17	4.174
Lindsay	11,117	10,968	149	3,006	2,013	204	246	358	185	2,852	5.12	3.846
Porterville	44,954	43,423	1,531	14,084	9,909	483	1,591	1,456	645	13,188	6.36	3.293
Tulare	51,162	50,715	447	16,114	12,284	511	1,409	1,134	776	15,312	4.98	3.312
Visalia	110,488	108,866	1,622	38,433	28,600	1,572	3,762	3,029	1,470	36,329	5.47	2.997
Woodlake	7,260	7,251	9	1,986	1,315	126	154	331	60	1,883	5.19	3.851
Balance Of County	152,698	150,738	1,960	47,443	35,787	1,541	1,525	890	7,700	41,929	11.62	3.595
Incorporated	265,362	261,379	3,983	85,026	63,026	3,373	7,790	7,202	3,635	80,448	5.38	3.249
County Total	418,060	412,117	5,943	132,469	98,813	4,914	9,315	8,092	11,335	122,377	7.62	3.368
Tuolumne County												
Sonora	4,686	4,487	199	2,365	1,403	86	397	447	32	2,208	6.64	2.032
Balance Of County	52,175	47,517	4,658	27,706	21,566	566	791	651	4,132	20,090	27.49	2.365
Incorporated	4,686	4,487	199	2,365	1,403	86	397	447	32	2,208	6.64	2.032

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Table 2: E-5 City/County Population and Housing Estimates, Revised 1/1/2006

	POPULATION			HOUSING UNITS								PERSONS PER HOUSEHOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSEHOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	
County Total	56,861	52,004	4,857	30,071	22,969	652	1,188	1,098	4,164	22,298	25.85	2.332
Ventura County												
Camarillo	63,951	62,518	1,433	24,259	14,690	4,495	884	3,132	1,058	23,725	2.20	2.635
Fillmore	15,139	14,893	246	4,257	3,092	281	236	322	326	4,158	2.33	3.582
Moorpark	35,706	35,694	12	10,275	7,327	1,234	223	1,189	302	10,162	1.10	3.512
Ojai	8,134	7,944	190	3,324	2,271	289	304	452	8	3,180	4.33	2.498
Oxnard	189,485	186,888	2,597	50,017	28,509	4,576	4,447	9,539	2,946	48,257	3.52	3.873
Port Hueneme	22,348	21,352	996	8,068	2,451	2,204	1,201	2,171	41	7,472	7.39	2.858
San Buenaventura	106,428	103,675	2,753	41,626	23,272	3,428	4,224	8,079	2,623	40,288	3.21	2.573
Santa Paula	29,054	28,811	243	8,425	5,038	731	778	1,091	787	8,219	2.45	3.505
Simi Valley	122,377	121,577	800	40,746	30,120	3,102	1,659	4,973	892	39,815	2.28	3.054
Thousand Oaks	127,303	125,352	1,951	46,525	31,179	5,230	1,773	7,271	1,072	45,263	2.71	2.769
Balance Of County	95,833	93,619	2,214	33,065	26,279	2,348	1,019	1,168	2,251	31,100	5.94	3.010
Incorporated	719,925	708,704	11,221	237,522	147,949	25,570	15,729	38,219	10,055	230,539	2.94	3.074
County Total	815,758	802,323	13,435	270,587	174,228	27,918	16,748	39,387	12,306	261,639	3.31	3.067
Yolo County												
Davis	64,903	61,814	3,089	25,596	11,507	2,394	2,356	8,954	385	25,039	2.18	2.469
West Sacramento	43,403	43,197	206	16,892	10,720	879	961	2,774	1,558	15,877	6.01	2.721
Winters	6,904	6,898	6	2,230	1,798	105	67	182	78	2,176	2.42	3.170
Woodland	53,236	51,858	1,378	18,584	11,563	1,313	1,149	3,878	681	18,183	2.16	2.852
Balance Of County	22,834	18,947	3,887	7,240	4,954	305	194	804	983	6,813	5.90	2.781
Incorporated	168,446	163,767	4,679	63,302	35,588	4,691	4,533	15,788	2,702	61,275	3.20	2.673
County Total	191,280	182,714	8,566	70,542	40,542	4,996	4,727	16,592	3,685	68,088	3.48	2.683
Yuba County												
Marysville	12,787	12,180	607	5,017	2,789	339	762	1,119	8	4,704	6.24	2.589
Wheatland	3,522	3,522	0	1,214	928	37	155	55	39	1,167	3.87	3.018
Balance Of County	52,944	52,344	600	19,431	12,980	915	692	1,076	3,768	17,040	12.31	3.072
Incorporated	16,309	15,702	607	6,231	3,717	376	917	1,174	47	5,871	5.78	2.675
County Total	69,253	68,046	1,207	25,662	16,697	1,291	1,609	2,250	3,815	22,911	10.72	2.970
California												
Incorporated Total	30,525,180	29,846,055	679,125	10,697,204	5,749,155	840,263	953,443	2,837,778	316,565	10,191,233	4.73	2.929
Balance Of State Total	6,589,418	6,409,287	180,131	2,442,957	1,784,058	109,472	98,135	180,914	270,378	2,179,651	10.78	2.941
State Total	37,114,598	36,255,342	859,256	13,140,161	7,533,213	949,735	1,051,578	3,018,692	586,943	12,370,884	5.85	2.931

Table 1: E-5 County/State Population and Housing Estimates, Revised, 1/1/2007

	POPULATION			HOUSING UNITS								PERSONS PER HOUSEHOLD
					SINGLE		MULTIPLE					
COUNTY	TOTAL	HOUSEHOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	
Alameda	1,522,597	1,493,679	28,918	565,964	302,610	39,575	61,935	154,194	7,650	549,031	2.99	2.721
Alpine	1,242	1,241	1	1,734	1,000	51	35	586	62	552	68.17	2.248
Amador	38,002	33,350	4,652	17,173	13,930	409	450	799	1,585	14,611	14.92	2.283
Butte	218,312	211,904	6,408	94,799	58,189	2,436	7,994	10,528	15,652	88,494	6.65	2.395
Calaveras	45,850	45,393	457	27,349	23,153	561	529	355	2,751	19,647	28.16	2.310
Colusa	21,648	21,228	420	7,704	5,755	229	414	463	843	6,947	9.83	3.056
Contra Costa	1,037,580	1,026,181	11,399	393,406	261,257	31,967	25,996	66,563	7,623	381,489	3.03	2.690
Del Norte	29,216	25,203	4,013	11,046	6,520	188	802	584	2,952	9,705	12.14	2.597
El Dorado	177,766	176,712	1,054	82,695	67,048	1,828	3,629	5,813	4,377	68,701	16.92	2.572
Fresno	914,893	895,493	19,400	304,144	202,881	10,061	25,163	52,125	13,914	284,334	6.51	3.149
Glenn	28,833	28,425	408	10,686	7,437	219	784	700	1,546	9,826	8.05	2.893
Humboldt	131,977	127,609	4,368	58,963	40,567	1,604	5,855	4,783	6,154	54,017	8.39	2.362
Imperial	171,576	159,545	12,031	54,789	33,840	2,003	3,845	7,270	7,831	49,032	10.51	3.254
Inyo	18,189	17,905	284	9,250	5,526	212	407	468	2,637	7,879	14.82	2.272
Kern	800,699	762,696	38,003	270,616	189,627	8,549	22,326	24,472	25,642	243,594	9.99	3.131
Kings	151,607	127,689	23,918	41,524	29,504	2,425	2,915	4,445	2,235	39,155	5.71	3.261
Lake	63,740	62,546	1,194	34,821	21,850	733	928	1,040	10,270	25,656	26.32	2.438
Lassen	35,804	25,367	10,437	12,979	8,912	352	520	531	2,664	10,476	19.28	2.421
Los Angeles	10,275,914	10,096,105	179,809	3,382,356	1,638,521	243,978	291,406	1,151,750	56,701	3,239,511	4.22	3.117
Madera	147,944	139,012	8,932	48,460	38,016	1,336	2,469	2,945	3,694	43,499	10.24	3.196
Marin	255,080	244,427	10,653	108,380	65,683	8,581	9,794	22,191	2,131	103,955	4.08	2.351
Mariposa	18,262	16,824	1,438	10,203	6,306	582	214	383	2,718	7,646	25.06	2.200
Mendocino	89,518	87,249	2,269	39,278	27,709	1,163	2,180	2,782	5,444	35,346	10.01	2.468
Merced	250,380	245,624	4,756	83,402	61,587	2,539	5,375	8,227	5,674	77,966	6.52	3.150
Modoc	9,679	9,271	408	5,125	3,487	90	97	159	1,292	4,026	21.44	2.303
Mono	13,730	13,354	376	13,640	5,211	1,259	2,187	3,915	1,068	6,040	55.72	2.211
Monterey	423,762	401,465	22,297	139,673	85,766	12,583	12,163	23,208	5,953	128,610	7.92	3.122
Napa	134,844	129,571	5,273	53,543	35,966	3,515	3,732	6,356	3,974	50,200	6.24	2.581
Nevada	99,026	98,047	979	49,671	40,534	919	1,963	2,407	3,848	41,146	17.16	2.383
Orange	3,089,707	3,045,714	43,993	1,024,692	518,327	127,849	90,977	255,442	32,097	990,441	3.34	3.075
Placer	326,503	323,253	3,250	144,207	112,473	4,174	6,296	16,524	4,740	128,601	10.82	2.514
Plumas	20,941	20,753	188	15,253	11,723	450	375	396	2,309	10,236	32.89	2.027
Riverside	2,034,840	1,997,866	36,974	753,968	499,162	45,662	32,578	90,539	86,027	653,826	13.28	3.056
Sacramento	1,405,694	1,380,061	25,633	545,287	350,809	34,278	36,785	107,663	15,752	521,594	4.35	2.646
San Benito	57,296	56,789	507	17,739	13,782	1,022	1,135	921	879	17,074	3.75	3.326
San Bernardino	2,026,325	1,973,415	52,910	676,909	476,647	28,249	39,881	87,903	44,229	597,614	11.71	3.302
San Diego	3,100,132	2,999,887	100,245	1,129,749	580,105	98,564	83,313	320,122	47,645	1,079,330	4.46	2.779
San Francisco	812,241	791,893	20,348	359,121	63,002	48,700	81,906	164,953	560	342,099	4.74	2.315

San Joaquin	675,463	658,422	17,041	224,183	161,858	11,367	13,684	27,598	9,676	215,335	3.95	3.058
San Luis Obispo	266,372	250,640	15,732	114,703	75,354	6,810	8,800	11,688	12,051	104,051	9.29	2.409
San Mateo	730,339	719,764	10,575	267,102	153,284	22,922	18,557	68,747	3,592	262,073	1.88	2.746
Santa Barbara	423,540	405,961	17,579	153,903	89,841	11,548	13,795	30,006	8,713	147,226	4.34	2.757
Santa Clara	1,805,314	1,774,777	30,537	617,175	335,312	54,656	46,886	160,658	19,663	603,022	2.29	2.943
Santa Cruz	263,499	253,603	9,896	104,048	65,440	9,142	8,563	13,647	7,256	95,930	7.80	2.644
Shasta	180,666	177,225	3,441	76,369	52,104	1,525	5,750	5,645	11,345	70,417	7.79	2.517
Sierra	3,432	3,396	36	2,274	1,883	49	47	63	232	1,575	30.74	2.156
Siskiyou	45,667	44,989	678	23,749	16,646	499	1,134	1,416	4,054	20,060	15.53	2.243
Solano	422,974	407,386	15,588	151,054	107,695	7,286	10,643	20,775	4,655	144,917	4.06	2.811
Sonoma	479,668	467,699	11,969	195,517	133,773	14,675	12,471	23,185	11,413	184,275	5.75	2.538
Stanislaus	518,938	511,104	7,834	175,040	130,817	7,526	11,222	16,236	9,239	168,483	3.75	3.034
Sutter	93,835	92,409	1,426	33,069	24,278	1,203	1,918	3,957	1,713	31,584	4.49	2.926
Tehama	61,709	60,691	1,018	26,742	16,356	507	1,323	1,663	6,893	23,840	10.85	2.546
Trinity	13,970	13,733	237	8,416	5,568	112	108	144	2,484	5,892	29.99	2.331
Tulare	426,798	420,897	5,901	136,059	101,897	4,915	9,756	8,110	11,381	125,836	7.51	3.345
Tuolumne	56,741	51,947	4,794	30,331	23,177	662	1,194	1,098	4,200	22,494	25.84	2.309
Ventura	823,129	809,595	13,534	274,224	175,906	28,088	16,963	40,933	12,334	265,172	3.30	3.053
Yolo	195,354	186,380	8,974	71,755	41,395	5,012	4,753	16,882	3,713	69,223	3.53	2.692
Yuba	70,683	69,508	1,175	26,718	17,688	1,291	1,609	2,250	3,880	23,627	11.57	2.942
California	37,559,440	36,692,872	866,568	13,312,729	7,644,694	958,690	1,058,529	3,059,206	591,610	12,526,938	5.90	2.929

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

	------------POPULATION------------			---------------------------------- HOUSING UNITS ----------------------------------								PERSONS PER HOUSE-HOLD
					-------- SINGLE --------		----- MULTIPLE -----					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Alameda County												
Alameda	75,077	74,351	726	32,403	13,269	3,999	5,071	9,764	300	31,482	2.84	2.362
Albany	16,722	16,689	33	7,328	3,786	198	828	2,510	6	7,088	3.28	2.355
Berkeley	106,110	99,241	6,869	47,798	20,158	1,756	9,335	16,490	59	45,827	4.12	2.166
Dublin	43,592	38,206	5,386	14,911	7,982	1,304	444	5,153	28	14,361	3.69	2.660
Emeryville	9,137	9,070	67	5,657	270	329	507	4,514	37	5,262	6.98	1.724
Fremont	211,162	209,403	1,759	71,699	42,376	7,216	3,057	18,294	756	70,445	1.75	2.973
Hayward	147,501	145,138	2,363	48,052	24,018	3,572	3,454	14,709	2,299	46,882	2.43	3.096
Livermore	82,646	82,359	287	29,794	21,529	2,555	1,254	4,025	431	29,248	1.83	2.816
Newark	43,587	43,498	89	13,418	9,207	1,240	766	2,146	59	13,257	1.20	3.281
Oakland	414,516	407,259	7,257	162,552	72,519	6,775	29,257	53,545	456	155,618	4.27	2.617
Piedmont	11,029	11,027	2	3,863	3,786	0	35	34	8	3,808	1.42	2.896
Pleasanton	68,567	68,332	235	25,673	16,881	2,753	1,163	4,420	456	24,978	2.71	2.736
San Leandro	81,273	80,446	827	31,872	19,443	2,028	2,248	7,249	904	31,169	2.21	2.581
Union City	72,124	71,782	342	20,249	12,831	2,381	1,119	2,996	922	19,996	1.25	3.590
Balance Of County	139,554	136,878	2,676	50,695	34,555	3,469	3,397	8,345	929	49,610	2.14	2.759
Incorporated	1,383,043	1,356,801	26,242	515,269	268,055	36,106	58,538	145,849	6,721	499,421	3.08	2.717
County Total	1,522,597	1,493,679	28,918	565,964	302,610	39,575	61,935	154,194	7,650	549,031	2.99	2.721
Alpine County												
County Total	1,242	1,241	1	1,734	1,000	51	35	586	62	552	68.17	2.248
Amador County												
Amador	211	211	0	103	84	12	5	2	0	97	5.83	2.175
Ione	7,788	3,480	4,308	1,454	1,162	54	66	87	85	1,361	6.40	2.557
Jackson	4,320	4,052	268	2,121	1,358	112	168	247	236	1,993	6.03	2.033
Plymouth	1,034	1,034	0	506	281	31	24	26	144	434	14.23	2.382
Sutter Creek	2,903	2,902	1	1,461	823	111	61	384	82	1,353	7.39	2.145
Balance Of County	21,746	21,671	75	11,528	10,222	89	126	53	1,038	9,373	18.69	2.312
Incorporated	16,256	11,679	4,577	5,645	3,708	320	324	746	547	5,238	7.21	2.230
County Total	38,002	33,350	4,652	17,173	13,930	409	450	799	1,585	14,611	14.92	2.283
Butte County												
Biggs	1,773	1,773	0	625	519	28	30	5	43	583	6.72	3.041
Chico	84,491	80,303	4,188	35,505	18,416	993	5,484	8,759	1,853	34,180	3.73	2.349
Gridley	6,174	6,052	122	2,331	1,924	45	144	141	77	2,187	6.18	2.767
Oroville	14,458	13,626	832	6,254	3,506	206	811	1,333	398	5,632	9.95	2.419
Paradise	26,327	25,707	620	12,729	8,816	338	812	290	2,473	11,924	6.32	2.156
Balance Of County	85,089	84,443	646	37,355	25,008	826	713	0	10,808	33,988	9.01	2.484
Incorporated	133,223	127,461	5,762	57,444	33,181	1,610	7,281	10,528	4,844	54,506	5.11	2.338

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	218,312	211,904	6,408	94,799	58,189	2,436	7,994	10,528	15,652	88,494	6.65	2.395
Calaveras County												
Angels City	3,572	3,572	0	1,783	1,265	67	122	113	216	1,612	9.59	2.216
Balance Of County	42,278	41,821	457	25,566	21,888	494	407	242	2,535	18,035	29.46	2.319
Incorporated	3,572	3,572	0	1,783	1,265	67	122	113	216	1,612	9.59	2.216
County Total	45,850	45,393	457	27,349	23,153	561	529	355	2,751	19,647	28.16	2.310
Colusa County												
Colusa	5,692	5,619	73	2,118	1,606	84	193	183	52	1,995	5.81	2.817
Williams	5,185	4,935	250	1,391	1,028	33	98	165	67	1,327	4.60	3.719
Balance Of County	10,771	10,674	97	4,195	3,121	112	123	115	724	3,625	13.59	2.945
Incorporated	10,877	10,554	323	3,509	2,634	117	291	348	119	3,322	5.33	3.177
County Total	21,648	21,228	420	7,704	5,755	229	414	463	843	6,947	9.83	3.056
Contra Costa County												
Antioch	99,684	99,268	416	33,781	25,446	2,205	1,783	4,078	269	32,908	2.58	3.017
Brentwood	48,677	48,550	127	16,740	14,922	525	351	591	351	16,069	4.01	3.021
Clayton	10,730	10,704	26	3,984	3,252	681	19	27	5	3,943	1.03	2.715
Concord	122,951	121,529	1,422	46,328	27,722	2,911	2,929	11,389	1,377	45,237	2.35	2.686
Danville	42,457	41,993	464	15,684	12,054	2,564	288	778	0	15,359	2.07	2.734
El Cerrito	23,086	22,910	176	10,614	7,342	355	1,315	1,570	32	10,357	2.42	2.212
Hercules	23,864	23,825	39	8,165	5,460	1,631	294	780	0	8,012	1.87	2.974
Lafayette	23,841	23,705	136	9,478	7,527	294	434	1,223	0	9,294	1.94	2.551
Martinez	36,018	34,674	1,344	14,932	9,576	2,237	988	2,107	24	14,628	2.04	2.370
Moraga	16,099	14,468	1,631	5,788	4,025	968	243	545	7	5,690	1.69	2.543
Oakley	31,755	31,688	67	10,079	9,330	84	74	170	421	9,891	1.87	3.204
Orinda	17,434	17,367	67	6,803	6,302	188	87	219	7	6,655	2.18	2.610
Pinole	19,143	18,925	218	6,992	5,132	498	366	981	15	6,906	1.23	2.740
Pittsburg	62,712	62,206	506	20,603	14,054	1,298	1,320	3,250	681	19,974	3.05	3.114
Pleasant Hill	32,964	32,504	460	14,347	8,432	1,631	727	3,505	52	14,059	2.01	2.312
Richmond	103,351	101,723	1,628	38,258	21,694	2,931	5,421	8,091	121	36,751	3.94	2.768
San Pablo	30,822	30,357	465	9,706	4,235	852	1,362	2,449	808	9,406	3.09	3.227
San Ramon	57,766	57,681	85	23,116	14,284	2,492	1,047	5,282	11	22,317	3.46	2.585
Walnut Creek	65,085	63,934	1,151	32,303	12,254	4,854	4,308	10,839	48	31,148	3.58	2.053
Balance Of County	169,141	168,170	971	65,705	48,214	2,768	2,640	8,689	3,394	62,885	4.29	2.674
Incorporated	868,439	858,011	10,428	327,701	213,043	29,199	23,356	57,874	4,229	318,604	2.78	2.693
County Total	1,037,580	1,026,181	11,399	393,406	261,257	31,967	25,996	66,563	7,623	381,489	3.03	2.690

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

	POPULATION			HOUSING UNITS								PERSONS PER HOUSEHOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSEHOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Del Norte County												
Crescent City	7,742	4,012	3,730	1,845	937	56	394	424	34	1,659	10.08	2.418
Balance Of County	21,474	21,191	283	9,201	5,583	132	408	160	2,918	8,046	12.55	2.634
Incorporated	7,742	4,012	3,730	1,845	937	56	394	424	34	1,659	10.08	2.418
County Total	29,216	25,203	4,013	11,046	6,520	188	802	584	2,952	9,705	12.14	2.597
El Dorado County												
Placerville	10,187	9,925	262	4,607	2,828	260	628	728	163	4,346	5.67	2.284
South Lake Tahoe	23,582	23,454	128	14,311	9,023	361	2,036	2,223	668	9,615	32.81	2.439
Balance Of County	143,997	143,333	664	63,777	55,197	1,207	965	2,862	3,546	54,740	14.17	2.618
Incorporated	33,769	33,379	390	18,918	11,851	621	2,664	2,951	831	13,961	26.20	2.391
County Total	177,766	176,712	1,054	82,695	67,048	1,828	3,629	5,813	4,377	68,701	16.92	2.572
Fresno County												
Clovis	91,836	91,356	480	33,353	23,649	550	3,090	5,147	917	32,164	3.56	2.840
Coalinga	18,007	11,573	6,434	4,040	2,763	127	285	546	319	3,678	8.96	3.147
Firebaugh	6,658	6,597	61	1,803	1,201	155	194	141	112	1,617	10.32	4.080
Fowler	5,267	5,178	89	1,668	1,240	50	168	163	47	1,615	3.18	3.206
Fresno	478,808	470,018	8,790	164,190	98,648	6,028	16,965	38,626	3,923	154,143	6.12	3.049
Huron	7,460	7,288	172	1,650	524	204	231	586	105	1,609	2.48	4.530
Kerman	13,527	13,496	31	3,830	2,794	153	264	503	116	3,717	2.95	3.631
Kingsburg	11,183	11,092	91	4,024	3,053	102	266	439	164	3,867	3.90	2.868
Mendota	9,383	9,375	8	2,193	1,253	139	334	393	74	2,133	2.74	4.395
Orange Cove	10,496	10,496	0	2,371	1,253	206	224	662	26	2,261	4.64	4.642
Parlier	13,017	12,915	102	3,037	2,120	234	184	485	14	2,810	7.47	4.596
Reedley	24,793	24,398	395	7,028	5,145	216	612	864	191	6,780	3.53	3.599
Sanger	24,796	24,656	140	7,031	5,337	194	579	758	163	6,725	4.35	3.666
San Joaquin	3,851	3,851	0	850	532	80	115	63	60	814	4.24	4.731
Selma	23,086	22,956	130	6,787	5,074	148	338	801	426	6,532	3.76	3.514
Balance Of County	172,725	170,248	2,477	60,289	48,295	1,475	1,314	1,948	7,257	53,869	10.65	3.160
Incorporated	742,168	725,245	16,923	243,855	154,586	8,586	23,849	50,177	6,657	230,465	5.49	3.147
County Total	914,893	895,493	19,400	304,144	202,881	10,061	25,163	52,125	13,914	284,334	6.51	3.149
Glenn County												
Orland	7,169	7,131	38	2,585	1,907	56	384	197	41	2,452	5.15	2.908
Willows	6,453	6,272	181	2,415	1,589	54	307	458	7	2,177	9.86	2.881
Balance Of County	15,211	15,022	189	5,686	3,941	109	93	45	1,498	5,197	8.60	2.891
Incorporated	13,622	13,403	219	5,000	3,496	110	691	655	48	4,629	7.42	2.895

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
County Total	28,833	28,425	408	10,686	7,437	219	784	700	1,546	9,826	8.05	2.893
Humboldt County												
Arcata	17,417	15,665	1,752	7,578	3,512	303	1,192	1,887	684	7,347	3.05	2.132
Blue Lake	1,165	1,165	0	578	382	21	68	36	71	525	9.17	2.219
Eureka	26,097	24,771	1,326	11,781	7,268	381	2,254	1,704	174	11,093	5.84	2.233
Ferndale	1,429	1,429	0	694	565	27	83	10	9	641	7.64	2.229
Fortuna	11,329	11,063	266	4,817	3,215	235	554	368	445	4,566	5.21	2.423
Rio Dell	3,273	3,263	10	1,498	1,044	26	149	36	243	1,275	14.89	2.559
Trinidad	314	314	0	233	183	8	11	0	31	172	26.18	1.826
Balance Of County	70,953	69,939	1,014	31,784	24,398	603	1,544	742	4,497	28,398	10.65	2.463
Incorporated	61,024	57,670	3,354	27,179	16,169	1,001	4,311	4,041	1,657	25,619	5.74	2.251
County Total	131,977	127,609	4,368	58,963	40,567	1,604	5,855	4,783	6,154	54,017	8.39	2.362
Imperial County												
Brawley	25,522	25,210	312	8,417	5,470	362	717	1,413	455	7,931	5.77	3.179
Calexico	37,295	37,192	103	9,919	6,859	439	957	1,459	205	9,680	2.41	3.842
Calipatria	7,750	3,523	4,227	1,082	748	38	75	158	63	1,011	6.56	3.485
El Centro	41,789	40,902	887	13,901	7,626	563	1,114	3,280	1,318	12,971	6.69	3.153
Holtville	6,257	6,127	130	1,873	1,126	111	198	243	195	1,803	3.74	3.398
Imperial	11,772	11,740	32	3,876	3,310	117	251	164	34	3,713	4.21	3.162
Westmorland	2,359	2,359	0	756	443	16	90	167	40	710	6.08	3.323
Balance Of County	38,832	32,492	6,340	14,965	8,258	357	443	386	5,521	11,213	25.07	2.898
Incorporated	132,744	127,053	5,691	39,824	25,582	1,646	3,402	6,884	2,310	37,819	5.03	3.360
County Total	171,576	159,545	12,031	54,789	33,840	2,003	3,845	7,270	7,831	49,032	10.51	3.254
Inyo County												
Bishop	3,546	3,469	77	1,882	847	78	262	323	372	1,699	9.72	2.042
Balance Of County	14,643	14,436	207	7,368	4,679	134	145	145	2,265	6,180	16.12	2.336
Incorporated	3,546	3,469	77	1,882	847	78	262	323	372	1,699	9.72	2.042
County Total	18,189	17,905	284	9,250	5,526	212	407	468	2,637	7,879	14.82	2.272
Kern County												
Arvin	16,118	16,047	71	3,785	2,552	218	264	494	257	3,623	4.28	4.429
Bakersfield	322,818	319,046	3,772	112,106	79,437	3,224	11,158	15,590	2,697	105,789	5.63	3.016
California City	13,107	10,473	2,634	4,359	3,385	68	338	226	342	3,729	14.45	2.809
Delano	52,987	41,839	11,148	10,571	7,582	549	658	1,332	450	10,067	4.77	4.156
Maricopa	1,134	1,134	0	458	244	7	5	9	193	402	12.23	2.821
Mcfarland	12,672	11,675	997	2,680	2,011	246	270	124	29	2,626	2.01	4.446

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Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Ridgecrest	27,910	27,593	317	11,718	7,802	414	1,713	765	1,024	10,700	8.69	2.579
Shafter	14,966	14,315	651	4,147	3,290	177	234	237	209	3,768	9.14	3.799
Taft	9,154	6,175	2,979	2,531	1,842	52	315	222	100	2,281	9.88	2.707
Tehachapi	13,053	7,933	5,120	3,406	2,223	150	405	281	347	2,962	13.04	2.678
Wasco	24,134	18,012	6,122	4,924	3,684	360	428	318	134	4,595	6.68	3.920
Balance Of County	292,646	288,454	4,192	109,931	75,575	3,084	6,538	4,874	19,860	93,052	15.35	3.100
Incorporated	508,053	474,242	33,811	160,685	114,052	5,465	15,788	19,598	5,782	150,542	6.31	3.150
County Total	800,699	762,696	38,003	270,616	189,627	8,549	22,326	24,472	25,642	243,594	9.99	3.131
Kings County												
Avenal	16,753	8,955	7,798	2,251	1,395	147	309	305	95	2,106	6.44	4.252
Corcoran	25,440	12,503	12,937	3,849	2,831	180	361	314	163	3,532	8.24	3.540
Hanford	50,459	49,611	848	17,389	12,974	552	1,468	2,053	342	16,455	5.37	3.015
Lemoore	24,140	24,138	2	8,125	5,419	154	560	1,663	329	7,681	5.46	3.143
Balance Of County	34,815	32,482	2,333	9,910	6,885	1,392	217	110	1,306	9,381	5.34	3.463
Incorporated	116,792	95,207	21,585	31,614	22,619	1,033	2,698	4,335	929	29,774	5.82	3.198
County Total	151,607	127,689	23,918	41,524	29,504	2,425	2,915	4,445	2,235	39,155	5.71	3.261
Lake County												
Clearlake	14,032	13,913	119	7,962	3,680	299	251	436	3,296	5,793	27.24	2.402
Lakeport	5,060	4,886	174	2,432	1,468	119	166	223	456	1,999	17.80	2.444
Balance Of County	44,648	43,747	901	24,427	16,702	315	511	381	6,518	17,864	26.87	2.449
Incorporated	19,092	18,799	293	10,394	5,148	418	417	659	3,752	7,792	25.03	2.413
County Total	63,740	62,546	1,194	34,821	21,850	733	928	1,040	10,270	25,656	26.32	2.438
Lassen County												
Susanville	17,883	8,790	9,093	4,179	2,984	131	382	472	210	3,786	9.40	2.322
Balance Of County	17,921	16,577	1,344	8,800	5,928	221	138	59	2,454	6,690	23.98	2.478
Incorporated	17,883	8,790	9,093	4,179	2,984	131	382	472	210	3,786	9.40	2.322
County Total	35,804	25,367	10,437	12,979	8,912	352	520	531	2,664	10,476	19.28	2.421
Los Angeles County												
Agoura Hills	23,208	23,185	23	7,561	5,288	979	180	1,114	0	7,433	1.69	3.119
Alhambra	88,993	87,070	1,923	30,185	12,739	3,286	3,983	10,160	17	29,222	3.19	2.980
Arcadia	56,241	55,660	581	20,264	11,848	1,699	1,493	5,198	26	19,431	4.11	2.864
Artesia	17,492	16,920	572	4,708	3,221	327	329	735	96	4,578	2.76	3.696
Avalon	3,503	3,441	62	1,925	498	487	560	371	9	1,229	36.16	2.800

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Azusa	48,379	46,430	1,949	13,516	6,229	1,769	1,469	3,460	589	13,034	3.57	3.562
Baldwin Park	80,831	80,225	606	17,781	11,997	1,878	610	2,953	343	17,302	2.69	4.637
Bell	38,764	38,226	538	9,328	3,602	1,517	1,457	2,291	461	9,028	3.22	4.234
Bellflower	76,803	76,180	623	24,455	11,253	2,085	1,431	8,084	1,602	23,567	3.63	3.232
Bell Gardens	46,496	46,040	456	9,888	3,980	2,470	1,457	1,585	396	9,562	3.30	4.815
Beverly Hills	35,882	35,843	39	16,110	5,747	236	1,802	8,297	28	15,276	5.18	2.346
Bradbury	932	932	0	328	326	0	2	0	0	299	8.84	3.117
Burbank	107,318	106,492	826	43,873	19,929	1,731	4,654	17,447	112	42,604	2.89	2.500
Calabasas	23,521	23,461	60	8,552	5,957	804	204	1,334	253	8,277	3.22	2.834
Carson	97,820	96,496	1,324	26,422	18,656	2,280	716	2,265	2,505	25,703	2.72	3.754
Cerritos	54,728	54,635	93	15,871	13,378	1,220	600	641	32	15,651	1.39	3.491
Claremont	36,963	31,521	5,442	12,063	8,419	887	635	2,109	13	11,773	2.40	2.677
Commerce	13,418	13,215	203	3,425	1,945	593	332	551	4	3,332	2.72	3.966
Compton	98,893	98,243	650	24,087	16,072	2,150	2,314	2,903	648	22,602	6.17	4.347
Covina	49,441	48,839	602	16,537	9,454	1,321	987	4,187	588	16,140	2.40	3.026
Cudahy	25,728	25,716	12	5,634	1,690	1,293	344	1,893	414	5,509	2.22	4.668
Culver City	40,564	40,040	524	17,135	6,618	1,903	2,286	6,147	181	16,616	3.03	2.410
Diamond Bar	59,870	59,752	118	18,276	12,893	2,531	823	1,696	333	17,964	1.71	3.326
Downey	112,957	111,192	1,765	35,026	20,477	1,667	1,663	11,026	193	34,250	2.22	3.246
Duarte	22,991	22,501	490	6,977	4,354	892	224	1,278	229	6,803	2.49	3.308
El Monte	125,581	124,311	1,270	28,780	15,457	3,396	2,023	6,498	1,406	28,029	2.61	4.435
El Segundo	16,981	16,958	23	7,357	3,145	426	820	2,955	11	7,154	2.76	2.370
Gardena	61,603	60,799	804	21,492	9,310	1,711	2,710	6,658	1,103	20,759	3.41	2.929
Glendale	206,007	203,143	2,864	74,565	26,124	3,814	6,918	37,612	97	72,635	2.59	2.797
Glendora	52,265	51,252	1,013	17,365	12,610	1,094	699	2,079	883	17,035	1.90	3.009
Hawaiian Gardens	15,830	15,826	4	3,714	1,522	502	455	960	275	3,595	3.20	4.402
Hawthorne	88,583	88,083	500	29,859	8,293	2,471	3,325	15,597	173	28,758	3.69	3.063
Hermosa Beach	19,377	19,264	113	9,827	4,145	1,031	2,025	2,544	82	9,461	3.72	2.036
Hidden Hills	2,027	2,027	0	612	610	2	0	0	0	588	3.92	3.447
Huntington Park	64,547	64,366	181	15,437	5,276	2,380	2,224	5,542	15	14,959	3.10	4.303
Industry	801	537	264	124	101	23	0	0	0	121	2.42	4.438
Inglewood	118,550	117,180	1,370	38,956	14,340	3,232	4,726	16,420	238	37,098	4.77	3.159
Irwindale	1,647	1,645	2	412	351	16	13	24	8	397	3.64	4.144
La Canada Flintridge	21,233	21,044	189	7,068	6,561	200	132	175	0	6,901	2.36	3.049
La Habra Heights	6,109	6,109	0	2,019	1,987	24	8	0	0	1,953	3.27	3.128
Lakewood	83,171	82,977	194	27,388	22,243	741	730	3,576	98	26,930	1.67	3.081
La Mirada	49,998	47,497	2,501	15,074	11,891	800	480	1,737	166	14,839	1.56	3.201
Lancaster	143,051	135,805	7,246	48,550	33,288	1,188	2,621	7,955	3,498	44,456	8.43	3.055
La Puente	43,095	43,063	32	9,699	6,362	642	340	2,246	109	9,500	2.05	4.533
La Verne	33,264	32,556	708	11,364	7,566	597	736	702	1,763	11,148	1.90	2.920
Lawndale	33,382	33,296	86	9,940	4,964	1,606	919	2,323	128	9,624	3.18	3.460
Lomita	21,009	20,876	133	8,319	4,019	774	581	2,447	498	8,038	3.38	2.597
Long Beach	490,193	479,822	10,371	174,547	69,277	10,091	23,294	69,356	2,529	165,858	4.98	2.893
Los Angeles	3,996,070	3,910,799	85,271	1,386,169	530,241	88,323	131,774	626,744	9,087	1,321,224	4.69	2.960
Lynwood	72,771	70,571	2,200	14,957	8,131	1,691	1,686	3,337	112	14,365	3.96	4.913
Malibu	13,671	13,371	300	6,384	4,043	487	404	840	610	5,353	16.15	2.498
Manhattan Beach	36,388	36,374	14	15,466	10,565	1,417	2,580	871	33	14,892	3.71	2.443
Maywood	29,787	29,693	94	6,801	2,815	1,118	1,446	1,414	8	6,566	3.46	4.522
Monrovia	39,089	38,796	293	14,139	7,841	1,549	1,318	3,316	115	13,678	3.26	2.836

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COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Montebello	65,318	65,009	309	19,525	9,382	1,582	2,863	5,465	233	18,950	2.94	3.431
Monterey Park	64,258	63,981	277	20,693	11,740	2,204	1,994	4,675	80	20,033	3.19	3.194
Norwalk	109,432	107,586	1,846	27,816	20,183	1,430	830	4,900	473	27,144	2.42	3.964
Palmdale	144,650	144,556	94	44,031	35,004	905	938	5,402	1,782	40,699	7.57	3.552
Palos Verdes Estates	14,004	13,999	5	5,283	4,861	40	44	338	0	5,072	3.99	2.760
Paramount	57,761	57,441	320	14,592	6,049	2,165	1,084	3,922	1,372	13,972	4.25	4.111
Pasadena	146,452	142,934	3,518	56,753	24,871	5,148	4,658	22,003	73	54,354	4.23	2.630
Pico Rivera	66,852	66,502	350	16,951	12,697	945	337	2,382	590	16,609	2.02	4.004
Pomona	161,442	155,481	5,961	40,778	24,708	3,339	3,289	7,737	1,705	38,982	4.40	3.989
Rancho Palos Verdes	42,852	42,343	509	15,833	12,246	1,287	249	2,051	0	15,377	2.88	2.754
Redondo Beach	67,114	66,927	187	29,988	11,821	4,334	4,012	9,441	380	28,995	3.31	2.308
Rolling Hills	1,959	1,959	0	691	684	7	0	0	0	654	5.35	2.995
Rolling Hills Estates	8,052	8,040	12	2,923	2,306	565	41	7	4	2,849	2.53	2.822
Rosemead	57,107	56,495	612	14,657	9,951	2,030	917	1,355	404	14,215	3.02	3.974
San Dimas	36,810	35,601	1,209	12,609	7,591	2,100	357	1,618	943	12,267	2.71	2.902
San Fernando	25,004	24,958	46	6,022	4,044	634	469	802	73	5,863	2.64	4.257
San Gabriel	42,455	41,700	755	13,187	7,078	1,205	1,159	3,701	44	12,858	2.49	3.243
San Marino	13,430	13,423	7	4,453	4,417	19	8	9	0	4,282	3.84	3.135
Santa Clarita	176,168	174,775	1,393	58,568	36,020	6,938	2,824	10,546	2,240	56,715	3.16	3.082
Santa Fe Springs	17,750	17,532	218	5,108	3,102	286	158	1,435	127	5,005	2.02	3.503
Santa Monica	90,627	88,021	2,606	49,409	9,356	1,929	5,528	32,307	289	45,934	7.03	1.916
Sierra Madre	10,978	10,851	127	4,944	3,415	205	377	920	27	4,777	3.38	2.272
Signal Hill	11,165	11,111	54	4,350	1,422	488	757	1,675	8	4,150	4.60	2.677
South El Monte	22,335	22,317	18	4,774	2,984	458	233	595	504	4,669	2.20	4.780
South Gate	101,659	101,518	141	24,491	12,351	3,285	3,706	4,860	289	23,425	4.35	4.334
South Pasadena	25,678	25,491	187	10,980	5,095	646	1,118	4,107	14	10,603	3.43	2.404
Temple City	35,504	34,993	511	11,890	9,626	802	421	983	58	11,548	2.88	3.030
Torrance	147,730	146,481	1,249	57,404	30,652	3,693	3,411	18,465	1,183	55,945	2.54	2.618
Vernon	95	95	0	26	19	0	0	7	0	25	3.85	3.800
Walnut	32,117	32,077	40	8,597	8,132	119	46	300	0	8,459	1.61	3.792
West Covina	112,321	111,513	808	32,797	21,342	2,812	1,570	6,725	348	32,136	2.02	3.470
West Hollywood	37,440	37,204	236	24,450	1,802	681	1,852	20,115	0	23,450	4.09	1.587
Westlake Village	8,845	8,836	9	3,384	2,242	608	158	201	175	3,306	2.30	2.673
Whittier	86,708	85,118	1,590	29,006	19,080	1,480	2,058	6,174	214	28,299	2.44	3.008
Balance Of County	1,086,026	1,068,942	17,084	309,082	212,600	22,258	18,398	44,874	10,952	294,791	4.62	3.626
Incorporated	9,189,888	9,027,163	162,725	3,073,274	1,425,921	221,720	273,008	1,106,876	45,749	2,944,720	4.18	3.066
County Total	10,275,914	10,096,105	179,809	3,382,356	1,638,521	243,978	291,406	1,151,750	56,701	3,239,511	4.22	3.117
Madera County												
Chowchilla	17,771	10,153	7,618	3,670	3,027	31	272	304	36	3,452	5.94	2.941
Madera	55,475	54,947	528	16,034	11,174	742	1,592	2,224	302	15,338	4.34	3.582
Balance Of County	74,698	73,912	786	28,756	23,815	563	605	417	3,356	24,709	14.07	2.991
Incorporated	73,246	65,100	8,146	19,704	14,201	773	1,864	2,528	338	18,790	4.64	3.465
County Total	147,944	139,012	8,932	48,460	38,016	1,336	2,469	2,945	3,694	43,499	10.24	3.196

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Marin County												
Belvedere	2,143	2,143	0	1,065	874	54	94	43	0	962	9.67	2.228
Corte Madera	9,431	9,423	8	3,980	2,624	416	369	561	10	3,904	1.91	2.414
Fairfax	7,347	7,317	30	3,423	2,336	193	490	393	11	3,311	3.27	2.210
Larkspur	12,078	11,923	155	6,431	2,456	359	544	2,833	239	6,160	4.21	1.936
Mill Valley	13,771	13,680	91	6,350	4,138	550	535	1,127	0	6,210	2.20	2.203
Novato	52,238	51,368	870	20,881	12,174	2,671	1,418	3,900	718	20,366	2.47	2.522
Ross	2,370	2,276	94	818	798	0	12	0	8	774	5.38	2.941
San Anselmo	12,473	12,217	256	5,437	3,997	187	468	767	18	5,296	2.59	2.307
San Rafael	57,843	55,773	2,070	23,622	10,652	2,001	2,459	8,021	489	23,028	2.51	2.422
Sausalito	7,428	7,416	12	4,560	1,737	423	1,349	827	224	4,301	5.68	1.724
Tiburon	8,849	8,743	106	3,966	2,425	237	467	837	0	3,781	4.66	2.312
Balance Of County	69,109	62,148	6,961	27,847	21,472	1,490	1,589	2,882	414	25,862	7.13	2.403
Incorporated	185,971	182,279	3,692	80,533	44,211	7,091	8,205	19,309	1,717	78,093	3.03	2.334
County Total	255,080	244,427	10,653	108,380	65,683	8,581	9,794	22,191	2,131	103,955	4.08	2.351
Mariposa County												
County Total	18,262	16,824	1,438	10,203	6,306	582	214	383	2,718	7,646	25.06	2.200
Mendocino County												
Fort Bragg	6,860	6,734	126	3,148	2,044	158	324	459	163	2,930	6.93	2.298
Point Arena	491	491	0	232	148	7	45	13	19	204	12.07	2.407
Ukiah	15,742	15,008	734	6,394	3,545	379	767	1,241	462	6,235	2.49	2.407
Willits	5,007	4,881	126	2,035	1,192	84	317	291	151	1,957	3.83	2.494
Balance Of County	61,418	60,135	1,283	27,469	20,780	535	727	778	4,649	24,020	12.56	2.504
Incorporated	28,100	27,114	986	11,809	6,929	628	1,453	2,004	795	11,326	4.09	2.394
County Total	89,518	87,249	2,269	39,278	27,709	1,163	2,180	2,782	5,444	35,346	10.01	2.468
Merced County												
Atwater	27,497	25,703	1,794	9,442	6,529	584	832	990	507	8,433	10.69	3.048
Dos Palos	4,875	4,851	24	1,653	1,432	55	48	78	40	1,577	4.60	3.076
Gustine	5,126	5,126	0	1,990	1,628	31	98	105	128	1,900	4.52	2.698
Livingston	13,223	13,186	37	3,201	2,574	80	206	305	36	3,123	2.44	4.222
Los Banos	35,044	34,869	175	11,311	9,543	263	570	658	277	10,851	4.07	3.213
Merced	79,381	78,011	1,370	27,652	17,756	944	2,781	5,463	708	26,245	5.09	2.972
Balance Of County	85,234	83,878	1,356	28,153	22,125	582	840	628	3,978	25,837	8.23	3.246
Incorporated	165,146	161,746	3,400	55,249	39,462	1,957	4,535	7,599	1,696	52,129	5.65	3.103
	250,380	245,624	4,756	83,402	61,587	2,539	5,375	8,227	5,674	77,966		
County Total	250,380	245,624	4,756	83,402	61,587	2,539	5,375	8,227	5,674	77,966	6.52	3.150

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Modoc County												
Alturas	2,815	2,735	80	1,379	1,021	57	47	144	110	1,191	13.63	2.296
Balance Of County	6,864	6,536	328	3,746	2,466	33	50	15	1,182	2,835	24.32	2.305
Incorporated	2,815	2,735	80	1,379	1,021	57	47	144	110	1,191	13.63	2.296
County Total	9,679	9,271	408	5,125	3,487	90	97	159	1,292	4,026	21.44	2.303
Mono County												
Mammoth Lakes	7,407	7,189	218	9,223	2,306	1,003	1,880	3,841	193	3,260	64.65	2.205
Balance Of County	6,323	6,165	158	4,417	2,905	256	307	74	875	2,780	37.06	2.218
Incorporated	7,407	7,189	218	9,223	2,306	1,003	1,880	3,841	193	3,260	64.65	2.205
County Total	13,730	13,354	376	13,640	5,211	1,259	2,187	3,915	1,068	6,040	55.72	2.211
Monterey County												
Carmel-By-The-Sea	4,041	4,041	0	3,359	2,754	114	221	270	0	2,303	31.44	1.755
Del Rey Oaks	1,623	1,623	0	727	567	25	23	109	3	704	3.16	2.305
Gonzales	8,717	8,644	73	2,023	1,474	133	205	169	42	1,989	1.68	4.346
Greenfield	16,589	16,493	96	3,641	2,732	282	294	247	86	3,530	3.05	4.672
King City	11,491	11,307	184	2,945	1,660	278	302	415	290	2,854	3.09	3.962
Marina	18,914	18,783	131	8,677	3,491	1,537	1,457	1,748	444	6,855	21.00	2.740
Monterey	30,057	27,031	3,026	13,538	5,921	913	2,268	4,415	21	12,788	5.54	2.114
Pacific Grove	15,408	15,233	175	8,108	5,015	451	992	1,559	91	7,385	8.92	2.063
Salinas	149,208	146,756	2,452	42,205	22,785	3,594	3,479	11,061	1,286	40,755	3.44	3.601
Sand City	300	236	64	106	58	6	28	9	5	98	7.55	2.408
Seaside	33,306	31,034	2,272	11,269	6,296	2,351	920	1,270	432	9,817	12.88	3.161
Soledad	28,323	16,146	12,177	3,711	2,792	204	382	210	123	3,621	2.43	4.459
Balance Of County	105,785	104,138	1,647	39,364	30,221	2,695	1,592	1,726	3,130	35,911	8.77	2.900
Incorporated	317,977	297,327	20,650	100,309	55,545	9,888	10,571	21,482	2,823	92,699	7.59	3.207
County Total	423,762	401,465	22,297	139,673	85,766	12,583	12,163	23,208	5,953	128,610	7.92	3.122
Napa County												
American Canyon	15,925	15,791	134	5,481	4,334	23	68	277	779	5,373	1.97	2.939
Calistoga	5,258	5,191	67	2,329	1,077	97	190	361	604	2,116	9.15	2.453
Napa	76,316	74,857	1,459	29,874	18,068	2,358	2,862	5,197	1,389	29,016	2.87	2.580
St Helena	5,941	5,889	52	2,762	1,691	215	216	478	162	2,429	12.06	2.424
Yountville	3,272	2,103	1,169	1,194	636	172	43	35	308	1,100	7.87	1.912
Balance Of County	28,132	25,740	2,392	11,903	10,160	650	353	8	732	10,166	14.59	2.532
Incorporated	106,712	103,831	2,881	41,640	25,806	2,865	3,379	6,348	3,242	40,034	3.86	2.594

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

	------------POPULATION------------			--------- HOUSING UNITS ---------								PERSONS
					-------- SINGLE --------		----- MULTIPLE -----					PER
COUNTY/CITY	TOTAL	HOUSE- HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU- PIED	PCT VACANT	HOUSE- HOLD
County Total	134,844	129,571	5,273	53,543	35,966	3,515	3,732	6,356	3,974	50,200	6.24	2.581
Nevada County												
Grass Valley	12,915	12,565	350	6,392	3,033	259	759	1,645	696	6,088	4.76	2.064
Nevada City	3,057	2,870	187	1,498	1,142	53	139	90	74	1,390	7.21	2.065
Truckee	15,901	15,860	41	11,608	9,647	287	794	582	298	6,126	47.23	2.589
Balance Of County	67,153	66,752	401	30,173	26,712	320	271	90	2,780	27,542	8.72	2.424
Incorporated	31,873	31,295	578	19,498	13,822	599	1,692	2,317	1,068	13,604	30.23	2.300
County Total	99,026	98,047	979	49,671	40,534	919	1,963	2,407	3,848	41,146	17.16	2.383
Orange County												
Aliso Viejo	44,832	44,672	160	17,980	6,455	4,947	739	5,824	15	17,483	2.76	2.555
Anaheim	343,973	340,177	3,796	101,510	43,663	9,064	10,394	34,004	4,385	98,712	2.76	3.446
Brea	39,685	39,557	128	14,517	8,488	1,095	563	3,501	870	14,236	1.94	2.779
Buena Park	82,075	81,141	934	24,209	14,181	1,911	1,450	6,376	291	23,707	2.07	3.423
Costa Mesa	113,292	110,264	3,028	40,987	15,733	4,171	5,920	14,067	1,096	39,769	2.97	2.773
Cypress	49,058	48,737	321	16,540	10,182	2,627	525	2,842	364	16,154	2.33	3.017
Dana Point	36,773	36,531	242	15,940	7,933	2,271	2,821	2,622	293	14,696	7.80	2.486
Fountain Valley	57,475	56,963	512	18,742	12,393	2,199	672	3,080	398	18,427	1.68	3.091
Fullerton	136,741	133,524	3,217	47,061	23,948	3,847	3,742	14,603	921	45,840	2.59	2.913
Garden Grove	171,991	169,757	2,234	47,197	26,775	4,489	3,414	10,691	1,828	46,276	1.95	3.668
Huntington Beach	201,315	200,523	792	77,962	38,564	9,467	9,866	16,924	3,141	75,896	2.65	2.642
Irvine	201,154	192,939	8,215	74,936	27,631	14,591	4,966	26,726	1,022	71,368	4.76	2.703
Laguna Beach	25,013	24,891	122	13,264	8,307	759	1,769	2,105	324	11,775	11.23	2.114
Laguna Hills	33,237	32,813	424	11,153	5,873	2,183	608	2,272	217	10,807	3.10	3.036
Laguna Niguel	66,302	65,999	303	24,831	13,757	5,007	1,441	4,610	16	24,136	2.80	2.734
Laguna Woods	18,340	18,266	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.451
La Habra	62,197	61,602	595	19,902	10,550	1,750	1,360	5,508	734	19,396	2.54	3.176
Lake Forest	77,886	77,042	844	26,384	14,165	3,923	1,276	5,734	1,286	25,711	2.55	2.996
La Palma	16,086	16,055	31	5,131	3,637	376	102	989	27	5,043	1.72	3.184
Los Alamitos	12,091	11,685	406	4,409	1,950	269	1,047	1,014	129	4,325	1.91	2.702
Mission Viejo	98,030	96,965	1,065	33,713	24,474	4,021	1,201	3,928	89	33,165	1.63	2.924
Newport Beach	83,834	82,894	940	42,580	19,186	7,166	5,520	9,845	863	37,934	10.91	2.185
Orange	138,024	132,556	5,468	43,637	24,989	5,149	4,718	7,442	1,339	42,624	2.32	3.110
Placentia	51,357	51,054	303	16,436	9,744	2,053	1,108	2,954	577	16,126	1.89	3.166
Rancho Santa Margarita	49,487	49,473	14	16,793	9,118	3,883	598	3,194	0	16,526	1.59	2.994
San Clemente	67,063	66,771	292	26,948	15,312	2,669	4,079	4,485	403	25,305	6.10	2.639
San Juan Capistrano	36,285	35,827	458	11,780	6,066	2,395	944	865	1,510	11,374	3.45	3.150
Santa Ana	351,812	346,165	5,647	75,375	33,758	6,609	7,491	23,608	3,909	73,771	2.13	4.692
Seal Beach	25,845	25,582	263	14,538	4,696	2,121	1,168	6,390	163	13,440	7.55	1.903
Stanton	38,804	38,286	518	11,087	3,010	1,873	988	3,954	1,262	10,842	2.21	3.531
Tustin	72,348	71,930	418	25,477	8,697	3,807	3,110	8,955	908	24,787	2.71	2.902
Villa Park	6,224	6,203	21	2,021	1,992	18	0	6	5	1,963	2.87	3.160
Westminster	92,443	91,891	552	27,398	14,880	2,553	2,089	4,808	3,068	26,855	1.98	3.422

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Yorba Linda	67,592	67,457	135	21,783	17,147	2,395	570	1,360	311	21,432	1.61	3.147
Balance Of County	121,043	119,522	1,521	38,842	30,346	2,179	2,244	3,766	307	37,949	2.30	3.150
Incorporated	2,968,664	2,926,192	42,472	985,850	487,981	125,670	88,733	251,676	31,790	952,492	3.38	3.072
County Total	3,089,707	3,045,714	43,993	1,024,692	518,327	127,849	90,977	255,442	32,097	990,441	3.34	3.075
Placer County												
Auburn	13,194	12,988	206	5,971	4,080	211	655	1,025	0	5,802	2.83	2.239
Colfax	1,849	1,848	1	811	521	22	172	63	33	784	3.33	2.357
Lincoln	37,642	37,528	114	16,632	15,243	196	384	713	96	15,958	4.05	2.352
Loomis	6,570	6,536	34	2,452	2,068	210	58	2	114	2,381	2.90	2.745
Rocklin	52,270	51,892	378	20,366	14,649	537	831	3,910	439	19,608	3.72	2.646
Roseville	106,925	105,871	1,054	44,187	32,478	1,082	1,627	8,457	543	42,606	3.58	2.485
Balance Of County	108,053	106,590	1,463	53,788	43,434	1,916	2,569	2,354	3,515	41,462	22.92	2.571
Incorporated	218,450	216,663	1,787	90,419	69,039	2,258	3,727	14,170	1,225	87,139	3.63	2.486
County Total	326,503	323,253	3,250	144,207	112,473	4,174	6,296	16,524	4,740	128,601	10.82	2.514
Plumas County												
Portola	2,086	2,065	21	1,066	798	17	72	110	69	951	10.79	2.171
Balance Of County	18,855	18,688	167	14,187	10,925	433	303	286	2,240	9,285	34.55	2.013
Incorporated	2,086	2,065	21	1,066	798	17	72	110	69	951	10.79	2.171
County Total	20,941	20,753	188	15,253	11,723	450	375	396	2,309	10,236	32.89	2.027
Riverside County												
Banning	28,293	27,955	338	11,618	8,715	728	424	595	1,156	10,643	8.39	2.627
Beaumont	28,271	28,116	155	10,640	9,030	172	363	728	347	9,575	10.01	2.936
Blythe	22,636	13,360	9,276	5,376	2,964	152	498	881	881	4,510	16.11	2.962
Calimesa	7,420	7,324	96	3,322	1,833	113	57	64	1,255	3,051	8.16	2.401
Canyon Lake	10,979	10,963	16	4,391	4,000	160	6	84	141	3,954	9.95	2.773
Cathedral City	52,151	51,955	196	21,511	11,505	2,659	2,433	2,065	2,849	16,863	21.61	3.081
Coachella	38,515	38,471	44	8,426	5,888	319	700	1,062	457	8,018	4.84	4.798
Corona	146,147	145,515	632	45,127	31,516	2,186	2,225	7,587	1,613	43,482	3.65	3.347
Desert Hot Springs	24,907	24,733	174	10,427	6,947	180	1,309	1,313	678	8,685	16.71	2.848
Hemet	73,299	71,620	1,679	35,342	17,065	1,766	2,215	4,517	9,779	30,935	12.47	2.315
Indian Wells	4,945	4,945	0	4,898	3,298	884	239	469	8	2,527	48.41	1.957
Indio	77,208	76,352	856	26,464	17,068	878	1,542	3,795	3,181	21,601	18.38	3.535
Lake Elsinore	47,669	47,596	73	15,587	9,881	2,451	728	1,742	785	14,322	8.12	3.323
La Quinta	41,125	41,085	40	20,176	16,541	1,789	487	1,102	257	14,425	28.50	2.848
Moreno Valley	180,603	179,906	697	51,939	42,125	891	1,716	6,164	1,043	49,082	5.50	3.665
Murrieta	97,329	96,669	660	33,298	24,473	483	730	5,899	1,713	31,758	4.62	3.044
Norco	27,375	22,609	4,766	7,221	6,806	137	9	177	92	7,058	2.26	3.203

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	HOUSE-HOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Palm Desert	49,789	49,405	384	33,394	13,169	9,697	2,513	4,706	3,309	23,048	30.98	2.144
Palm Springs	46,893	46,197	696	33,250	11,952	6,609	2,543	9,915	2,231	22,135	33.43	2.087
Perris	50,701	50,469	232	14,567	10,780	321	371	1,264	1,831	13,323	8.54	3.788
Rancho Mirage	16,957	16,424	533	14,555	7,072	3,680	615	1,196	1,992	8,392	42.34	1.957
Riverside	291,611	281,921	9,690	96,446	60,838	4,144	5,840	23,147	2,477	92,027	4.58	3.063
San Jacinto	34,371	34,181	190	13,594	9,123	596	657	567	2,651	11,848	12.84	2.885
Temecula	98,009	97,987	22	31,501	25,328	453	606	4,793	321	30,222	4.06	3.242
Balance Of County	537,637	532,108	5,529	200,898	141,245	4,214	3,752	6,707	44,980	172,342	14.21	3.088
Incorporated	1,497,203	1,465,758	31,445	553,070	357,917	41,448	28,826	83,832	41,047	481,484	12.94	3.044
County Total	2,034,840	1,997,866	36,974	753,968	499,162	45,662	32,578	90,539	86,027	653,826	13.28	3.056
Sacramento County												
Citrus Heights	86,951	86,074	877	35,624	19,834	3,531	3,025	7,355	1,879	34,177	4.06	2.518
Elk Grove	136,210	135,460	750	46,495	42,281	1,327	525	2,089	273	45,318	2.53	2.989
Folsom	70,783	63,931	6,852	25,594	18,077	637	744	5,253	883	24,495	4.29	2.610
Galt	23,448	23,260	188	7,502	6,082	226	340	482	372	7,216	3.81	3.223
Isleton	815	815	0	378	223	0	72	36	47	338	10.58	2.411
Rancho Cordova	58,991	58,641	350	23,410	12,357	2,024	1,987	5,653	1,389	22,363	4.47	2.622
Sacramento	466,981	457,998	8,983	189,517	112,093	12,934	16,158	44,646	3,686	178,607	5.76	2.564
Balance Of County	561,515	553,882	7,633	216,767	139,862	13,599	13,934	42,149	7,223	209,080	3.55	2.649
Incorporated	844,179	826,179	18,000	328,520	210,947	20,679	22,851	65,514	8,529	312,514	4.87	2.644
County Total	1,405,694	1,380,061	25,633	545,287	350,809	34,278	36,785	107,663	15,752	521,594	4.35	2.646
San Benito County												
Hollister	36,794	36,623	171	10,583	7,979	525	992	781	306	10,361	2.10	3.535
San Juan Bautista	1,811	1,811	0	716	458	70	73	98	17	660	7.82	2.744
Balance Of County	18,691	18,355	336	6,440	5,345	427	70	42	556	6,053	6.01	3.032
Incorporated	38,605	38,434	171	11,299	8,437	595	1,065	879	323	11,021	2.46	3.487
County Total	57,296	56,789	507	17,739	13,782	1,022	1,135	921	879	17,074	3.75	3.326
San Bernardino County												
Adelanto	27,088	26,000	1,088	8,304	6,443	148	382	823	508	7,013	15.55	3.707
Apple Valley	70,160	69,797	363	24,866	19,322	726	2,089	1,686	1,043	22,886	7.96	3.050
Barstow	23,893	23,563	330	9,949	5,524	356	1,292	1,662	1,115	8,261	16.97	2.852
Big Bear Lake	6,195	6,170	25	9,444	7,952	326	366	410	390	2,542	73.08	2.427
Chino	81,087	69,593	11,494	19,978	14,227	952	901	3,370	528	19,315	3.32	3.603
Chino Hills	78,512	78,361	151	22,853	18,370	1,378	308	2,111	686	22,433	1.84	3.493
Colton	51,696	51,432	264	16,197	9,607	602	1,063	4,110	815	14,999	7.40	3.429
Fontana	181,282	180,723	559	48,075	38,243	1,208	1,644	5,821	1,159	45,544	5.26	3.968
Grand Terrace	12,356	12,147	209	4,515	2,904	191	265	905	250	4,275	5.32	2.841

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Hesperia	85,708	85,377	331	27,874	22,557	893	1,166	1,958	1,300	26,071	6.47	3.275
Highland	52,081	51,841	240	16,525	12,382	555	598	2,129	861	14,991	9.28	3.458
Loma Linda	22,409	21,445	964	9,072	3,836	939	1,310	2,425	562	8,456	6.79	2.536
Montclair	36,549	35,937	612	9,562	5,559	758	1,042	1,342	861	9,282	2.93	3.872
Needles	5,751	5,740	11	2,892	1,533	110	254	367	628	2,199	23.96	2.610
Ontario	172,363	171,265	1,098	46,959	27,530	3,649	4,057	9,512	2,211	45,238	3.66	3.786
Rancho Cucamonga	172,001	168,375	3,626	54,412	35,139	3,059	1,942	12,892	1,380	52,771	3.02	3.191
Redlands	71,237	69,271	1,966	26,527	17,137	900	2,436	5,135	919	25,246	4.83	2.744
Rialto	98,870	98,066	804	26,637	18,918	586	1,830	3,500	1,803	25,221	5.32	3.888
San Bernardino	204,620	198,008	6,612	66,486	39,084	2,717	5,733	14,467	4,485	59,146	11.04	3.348
Twentynine Palms	27,003	19,435	7,568	8,955	4,973	1,303	1,691	445	543	6,933	22.58	2.803
Upland	75,021	74,436	585	26,613	15,285	1,770	2,677	6,036	845	25,655	3.60	2.901
Victorville	102,349	97,133	5,216	32,979	26,190	389	1,333	3,286	1,781	30,490	7.55	3.186
Yucaipa	51,683	51,111	572	19,292	13,035	394	743	893	4,227	18,190	5.71	2.810
Yucca Valley	21,004	20,693	311	9,463	7,563	140	675	378	707	8,269	12.62	2.502
Balance Of County	295,407	287,496	7,911	128,480	103,334	4,200	4,084	2,240	14,622	92,188	28.25	3.119
Incorporated	1,730,918	1,685,919	44,999	548,429	373,313	24,049	35,797	85,663	29,607	505,426	7.84	3.336
County Total	2,026,325	1,973,415	52,910	676,909	476,647	28,249	39,881	87,903	44,229	597,614	11.71	3.302
San Diego County												
Carlsbad	101,398	100,485	913	43,120	23,653	5,770	2,729	9,677	1,291	40,217	6.73	2.499
Chula Vista	227,863	226,422	1,441	76,838	41,637	5,496	5,714	20,353	3,638	74,527	3.01	3.038
Coronado	22,968	18,046	4,922	9,592	4,486	870	830	3,383	23	7,809	18.59	2.311
Del Mar	4,553	4,551	2	2,609	1,367	366	204	672	0	2,223	14.79	2.047
El Cajon	97,313	94,740	2,573	35,502	13,701	1,566	2,244	15,957	2,034	34,502	2.82	2.746
Encinitas	63,298	62,739	559	25,625	14,522	4,575	2,128	3,631	769	24,537	4.25	2.557
Escondido	141,874	140,109	1,765	47,122	23,299	2,938	3,123	13,885	3,877	45,833	2.74	3.057
Imperial Beach	27,726	27,097	629	9,862	4,081	687	1,064	3,690	340	9,388	4.81	2.886
La Mesa	56,286	55,240	1,046	25,240	11,347	1,923	2,003	9,608	359	24,475	3.03	2.257
Lemon Grove	25,467	24,876	591	8,774	5,797	716	694	1,470	97	8,540	2.67	2.913
National City	61,146	52,611	8,535	15,677	6,789	1,405	1,686	5,360	437	15,267	2.62	3.446
Oceanside	176,755	175,475	1,280	64,382	33,693	8,360	4,533	14,264	3,532	61,039	5.19	2.875
Poway	50,862	50,436	426	16,374	12,252	877	345	2,209	691	16,117	1.57	3.129
San Diego	1,317,625	1,276,067	41,558	501,320	228,981	45,833	43,850	176,315	6,341	480,935	4.07	2.653
San Marcos	79,863	79,226	637	26,820	13,908	1,083	1,427	6,742	3,660	25,754	3.97	3.076
Santee	55,193	54,150	1,043	19,320	10,766	1,828	1,225	2,998	2,503	18,947	1.93	2.858
Solana Beach	13,427	13,393	34	6,571	3,015	1,265	621	1,631	39	5,858	10.85	2.286
Vista	95,020	92,754	2,266	31,059	15,509	2,029	2,221	9,171	2,129	30,083	3.14	3.083
Balance Of County	481,495	451,470	30,025	163,942	111,302	10,977	6,672	19,106	15,885	153,279	6.50	2.945
Incorporated	2,618,637	2,548,417	70,220	965,807	468,803	87,587	76,641	301,016	31,760	926,051	4.12	2.752
County Total	3,100,132	2,999,887	100,245	1,129,749	580,105	98,564	83,313	320,122	47,645	1,079,330	4.46	2.779
San Francisco County												

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
City and County Total	812,241	791,893	20,348	359,121	63,002	48,700	81,906	164,953	560	342,099	4.74	2.315
San Joaquin County												
Escalon	7,041	7,015	26	2,479	2,073	20	153	98	135	2,391	3.55	2.934
Lathrop	16,358	16,348	10	4,652	4,132	63	94	12	351	4,482	3.65	3.647
Lodi	62,934	61,870	1,064	23,253	15,032	1,486	1,764	4,506	465	22,507	3.21	2.749
Manteca	64,596	64,119	477	21,910	16,611	739	1,129	2,561	870	21,174	3.36	3.028
Ripon	14,467	14,356	111	4,849	4,127	192	179	340	11	4,739	2.27	3.029
Stockton	287,677	283,117	4,560	95,864	62,044	6,592	8,483	17,457	1,288	91,790	4.25	3.084
Tracy	80,592	80,247	345	25,244	20,854	1,021	987	1,906	476	24,592	2.58	3.263
Balance Of County	141,798	131,350	10,448	45,932	36,985	1,254	895	718	6,080	43,660	4.95	3.008
Incorporated	533,665	527,072	6,593	178,251	124,873	10,113	12,789	26,880	3,596	171,675	3.69	3.070
County Total	675,463	658,422	17,041	224,183	161,858	11,367	13,684	27,598	9,676	215,335	3.95	3.058
San Luis Obispo County												
Arroyo Grande	16,856	16,646	210	7,476	4,999	674	492	763	548	7,174	4.04	2.320
Atascadero	27,935	26,381	1,554	10,829	7,682	449	903	1,228	567	10,483	3.20	2.517
El Paso De Robles	29,685	29,369	316	11,471	7,786	920	1,080	1,268	417	11,164	2.68	2.631
Grover Beach	13,161	13,035	126	5,642	3,274	792	730	599	247	5,266	6.66	2.475
Morro Bay	10,497	10,299	198	6,600	4,308	405	664	464	759	5,265	20.23	1.956
Pismo Beach	8,593	8,566	27	5,748	3,115	576	473	497	1,087	4,424	23.03	1.936
San Luis Obispo	44,489	42,627	1,862	20,102	9,380	1,311	2,253	5,656	1,502	19,408	3.45	2.196
Balance Of County	115,156	103,717	11,439	46,835	34,810	1,683	2,205	1,213	6,924	40,867	12.74	2.538
Incorporated	151,216	146,923	4,293	67,868	40,544	5,127	6,595	10,475	5,127	63,184	6.90	2.325
County Total	266,372	250,640	15,732	114,703	75,354	6,810	8,800	11,688	12,051	104,051	9.29	2.409
San Mateo County												
Atherton	7,391	7,073	318	2,558	2,519	32	0	7	0	2,481	3.01	2.851
Belmont	25,788	25,161	627	10,816	6,296	649	275	3,596	0	10,695	1.12	2.353
Brisbane	3,775	3,735	40	1,910	1,070	260	179	358	43	1,700	10.99	2.197
Burlingame	28,544	28,058	486	12,964	6,163	423	993	5,385	0	12,679	2.20	2.213
Colma	1,589	1,540	49	458	218	66	98	70	6	443	3.28	3.476
Daly City	105,688	104,898	790	31,755	16,136	4,507	2,837	7,612	663	31,378	1.19	3.343
East Palo Alto	32,489	32,300	189	7,762	3,964	342	360	2,937	159	7,681	1.04	4.205
Foster City	30,138	30,051	87	12,478	4,809	2,464	767	4,431	7	12,146	2.66	2.474
Half Moon Bay	12,860	12,012	848	4,463	2,807	536	314	379	427	4,372	2.04	2.747
Hillsborough	11,075	11,073	2	3,863	3,842	12	9	0	0	3,772	2.36	2.936
Menlo Park	31,017	30,050	967	12,720	6,845	930	1,574	3,366	5	12,470	1.97	2.410
Millbrae	20,876	20,544	332	8,118	5,322	269	434	2,082	11	8,013	1.29	2.564
Pacifica	39,081	38,900	181	14,399	10,374	790	725	2,412	98	14,241	1.10	2.732
Portola Valley	4,599	4,529	70	1,814	1,506	33	8	267	0	1,752	3.42	2.585
Redwood City	76,695	74,768	1,927	29,219	13,557	3,656	2,621	8,552	833	28,539	2.33	2.620

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
San Bruno	41,962	41,631	331	15,504	9,155	566	1,188	4,573	22	15,289	1.39	2.723
San Carlos	28,515	28,332	183	11,947	8,277	609	492	2,553	16	11,781	1.39	2.405
San Mateo	95,098	93,782	1,316	39,109	17,733	3,492	3,040	14,799	45	38,423	1.75	2.441
South San Francisco	62,342	61,899	443	20,588	12,009	2,550	1,686	3,934	409	20,253	1.63	3.056
Woodside	5,540	5,534	6	2,086	2,024	28	28	5	1	2,017	3.31	2.744
Balance Of County	65,277	63,894	1,383	22,571	18,658	708	929	1,429	847	21,948	2.76	2.911
Incorporated	665,062	655,870	9,192	244,531	134,626	22,214	17,628	67,318	2,745	240,125	1.80	2.731
County Total	730,339	719,764	10,575	267,102	153,284	22,922	18,557	68,747	3,592	262,073	1.88	2.746
Santa Barbara County												
Buellton	4,653	4,647	6	1,838	1,149	119	48	103	419	1,776	3.37	2.617
Carpinteria	14,092	13,967	125	5,530	2,160	425	538	1,467	940	5,050	8.68	2.766
Goleta	30,096	29,754	342	11,502	5,865	1,588	757	2,671	621	11,217	2.48	2.653
Guadalupe	6,383	6,383	0	1,667	1,158	168	187	146	8	1,627	2.40	3.923
Lompoc	41,930	38,226	3,704	14,092	7,451	1,045	1,955	2,701	940	13,512	4.12	2.829
Santa Barbara	89,266	87,404	1,862	37,619	17,256	2,912	5,621	11,312	518	36,127	3.97	2.419
Santa Maria	90,144	87,946	2,198	27,214	16,999	1,608	1,777	5,249	1,581	26,379	3.07	3.334
Solvang	5,482	5,322	160	2,336	1,341	152	171	453	219	2,291	1.93	2.323
Balance Of County	141,494	132,312	9,182	52,105	36,462	3,531	2,741	5,904	3,467	49,247	5.49	2.687
Incorporated	282,046	273,649	8,397	101,798	53,379	8,017	11,054	24,102	5,246	97,979	3.75	2.793
County Total	423,540	405,961	17,579	153,903	89,841	11,548	13,795	30,006	8,713	147,226	4.34	2.757
Santa Clara County												
Campbell	39,689	39,399	290	16,855	7,310	2,095	2,438	4,755	257	16,479	2.23	2.391
Cupertino	55,078	54,597	481	20,146	12,218	2,136	1,698	4,085	9	19,635	2.54	2.781
Gilroy	49,571	49,141	430	14,490	9,807	757	1,322	2,173	431	14,154	2.32	3.472
Los Altos	28,061	27,642	419	10,810	9,228	364	275	927	16	10,542	2.48	2.622
Los Altos Hills	8,592	8,527	65	3,059	2,995	32	17	9	6	2,978	2.65	2.863
Los Gatos	29,362	28,660	702	12,636	7,148	1,839	936	2,590	123	12,250	3.05	2.340
Milpitas	66,472	63,298	3,174	18,359	11,013	2,225	1,662	2,873	586	18,114	1.33	3.494
Monte Sereno	3,559	3,559	0	1,257	1,153	13	18	73	0	1,231	2.07	2.891
Morgan Hill	38,360	37,847	513	12,629	7,890	1,832	728	1,267	912	12,349	2.22	3.065
Mountain View	73,149	72,633	516	33,362	9,287	3,928	2,652	16,264	1,231	32,138	3.67	2.260
Palo Alto	62,520	61,771	749	27,763	15,601	980	1,731	9,287	164	26,876	3.19	2.298
San Jose	972,190	960,739	11,451	304,698	167,470	28,079	23,418	74,703	11,028	298,894	1.90	3.214
Santa Clara	114,066	111,279	2,787	44,033	18,621	3,737	3,925	17,641	109	42,807	2.78	2.600
Saratoga	31,352	30,991	361	11,089	9,724	560	241	557	7	10,882	1.87	2.848
Sunnyvale	135,514	134,639	875	54,976	21,232	4,540	4,908	20,200	4,096	53,735	2.26	2.506
Balance Of County	97,779	90,055	7,724	31,013	24,615	1,539	917	3,254	688	29,958	3.40	3.006
Incorporated	1,707,535	1,684,722	22,813	586,162	310,697	53,117	45,969	157,404	18,975	573,064	2.23	2.940
County Total	1,805,314	1,774,777	30,537	617,175	335,312	54,656	46,886	160,658	19,663	603,022	2.29	2.943

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Santa Cruz County												
Capitola	9,935	9,779	156	5,412	1,999	516	1,140	1,107	650	4,782	11.64	2.045
Santa Cruz	57,423	51,937	5,486	23,264	12,341	2,032	2,605	5,845	441	21,980	5.52	2.363
Scotts Valley	11,588	11,136	452	4,639	2,503	415	417	497	807	4,481	3.41	2.485
Watsonville	51,132	50,579	553	13,971	7,268	1,800	1,720	2,283	900	13,597	2.68	3.720
Balance Of County	133,421	130,172	3,249	56,762	41,329	4,379	2,681	3,915	4,458	51,090	9.99	2.548
Incorporated	130,078	123,431	6,647	47,286	24,111	4,763	5,882	9,732	2,798	44,840	5.17	2.753
County Total	263,499	253,603	9,896	104,048	65,440	9,142	8,563	13,647	7,256	95,930	7.80	2.644
Shasta County												
Anderson	10,552	10,434	118	4,188	2,687	213	380	729	179	3,946	5.78	2.644
Redding	89,682	87,225	2,457	37,634	24,697	1,010	4,706	4,604	2,617	35,742	5.03	2.440
Shasta Lake	10,250	10,198	52	4,257	3,382	27	247	114	487	3,872	9.04	2.634
Balance Of County	70,182	69,368	814	30,290	21,338	275	417	198	8,062	26,857	11.33	2.583
Incorporated	110,484	107,857	2,627	46,079	30,766	1,250	5,333	5,447	3,283	43,560	5.47	2.476
County Total	180,666	177,225	3,441	76,369	52,104	1,525	5,750	5,645	11,345	70,417	7.79	2.517
Sierra County												
Loyalton	865	835	30	375	326	13	3	0	33	350	6.67	2.386
Balance Of County	2,567	2,561	6	1,899	1,557	36	44	63	199	1,225	35.49	2.091
Incorporated	865	835	30	375	326	13	3	0	33	350	6.67	2.386
County Total	3,432	3,396	36	2,274	1,883	49	47	63	232	1,575	30.74	2.156
Siskiyou County												
Dorris	868	868	0	407	318	2	16	0	71	353	13.27	2.459
Dunsmuir	1,838	1,838	0	1,173	794	23	126	184	46	869	25.92	2.115
Etna	754	754	0	367	270	10	19	13	55	334	8.99	2.257
Fort Jones	660	660	0	344	243	11	34	2	54	314	8.72	2.102
Montague	1,504	1,485	19	660	488	15	10	43	104	607	8.03	2.446
Mount Shasta	3,616	3,568	48	1,882	1,197	89	266	256	74	1,746	7.23	2.044
Tulelake	977	977	0	461	316	2	44	19	80	360	21.91	2.714
Weed	3,010	2,883	127	1,369	902	19	136	251	61	1,254	8.40	2.299
Yreka	7,312	7,092	220	3,473	2,235	140	294	552	252	3,275	5.70	2.165
Balance Of County	25,128	24,864	264	13,613	9,883	188	189	96	3,257	10,948	19.58	2.271
Incorporated	20,539	20,125	414	10,136	6,763	311	945	1,320	797	9,112	10.10	2.209
County Total	45,667	44,989	678	23,749	16,646	499	1,134	1,416	4,054	20,060	15.53	2.243

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Solano County												
Benicia	27,791	27,737	54	11,229	7,350	1,049	944	1,560	326	10,996	2.07	2.522
Dixon	17,563	17,522	41	5,807	4,689	213	381	438	86	5,696	1.91	3.076
Fairfield	104,955	101,848	3,107	38,094	25,960	2,519	2,512	6,211	892	35,463	6.91	2.872
Rio Vista	7,789	7,789	0	3,538	3,119	34	103	171	111	3,379	4.49	2.305
Suisun City	27,854	27,760	94	8,943	7,605	189	329	754	66	8,768	1.96	3.166
Vacaville	96,096	86,662	9,434	32,254	22,421	1,040	2,150	5,335	1,308	31,591	2.06	2.743
Vallejo	120,889	118,633	2,256	43,756	30,507	1,792	3,924	6,187	1,346	42,039	3.92	2.822
Balance Of County	20,037	19,435	602	7,433	6,044	450	300	119	520	6,985	6.03	2.782
Incorporated	402,937	387,951	14,986	143,621	101,651	6,836	10,343	20,656	4,135	137,932	3.96	2.813
County Total	422,974	407,386	15,588	151,054	107,695	7,286	10,643	20,775	4,655	144,917	4.06	2.811
Sonoma County												
Cloverdale	8,479	8,402	77	3,334	2,517	165	120	323	209	3,176	4.74	2.645
Cotati	7,503	7,485	18	3,067	1,663	547	373	363	121	3,003	2.09	2.493
Healdsburg	11,654	11,531	123	4,582	3,292	254	452	485	99	4,395	4.08	2.624
Petaluma	56,743	56,003	740	21,623	15,537	1,696	1,368	2,091	931	21,227	1.83	2.638
Rohnert Park	42,772	41,671	1,101	16,385	7,660	1,701	929	4,682	1,413	16,069	1.93	2.593
Santa Rosa	157,319	153,585	3,734	62,972	37,907	5,948	4,929	11,484	2,704	61,292	2.67	2.506
Sebastopol	7,727	7,516	211	3,377	2,024	259	535	497	62	3,306	2.10	2.273
Sonoma	9,898	9,807	91	5,180	2,935	736	480	592	437	4,854	6.29	2.020
Windsor	26,315	26,224	91	9,153	7,155	461	254	461	822	8,988	1.80	2.918
Balance Of County	151,258	145,475	5,783	65,844	53,083	2,908	3,031	2,207	4,615	57,965	11.97	2.510
Incorporated	328,410	322,224	6,186	129,673	80,690	11,767	9,440	20,978	6,798	126,310	2.59	2.551
County Total	479,668	467,699	11,969	195,517	133,773	14,675	12,471	23,185	11,413	184,275	5.75	2.538
Stanislaus County												
Ceres	41,787	41,688	99	13,040	10,236	347	654	1,091	712	12,632	3.13	3.300
Hughson	6,054	6,048	6	1,907	1,552	65	66	135	89	1,862	2.36	3.248
Modesto	208,150	204,919	3,231	74,297	52,417	4,010	6,291	9,541	2,038	71,842	3.30	2.852
Newman	10,254	10,188	66	3,160	2,694	76	247	117	26	3,020	4.43	3.374
Oakdale	18,538	18,359	179	6,968	5,347	207	512	691	211	6,735	3.34	2.726
Patterson	20,773	20,544	229	5,932	5,399	190	151	63	129	5,692	4.05	3.609
Riverbank	21,384	21,249	135	6,375	5,537	187	180	182	289	6,167	3.26	3.446
Turlock	68,984	66,582	2,402	23,711	16,352	961	1,982	3,812	604	22,858	3.60	2.913
Waterford	8,547	8,530	17	2,574	2,132	64	181	168	29	2,463	4.31	3.463
Balance Of County	114,467	112,997	1,470	37,076	29,151	1,419	958	436	5,112	35,212	5.03	3.209
Incorporated	404,471	398,107	6,364	137,964	101,666	6,107	10,264	15,800	4,127	133,271	3.40	2.987
County Total	518,938	511,104	7,834	175,040	130,817	7,526	11,222	16,236	9,239	168,483	3.75	3.034

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSE-HOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	SINGLE: DETACHED	SINGLE: ATTACHED	MULTIPLE: 2 TO 4	MULTIPLE: 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Sutter County												
Live Oak	8,119	7,814	305	2,332	1,853	92	141	104	142	2,216	4.97	3.526
Yuba City	62,028	61,065	963	22,130	14,912	851	1,628	3,785	954	21,216	4.13	2.878
Balance Of County	23,688	23,530	158	8,607	7,513	260	149	68	617	8,152	5.29	2.886
Incorporated	70,147	68,879	1,268	24,462	16,765	943	1,769	3,889	1,096	23,432	4.21	2.940
County Total	93,835	92,409	1,426	33,069	24,278	1,203	1,918	3,957	1,713	31,584	4.49	2.926
Tehama County												
Corning	7,172	7,115	57	2,818	1,716	70	298	495	239	2,611	7.35	2.725
Red Bluff	13,688	13,153	535	5,991	3,568	219	749	1,090	365	5,497	8.25	2.393
Tehama	427	427	0	200	171	4	10	0	15	183	8.50	2.333
Balance Of County	40,422	39,996	426	17,733	10,901	214	266	78	6,274	15,549	12.32	2.572
Incorporated	21,287	20,695	592	9,009	5,455	293	1,057	1,585	619	8,291	7.97	2.496
County Total	61,709	60,691	1,018	26,742	16,356	507	1,323	1,663	6,893	23,840	10.85	2.546
Trinity County												
County Total	13,970	13,733	237	8,416	5,568	112	108	144	2,484	5,892	29.99	2.331
Tulare County												
Dinuba	19,900	19,786	114	5,380	4,062	280	268	563	207	5,178	3.75	3.821
Exeter	10,675	10,583	92	3,599	2,907	107	205	192	188	3,409	5.28	3.104
Farmersville	10,413	10,394	19	2,635	2,128	90	155	157	105	2,499	5.16	4.159
Lindsay	11,114	10,965	149	3,016	2,023	204	246	358	185	2,861	5.14	3.833
Porterville	51,210	49,702	1,508	16,012	11,618	483	1,738	1,456	717	15,045	6.04	3.304
Tulare	55,645	55,198	447	17,600	13,536	511	1,597	1,180	776	16,724	4.98	3.301
Visalia	117,138	115,516	1,622	40,924	30,937	1,572	3,900	3,045	1,470	38,684	5.47	2.986
Woodlake	7,358	7,349	9	2,020	1,349	126	154	331	60	1,915	5.20	3.838
Balance Of County	143,345	141,404	1,941	44,873	33,337	1,542	1,493	828	7,673	39,521	11.93	3.578
Incorporated	283,453	279,493	3,960	91,186	68,560	3,373	8,263	7,282	3,708	86,315	5.34	3.238
County Total	426,798	420,897	5,901	136,059	101,897	4,915	9,756	8,110	11,381	125,836	7.51	3.345
Tuolumne County												
Sonora	4,707	4,508	199	2,399	1,431	86	403	447	32	2,240	6.63	2.013
Balance Of County	52,034	47,439	4,595	27,932	21,746	576	791	651	4,168	20,254	27.49	2.342
Incorporated	4,707	4,508	199	2,399	1,431	86	403	447	32	2,240	6.63	2.013

Table 2: E-5 City/County Population and Housing Estimates, Revised, 1/1/2007

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
County Total	56,741	51,947	4,794	30,331	23,177	662	1,194	1,098	4,200	22,494	25.84	2.309
Ventura County												
Camarillo	65,409	63,872	1,537	24,903	14,836	4,495	939	3,575	1,058	24,356	2.20	2.622
Fillmore	15,201	14,955	246	4,295	3,122	281	244	322	326	4,195	2.33	3.565
Moorpark	36,045	36,033	12	10,422	7,459	1,253	223	1,189	298	10,307	1.10	3.496
Ojai	8,110	7,920	190	3,330	2,274	292	304	452	8	3,186	4.32	2.486
Oxnard	192,440	189,843	2,597	51,050	29,077	4,633	4,454	9,940	2,946	49,254	3.52	3.854
Port Hueneme	22,283	21,287	996	8,082	2,467	2,202	1,201	2,171	41	7,485	7.39	2.844
San Buenaventura	107,182	104,429	2,753	42,129	23,388	3,428	4,322	8,368	2,623	40,775	3.21	2.561
Santa Paula	29,138	28,895	243	8,490	5,056	767	789	1,091	787	8,282	2.45	3.489
Simi Valley	124,160	123,360	800	41,541	30,545	3,147	1,674	5,283	892	40,592	2.28	3.039
Thousand Oaks	127,337	125,386	1,951	46,760	31,270	5,241	1,803	7,374	1,072	45,492	2.71	2.756
Balance Of County	95,824	93,615	2,209	33,222	26,412	2,349	1,010	1,168	2,283	31,248	5.94	2.996
Incorporated	727,305	715,980	11,325	241,002	149,494	25,739	15,953	39,765	10,051	233,924	2.94	3.061
County Total	823,129	809,595	13,534	274,224	175,906	28,088	16,963	40,933	12,334	265,172	3.30	3.053
Yolo County												
Davis	65,397	62,262	3,135	25,729	11,529	2,411	2,372	9,032	385	25,143	2.28	2.476
West Sacramento	45,259	45,053	206	17,566	11,185	879	967	2,958	1,577	16,511	6.01	2.729
Winters	6,936	6,930	6	2,234	1,802	105	67	182	78	2,180	2.42	3.179
Woodland	54,450	53,072	1,378	18,963	11,914	1,313	1,149	3,906	681	18,554	2.16	2.860
Balance Of County	23,312	19,063	4,249	7,263	4,965	304	198	804	992	6,835	5.89	2.789
Incorporated	172,042	167,317	4,725	64,492	36,430	4,708	4,555	16,078	2,721	62,388	3.26	2.682
County Total	195,354	186,380	8,974	71,755	41,395	5,012	4,753	16,882	3,713	69,223	3.53	2.692
Yuba County												
Marysville	12,716	12,109	607	5,016	2,788	339	762	1,119	8	4,703	6.24	2.575
Wheatland	3,518	3,518	0	1,216	930	37	155	55	39	1,169	3.87	3.009
Balance Of County	54,449	53,881	568	20,486	13,970	915	692	1,076	3,833	17,755	13.33	3.035
Incorporated	16,234	15,627	607	6,232	3,718	376	917	1,174	47	5,872	5.78	2.661
County Total	70,683	69,508	1,175	26,718	17,688	1,291	1,609	2,250	3,880	23,627	11.57	2.942
California												
Incorporated Total	30,944,446	30,257,911	686,535	10,845,451	5,841,563	849,301	960,184	2,876,570	317,833	10,329,335	4.76	2.929
Balance Of State Total	6,614,994	6,434,961	180,033	2,467,278	1,803,131	109,389	98,345	182,636	273,777	2,197,603	10.93	2.928
State Total	37,559,440	36,692,872	866,568	13,312,729	7,644,694	958,690	1,058,529	3,059,206	591,610	12,526,938	5.90	2.929

Table 1: E-5 County/State Population and Housing Estimates, 1/1/2008

COUNTY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Alameda	1,543,000	1,514,193	28,807	570,619	303,613	39,742	62,584	157,025	7,655	553,501	3.00	2.736
Alpine	1,222	1,221	1	1,748	1,014	51	35	586	62	556	68.19	2.196
Amador	37,943	33,713	4,230	17,345	14,078	409	458	804	1,596	14,964	13.73	2.253
Butte	220,407	213,968	6,439	95,692	58,749	2,436	8,045	10,615	15,847	89,506	6.46	2.391
Calaveras	46,127	45,674	453	27,803	23,548	573	531	355	2,796	19,973	28.16	2.287
Colusa	21,910	21,490	420	7,763	5,804	229	418	463	849	7,002	9.80	3.069
Contra Costa	1,051,674	1,040,275	11,399	397,499	264,592	32,057	26,016	67,211	7,623	385,733	2.96	2.697
Del Norte	29,419	25,498	3,921	11,100	6,570	188	799	584	2,959	9,752	12.14	2.615
El Dorado	179,722	178,671	1,051	83,275	67,596	1,833	3,655	5,814	4,377	69,251	16.84	2.580
Fresno	931,098	911,231	19,867	308,403	206,494	10,169	25,497	52,248	13,995	288,552	6.44	3.158
Glenn	29,195	28,801	394	10,804	7,543	222	787	700	1,552	9,936	8.03	2.899
Humboldt	132,821	128,424	4,397	59,370	40,843	1,610	5,895	4,845	6,177	54,389	8.39	2.361
Imperial	176,158	164,421	11,737	55,599	34,235	2,124	3,888	7,497	7,855	49,484	11.00	3.323
Inyo	18,152	17,871	281	9,277	5,536	215	407	480	2,639	7,903	14.81	2.261
Kern	817,517	779,206	38,311	276,602	193,696	8,550	23,096	25,069	26,191	249,380	9.84	3.125
Kings	154,434	130,698	23,736	42,161	29,696	2,737	2,982	4,494	2,252	39,767	5.68	3.287
Lake	64,059	62,858	1,201	35,348	22,129	863	940	1,091	10,325	26,042	26.33	2.414
Lassen	35,757	25,928	9,829	13,067	8,989	352	508	531	2,687	10,546	19.29	2.459
Los Angeles	10,363,850	10,183,439	180,411	3,403,480	1,642,973	244,606	292,421	1,166,794	56,686	3,260,434	4.20	3.123
Madera	150,887	141,569	9,318	49,372	38,773	1,336	2,497	3,026	3,740	44,353	10.17	3.192
Marin	257,406	246,762	10,644	108,538	65,793	8,624	9,791	22,199	2,131	104,113	4.08	2.370
Mariposa	18,406	16,961	1,445	10,347	6,336	648	214	383	2,766	7,754	25.06	2.187
Mendocino	90,163	87,896	2,267	39,563	27,958	1,163	2,202	2,782	5,458	35,598	10.02	2.469
Merced	255,250	250,430	4,820	84,631	62,684	2,551	5,409	8,246	5,741	78,952	6.71	3.172
Modoc	9,702	9,292	410	5,166	3,506	88	97	159	1,316	4,058	21.45	2.290
Mono	13,759	13,383	376	13,691	5,251	1,259	2,187	3,915	1,079	6,069	55.67	2.205
Monterey	428,549	407,282	21,267	140,296	86,242	12,587	12,157	23,310	6,000	129,271	7.86	3.151
Napa	136,704	131,021	5,683	53,950	36,246	3,585	3,738	6,400	3,981	50,588	6.23	2.590
Nevada	99,186	98,212	974	50,364	41,027	964	1,986	2,512	3,875	41,658	17.29	2.358
Orange	3,121,251	3,077,295	43,956	1,030,289	519,755	128,489	91,146	258,801	32,098	995,989	3.33	3.090
Placer	333,401	330,151	3,250	147,408	114,893	4,738	6,338	16,694	4,745	131,707	10.65	2.507
Plumas	20,917	20,729	188	15,457	11,912	447	375	396	2,327	10,368	32.92	1.999
Riverside	2,088,322	2,052,807	35,515	773,331	512,205	46,960	33,104	94,636	86,426	671,036	13.23	3.059
Sacramento	1,424,415	1,398,950	25,465	551,219	354,371	34,360	36,960	109,747	15,781	527,592	4.29	2.652
San Benito	57,784	57,277	507	17,769	13,798	1,034	1,137	921	879	17,102	3.75	3.349
San Bernardino	2,055,766	2,003,608	52,158	685,642	483,447	28,459	40,321	88,714	44,701	606,005	11.61	3.306
San Diego	3,146,274	3,040,956	105,318	1,138,857	582,188	98,809	83,503	326,475	47,882	1,088,700	4.40	2.793
San Francisco	824,525	803,419	21,106	361,777	63,046	48,700	82,038	167,433	560	344,792	4.69	2.330

San Joaquin	685,660	669,102	16,558	227,339	164,378	11,689	13,765	27,776	9,731	218,390	3.94	3.064
San Luis Obispo	269,337	253,273	16,064	116,171	76,414	6,815	9,002	11,820	12,120	105,391	9.28	2.403
San Mateo	739,469	729,012	10,457	268,301	153,583	22,937	18,575	69,607	3,599	263,252	1.88	2.769
Santa Barbara	428,655	410,465	18,190	154,452	90,185	11,602	13,858	30,063	8,744	147,855	4.27	2.776
Santa Clara	1,837,075	1,806,031	31,044	622,779	336,196	55,834	46,932	164,151	19,666	608,652	2.27	2.967
Santa Cruz	266,519	256,571	9,948	104,479	65,650	9,213	8,641	13,720	7,255	96,311	7.82	2.664
Shasta	182,236	178,790	3,446	77,118	52,672	1,525	5,876	5,683	11,362	71,107	7.79	2.514
Sierra	3,380	3,344	36	2,289	1,898	49	47	63	232	1,585	30.76	2.110
Siskiyou	45,971	45,228	743	24,044	16,781	499	1,134	1,497	4,133	20,311	15.53	2.227
Solano	426,757	411,084	15,673	152,041	108,624	7,291	10,668	20,782	4,676	146,191	3.85	2.812
Sonoma	484,470	472,254	12,216	197,907	134,808	14,842	12,501	24,319	11,437	186,568	5.73	2.531
Stanislaus	525,903	518,103	7,800	176,622	131,959	7,753	11,319	16,260	9,331	170,036	3.73	3.047
Sutter	95,878	94,372	1,506	33,491	24,657	1,203	1,915	4,003	1,713	31,988	4.49	2.950
Tehama	62,419	61,402	1,017	27,308	16,614	522	1,447	1,663	7,062	24,343	10.86	2.522
Trinity	13,966	13,723	243	8,482	5,613	112	108	144	2,505	5,938	29.99	2.311
Tulare	435,254	429,387	5,867	139,359	104,229	4,915	10,109	8,544	11,562	128,936	7.48	3.330
Tuolumne	56,799	51,904	4,895	30,521	23,328	662	1,194	1,098	4,239	22,634	25.84	2.293
Ventura	831,587	817,920	13,667	276,320	176,979	28,131	17,181	41,698	12,331	266,885	3.41	3.065
Yolo	199,066	190,277	8,789	73,138	42,189	5,019	4,790	17,423	3,717	70,575	3.50	2.696
Yuba	71,929	70,688	1,241	27,672	18,563	1,291	1,630	2,250	3,938	24,310	12.15	2.908
California	38,049,462	37,178,510	870,952	13,444,455	7,712,449	965,671	1,064,854	3,106,519	594,962	12,653,634	5.88	2.938

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
Alameda County												
Alameda	75,823	75,097	726	32,527	13,379	4,011	5,073	9,764	300	31,602	2.84	2.376
Albany	16,877	16,844	33	7,351	3,784	198	828	2,535	6	7,110	3.28	2.369
Berkeley	106,697	100,031	6,666	48,036	20,162	1,760	9,337	16,718	59	46,013	4.21	2.174
Dublin	46,934	41,594	5,340	16,029	8,138	1,304	462	6,097	28	15,463	3.53	2.690
Emeryville	9,727	9,660	67	5,988	270	397	506	4,778	37	5,570	6.98	1.734
Fremont	213,512	211,753	1,759	72,059	42,466	7,221	3,057	18,559	756	70,799	1.75	2.991
Hayward	149,205	146,706	2,499	48,273	24,223	3,578	3,462	14,709	2,301	47,098	2.43	3.115
Livermore	83,604	83,315	289	29,955	21,624	2,621	1,254	4,025	431	29,406	1.83	2.833
Newark	43,872	43,783	89	13,423	9,212	1,240	766	2,146	59	13,262	1.20	3.301
Oakland	420,183	412,926	7,257	164,053	72,659	6,775	29,817	54,346	456	157,055	4.27	2.629
Piedmont	11,100	11,098	2	3,864	3,787	0	35	34	8	3,809	1.42	2.914
Pleasanton	69,388	69,153	235	25,822	17,017	2,754	1,165	4,430	456	25,123	2.71	2.753
San Leandro	81,851	81,024	827	31,904	19,467	2,028	2,256	7,249	904	31,200	2.21	2.597
Union City	73,402	73,060	342	20,483	12,926	2,381	1,133	3,116	927	20,227	1.25	3.612
Balance Of County	140,825	138,149	2,676	50,852	34,499	3,474	3,433	8,519	927	49,764	2.14	2.776
Incorporated	1,402,175	1,376,044	26,131	519,767	269,114	36,268	59,151	148,506	6,728	503,737	3.08	2.732
County Total	1,543,000	1,514,193	28,807	570,619	303,613	39,742	62,584	157,025	7,655	553,501	3.00	2.736
Alpine County												
County Total	1,222	1,221	1	1,748	1,014	51	35	586	62	556	68.19	2.196
Amador County												
Amador	208	208	0	103	84	12	5	2	0	97	5.83	2.144
Ione	7,416	3,526	3,890	1,495	1,203	54	66	87	85	1,399	6.42	2.520
Jackson	4,319	4,051	268	2,152	1,383	112	174	247	236	2,022	6.04	2.003
Plymouth	1,033	1,033	0	506	281	31	24	26	144	434	14.23	2.380
Sutter Creek	2,902	2,901	1	1,467	829	111	61	384	82	1,359	7.36	2.135
Balance Of County	22,065	21,994	71	11,622	10,298	89	128	58	1,049	9,653	16.94	2.278
Incorporated	15,878	11,719	4,159	5,723	3,780	320	330	746	547	5,311	7.20	2.207
County Total	37,943	33,713	4,230	17,345	14,078	409	458	804	1,596	14,964	13.73	2.253
Butte County												
Biggs	1,776	1,776	0	627	523	28	30	5	41	585	6.70	3.036
Chico	86,949	82,730	4,219	36,484	19,167	993	5,624	8,846	1,854	35,265	3.34	2.346
Gridley	6,403	6,281	122	2,420	2,005	52	144	141	78	2,271	6.16	2.766
Oroville	14,490	13,658	832	6,278	3,530	206	811	1,333	398	5,654	9.94	2.416
Paradise	26,368	25,748	620	12,768	8,857	338	812	290	2,471	11,961	6.32	2.153
Balance Of County	84,421	83,775	646	37,115	24,667	819	624	0	11,005	33,770	9.01	2.481
Incorporated	135,986	130,193	5,793	58,577	34,082	1,617	7,421	10,615	4,842	55,736	4.85	2.336

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
County Total	220,407	213,968	6,439	95,692	58,749	2,436	8,045	10,615	15,847	89,506	6.46	2.391
Calaveras County												
Angels City	3,593	3,593	0	1,812	1,294	67	122	113	216	1,638	9.60	2.194
Balance Of County	42,534	42,081	453	25,991	22,254	506	409	242	2,580	18,335	29.46	2.295
Incorporated	3,593	3,593	0	1,812	1,294	67	122	113	216	1,638	9.60	2.194
County Total	46,127	45,674	453	27,803	23,548	573	531	355	2,796	19,973	28.16	2.287
Colusa County												
Colusa	5,727	5,654	73	2,123	1,607	84	197	183	52	2,000	5.79	2.827
Williams	5,310	5,060	250	1,421	1,058	33	98	165	67	1,356	4.57	3.732
Balance Of County	10,873	10,776	97	4,219	3,139	112	123	115	730	3,646	13.58	2.956
Incorporated	11,037	10,714	323	3,544	2,665	117	295	348	119	3,356	5.30	3.192
County Total	21,910	21,490	420	7,763	5,804	229	418	463	849	7,002	9.80	3.069
Contra Costa County												
Antioch	100,361	99,945	416	33,936	25,601	2,205	1,783	4,078	269	33,059	2.58	3.023
Brentwood	50,614	50,487	127	17,309	15,405	527	355	671	351	16,673	3.67	3.028
Clayton	10,784	10,758	26	3,995	3,263	681	19	27	5	3,954	1.03	2.721
Concord	123,776	122,354	1,422	46,539	27,789	2,911	2,929	11,533	1,377	45,443	2.36	2.692
Danville	42,629	42,165	464	15,713	12,077	2,570	288	778	0	15,387	2.07	2.740
El Cerrito	23,320	23,144	176	10,699	7,347	355	1,319	1,646	32	10,440	2.42	2.217
Hercules	24,324	24,285	39	8,304	5,508	1,631	294	871	0	8,148	1.88	2.980
Lafayette	23,962	23,826	136	9,505	7,554	294	434	1,223	0	9,320	1.95	2.556
Martinez	36,144	34,800	1,344	14,953	9,589	2,245	988	2,107	24	14,649	2.03	2.376
Moraga	16,138	14,507	1,631	5,791	4,028	968	243	545	7	5,693	1.69	2.548
Oakley	33,210	33,143	67	10,476	9,727	84	74	170	421	10,322	1.47	3.211
Orinda	17,542	17,475	67	6,830	6,329	188	87	219	7	6,681	2.18	2.616
Pinole	19,193	18,975	218	6,995	5,135	498	366	981	15	6,909	1.23	2.746
Pittsburg	63,652	63,146	506	20,818	14,269	1,298	1,320	3,250	681	20,268	2.64	3.116
Pleasant Hill	33,377	32,917	460	14,497	8,435	1,631	727	3,652	52	14,206	2.01	2.317
Richmond	103,577	101,949	1,628	38,258	21,694	2,931	5,421	8,091	121	36,751	3.94	2.774
San Pablo	31,190	30,725	465	9,802	4,243	852	1,366	2,533	808	9,499	3.09	3.235
San Ramon	59,002	58,917	85	23,559	14,656	2,563	1,047	5,282	11	22,745	3.46	2.590
Walnut Creek	65,306	64,155	1,151	32,343	12,257	4,857	4,316	10,865	48	31,187	3.57	2.057
Balance Of County	173,573	172,602	971	67,177	49,686	2,768	2,640	8,689	3,394	64,399	4.14	2.680
Incorporated	878,101	867,673	10,428	330,322	214,906	29,289	23,376	58,522	4,229	321,334	2.72	2.700
County Total	1,051,674	1,040,275	11,399	397,499	264,592	32,057	26,016	67,211	7,623	385,733	2.96	2.697

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Del Norte County												
Crescent City	7,683	4,039	3,644	1,845	938	56	393	424	34	1,659	10.08	2.435
Balance Of County	21,736	21,459	277	9,255	5,632	132	406	160	2,925	8,093	12.56	2.652
Incorporated	7,683	4,039	3,644	1,845	938	56	393	424	34	1,659	10.08	2.435
County Total	29,419	25,498	3,921	11,100	6,570	188	799	584	2,959	9,752	12.14	2.615
El Dorado County												
Placerville	10,271	10,009	262	4,632	2,861	260	628	720	163	4,370	5.66	2.290
South Lake Tahoe	23,725	23,597	128	14,355	9,063	361	2,040	2,223	668	9,645	32.81	2.447
Balance Of County	145,726	145,065	661	64,288	55,672	1,212	987	2,871	3,546	55,236	14.08	2.626
Incorporated	33,996	33,606	390	18,987	11,924	621	2,668	2,943	831	14,015	26.19	2.398
County Total	179,722	178,671	1,051	83,275	67,596	1,833	3,655	5,814	4,377	69,251	16.84	2.580
Fresno County												
Clovis	94,289	93,809	480	34,118	24,378	550	3,126	5,147	917	32,902	3.56	2.851
Coalinga	19,064	12,186	6,878	4,238	2,763	213	387	556	319	3,858	8.97	3.159
Firebaugh	6,812	6,751	61	1,838	1,236	155	194	141	112	1,648	10.34	4.096
Fowler	5,573	5,480	93	1,751	1,301	72	170	163	45	1,703	2.74	3.218
Fresno	486,171	477,402	8,769	166,206	100,466	6,028	17,058	38,731	3,923	156,225	6.01	3.056
Huron	7,554	7,382	172	1,665	530	204	231	586	114	1,624	2.46	4.546
Kerman	13,880	13,849	31	3,915	2,879	153	264	503	116	3,799	2.96	3.645
Kingsburg	11,259	11,168	91	4,036	3,065	102	266	439	164	3,879	3.89	2.879
Mendota	9,788	9,780	8	2,279	1,340	139	334	393	73	2,217	2.72	4.412
Orange Cove	10,775	10,775	0	2,413	1,285	206	226	670	26	2,312	4.19	4.661
Parlier	13,326	13,224	102	3,098	2,181	234	184	485	14	2,866	7.49	4.614
Reedley	25,587	25,192	395	7,229	5,346	216	612	864	191	6,974	3.53	3.612
Sanger	25,404	25,264	140	7,177	5,478	194	584	758	163	6,865	4.35	3.680
San Joaquin	4,062	4,062	0	895	531	80	161	63	60	857	4.22	4.740
Selma	23,286	23,156	130	6,820	5,103	148	342	801	426	6,564	3.75	3.528
Balance Of County	174,268	171,751	2,517	60,725	48,612	1,475	1,358	1,948	7,332	54,259	10.65	3.165
Incorporated	756,830	739,480	17,350	247,678	157,882	8,694	24,139	50,300	6,663	234,293	5.40	3.156
County Total	931,098	911,231	19,867	308,403	206,494	10,169	25,497	52,248	13,995	288,552	6.44	3.158
Glenn County												
Orland	7,353	7,315	38	2,643	1,932	59	384	197	71	2,507	5.15	2.918
Willows	6,502	6,321	181	2,430	1,601	54	310	458	7	2,191	9.84	2.885
Balance Of County	15,340	15,165	175	5,731	4,010	109	93	45	1,474	5,238	8.60	2.895
Incorporated	13,855	13,636	219	5,073	3,533	113	694	655	78	4,698	7.39	2.903

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	29,195	28,801	394	10,804	7,543	222	787	700	1,552	9,936	8.03	2.899
Humboldt County												
Arcata	17,558	15,805	1,753	7,650	3,533	309	1,201	1,923	684	7,417	3.05	2.131
Blue Lake	1,166	1,166	0	579	383	21	68	36	71	526	9.15	2.217
Eureka	26,157	24,805	1,352	11,804	7,282	381	2,263	1,704	174	11,115	5.84	2.232
Ferndale	1,428	1,428	0	694	565	27	83	10	9	641	7.64	2.228
Fortuna	11,374	11,108	266	4,839	3,229	235	562	368	445	4,587	5.21	2.422
Rio Dell	3,284	3,274	10	1,504	1,047	26	151	36	244	1,280	14.89	2.558
Trinidad	314	314	0	233	183	8	11	0	31	172	26.18	1.826
Balance Of County	71,540	70,524	1,016	32,067	24,621	603	1,556	768	4,519	28,651	10.65	2.461
Incorporated	61,281	57,900	3,381	27,303	16,222	1,007	4,339	4,077	1,658	25,738	5.73	2.250
County Total	132,821	128,424	4,397	59,370	40,843	1,610	5,895	4,845	6,177	54,389	8.39	2.361
Imperial County												
Brawley	26,513	26,201	312	8,577	5,550	368	719	1,485	455	8,082	5.77	3.242
Calexico	38,733	38,630	103	10,101	6,926	523	988	1,459	205	9,858	2.41	3.919
Calipatria	7,774	3,600	4,174	1,084	750	38	75	158	63	1,013	6.55	3.554
El Centro	43,316	42,429	887	14,138	7,733	563	1,124	3,400	1,318	13,192	6.69	3.216
Holtville	6,467	6,337	130	1,891	1,144	111	198	243	195	1,828	3.33	3.467
Imperial	12,752	12,720	32	4,082	3,481	117	251	199	34	3,944	3.38	3.225
Westmorland	2,406	2,406	0	756	443	16	90	167	40	710	6.08	3.389
Balance Of County	38,197	32,098	6,099	14,970	8,208	388	443	386	5,545	10,857	27.47	2.956
Incorporated	137,961	132,323	5,638	40,629	26,027	1,736	3,445	7,111	2,310	38,627	4.93	3.426
County Total	176,158	164,421	11,737	55,599	34,235	2,124	3,888	7,497	7,855	49,484	11.00	3.323
Inyo County												
Bishop	3,551	3,474	77	1,894	847	78	262	335	372	1,710	9.71	2.032
Balance Of County	14,601	14,397	204	7,383	4,689	137	145	145	2,267	6,193	16.12	2.325
Incorporated	3,551	3,474	77	1,894	847	78	262	335	372	1,710	9.71	2.032
County Total	18,152	17,871	281	9,277	5,536	215	407	480	2,639	7,903	14.81	2.261
Kern County												
Arvin	16,517	16,446	71	3,887	2,654	218	264	494	257	3,721	4.27	4.420
Bakersfield	328,692	324,905	3,787	114,187	81,193	3,224	11,397	15,654	2,719	107,948	5.46	3.010
California City	14,365	11,783	2,582	4,883	3,803	68	444	226	342	4,204	13.91	2.803
Delano	53,855	42,549	11,306	10,772	7,699	549	672	1,402	450	10,258	4.77	4.148
Maricopa	1,132	1,132	0	458	244	7	5	9	193	402	12.23	2.816
Mcfarland	13,390	12,043	1,347	2,770	2,099	246	272	124	29	2,714	2.02	4.437

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Ridgecrest	28,038	27,772	266	11,830	7,900	414	1,715	765	1,036	10,826	8.49	2.565
Shafter	15,609	14,968	641	4,345	3,395	177	281	283	209	3,948	9.14	3.791
Taft	9,228	6,170	3,058	2,534	1,843	52	317	222	100	2,284	9.87	2.701
Tehachapi	13,089	8,328	4,761	3,583	2,400	150	405	281	347	3,116	13.03	2.673
Wasco	24,999	18,702	6,297	5,123	3,797	361	432	399	134	4,781	6.68	3.912
Balance Of County	298,603	294,408	4,195	112,230	76,669	3,084	6,892	5,210	20,375	95,178	15.19	3.093
Incorporated	518,914	484,798	34,116	164,372	117,027	5,466	16,204	19,859	5,816	154,202	6.19	3.144
County Total	817,517	779,206	38,311	276,602	193,696	8,550	23,096	25,069	26,191	249,380	9.84	3.125
Kings County												
Avenal	16,609	9,039	7,570	2,258	1,401	147	309	305	96	2,113	6.42	4.278
Corcoran	26,047	12,914	13,133	3,951	2,899	180	373	334	165	3,626	8.23	3.562
Hanford	51,965	51,117	848	17,806	12,994	864	1,523	2,082	343	16,850	5.37	3.034
Lemoore	24,502	24,500	2	8,196	5,490	154	560	1,663	329	7,748	5.47	3.162
Balance Of County	35,311	33,128	2,183	9,950	6,912	1,392	217	110	1,319	9,430	5.23	3.513
Incorporated	119,123	97,570	21,553	32,211	22,784	1,345	2,765	4,384	933	30,337	5.82	3.216
County Total	154,434	130,698	23,736	42,161	29,696	2,737	2,982	4,494	2,252	39,767	5.68	3.287
Lake County												
Clearlake	14,247	14,128	119	8,166	3,683	429	253	490	3,311	5,941	27.25	2.378
Lakeport	5,045	4,871	174	2,449	1,479	119	172	223	456	2,013	17.80	2.420
Balance Of County	44,767	43,859	908	24,733	16,967	315	515	378	6,558	18,088	26.87	2.425
Incorporated	19,292	18,999	293	10,615	5,162	548	425	713	3,767	7,954	25.07	2.389
County Total	64,059	62,858	1,201	35,348	22,129	863	940	1,091	10,325	26,042	26.33	2.414
Lassen County												
Susanville	17,570	8,971	8,599	4,197	3,008	131	376	472	210	3,802	9.41	2.360
Balance Of County	18,187	16,957	1,230	8,870	5,981	221	132	59	2,477	6,744	23.97	2.514
Incorporated	17,570	8,971	8,599	4,197	3,008	131	376	472	210	3,802	9.41	2.360
County Total	35,757	25,928	9,829	13,067	8,989	352	508	531	2,687	10,546	19.29	2.459
Los Angeles County												
Agoura Hills	23,337	23,314	23	7,584	5,292	979	180	1,133	0	7,456	1.69	3.127
Alhambra	89,259	87,336	1,923	30,216	12,747	3,286	3,979	10,187	17	29,252	3.19	2.986
Arcadia	56,491	55,910	581	20,304	11,857	1,730	1,493	5,198	26	19,469	4.11	2.872
Artesia	17,552	16,980	572	4,713	3,224	327	331	735	96	4,583	2.76	3.705
Avalon	3,532	3,470	62	1,937	502	490	565	371	9	1,237	36.14	2.805

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	POPULATION			HOUSING UNITS								
					SINGLE		MULTIPLE					PERSONS PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Azusa	48,743	46,794	1,949	13,588	6,293	1,769	1,477	3,460	589	13,103	3.57	3.571
Baldwin Park	81,281	80,675	606	17,867	12,081	1,878	612	2,953	343	17,386	2.69	4.640
Bell	38,762	38,224	538	9,304	3,596	1,517	1,439	2,291	461	9,005	3.21	4.245
Bellflower	77,110	76,487	623	24,506	11,249	2,085	1,444	8,126	1,602	23,616	3.63	3.239
Bell Gardens	46,766	46,310	456	9,921	4,001	2,470	1,469	1,585	396	9,594	3.30	4.827
Beverly Hills	35,983	35,944	39	16,125	5,751	236	1,806	8,304	28	15,290	5.18	2.351
Bradbury	948	948	0	333	331	0	2	0	0	304	8.71	3.118
Burbank	108,029	107,203	826	44,055	19,940	1,752	4,641	17,610	112	42,781	2.89	2.506
Calabasas	23,725	23,665	60	8,605	6,010	804	204	1,334	253	8,328	3.22	2.842
Carson	97,960	96,620	1,340	26,442	18,654	2,280	728	2,275	2,505	25,722	2.72	3.756
Cerritos	54,870	54,777	93	15,900	13,389	1,220	600	659	32	15,680	1.38	3.493
Claremont	37,242	31,800	5,442	12,139	8,463	919	635	2,109	13	11,847	2.41	2.684
Commerce	13,536	13,333	203	3,447	1,945	615	332	551	4	3,353	2.73	3.976
Compton	99,242	98,592	650	24,112	16,086	2,150	2,325	2,903	648	22,625	6.17	4.358
Covina	49,552	48,950	602	16,533	9,450	1,321	987	4,187	588	16,136	2.40	3.034
Cudahy	25,879	25,867	12	5,653	1,709	1,293	344	1,893	414	5,528	2.21	4.679
Culver City	40,694	40,170	524	17,148	6,623	1,912	2,285	6,147	181	16,629	3.03	2.416
Diamond Bar	60,360	60,242	118	18,380	12,937	2,531	823	1,756	333	18,066	1.71	3.335
Downey	113,379	111,614	1,765	35,071	20,493	1,696	1,663	11,026	193	34,294	2.22	3.255
Duarte	22,953	22,463	490	6,948	4,343	874	224	1,278	229	6,775	2.49	3.316
El Monte	126,053	124,783	1,270	28,817	15,499	3,391	2,023	6,498	1,406	28,065	2.61	4.446
El Segundo	17,002	16,979	23	7,357	3,145	426	820	2,955	11	7,154	2.76	2.373
Gardena	61,781	60,977	804	21,501	9,316	1,714	2,710	6,658	1,103	20,768	3.41	2.936
Glendale	207,157	204,293	2,864	74,799	26,114	3,814	6,919	37,855	97	72,863	2.59	2.804
Glendora	52,362	51,349	1,013	17,354	12,639	1,094	699	2,079	843	17,024	1.90	3.016
Hawaiian Gardens	15,900	15,896	4	3,721	1,525	504	457	960	275	3,602	3.20	4.413
Hawthorne	90,014	89,514	500	30,268	8,362	2,471	3,325	15,937	173	29,152	3.69	3.071
Hermosa Beach	19,527	19,414	113	9,884	4,198	1,053	2,012	2,539	82	9,516	3.72	2.040
Hidden Hills	2,016	2,016	0	607	605	2	0	0	0	583	3.95	3.458
Huntington Park	64,747	64,566	181	15,446	5,276	2,381	2,232	5,542	15	14,968	3.09	4.314
Industry	798	534	264	123	100	23	0	0	0	120	2.44	4.450
Inglewood	118,878	117,508	1,370	38,967	14,347	3,234	4,741	16,407	238	37,108	4.77	3.167
Irwindale	1,724	1,722	2	430	369	16	13	24	8	414	3.72	4.159
La Canada Flintridge	21,276	21,086	190	7,069	6,562	200	132	175	0	6,902	2.36	3.055
La Habra Heights	6,140	6,140	0	2,024	1,992	24	8	0	0	1,958	3.26	3.136
Lakewood	83,486	83,292	194	27,423	22,243	741	745	3,596	98	26,964	1.67	3.089
La Mirada	50,092	47,591	2,501	15,075	11,892	800	480	1,737	166	14,840	1.56	3.207
Lancaster	145,243	137,332	7,911	48,973	33,718	1,188	2,619	7,950	3,498	44,843	8.43	3.063
La Puente	43,256	43,224	32	9,711	6,370	642	344	2,246	109	9,512	2.05	4.544
La Verne	34,046	32,821	1,225	11,428	7,604	597	736	728	1,763	11,211	1.90	2.928
Lawndale	33,540	33,454	86	9,962	4,986	1,606	919	2,323	128	9,645	3.18	3.469
Lomita	21,056	20,923	133	8,317	4,017	774	581	2,447	498	8,036	3.38	2.604
Long Beach	492,642	482,257	10,385	174,993	69,316	10,115	23,308	69,725	2,529	166,282	4.98	2.900
Los Angeles	4,045,873	3,959,760	86,113	1,399,309	530,708	88,450	132,464	638,599	9,088	1,334,539	4.63	2.967
Lynwood	73,147	70,947	2,200	14,999	8,169	1,691	1,690	3,337	112	14,405	3.96	4.925
Malibu	13,700	13,400	300	6,382	4,039	491	402	840	610	5,351	16.15	2.504
Manhattan Beach	36,505	36,491	14	15,486	10,600	1,417	2,581	855	33	14,911	3.71	2.447
Maywood	29,971	29,877	94	6,826	2,822	1,120	1,454	1,422	8	6,590	3.46	4.534
Monrovia	39,327	39,034	293	14,190	7,878	1,563	1,318	3,316	115	13,727	3.26	2.844

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Montebello	65,668	65,359	309	19,581	9,382	1,581	2,865	5,520	233	19,004	2.95	3.439
Monterey Park	64,434	64,157	277	20,734	11,782	2,204	1,993	4,675	80	20,073	3.19	3.196
Norwalk	109,695	107,848	1,847	27,814	20,173	1,430	838	4,900	473	27,142	2.42	3.973
Palmdale	147,897	147,803	94	44,907	35,880	905	938	5,402	1,782	41,509	7.57	3.561
Palos Verdes Estates	14,046	14,041	5	5,289	4,867	40	44	338	0	5,078	3.99	2.765
Paramount	57,969	57,649	320	14,608	6,064	2,166	1,084	3,922	1,372	13,987	4.25	4.122
Pasadena	148,126	144,608	3,518	57,274	24,875	5,282	4,668	22,376	73	54,853	4.23	2.636
Pico Rivera	66,867	66,517	350	16,952	12,698	945	337	2,382	590	16,610	2.02	4.005
Pomona	163,405	157,546	5,859	41,264	24,713	3,343	3,330	8,173	1,705	39,447	4.40	3.994
Rancho Palos Verdes	42,964	42,455	509	15,845	12,258	1,287	249	2,051	0	15,389	2.88	2.759
Redondo Beach	67,488	67,301	187	30,080	11,836	4,426	3,997	9,441	380	29,084	3.31	2.314
Rolling Hills	1,967	1,967	0	696	689	7	0	0	0	655	5.89	3.003
Rolling Hills Estates	8,185	8,173	12	2,964	2,306	565	41	48	4	2,889	2.53	2.829
Rosemead	57,422	56,810	612	14,702	9,996	2,030	917	1,355	404	14,259	3.01	3.984
San Dimas	36,874	35,665	1,209	12,600	7,582	2,100	357	1,618	943	12,258	2.71	2.910
San Fernando	25,230	25,184	46	6,061	4,044	671	471	802	73	5,901	2.64	4.268
San Gabriel	42,762	42,007	755	13,251	7,117	1,223	1,159	3,708	44	12,920	2.50	3.251
San Marino	13,455	13,448	7	4,453	4,417	19	8	9	0	4,282	3.84	3.141
Santa Clarita	177,045	175,652	1,393	58,714	36,160	6,937	2,831	10,546	2,240	56,856	3.16	3.089
Santa Fe Springs	17,790	17,572	218	5,107	3,101	286	158	1,435	127	5,004	2.02	3.512
Santa Monica	91,439	88,833	2,606	49,740	9,346	1,931	5,511	32,663	289	46,242	7.03	1.921
Sierra Madre	11,116	10,989	127	5,000	3,415	215	377	966	27	4,831	3.38	2.275
Signal Hill	11,402	11,348	54	4,432	1,444	488	757	1,735	8	4,228	4.60	2.684
South El Monte	22,391	22,373	18	4,774	2,984	458	233	595	504	4,669	2.20	4.792
South Gate	102,816	102,675	141	24,708	12,543	3,294	3,722	4,860	289	23,633	4.35	4.345
South Pasadena	25,792	25,605	187	11,001	5,101	646	1,118	4,122	14	10,623	3.44	2.410
Temple City	35,683	35,172	511	11,921	9,657	802	421	983	58	11,578	2.88	3.038
Torrance	148,965	147,716	1,249	57,743	30,704	3,693	3,469	18,694	1,183	56,275	2.54	2.625
Vernon	95	95	0	26	19	0	0	7	0	25	3.85	3.800
Walnut	32,299	32,259	40	8,624	8,159	119	46	300	0	8,486	1.60	3.801
West Covina	112,666	111,858	808	32,816	21,361	2,812	1,570	6,725	348	32,155	2.01	3.479
West Hollywood	37,563	37,327	236	24,499	1,796	679	1,852	20,172	0	23,497	4.09	1.589
Westlake Village	8,867	8,858	9	3,384	2,242	608	158	201	175	3,306	2.30	2.679
Whittier	86,945	85,355	1,590	29,014	19,088	1,480	2,058	6,174	214	28,307	2.44	3.015
Balance Of County	1,092,078	1,076,346	15,732	310,630	213,797	22,258	18,524	45,075	10,976	296,267	4.62	3.633
Incorporated	9,271,772	9,107,093	164,679	3,092,850	1,429,176	222,348	273,897	1,121,719	45,710	2,964,167	4.16	3.072
County Total	10,363,850	10,183,439	180,411	3,403,480	1,642,973	244,606	292,421	1,166,794	56,686	3,260,434	4.20	3.123
Madera County												
Chowchilla	18,780	10,776	8,004	3,884	3,144	31	288	385	36	3,669	5.54	2.937
Madera	56,710	56,182	528	16,418	11,540	748	1,604	2,224	302	15,705	4.34	3.577
Balance Of County	75,397	74,611	786	29,070	24,089	557	605	417	3,402	24,979	14.07	2.987
Incorporated	75,490	66,958	8,532	20,302	14,684	779	1,892	2,609	338	19,374	4.57	3.456
County Total	150,887	141,569	9,318	49,372	38,773	1,336	2,497	3,026	3,740	44,353	10.17	3.192

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION: TOTAL	POPULATION: HOUSEHOLD	POPULATION: GROUP QUARTERS	HOUSING UNITS: TOTAL	SINGLE: DETACHED	SINGLE: ATTACHED	MULTIPLE: 2 TO 4	MULTIPLE: 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Marin County												
Belvedere	2,161	2,161	0	1,065	874	54	94	43	0	962	9.67	2.246
Corte Madera	9,512	9,504	8	3,980	2,624	416	369	561	10	3,904	1.91	2.434
Fairfax	7,412	7,382	30	3,424	2,337	193	490	393	11	3,312	3.27	2.229
Larkspur	12,204	12,049	155	6,444	2,457	371	544	2,833	239	6,172	4.22	1.952
Mill Valley	13,925	13,834	91	6,367	4,153	552	535	1,127	0	6,227	2.20	2.222
Novato	52,737	51,867	870	20,905	12,196	2,673	1,418	3,900	718	20,389	2.47	2.544
Ross	2,393	2,299	94	819	799	0	12	0	8	775	5.37	2.966
San Anselmo	12,601	12,340	261	5,445	3,997	187	468	775	18	5,304	2.59	2.327
San Rafael	58,235	56,165	2,070	23,636	10,661	2,006	2,459	8,021	489	23,042	2.51	2.438
Sausalito	7,503	7,491	12	4,567	1,743	427	1,346	827	224	4,308	5.67	1.739
Tiburon	8,917	8,811	106	3,963	2,422	237	467	837	0	3,778	4.67	2.332
Balance Of County	69,806	62,859	6,947	27,923	21,530	1,508	1,589	2,882	414	25,940	7.10	2.423
Incorporated	187,600	183,903	3,697	80,615	44,263	7,116	8,202	19,317	1,717	78,173	3.03	2.353
County Total	257,406	246,762	10,644	108,538	65,793	8,624	9,791	22,199	2,131	104,113	4.08	2.370
Mariposa County												
County Total	18,406	16,961	1,445	10,347	6,336	648	214	383	2,766	7,754	25.06	2.187
Mendocino County												
Fort Bragg	6,890	6,764	126	3,161	2,053	158	328	459	163	2,942	6.93	2.299
Point Arena	493	493	0	233	149	7	45	13	19	205	12.02	2.405
Ukiah	15,758	15,024	734	6,399	3,548	379	769	1,241	462	6,240	2.48	2.408
Willits	5,032	4,906	126	2,045	1,196	84	323	291	151	1,967	3.81	2.494
Balance Of County	61,990	60,709	1,281	27,725	21,012	535	737	778	4,663	24,244	12.56	2.504
Incorporated	28,173	27,187	986	11,838	6,946	628	1,465	2,004	795	11,354	4.09	2.394
County Total	90,163	87,896	2,267	39,563	27,958	1,163	2,202	2,782	5,458	35,598	10.02	2.469
Merced County												
Atwater	27,571	26,112	1,459	9,529	6,616	584	832	990	507	8,511	10.68	3.068
Dos Palos	5,024	5,000	24	1,693	1,472	55	48	78	40	1,615	4.61	3.096
Gustine	5,199	5,199	0	2,005	1,643	31	98	105	128	1,914	4.54	2.716
Livingston	13,795	13,758	37	3,318	2,686	80	206	305	41	3,237	2.44	4.250
Los Banos	36,052	35,877	175	11,596	9,813	275	573	658	277	11,092	4.35	3.234
Merced	80,608	79,238	1,370	28,066	18,130	944	2,802	5,482	708	26,497	5.59	2.990
Balance Of County	87,001	85,246	1,755	28,424	22,324	582	850	628	4,040	26,086	8.23	3.268
Incorporated	168,249	165,184	3,065	56,207	40,360	1,969	4,559	7,618	1,701	52,866	5.94	3.125
	255,250	250,430	4,820	84,631	62,684	2,551	5,409	8,246	5,741	78,952		
County Total	255,250	250,430	4,820	84,631	62,684	2,551	5,409	8,246	5,741	78,952	6.71	3.172

California Department of Finance
Demographic Research Unit

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	HOUSEHOLD	GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Modoc County												
Alturas	2,804	2,724	80	1,381	1,021	57	47	144	112	1,193	13.61	2.283
Balance Of County	6,898	6,568	330	3,785	2,485	31	50	15	1,204	2,865	24.31	2.292
Incorporated	2,804	2,724	80	1,381	1,021	57	47	144	112	1,193	13.61	2.283
County Total	9,702	9,292	410	5,166	3,506	88	97	159	1,316	4,058	21.45	2.290
Mono County												
Mammoth Lakes	7,413	7,195	218	9,235	2,318	1,003	1,880	3,841	193	3,264	64.66	2.204
Balance Of County	6,346	6,188	158	4,456	2,933	256	307	74	886	2,805	37.05	2.206
Incorporated	7,413	7,195	218	9,235	2,318	1,003	1,880	3,841	193	3,264	64.66	2.204
County Total	13,759	13,383	376	13,691	5,251	1,259	2,187	3,915	1,079	6,069	55.67	2.205
Monterey County												
Carmel-By-The-Sea	4,049	4,049	0	3,363	2,756	114	223	270	0	2,306	31.43	1.756
Del Rey Oaks	1,627	1,627	0	727	567	25	23	109	3	704	3.16	2.311
Gonzales	8,803	8,730	73	2,023	1,474	133	205	169	42	1,989	1.68	4.389
Greenfield	17,316	17,220	96	3,764	2,830	282	319	247	86	3,649	3.06	4.719
King City	11,852	11,668	184	3,009	1,712	282	304	421	290	2,916	3.09	4.001
Marina	19,171	19,040	131	8,709	3,510	1,537	1,457	1,748	457	6,880	21.00	2.767
Monterey	29,322	26,839	2,483	13,549	5,934	914	2,265	4,415	21	12,783	5.65	2.100
Pacific Grove	15,472	15,297	175	8,108	5,017	451	990	1,559	91	7,343	9.44	2.083
Salinas	150,898	148,446	2,452	42,268	22,848	3,594	3,479	11,061	1,286	40,816	3.44	3.637
Sand City	298	234	64	138	58	7	28	40	5	96	30.43	2.438
Seaside	34,194	31,576	2,618	11,257	6,296	2,339	920	1,270	432	9,943	11.67	3.176
Soledad	27,905	16,743	11,162	3,810	2,834	214	364	275	123	3,718	2.41	4.503
Balance Of County	107,642	105,813	1,829	39,571	30,406	2,695	1,580	1,726	3,164	36,128	8.70	2.929
Incorporated	320,907	301,469	19,438	100,725	55,836	9,892	10,577	21,584	2,836	93,143	7.53	3.237
County Total	428,549	407,282	21,267	140,296	86,242	12,587	12,157	23,310	6,000	129,271	7.86	3.151
Napa County												
American Canyon	16,293	16,159	134	5,591	4,444	23	68	277	779	5,481	1.97	2.948
Calistoga	5,302	5,235	67	2,341	1,086	99	190	361	605	2,127	9.14	2.461
Napa	77,106	75,647	1,459	30,094	18,172	2,426	2,866	5,241	1,389	29,230	2.87	2.588
St Helena	5,924	5,872	52	2,745	1,691	215	216	478	145	2,414	12.06	2.432
Yountville	3,263	2,112	1,151	1,195	637	172	43	35	308	1,101	7.87	1.918
Balance Of County	28,816	25,996	2,820	11,984	10,216	650	355	8	755	10,235	14.59	2.540
Incorporated	107,888	105,025	2,863	41,966	26,030	2,935	3,383	6,392	3,226	40,353	3.84	2.603

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	POPULATION			HOUSING UNITS								PERSONS PER HOUSEHOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSEHOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	
County Total	136,704	131,021	5,683	53,950	36,246	3,585	3,738	6,400	3,981	50,588	6.23	2.590
Nevada County												
Grass Valley	12,929	12,579	350	6,469	3,099	259	770	1,645	696	6,161	4.76	2.042
Nevada City	3,074	2,887	187	1,523	1,161	53	139	95	75	1,413	7.22	2.043
Truckee	16,165	16,124	41	11,930	9,814	330	806	682	298	6,296	47.23	2.561
Balance Of County	67,018	66,622	396	30,442	26,953	322	271	90	2,806	27,788	8.72	2.398
Incorporated	32,168	31,590	578	19,922	14,074	642	1,715	2,422	1,069	13,870	30.38	2.278
County Total	99,186	98,212	974	50,364	41,027	964	1,986	2,512	3,875	41,658	17.29	2.358
Orange County												
Aliso Viejo	45,249	45,089	160	18,047	6,463	4,947	749	5,873	15	17,548	2.77	2.569
Anaheim	346,823	343,027	3,796	101,791	43,712	9,064	10,415	34,215	4,385	98,985	2.76	3.465
Brea	40,081	39,953	128	14,581	8,499	1,095	569	3,548	870	14,299	1.93	2.794
Buena Park	82,768	81,834	934	24,280	14,191	1,958	1,450	6,390	291	23,777	2.07	3.442
Costa Mesa	113,955	110,970	2,985	41,020	15,775	4,177	5,920	14,067	1,081	39,801	2.97	2.788
Cypress	49,541	49,220	321	16,611	10,184	2,692	529	2,842	364	16,223	2.34	3.034
Dana Point	36,982	36,740	242	15,942	7,933	2,271	2,823	2,622	293	14,698	7.80	2.500
Fountain Valley	57,925	57,413	512	18,785	12,393	2,200	672	3,122	398	18,469	1.68	3.109
Fullerton	137,437	134,222	3,215	47,044	23,954	3,862	3,688	14,619	921	45,823	2.60	2.929
Garden Grove	173,067	170,833	2,234	47,232	26,807	4,492	3,414	10,691	1,828	46,310	1.95	3.689
Huntington Beach	201,993	201,201	792	78,007	38,581	9,467	9,894	16,924	3,141	75,940	2.65	2.649
Irvine	209,806	201,529	8,277	77,680	27,880	14,591	5,030	29,157	1,022	74,151	4.54	2.718
Laguna Beach	25,131	25,009	122	13,253	8,308	759	1,762	2,100	324	11,765	11.23	2.126
Laguna Hills	33,421	32,997	424	11,153	5,873	2,183	608	2,272	217	10,807	3.10	3.053
Laguna Niguel	66,877	66,574	303	24,908	13,834	5,007	1,441	4,610	16	24,211	2.80	2.750
Laguna Woods	18,442	18,368	74	13,629	727	4,012	2,474	6,390	26	12,591	7.62	1.459
La Habra	62,635	62,040	595	19,932	10,581	1,750	1,360	5,508	733	19,425	2.54	3.194
Lake Forest	78,317	77,473	844	26,384	14,165	3,923	1,276	5,734	1,286	25,711	2.55	3.013
La Palma	16,176	16,145	31	5,131	3,637	376	102	989	27	5,043	1.72	3.201
Los Alamitos	12,191	11,785	406	4,422	1,945	269	1,056	1,023	129	4,338	1.90	2.717
Mission Viejo	98,572	97,507	1,065	33,713	24,474	4,021	1,201	3,928	89	33,165	1.63	2.940
Newport Beach	84,554	83,614	940	42,711	19,267	7,166	5,570	9,845	863	38,051	10.91	2.197
Orange	140,849	135,381	5,468	44,319	25,129	5,218	4,721	7,912	1,339	43,290	2.32	3.127
Placentia	51,727	51,424	303	16,463	9,746	2,065	1,111	2,954	587	16,152	1.89	3.184
Rancho Santa Margarita	49,764	49,750	14	16,793	9,118	3,883	598	3,194	0	16,526	1.59	3.010
San Clemente	67,892	67,600	292	27,131	15,488	2,669	4,087	4,485	402	25,477	6.10	2.653
San Juan Capistrano	36,782	36,324	458	11,877	6,154	2,395	944	865	1,519	11,468	3.44	3.167
Santa Ana	353,184	347,537	5,647	75,462	33,750	6,702	7,493	23,608	3,909	73,856	2.13	4.706
Seal Beach	25,986	25,723	263	14,537	4,699	2,121	1,164	6,390	163	13,439	7.55	1.914
Stanton	39,276	38,758	518	11,161	3,029	1,873	988	4,009	1,262	10,914	2.21	3.551
Tustin	74,218	73,800	418	25,994	8,888	4,133	3,110	8,955	908	25,290	2.71	2.918
Villa Park	6,259	6,238	21	2,021	1,992	18	0	6	5	1,963	2.87	3.178
Westminster	93,027	92,475	552	27,419	14,895	2,553	2,095	4,808	3,068	26,876	1.98	3.441

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	------------POPULATION------------			------------ HOUSING UNITS ------------								PERSONS
					-------- SINGLE --------		----- MULTIPLE -----					PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
Yorba Linda	68,312	68,177	135	21,893	17,205	2,395	622	1,360	311	21,540	1.61	3.165
Balance Of County	122,032	120,565	1,467	38,963	30,479	2,182	2,210	3,786	306	38,067	2.30	3.167
Incorporated	2,999,219	2,956,730	42,489	991,326	489,276	126,307	88,936	255,015	31,792	957,922	3.37	3.087
County Total	3,121,251	3,077,295	43,956	1,030,289	519,755	128,489	91,146	258,801	32,098	995,989	3.33	3.090
Placer County												
Auburn	13,273	13,067	206	6,004	4,113	211	655	1,025	0	5,852	2.53	2.233
Colfax	1,855	1,854	1	816	525	22	172	63	34	789	3.31	2.350
Lincoln	39,758	39,644	114	17,514	15,967	236	426	789	96	16,900	3.51	2.346
Loomis	6,624	6,590	34	2,460	2,069	217	58	2	114	2,407	2.15	2.738
Rocklin	53,843	53,465	378	21,036	14,865	990	831	3,910	440	20,253	3.72	2.640
Roseville	109,154	108,100	1,054	45,230	33,427	1,082	1,627	8,551	543	43,612	3.58	2.479
Balance Of County	108,894	107,431	1,463	54,348	43,927	1,980	2,569	2,354	3,518	41,894	22.92	2.564
Incorporated	224,507	222,720	1,787	93,060	70,966	2,758	3,769	14,340	1,227	89,813	3.49	2.480
County Total	333,401	330,151	3,250	147,408	114,893	4,738	6,338	16,694	4,745	131,707	10.65	2.507
Plumas County												
Portola	2,051	2,030	21	1,063	798	14	72	110	69	948	10.82	2.141
Balance Of County	18,866	18,699	167	14,394	11,114	433	303	286	2,258	9,420	34.56	1.985
Incorporated	2,051	2,030	21	1,063	798	14	72	110	69	948	10.82	2.141
County Total	20,917	20,729	188	15,457	11,912	447	375	396	2,327	10,368	32.92	1.999
Riverside County												
Banning	28,348	28,010	338	11,631	8,728	728	424	595	1,156	10,655	8.39	2.629
Beaumont	31,477	31,322	155	11,800	10,190	172	363	728	347	10,658	9.68	2.939
Blythe	21,695	13,541	8,154	5,444	3,020	152	500	881	891	4,567	16.11	2.965
Calimesa	7,536	7,440	96	3,372	1,883	113	57	64	1,255	3,097	8.16	2.402
Canyon Lake	11,051	11,035	16	4,416	4,020	164	6	84	142	3,977	9.94	2.775
Cathedral City	52,465	52,270	195	21,561	11,557	2,659	2,432	2,065	2,848	17,008	21.12	3.073
Coachella	40,517	40,473	44	8,814	6,276	319	700	1,062	457	8,428	4.38	4.802
Corona	147,428	146,796	632	45,485	31,623	2,186	2,229	7,834	1,613	43,827	3.65	3.349
Desert Hot Springs	26,068	25,894	174	10,907	7,358	180	1,377	1,313	679	9,085	16.70	2.850
Hemet	74,185	72,506	1,679	35,748	17,059	2,178	2,215	4,517	9,779	31,290	12.47	2.317
Indian Wells	5,025	5,025	0	4,973	3,373	884	239	469	8	2,566	48.40	1.958
Indio	81,512	80,656	856	27,794	18,312	878	1,549	3,795	3,260	22,799	17.97	3.538
Lake Elsinore	49,807	49,734	73	16,140	9,910	2,928	739	1,777	786	14,952	7.36	3.326
La Quinta	42,958	42,918	40	21,058	17,035	1,841	495	1,430	257	15,056	28.50	2.851
Moreno Valley	183,860	183,163	697	53,127	42,595	1,031	1,731	6,727	1,043	49,927	6.02	3.669
Murrieta	100,173	99,513	660	34,248	24,487	559	806	6,683	1,713	32,664	4.63	3.047
Norco	27,255	22,632	4,623	7,222	6,807	137	9	177	92	7,059	2.26	3.206

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Palm Desert	50,907	50,523	384	34,120	13,453	9,697	2,541	5,120	3,309	23,549	30.98	2.145
Palm Springs	47,251	46,555	696	33,479	12,099	6,679	2,558	9,915	2,228	22,287	33.43	2.089
Perris	53,605	53,373	232	15,392	11,603	323	371	1,264	1,831	14,078	8.54	3.791
Rancho Mirage	17,057	16,527	530	14,634	7,147	3,680	615	1,196	1,996	8,438	42.34	1.959
Riverside	296,842	287,341	9,501	98,441	61,595	4,144	5,887	24,338	2,477	93,973	4.54	3.058
San Jacinto	35,672	35,482	190	14,015	9,527	596	664	567	2,661	12,288	12.32	2.888
Temecula	101,057	101,035	22	32,453	25,976	511	731	4,914	321	31,135	4.06	3.245
Balance Of County	554,571	549,043	5,528	207,057	146,572	4,221	3,866	7,121	45,277	177,673	14.19	3.090
Incorporated	1,533,751	1,503,764	29,987	566,274	365,633	42,739	29,238	87,515	41,149	493,363	12.88	3.048
County Total	2,088,322	2,052,807	35,515	773,331	512,205	46,960	33,104	94,636	86,426	671,036	13.23	3.059
Sacramento County												
Citrus Heights	87,321	86,444	877	35,675	19,880	3,531	3,029	7,355	1,880	34,226	4.06	2.526
Elk Grove	139,542	138,862	680	47,423	42,979	1,327	525	2,319	273	46,323	2.32	2.998
Folsom	72,590	65,745	6,845	26,245	18,245	653	816	5,641	890	25,118	4.29	2.617
Galt	23,913	23,725	188	7,630	6,210	226	340	482	372	7,339	3.81	3.233
Isleton	817	817	0	378	223	0	72	36	47	338	10.58	2.417
Rancho Cordova	60,975	60,625	350	24,133	12,993	2,064	2,008	5,679	1,389	23,054	4.47	2.630
Sacramento	475,743	466,851	8,892	192,371	113,418	12,959	16,228	46,080	3,686	181,538	5.63	2.572
Balance Of County	563,514	555,881	7,633	217,364	140,423	13,600	13,942	42,155	7,244	209,656	3.55	2.651
Incorporated	860,901	843,069	17,832	333,855	213,948	20,760	23,018	67,592	8,537	317,936	4.77	2.652
County Total	1,424,415	1,398,950	25,465	551,219	354,371	34,360	36,960	109,747	15,781	527,592	4.29	2.652
San Benito County												
Hollister	37,051	36,880	171	10,584	7,980	525	992	781	306	10,362	2.10	3.559
San Juan Bautista	1,874	1,874	0	731	459	82	75	98	17	674	7.80	2.780
Balance Of County	18,859	18,523	336	6,454	5,359	427	70	42	556	6,066	6.01	3.054
Incorporated	38,925	38,754	171	11,315	8,439	607	1,067	879	323	11,036	2.47	3.512
County Total	57,784	57,277	507	17,769	13,798	1,034	1,137	921	879	17,102	3.75	3.349
San Bernardino County												
Adelanto	28,181	26,937	1,244	8,546	6,687	148	380	823	508	7,259	15.06	3.711
Apple Valley	70,092	69,729	363	24,925	19,380	727	2,089	1,686	1,043	22,841	8.36	3.053
Barstow	23,952	23,641	311	9,990	5,549	356	1,308	1,662	1,115	8,284	17.08	2.854
Big Bear Lake	6,256	6,231	25	9,528	8,023	330	371	410	394	2,565	73.08	2.429
Chino	82,670	71,751	10,919	20,577	14,664	952	1,063	3,370	528	19,894	3.32	3.607
Chino Hills	78,957	78,806	151	22,960	18,477	1,378	308	2,111	686	22,538	1.84	3.497
Colton	51,918	51,654	264	16,251	9,654	602	1,070	4,110	815	15,049	7.40	3.432
Fontana	188,498	187,939	559	49,945	39,668	1,307	1,687	5,997	1,286	47,316	5.26	3.972
Grand Terrace	12,543	12,334	209	4,580	2,923	191	311	905	250	4,337	5.31	2.844

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Hesperia	87,820	87,489	331	28,535	23,192	893	1,188	1,958	1,304	26,689	6.47	3.278
Highland	52,503	52,263	240	16,643	12,500	555	598	2,129	861	15,098	9.28	3.462
Loma Linda	22,632	21,681	951	9,163	3,925	939	1,312	2,425	562	8,541	6.79	2.538
Montclair	37,017	36,405	612	9,677	5,655	758	1,061	1,342	861	9,394	2.92	3.875
Needles	5,807	5,796	11	2,917	1,531	110	254	367	655	2,218	23.96	2.613
Ontario	173,690	172,592	1,098	47,276	27,569	3,649	4,075	9,820	2,163	45,543	3.67	3.790
Rancho Cucamonga	174,308	170,682	3,626	55,103	35,575	3,161	1,942	13,045	1,380	53,441	3.02	3.194
Redlands	71,807	69,841	1,966	26,719	17,254	900	2,442	5,204	919	25,429	4.83	2.747
Rialto	99,767	98,963	804	26,854	19,014	586	1,908	3,543	1,803	25,426	5.32	3.892
San Bernardino	205,493	198,562	6,931	66,606	39,273	2,729	5,652	14,467	4,485	59,253	11.04	3.351
Twentynine Palms	27,966	20,283	7,683	9,185	5,139	1,303	1,713	481	549	7,446	18.93	2.724
Upland	75,137	74,552	585	26,628	15,300	1,770	2,677	6,036	845	25,669	3.60	2.904
Victorville	107,408	102,637	4,771	34,876	27,767	389	1,441	3,488	1,791	32,186	7.71	3.189
Yucaipa	52,063	51,491	572	19,416	13,159	394	743	893	4,227	18,307	5.71	2.813
Yucca Valley	21,268	20,957	311	9,574	7,662	140	687	378	707	8,366	12.62	2.505
Balance Of County	298,013	290,392	7,621	129,168	103,907	4,192	4,041	2,064	14,964	92,916	28.07	3.125
Incorporated	1,757,753	1,713,216	44,537	556,474	379,540	24,267	36,280	86,650	29,737	513,089	7.80	3.339
County Total	2,055,766	2,003,608	52,158	685,642	483,447	28,459	40,321	88,714	44,701	606,005	11.61	3.306
San Diego County												
Carlsbad	103,811	103,146	665	44,027	23,882	5,772	2,773	10,308	1,292	41,063	6.73	2.512
Chula Vista	231,305	229,866	1,439	77,593	42,120	5,494	5,776	20,641	3,562	75,259	3.01	3.054
Coronado	23,101	18,179	4,922	9,611	4,506	868	826	3,388	23	7,825	18.58	2.323
Del Mar	4,580	4,578	2	2,611	1,369	366	204	672	0	2,225	14.78	2.058
El Cajon	97,934	95,361	2,573	35,545	13,744	1,566	2,244	15,957	2,034	34,544	2.82	2.761
Encinitas	63,864	63,305	559	25,719	14,594	4,589	2,136	3,631	769	24,627	4.25	2.571
Escondido	143,389	141,624	1,765	47,379	23,547	2,939	3,121	13,895	3,877	46,083	2.74	3.073
Imperial Beach	28,200	27,534	666	9,968	4,098	687	1,066	3,777	340	9,489	4.81	2.902
La Mesa	56,666	55,620	1,046	25,279	11,395	1,955	1,987	9,608	334	24,513	3.03	2.269
Lemon Grove	25,611	25,020	591	8,778	5,801	716	694	1,470	97	8,544	2.67	2.928
National City	61,194	53,040	8,154	15,721	6,829	1,405	1,690	5,360	437	15,310	2.61	3.464
Oceanside	178,806	177,526	1,280	64,789	33,880	8,364	4,570	14,408	3,567	61,425	5.19	2.890
Poway	51,103	50,677	426	16,365	12,186	877	345	2,265	692	16,108	1.57	3.146
San Diego	1,336,865	1,293,528	43,337	505,422	229,267	45,882	43,810	180,122	6,341	485,061	4.03	2.667
San Marcos	82,743	82,054	689	27,630	14,170	1,083	1,461	7,256	3,660	26,532	3.97	3.093
Santee	56,068	55,025	1,043	19,528	10,827	1,975	1,225	2,998	2,503	19,151	1.93	2.873
Solana Beach	13,500	13,466	34	6,572	3,020	1,265	617	1,631	39	5,859	10.85	2.298
Vista	95,770	93,504	2,266	31,144	15,540	2,029	2,247	9,199	2,129	30,165	3.14	3.100
Balance Of County	491,764	457,903	33,861	165,176	111,413	10,977	6,711	19,889	16,186	154,917	6.21	2.956
Incorporated	2,654,510	2,583,053	71,457	973,681	470,775	87,832	76,792	306,586	31,696	933,783	4.10	2.766
County Total	3,146,274	3,040,956	105,318	1,138,857	582,188	98,809	83,503	326,475	47,882	1,088,700	4.40	2.793
San Francisco County												

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	POPULATION			HOUSING UNITS								PERSONS
					SINGLE		MULTIPLE					PER
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	HOUSE-HOLD
City and County Total	824,525	803,419	21,106	361,777	63,046	48,700	82,038	167,433	560	344,792	4.69	2.330
San Joaquin County												
Escalon	7,131	7,105	26	2,504	2,098	20	153	98	135	2,415	3.55	2.942
Lathrop	17,429	17,419	10	4,917	4,132	328	94	12	351	4,763	3.13	3.657
Lodi	63,362	62,298	1,064	23,353	15,127	1,487	1,768	4,506	465	22,604	3.21	2.756
Manteca	66,451	65,974	477	22,485	17,198	739	1,136	2,561	851	21,730	3.36	3.036
Ripon	14,915	14,804	111	4,987	4,218	192	197	369	11	4,874	2.27	3.037
Stockton	289,927	285,367	4,560	96,553	62,729	6,592	8,487	17,457	1,288	92,450	4.25	3.087
Tracy	81,548	81,203	345	25,478	20,934	1,027	1,027	2,014	476	24,820	2.58	3.272
Balance Of County	144,897	134,932	9,965	47,062	37,942	1,304	903	759	6,154	44,734	4.95	3.016
Incorporated	540,763	534,170	6,593	180,277	126,436	10,385	12,862	27,017	3,577	173,656	3.67	3.076
County Total	685,660	669,102	16,558	227,339	164,378	11,689	13,765	27,776	9,731	218,390	3.94	3.064
San Luis Obispo County												
Arroyo Grande	17,036	16,826	210	7,565	5,064	669	518	766	548	7,259	4.04	2.318
Atascadero	28,590	26,947	1,643	11,102	7,896	459	925	1,265	557	10,747	3.20	2.507
El Paso De Robles	29,934	29,682	252	11,636	7,860	920	1,091	1,348	417	11,325	2.67	2.621
Grover Beach	13,213	13,087	126	5,670	3,291	792	732	608	247	5,292	6.67	2.473
Morro Bay	10,548	10,350	198	6,640	4,345	405	667	464	759	5,297	20.23	1.954
Pismo Beach	8,603	8,576	27	5,761	3,128	576	473	497	1,087	4,434	23.03	1.934
San Luis Obispo	44,697	42,835	1,862	20,222	9,418	1,311	2,337	5,654	1,502	19,524	3.45	2.194
Balance Of County	116,716	104,970	11,746	47,575	35,412	1,683	2,259	1,218	7,003	41,513	12.74	2.529
Incorporated	152,621	148,303	4,318	68,596	41,002	5,132	6,743	10,602	5,117	63,878	6.88	2.322
County Total	269,337	253,273	16,064	116,171	76,414	6,815	9,002	11,820	12,120	105,391	9.28	2.403
San Mateo County												
Atherton	7,475	7,157	318	2,560	2,521	32	0	7	0	2,483	3.01	2.882
Belmont	26,078	25,451	627	10,822	6,302	649	275	3,596	0	10,701	1.12	2.378
Brisbane	3,861	3,821	40	1,933	1,086	262	184	358	43	1,720	11.02	2.222
Burlingame	28,867	28,381	486	12,971	6,164	423	987	5,397	0	12,686	2.20	2.237
Colma	1,613	1,564	49	460	220	66	98	70	6	445	3.26	3.515
Daly City	106,361	105,571	790	31,778	16,136	4,517	2,843	7,612	670	31,401	1.19	3.362
East Palo Alto	32,897	32,708	189	7,775	3,977	342	360	2,937	159	7,694	1.04	4.251
Foster City	30,308	30,221	87	12,477	4,808	2,464	767	4,431	7	12,145	2.66	2.488
Half Moon Bay	13,046	12,198	848	4,483	2,827	536	314	379	427	4,392	2.03	2.777
Hillsborough	11,272	11,270	2	3,889	3,868	12	9	0	0	3,797	2.37	2.968
Menlo Park	31,490	30,546	944	12,790	6,915	930	1,574	3,366	5	12,539	1.96	2.436
Millbrae	21,387	21,055	332	8,230	5,327	269	436	2,187	11	8,124	1.29	2.592
Pacifica	39,616	39,435	181	14,439	10,410	791	728	2,412	98	14,281	1.09	2.761
Portola Valley	4,639	4,569	70	1,810	1,502	33	8	267	0	1,748	3.43	2.614
Redwood City	77,269	75,342	1,927	29,276	13,554	3,656	2,623	8,610	833	28,595	2.33	2.635

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

	POPULATION			HOUSING UNITS								PERSONS PER HOUSE-HOLD
					SINGLE		MULTIPLE					
COUNTY/CITY	TOTAL	HOUSE-HOLD	GROUP QUARTERS	TOTAL	DETACHED	ATTACHED	2 TO 4	5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	
San Bruno	43,444	43,208	236	15,917	9,155	566	1,188	4,986	22	15,696	1.39	2.753
San Carlos	28,857	28,674	183	11,960	8,285	609	492	2,558	16	11,794	1.39	2.431
San Mateo	95,776	94,460	1,316	39,168	17,736	3,493	3,042	14,852	45	38,481	1.75	2.455
South San Francisco	63,744	63,301	443	20,826	12,020	2,551	1,686	4,160	409	20,487	1.63	3.090
Woodside	5,625	5,619	6	2,095	2,033	28	28	5	1	2,026	3.29	2.773
Balance Of County	65,844	64,461	1,383	22,642	18,737	708	933	1,417	847	22,017	2.76	2.928
Incorporated	673,625	664,551	9,074	245,659	134,846	22,229	17,642	68,190	2,752	241,235	1.80	2.755
County Total	739,469	729,012	10,457	268,301	153,583	22,937	18,575	69,607	3,599	263,252	1.88	2.769
Santa Barbara County												
Buellton	4,700	4,694	6	1,840	1,149	120	48	104	419	1,778	3.37	2.640
Carpinteria	14,271	14,146	125	5,551	2,165	428	551	1,467	940	5,069	8.68	2.791
Goleta	30,400	30,058	342	11,516	5,870	1,588	761	2,676	621	11,231	2.47	2.676
Guadalupe	6,541	6,541	0	1,693	1,157	168	187	173	8	1,652	2.42	3.959
Lompoc	42,957	38,701	4,256	14,140	7,499	1,045	1,955	2,701	940	13,558	4.12	2.854
Santa Barbara	90,305	88,443	1,862	37,675	17,269	2,914	5,650	11,324	518	36,231	3.83	2.441
Santa Maria	91,110	88,912	2,198	27,387	17,098	1,655	1,796	5,257	1,581	26,602	2.87	3.342
Solvang	5,555	5,395	160	2,347	1,351	153	171	453	219	2,302	1.92	2.344
Balance Of County	142,816	133,575	9,241	52,303	36,627	3,531	2,739	5,908	3,498	49,432	5.49	2.702
Incorporated	285,839	276,890	8,949	102,149	53,558	8,071	11,119	24,155	5,246	98,423	3.65	2.813
County Total	428,655	410,465	18,190	154,452	90,185	11,602	13,858	30,063	8,744	147,855	4.27	2.776
Santa Clara County												
Campbell	40,161	39,871	290	16,932	7,341	2,095	2,438	4,801	257	16,554	2.23	2.409
Cupertino	55,551	55,070	481	20,172	12,235	2,145	1,698	4,085	9	19,660	2.54	2.801
Gilroy	51,173	50,743	430	14,853	9,991	925	1,333	2,173	431	14,509	2.32	3.497
Los Altos	28,291	27,872	419	10,820	9,219	383	275	927	16	10,552	2.48	2.641
Los Altos Hills	8,837	8,772	65	3,124	3,060	32	17	9	6	3,041	2.66	2.885
Los Gatos	30,296	29,594	702	12,952	7,172	1,841	936	2,880	123	12,556	3.06	2.357
Milpitas	69,419	66,245	3,174	19,073	11,061	2,225	1,665	3,533	589	18,818	1.34	3.520
Monte Sereno	3,579	3,579	0	1,255	1,151	13	18	73	0	1,229	2.07	2.912
Morgan Hill	39,218	38,705	513	12,821	7,967	1,892	728	1,322	912	12,537	2.22	3.087
Mountain View	73,932	73,416	516	33,475	9,318	4,038	2,650	16,238	1,231	32,247	3.67	2.277
Palo Alto	63,367	62,618	749	27,938	15,636	980	1,760	9,398	164	27,045	3.20	2.315
San Jose	989,496	977,529	11,967	307,613	167,873	28,227	23,425	77,060	11,028	301,892	1.86	3.238
Santa Clara	115,503	112,716	2,787	44,275	18,617	3,759	3,929	17,861	109	43,042	2.78	2.619
Saratoga	31,592	31,231	361	11,093	9,728	560	241	557	7	10,886	1.87	2.869
Sunnyvale	137,538	136,663	875	55,394	21,241	5,176	4,901	19,980	4,096	54,144	2.26	2.524
Balance Of County	99,122	91,407	7,715	30,989	24,586	1,543	918	3,254	688	29,940	3.39	3.053
Incorporated	1,737,953	1,714,624	23,329	591,790	311,610	54,291	46,014	160,897	18,978	578,712	2.21	2.963
County Total	1,837,075	1,806,031	31,044	622,779	336,196	55,834	46,932	164,151	19,666	608,652	2.27	2.967

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Santa Cruz County												
Capitola	10,015	9,859	156	5,412	1,997	516	1,142	1,107	650	4,782	11.64	2.062
Santa Cruz	58,125	52,581	5,544	23,379	12,386	2,082	2,610	5,860	441	22,069	5.60	2.383
Scotts Valley	11,697	11,245	452	4,646	2,512	415	417	497	805	4,488	3.40	2.506
Watsonville	51,703	51,150	553	14,066	7,294	1,819	1,723	2,330	900	13,689	2.68	3.737
Balance Of County	134,979	131,736	3,243	56,976	41,461	4,381	2,749	3,926	4,459	51,283	9.99	2.569
Incorporated	131,540	124,835	6,705	47,503	24,189	4,832	5,892	9,794	2,796	45,028	5.21	2.772
County Total	266,519	256,571	9,948	104,479	65,650	9,213	8,641	13,720	7,255	96,311	7.82	2.664
Shasta County												
Anderson	10,579	10,461	118	4,203	2,700	213	382	729	179	3,960	5.78	2.642
Redding	90,491	88,034	2,457	38,018	24,923	1,010	4,826	4,642	2,617	36,107	5.03	2.438
Shasta Lake	10,279	10,227	52	4,273	3,400	27	247	114	485	3,887	9.03	2.631
Balance Of County	70,887	70,068	819	30,624	21,649	275	421	198	8,081	27,153	11.33	2.580
Incorporated	111,349	108,722	2,627	46,494	31,023	1,250	5,455	5,485	3,281	43,954	5.46	2.474
County Total	182,236	178,790	3,446	77,118	52,672	1,525	5,876	5,683	11,362	71,107	7.79	2.514
Sierra County												
Loyalton	851	821	30	377	328	13	3	0	33	352	6.63	2.332
Balance Of County	2,529	2,523	6	1,912	1,570	36	44	63	199	1,233	35.51	2.046
Incorporated	851	821	30	377	328	13	3	0	33	352	6.63	2.332
County Total	3,380	3,344	36	2,289	1,898	49	47	63	232	1,585	30.76	2.110
Siskiyou County												
Dorris	864	864	0	408	318	2	16	0	72	354	13.24	2.441
Dunsmuir	1,831	1,831	0	1,177	798	23	126	184	46	872	25.91	2.100
Etna	751	751	0	368	271	10	19	13	55	335	8.97	2.242
Fort Jones	657	657	0	345	243	11	34	2	55	315	8.70	2.086
Montague	1,496	1,477	19	661	488	15	10	43	105	608	8.02	2.429
Mount Shasta	3,602	3,554	48	1,888	1,203	89	266	256	74	1,752	7.20	2.029
Tulelake	970	970	0	461	316	2	44	19	80	360	21.91	2.694
Weed	3,030	2,861	169	1,368	901	19	136	251	61	1,253	8.41	2.283
Yreka	7,441	7,221	220	3,561	2,242	140	294	633	252	3,358	5.70	2.150
Balance Of County	25,329	25,042	287	13,807	10,001	188	189	96	3,333	11,104	19.58	2.255
Incorporated	20,642	20,186	456	10,237	6,780	311	945	1,401	800	9,207	10.06	2.192
County Total	45,971	45,228	743	24,044	16,781	499	1,134	1,497	4,133	20,311	15.53	2.227

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSEHOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCUPIED	PCT VACANT	PERSONS PER HOUSEHOLD
Solano County												
Benicia	27,978	27,924	54	11,307	7,428	1,049	944	1,560	326	11,072	2.08	2.522
Dixon	17,577	17,536	41	5,813	4,687	216	386	438	86	5,702	1.91	3.075
Fairfield	106,753	103,593	3,160	38,317	26,183	2,519	2,512	6,211	892	35,995	6.06	2.878
Rio Vista	8,071	8,071	0	3,667	3,248	34	103	171	111	3,502	4.50	2.305
Suisun City	28,193	28,099	94	9,054	7,706	189	339	754	66	8,877	1.95	3.165
Vacaville	96,905	87,444	9,461	32,552	22,719	1,040	2,150	5,335	1,308	31,883	2.06	2.743
Vallejo	121,097	118,835	2,262	43,840	30,580	1,792	3,928	6,194	1,346	42,120	3.92	2.821
Balance Of County	20,183	19,582	601	7,491	6,073	452	306	119	541	7,040	6.02	2.782
Incorporated	406,574	391,502	15,072	144,550	102,551	6,839	10,362	20,663	4,135	139,151	3.74	2.814
County Total	426,757	411,084	15,673	152,041	108,624	7,291	10,668	20,782	4,676	146,191	3.85	2.812
Sonoma County												
Cloverdale	8,577	8,500	77	3,382	2,526	204	120	323	209	3,222	4.73	2.638
Cotati	7,532	7,514	18	3,087	1,680	550	373	363	121	3,023	2.07	2.486
Healdsburg	11,706	11,583	123	4,615	3,298	280	453	485	99	4,427	4.07	2.616
Petaluma	57,418	56,678	740	21,943	15,664	1,696	1,368	2,284	931	21,541	1.83	2.631
Rohnert Park	43,062	41,961	1,101	16,544	7,660	1,701	943	4,827	1,413	16,225	1.93	2.586
Santa Rosa	159,981	156,247	3,734	64,238	38,423	6,022	4,940	12,139	2,714	62,524	2.67	2.499
Sebastopol	7,714	7,503	211	3,380	2,029	257	535	497	62	3,309	2.10	2.267
Sonoma	9,943	9,852	91	5,218	2,957	752	480	592	437	4,890	6.29	2.015
Windsor	26,564	26,473	91	9,265	7,242	461	258	482	822	9,098	1.80	2.910
Balance Of County	151,973	145,943	6,030	66,235	53,329	2,919	3,031	2,327	4,629	58,309	11.97	2.503
Incorporated	332,497	326,311	6,186	131,672	81,479	11,923	9,470	21,992	6,808	128,259	2.59	2.544
County Total	484,470	472,254	12,216	197,907	134,808	14,842	12,501	24,319	11,437	186,568	5.73	2.531
Stanislaus County												
Ceres	42,813	42,714	99	13,279	10,406	347	717	1,097	712	12,864	3.13	3.320
Hughson	6,187	6,181	6	1,937	1,576	65	72	135	89	1,891	2.37	3.269
Modesto	209,936	206,705	3,231	74,700	52,785	4,010	6,313	9,541	2,051	72,232	3.30	2.862
Newman	10,586	10,520	66	3,243	2,777	76	247	117	26	3,099	4.44	3.395
Oakdale	19,337	19,158	179	7,227	5,520	256	517	691	243	6,985	3.35	2.743
Patterson	21,229	21,000	229	5,999	5,466	190	151	63	129	5,783	3.60	3.631
Riverbank	21,757	21,622	135	6,447	5,605	187	184	182	289	6,237	3.26	3.467
Turlock	70,158	67,790	2,368	23,993	16,614	961	1,977	3,837	604	23,130	3.60	2.931
Waterford	8,763	8,746	17	2,623	2,181	64	181	168	29	2,510	4.31	3.484
Balance Of County	115,137	113,667	1,470	37,174	29,029	1,597	960	429	5,159	35,305	5.03	3.220
Incorporated	410,766	404,436	6,330	139,448	102,930	6,156	10,359	15,831	4,172	134,731	3.38	3.002
County Total	525,903	518,103	7,800	176,622	131,959	7,753	11,319	16,260	9,331	170,036	3.73	3.047

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
Sutter County												
Live Oak	8,539	8,147	392	2,412	1,936	92	138	104	142	2,292	4.98	3.555
Yuba City	63,338	62,382	956	22,427	15,163	851	1,628	3,831	954	21,501	4.13	2.901
Balance Of County	24,001	23,843	158	8,652	7,558	260	149	68	617	8,195	5.28	2.909
Incorporated	71,877	70,529	1,348	24,839	17,099	943	1,766	3,935	1,096	23,793	4.21	2.964
County Total	95,878	94,372	1,506	33,491	24,657	1,203	1,915	4,003	1,713	31,988	4.49	2.950
Tehama County												
Corning	7,226	7,169	57	2,843	1,737	70	302	495	239	2,634	7.35	2.722
Red Bluff	13,828	13,293	535	6,117	3,566	234	861	1,090	366	5,613	8.24	2.368
Tehama	429	429	0	201	172	4	10	0	15	184	8.46	2.332
Balance Of County	40,936	40,511	425	18,147	11,139	214	274	78	6,442	15,912	12.32	2.546
Incorporated	21,483	20,891	592	9,161	5,475	308	1,173	1,585	620	8,431	7.97	2.478
County Total	62,419	61,402	1,017	27,308	16,614	522	1,447	1,663	7,062	24,343	10.86	2.522
Trinity County												
County Total	13,966	13,723	243	8,482	5,613	112	108	144	2,505	5,938	29.99	2.311
Tulare County												
Dinuba	20,993	20,879	114	5,698	4,245	282	268	644	259	5,484	3.76	3.807
Exeter	10,656	10,564	92	3,606	2,914	107	205	192	188	3,416	5.27	3.093
Farmersville	10,524	10,505	19	2,673	2,166	90	155	157	105	2,535	5.16	4.144
Lindsay	11,546	11,397	149	3,146	2,033	204	243	481	185	2,984	5.15	3.819
Porterville	51,638	50,161	1,477	16,219	11,772	483	1,738	1,509	717	15,239	6.04	3.292
Tulare	57,375	56,928	447	18,219	14,025	511	1,727	1,180	776	17,312	4.98	3.288
Visalia	120,958	119,336	1,622	42,434	32,092	1,572	4,102	3,198	1,470	40,111	5.47	2.975
Woodlake	7,489	7,480	9	2,064	1,369	126	154	355	60	1,957	5.18	3.822
Balance Of County	144,075	142,137	1,938	45,300	33,613	1,540	1,517	828	7,802	39,897	11.93	3.563
Incorporated	291,179	287,250	3,929	94,059	70,616	3,375	8,592	7,716	3,760	89,039	5.34	3.226
County Total	435,254	429,387	5,867	139,359	104,229	4,915	10,109	8,544	11,562	128,936	7.48	3.330
Tuolumne County												
Sonora	4,698	4,499	199	2,411	1,441	86	403	447	34	2,251	6.64	1.999
Balance Of County	52,101	47,405	4,696	28,110	21,887	576	791	651	4,205	20,383	27.49	2.326
Incorporated	4,698	4,499	199	2,411	1,441	86	403	447	34	2,251	6.64	1.999

Table 2: E-5 City/County Population and Housing Estimates, 1/1/2008

COUNTY/CITY	POPULATION TOTAL	POPULATION HOUSE-HOLD	POPULATION GROUP QUARTERS	HOUSING UNITS TOTAL	SINGLE DETACHED	SINGLE ATTACHED	MULTIPLE 2 TO 4	MULTIPLE 5 PLUS	MOBILE HOMES	OCCU-PIED	PCT VACANT	PERSONS PER HOUSE-HOLD
County Total	56,799	51,904	4,895	30,521	23,328	662	1,194	1,098	4,239	22,634	25.84	2.293
Ventura County												
Camarillo	65,453	63,717	1,736	24,975	14,861	4,495	986	3,575	1,058	24,257	2.87	2.627
Fillmore	15,641	15,395	246	4,405	3,182	281	244	372	326	4,302	2.34	3.579
Moorpark	36,814	36,802	12	10,605	7,630	1,253	235	1,189	298	10,488	1.10	3.509
Ojai	8,156	7,966	190	3,337	2,281	292	304	452	8	3,193	4.32	2.495
Oxnard	194,905	192,308	2,597	51,521	29,383	4,633	4,481	10,078	2,946	49,708	3.52	3.869
Port Hueneme	22,202	21,214	988	8,108	2,493	2,202	1,201	2,171	41	7,429	8.37	2.856
San Buenaventura	108,261	105,508	2,753	42,407	23,548	3,430	4,407	8,399	2,623	41,044	3.21	2.571
Santa Paula	29,539	29,296	243	8,576	5,060	767	791	1,171	787	8,366	2.45	3.502
Simi Valley	125,657	124,857	800	41,890	30,646	3,147	1,674	5,531	892	40,933	2.28	3.050
Thousand Oaks	128,650	126,699	1,951	47,075	31,353	5,256	1,846	7,548	1,072	45,798	2.71	2.766
Balance Of County	96,309	94,158	2,151	33,421	26,542	2,375	1,012	1,212	2,280	31,367	6.15	3.002
Incorporated	735,278	723,762	11,516	242,899	150,437	25,756	16,169	40,486	10,051	235,518	3.04	3.073
County Total	831,587	817,920	13,667	276,320	176,979	28,131	17,181	41,698	12,331	266,885	3.41	3.065
Yolo County												
Davis	65,814	62,733	3,081	25,876	11,551	2,417	2,380	9,143	385	25,313	2.18	2.478
West Sacramento	47,068	46,862	206	18,254	11,615	879	990	3,193	1,577	17,158	6.00	2.731
Winters	7,052	7,046	6	2,269	1,802	106	67	216	78	2,214	2.42	3.182
Woodland	55,867	54,489	1,378	19,451	12,239	1,313	1,151	4,067	681	19,031	2.16	2.863
Balance Of County	23,265	19,147	4,118	7,288	4,982	304	202	804	996	6,859	5.89	2.792
Incorporated	175,801	171,130	4,671	65,850	37,207	4,715	4,588	16,619	2,721	63,716	3.24	2.686
County Total	199,066	190,277	8,789	73,138	42,189	5,019	4,790	17,423	3,717	70,575	3.50	2.696
Yuba County												
Marysville	12,719	12,112	607	5,023	2,791	339	766	1,119	8	4,710	6.23	2.572
Wheatland	3,510	3,510	0	1,216	930	37	155	55	39	1,169	3.87	3.003
Balance Of County	55,700	55,066	634	21,433	14,842	915	709	1,076	3,891	18,431	14.01	2.988
Incorporated	16,229	15,622	607	6,239	3,721	376	921	1,174	47	5,879	5.77	2.657
County Total	71,929	70,688	1,241	27,672	18,563	1,291	1,630	2,250	3,938	24,310	12.15	2.908
California												
Incorporated Total	31,356,997	30,668,849	688,148	10,952,625	5,891,052	855,817	965,710	2,921,882	318,164	10,433,799	4.74	2.939
Balance Of State Total	6,692,465	6,509,661	182,804	2,491,830	1,821,397	109,854	99,144	184,637	276,798	2,219,835	10.92	2.932
State Total	38,049,462	37,178,510	870,952	13,444,455	7,712,449	965,671	1,064,854	3,106,519	594,962	12,653,634	5.88	2.938

MOBILITY 2030 for the next generation

LAKE TAHOE REGIONAL TRANSPORTATION PLAN

FINAL

August 27, 2008

Reducing Greenhouse Gas Emissions at Lake Tahoe

The Lake Tahoe Region is particularly vulnerable to the impacts of global climate change, just as it is to other environmental impacts. The region's economy is highly dependent on the health of its environmental assets, including its substantial snowpack, a clear lake, and healthy forests, all of which will be negatively affected by warming temperatures.

Emissions from motor vehicles, including cars, buses and boats, are a leading source of greenhouse gas emissions in the Basin. Motor vehicle use has been identified as a major contributor to the loss of clarity of Lake Tahoe, contributing to runoff from roadways and the emission of nitrogen oxides and particulate matter, causing algae growth in the Lake. Since 1982, the TRPA has strived to meet two air quality threshold indicators: Vehicle Miles Traveled (VMT) and traffic counts. Both of these criteria should be reduced to 1981 levels. These threshold indicators are consistent with the goals of California's Global Warming Solutions Act (AB32) of 2006, which specifies that the state must reduce greenhouse gas emissions to 1990 levels by 2020. Vehicle Miles Traveled have been decreasing in the Lake Tahoe Region over the last five years, and traffic counts, which, for the purposes of the threshold indicator, are measured at a location in South Lake Tahoe, are also trending downward.

Because of the air quality thresholds and the intense focus on environmental health in the Lake Tahoe Region, the goals and policies of past regional plans and regional transportation plans have focused on reducing emissions from motor vehicles, and on shifting people out of their cars and into other, lower impact modes such as transit, bicycling, and walking. This Regional Transportation Plan continues this trend, with the majority of policies and projects encouraging transit and pedestrian-oriented development, constructing pedestrian and bicycling facilities, and strengthening the transit system. Those projects that are related to roadway improvements are limited to minor changes such as adding left-hand turn lanes or improving traffic signalization to provide for a more efficient use of the current roadway network. These projects relieve congestion without widening roadways or adding major capacity for motor vehicles.

Concurrent with the development of this regional transportation plan is a comprehensive revision and update to the regional plan for the Lake Tahoe Region. The regional plan outlines goals and policies for many resource areas in addition to transportation, and will examine land-use and building strategies that can reduce greenhouse gas emissions. The regional plan will include a region-wide analysis that looks at all aspects of the plan with respect to climate change, including transportation.

Projects that affect greenhouse gas emissions

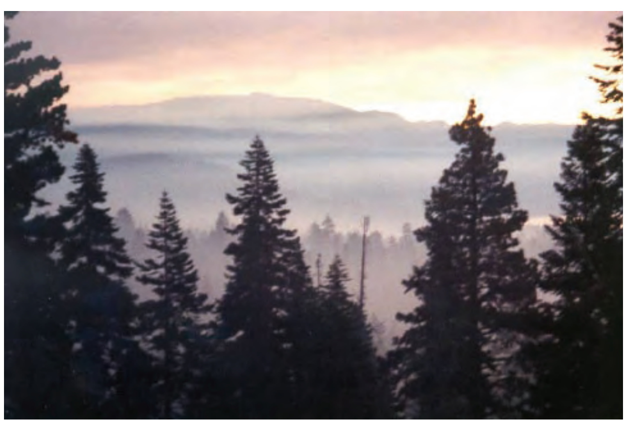
In the area of transportation, most greenhouse gas emissions are associated with motor vehicle use. Therefore, projects that shift people out of cars and into other, lower-emission alternatives will reduce greenhouse gas emissions. The projects proposed as part of Mobility 2030, the Lake Tahoe Regional Transportation Plan, are grouped below into three categories: projects that will likely reduce greenhouse gas emissions, projects that will likely increase greenhouse gas emissions, and those where the effect on emissions is unclear or may be neutral.

Projects that were placed in the "reduce" category are those that aim to reduce vehicle use or vehicle emissions as a primary goal. For instance, all bicycle trails and pedestrian improvements are considered to reduce emissions, since the primary goals of these projects getting drivers to walk or bicycle for trips they otherwise would have made by motor vehicle, thus reducing air quality emissions. Likewise, capital improvements in bus fleets were considered to reduce greenhouse gas emissions, since one of the main purposes of replacing buses is introducing newer, cleaner technologies to the fleets.

Projects included in the "increase" greenhouse gas emissions category are those that create capacity increases for motor vehicles. These capacity increases are still quite small, compared to those planned in larger, urban areas, but they create additional lane capacity for several thousand feet of roadway in order to alleviate reoccurring congestion at key points. Aviation service enhancements are also considered to increase greenhouse gas emissions as air travel is one of the most energy-intensive forms of travel.

Projects that are in the “unclear” column include certain transit and roadway improvement projects. These projects may reduce greenhouse gas emissions in some ways, but could increase them in others. New transit services get people out of their cars, but if older buses with out-of-date emissions technology are used to provide that transit service, then ridership must be high enough to outweigh the impacts of the additional bus emissions. As capital improvements are made to bus fleets, however, emissions will be reduced. Likewise, roadway improvements can decrease greenhouse gas emissions by reducing idling times, but at the same time they can increase the capacity of a roadway, allowing and encouraging more vehicles to use the roadway system. The roadway capacity increases in the 2008 RTP are intended to encourage greater flexibility to implement alternative mode options.

As a percentage of total project cost, projects that will likely reduce greenhouse gas emissions are estimated at approximately 57% of expenditures; those that will likely increase greenhouse gas emissions are approximately 1% of expenditures; and those whose effect is unclear make up 42% of expenditures. See Figure 6.6.



Policies that affect greenhouse gas emissions

Most of the goals and policies in the Regional Transportation Plan focus on reducing environmental impacts of motor vehicles, including emissions of greenhouse gasses.

GOAL #1 Pedestrian Transit Oriented Development (PTOD) Plan for and promote land use changes and development patterns consistent with the Regional Plan that encourage the development of walkable, mixed-use centers that support transportation enhancements and environmental improvements while improving the viability of transit systems.

GOAL #2 Pedestrian/Bicycle Friendly Communities Design an atmosphere elevating bicycle and pedestrian usage to the primary modes of transportation at Lake Tahoe.

GOAL #3 Utilization of Intelligent Transportation Systems (ITS). Technology shall be considered, implemented and used to increase usage of alternative modes.

GOAL #4 Actively pursue programs that promote the use and expansion of mass transit.

GOAL #5 Participate in state and local transportation planning efforts to ensure coordination and consistency in the transportation system, and to strengthen inter and intra-regional transportation.

GOAL #7 Develop parking management strategies for the Tahoe Region.

GOAL #8 Manage and respond to transportation demand through traffic management plans.

GOAL #10 Improve the mobility of the elderly, handicapped and other transit-dependent groups.

GOAL #12 Develop an on-going source of regional revenue to fund alternative transportation operations and maintenance.

For the full text of goals and associated policies, please refer to Chapter 2.

Figure 6.6. Regional Transportation Plan Project Strategies, Costs, and Greenhouse Gas Emission Effects

Project Strategies	Reduce GG	Increase GG	Unclear	Total
U.S. 50 Bicycle and Pedestrian Improvement Project(s)	$48,000,000			$48,000,000
Kings Beach Commercial Core Improvement Project	$50,000,000			$50,000,000
State Route 89 Realignment Project		$50,000,000		$50,000,000
Tahoe City Transit Center	$7,000,000			$7,000,000
U.S. 50 Stateline Corridor Project			$65,000,000	$65,000,000
Waterborne			$14,000,000	$14,000,000
Transit Strategies				
BlueGo Service Operational Enhancements			$4,073,400	$4,073,400
BlueGo Service Capital Enhancements	$4,740,000			$4,740,000
BlueGo Maintenance Facility			$7,000,000	$7,000,000
TART Service Operational Enhancements			$813,000	$813,000
TART Service Capital Enhancements	$281,300			$281,300
Lake Lapper Capital			$30,000	$30,000
Lake Lapper Operational			$240,000	$240,000
Aviation Capital		$1,500,000		$1,500,000
Aviation Operational		$800,000		$800,000
Bike and Pedestrian Strategies				
Pioneer Trl - from Lake Tahoe Blvd./US Hwy 50 to - Ski Run Blvd	$3,560,000			$3,560,000
Harrison Ave - from Lakeview Ave to Los Angelese Avenue	$450,000			$450,000
Lake Tahoe Nevada State Park - From Incline Village to Sand Harbor	$7,920,000			$7,920,000
Sawmill Rd - from Lake Tahoe Blvd to Us Hwy 50	$3,680,000			$3,680,000
Al Tahoe Trl - from Lake Tahoe Blvd/US Hwy 50 to Al Tahoe Trl	$500,000			$500,000
Lake Tahoe Blvd - from Sawmill Road to D Street	$2,100,000			$2,100,000
US Hwy 50 - from Cave Rock to Zephyr Cove	$9,500,000			$9,500,000
US Hwy 50 - from Zephyr Cove to Roundhill/Elks Point Trail	$2,960,000			$2,960,000
USFS Trl. - from Spring Creek to Cascade Rd.	$3,840,000			$3,840,000
Dollar Hill Trl - from Dollar Hill to N. Tahoe Regional Park	$6,160,000			$6,160,000
OLD Hwy 50 ROW - from CSLT City Limits to Douglas County Line	$6,760,000			$6,760,000

Figure 6.6

Project Strategies	Reduce GG	Increase GG	Unclear	Total
OLD Hwy 50 ROW - from CSR 89-Meyers to CSLT City Limits	$9,480,000			$9,480,000
Lake Tahoe-Nevada State Park - from Incline Village to Sand Harbor	$990,000			$990,000
College Drive - from Mt. Rose Hwy to Village Blvd	$200,000			$200,000
NSR 207/Kingsbury Grade - from Basin Boundary/Spooner Summit to US Hwy 50	$12,320,000			$12,320,000
Brockway Summit - from Kings Beach/CSR 28 to Brockway Summit	$1,610,000			$1,610,000
NSR 28 - from Sand Harbor to Chimney Beach	$120,800			$120,800
CSR 89 - from Cascade to N. Emerald Bay	$196,400			$196,400
Homewood - from Tahoe Ski Bowl Way to Silver Street	$2,000,000			$2,000,000
Incline Village/NSR 28 - from Southwood to Country Club Drive	$300,000			$300,000
Nevada South Demo - from Stateline to Round Hill Pines Beach	$6,000,000			$6,000,000
Smart Streets - Complete Streets Strategies				
US 50 and Sierra Blvd. Intersection Improvements		$755,000		$755,000
US 50 Signal Syncronization (Meyers to Stateline)			$3,000,000	$3,000,000
US 50 and Apache Intersection Improvements		$320,000		$320,000
Meyers Highway Corridor Operations Study			$700,000	$700,000
Tahoe City Traffic Management Program			$550,000	$550,000
Intersection Detection Equipment (various Locations)			$900,000	$900,000
Changeable Message Signs (Various Locations)			$2,850,000	$2,850,000
Sierra Traffic Operation System (TOS) (ITS at Various Locations in CA)	$5,300,000			$5,300,000
Traffic Monitoring Stations (various locations)	$520,000			$520,000
Bike & Pedestrian Facilities O&M	$2,000,000			$2,000,000
Safety and Rehabilitation Projects (Minor Projects-NV)	$1,800,000			$1,800,000
Safety and Rehabilitation Projects (Minor Projects-CA)	$2,800,000			$2,800,000
Emergency Roadway Repair Program	$600,000			$600,000
Total Project/Program Costs in 2008 dollars	**$203,688,500**	**$53,375,000**	**$99,156,400**	$356,219,900
Percentage of Total Cost	57%	15%	28%	

Figure 6.6 cont.

Conclusion

The main focus of the regional transportation plan is to implement projects that reduce dependency on the private automobile and ultimately reduce environmental and climate impacts. There is, however, a group of projects in the plan for which the environmental impact is as yet unclear. The impact of these individual projects on greenhouse gas emissions will be fully analyzed by project level environmental documentation during project development. Many of these projects provide mobility and social services that are vital to Lake Tahoe communities, such as frequent transit service in low-income neighborhoods. These systems provide the infrastructure necessary to shift people out of private vehicles, and as transit technology improves, will no doubt provide a reduction in greenhouse gases. Overall, the regional transportation plan directs over $200 million to projects that will reduce greenhouse gas emissions in the Basin from transportation-related sources over the next 20 years. The plan's strategies and overall policy direction set the stage for a strong focus on reducing greenhouse gas emissions in the Basin.

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Agenda item 4 (b) (ii)

REVIEW OF THE IMPLEMENTATION OF COMMITMENTS AND OF OTHER PROVISIONS OF THE CONVENTION

NATIONAL COMMUNICATIONS: GREENHOUSE GAS INVENTORIES FROM PARTIES INCLUDED IN ANNEX I TO THE CONVENTION

UNFCCC guidelines on reporting and review

CONTENTS

Introduction

This document contains two sets of revised guidelines pertaining to greenhouse gas (GHG) inventories of Parties included in Annex I to the Convention (Annex I Parties), adopted by the Conference of the Parties at its eighth session as annexes to decisions 18/CP.8 and 19/CP.8 (FCCC/CP/2002/7/Add.2).

The first, "Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC Reporting guidelines on annual inventories", was adopted with decision 18/CP.8. This decision requires Annex I Parties to begin using these guidelines for reporting the annual inventories due in the year 2004. For inventory submissions due in 2003, the decision states that Annex I Parties should continue to use the original inventory reporting guidelines adopted with decision 3/C.P.5. Annual inventories of Annex I Parties are due by 15 April each year.

The second, "Guidelines for the technical review of greenhouse gas inventories from Parties included in Annex I to the Convention", was adopted with decision 19/CP. 8. This decision requires that these guidelines be used for the reviews of GHG inventories beginning in the year 2003.

These guidelines have been compiled in a single document to facilitate ease of use by Annex I Parties.

GUIDELINES FOR THE PREPARATION OF NATIONAL COMMUNICATIONS BY PARTIES INCLUDED IN ANNEX I TO THE CONVENTION, PART I: UNFCCC REPORTING GUIDELINES ON ANNUAL INVENTORIES

A. Objectives

1. The objectives of the UNFCCC reporting guidelines on annual inventories are:

(a) To assist Parties included in Annex I to the Convention (Annex I Parties) in meeting their commitments under Articles 4 and 12 of the Convention and to assist Annex I Parties to the Kyoto Protocol in preparing to meet commitments under Articles 3, 5 and 7 of the Kyoto Protocol;

(b) To facilitate the process of considering annual national inventories, including the preparation of technical analysis and synthesis documentation;

(c) To facilitate the process of verification, technical assessment and expert review of the inventory information.

B. Principles and definitions

2. National greenhouse gas inventories, referred to below only as inventories, should be transparent, consistent, comparable, complete and accurate.

3. Inventories should be prepared using comparable methodologies agreed upon by the Conference of the Parties (COP), as indicated in paragraph 9 below.

4. In the context of these UNFCCC reporting guidelines on annual inventories:

Transparency means that the assumptions and methodologies used for an inventory should be clearly explained to facilitate replication and assessment of the inventory by users of the reported information. The transparency of inventories is fundamental to the success of the process for the communication and consideration of information;

Consistency means that an inventory should be internally consistent in all its elements with inventories of other years. An inventory is consistent if the same methodologies are used for the base and all subsequent years and if consistent data sets are used to estimate emissions or removals from sources or sinks. Under certain circumstances referred to in paragraphs 15 and 16, an inventory using different methodologies for different years can be considered to be consistent if it has been recalculated in a transparent manner, in accordance with the Intergovernmental Panel on Climate Change (IPCC) *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*;[1]

Comparability means that estimates of emissions and removals reported by Annex I Parties in inventories should be comparable among Annex I Parties. For this purpose, Annex I Parties should use the methodologies and formats agreed by the COP for estimating and reporting inventories. The allocation of different source/sink categories should follow the split of the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*,[2] at the level of its summary and sectoral tables;

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[1] Referred to in this document as the IPCC good practice guidance. The IPCC is currently developing *Good Practice Guidance for Land Use, Land-Use Change and Forestry*.

[2] Referred to in this document as the IPCC Guidelines.

Completeness means that an inventory covers all sources and sinks, as well as all gases, included in the IPCC Guidelines as well as other existing relevant source/sink categories which are specific to individual Annex I Parties and, therefore, may not be included in the IPCC Guidelines. Completeness also means full geographic coverage of sources and sinks of an Annex I Party;[3]

Accuracy is a relative measure of the exactness of an emission or removal estimate. Estimates should be accurate in the sense that they are systematically neither over nor under true emissions or removals, as far as can be judged, and that uncertainties are reduced as far as practicable. Appropriate methodologies should be used, in accordance with the IPCC good practice guidance, to promote *accuracy* in inventories.

5. In the context of these guidelines, definitions of common terms used in greenhouse gas inventory preparation are those provided in the IPCC good practice guidance.

C. Context

6. These UNFCCC reporting guidelines on annual inventories cover the estimation and reporting of greenhouse gas emissions and removals in both annual inventories and inventories included in national communications, as specified by decision 11/CP.4 and other relevant decisions of the COP.

7. An annual inventory submission shall consist of a national inventory report (NIR) and the common report format (CRF) tables, as described in paragraphs 38 through 43 and 44 through 50, respectively.

D. Base year

8. The year 1990 should be the base year for the estimation and reporting of inventories. According to the provisions of Article 4.6 of the Convention and decisions 9/CP.2 and 11/CP.4, the following Annex I Parties that are undergoing the process of transition to a market economy are allowed to use a base year or a period of years other than 1990, as follows:

Bulgaria:	1988
Hungary:	the average of the years 1985 to 1987
Poland:	1988
Romania:	1989
Slovenia:	1986

E. Methods

Methodology

9. Annex I Parties shall use the IPCC Guidelines to estimate and report on anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. In preparing national inventories of these gases, Annex I Parties shall also use the IPCC good practice guidance in order to improve transparency, consistency, comparability, completeness and accuracy.

10. In accordance with the IPCC Guidelines, Annex I Parties may use different methods (tiers) included in those guidelines, giving priority to those methods which, according to the decision trees in the IPCC good practice guidance, produce more accurate estimates. In accordance with the IPCC Guidelines, Annex I Parties may also use national methodologies which they consider better able to

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3 According to the instrument of ratification, acceptance, approval or accession to the Convention of each Annex I Party.

reflect their national situation, provided that these methodologies are compatible with the IPCC Guidelines and IPCC good practice guidance and are well documented and scientifically based.

11. For source categories that are determined to be key source categories, in accordance with IPCC good practice guidance, and estimated in accordance with the provisions in paragraph 13 below, Annex I Parties should make every effort to use a recommended method, in accordance with the corresponding decision trees of the IPCC good practice guidance. Annex I Parties should also make every effort to develop and/or select emission factors, and collect and select activity data, in accordance with the IPCC good practice guidance.

12. For most source categories, the IPCC Guidelines provide a default methodology which includes default emission factors and in some cases default activity data references. Furthermore, the IPCC good practice guidance provides updated default emission factors and default activity data for some sources and gases. As the assumptions implicit in these default data, factors and methods may not be appropriate for specific national contexts, it is preferable for Annex I Parties to use their own national emission factors and activity data, where available, provided that they are developed in a manner consistent with the IPCC good practice guidance, are considered to be more accurate, and reported transparently. The updated default activity data or emission factors provided in the IPCC good practice guidance should be used, where available, if Annex I Parties choose to use default factors or data due to lack of country-specific information.

Key source category determination

13. Annex I Parties shall identify their national key source categories for the base year and the latest reported inventory year, as described in the IPCC good practice guidance, using the tier 1 or tier 2 level and trend assessment.

Uncertainties

14. Annex I Parties shall quantitatively estimate the uncertainties in the data used for all source and sink categories using at least the tier 1 method, as provided in the IPCC good practice guidance. Alternatively, Annex I Parties may use the tier 2 method in the IPCC good practice guidance to address technical limitations in the tier 1 method. Uncertainty in the data used for all source and sink categories should also be qualitatively discussed in a transparent manner in the NIR, in particular for those sources that were identified as key sources.

Recalculations

15. The inventories of an entire time series, including the base year and all subsequent years for which inventories have been reported, should be estimated using the same methodologies, and the underlying activity data and emission factors should be obtained and used in a consistent manner. Recalculations should ensure consistency of the time series and shall be carried out only to improve accuracy and/or completeness. Where the methodology or manner in which underlying activity data and emission factors are gathered has changed, Annex I Parties should recalculate inventories for the base and subsequent years. Annex I Parties should evaluate the need for recalculations relative to the reasons provided by the IPCC good practice guidance, in particular for key sources. Recalculations should be performed in accordance with IPCC good practice guidance and the general principles set down in these UNFCCC guidelines.

16. In some cases it may not be possible to use the same methods and consistent data sets for all years due to a possible lack of activity data, emission factors or other parameters directly used in the calculation of emission estimates for some historical years, including the base year. In such cases, emissions or removals may need to be recalculated using alternative methods not generally covered by

paragraphs 9 through 12. In these instances, Annex I Parties should use one of the techniques provided by the IPCC good practice guidance (e.g., overlap, surrogate, interpolation, and extrapolation) to determine the missing values. Annex I Parties should document and demonstrate in the NIR that the time series is consistent, wherever such techniques are used.

Quality assurance/quality control (QA/QC)

17. Each Annex I Party shall elaborate an inventory QA/QC plan and implement general inventory QC procedures (tier 1)[4] in accordance with its QA/QC plan following the IPCC good practice guidance. In addition, Annex I Parties should apply source category specific QC procedures (tier 2) for key source categories and for those individual source categories in which significant methodological changes and/or data revisions have occurred, in accordance with IPCC good practice guidance. The implementation of tier 2 QC may be more efficiently implemented in conjunction with the evaluation of uncertainties in data sources. In addition, Annex I Parties should implement QA procedures by conducting a basic expert peer review (tier 1 QA) of their inventories in accordance with IPCC good practice guidance.

F. Reporting

1. General guidance

Estimates of emissions and removals

18. Article 12.1(a) of the Convention requires that each Party shall communicate to the COP, through the secretariat, inter alia, a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. As a minimum requirement, inventories shall contain information on the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). Annex I Parties should report anthropogenic emissions and removals of any other greenhouse gases whose 100-year global warming potential (GWP) values have been identified by the IPCC and adopted by the COP. Annex I Parties should also provide information on the following indirect greenhouse gases: carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs), as well as sulphur oxides (SO_x).

19. Greenhouse gas emissions and removals should be presented on a gas-by-gas basis in units of mass with emissions by sources listed separately from removals by sinks, except in cases where it may be technically impossible to separate information on sources and sinks in the areas of land use, land-use change and forestry. For HFCs and PFCs, emissions should be reported for each relevant chemical in the category on a disaggregated basis, except in cases where paragraph 27 below applies.

20. In addition, consistent with decision 2/CP.3, Annex I Parties should report aggregate emissions and removals of greenhouse gases, expressed in CO_2 equivalent terms at summary inventory level,[5] using GWP values provided by the IPCC in its Second Assessment Report, referred to below as 1995 IPCC GWP values, based on the effects of greenhouse gases over a 100-year time horizon. A list of these values is given in table 1 at the end of these guidelines. Table 1 will be amended to include any additional greenhouse gases and their 100-year GWP values, once the GWP values have been adopted by the COP.

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[4] As outlined in table 8.1 of the IPCC good practice guidance.

[5] CO_2 equivalent emissions should be provided at a level of category disaggregation similar to that specified in table Summary 1.A of the common reporting format.

21. Consistent with decision 2/CP.3, Annex I Parties should report actual emissions of HFCs, PFCs and SF_6, where data are available, providing disaggregated data by chemical (for example, HFC-134a) and source category in units of mass and in CO_2 equivalents. Annex I Parties should make every effort to develop the necessary sources of data for reporting actual emissions. For the source categories where the concept of potential emissions applies, and Annex I Parties do not yet have the necessary data to calculate actual emissions, Annex I Parties should report disaggregated potential emissions. Annex I Parties reporting actual emissions should also report potential emissions for the sources where the concept of potential emissions applies, for reasons of transparency and comparability.

22. Any Annex I Party that is a Party to the Kyoto Protocol and that in accordance with Article 3, paragraph 8 of the Kyoto Protocol chooses to use 1995 as its base year for HFCs, PFCs and SF_6 for the purposes of calculating assigned amounts pursuant to Article 3, paragraphs 7 and 8 of the Kyoto Protocol, should indicate this in its NIR and in the documentation boxes of the relevant tables of the CRF. Irrespective of the base year chosen for these gases for the purpose of the Kyoto Protocol, such Annex I Parties should report, to the extent that data are available, emission estimates and trends for these gases from 1990 onward, in accordance with the provisions of these guidelines.

23. Annex I Parties are strongly encouraged to also report emissions and removals of additional greenhouse gases for which 100-year GWP values are available, but not yet adopted by the COP. These emissions and removals should be reported separately from national totals. The GWP value and reference should be indicated.

24. In accordance with the IPCC Guidelines, international aviation and marine bunker fuel emissions should not be included in national totals but should be reported separately. Annex I Parties should make every effort to both apply and report according to the IPCC good practice guidance method for separation between domestic and international emissions. Annex I Parties should also report emissions from international aviation and marine bunker fuels as two separate entries in their inventories.

25. Annex I Parties should clearly indicate how feedstocks and non-energy use of fuels have been accounted for in the inventory, in the energy or industrial processes sector, in accordance with the IPCC good practice guidance.

26. If Annex I Parties account for effects of CO_2 capture from flue gases and subsequent CO_2 storage in their inventory, they should indicate in which source categories such effects are included, and provide transparent documentation of the methodologies used and the resulting effects.

27. Emissions and removals should be reported at the most disaggregated level of each source/sink category, taking into account that a minimum level of aggregation may be required to protect confidential business and military information.

Completeness

28. Where methodological or data gaps in inventories exist, information on these gaps should be presented in a transparent manner. Annex I Parties should clearly indicate the sources and sinks not considered in their inventories but which are included in the IPCC Guidelines, and explain the reasons for such exclusion. Similarly, Annex I Parties should indicate the parts of their geographical area, if any, not covered by their inventory and explain the reasons for their exclusion. In addition, Annex I Parties should use the notation keys presented below to fill in the blanks in all the tables in the CRF.[6]
This approach facilitates assessment of the completeness of an inventory.

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6 If notation keys are used in the NIR they should be consistent with those reported in the CRF.

The notation keys are as follows:

(a) "NO" (not occurring) for activities or processes in a particular source or sink category that do not occur within a country;

(b) "NE" (not estimated) for existing emissions by sources and removals by sinks of greenhouse gases which have not been estimated. Where "NE" is used in an inventory for emissions or removals of CO_2, N_2O, CH_4, HFCs, PFCs or SF_6, the Annex I Party should indicate in both the NIR and the CRF completeness table why emissions or removals have not been estimated; [7]

(c) "NA" (not applicable) for activities in a given source/sink category that do not result in emissions or removals of a specific gas. If categories in the CRF for which "NA" is applicable are shaded, they do not need to be filled in;

(d) "IE" (included elsewhere) for emissions by sources and removals by sinks of greenhouse gases estimated but included elsewhere in the inventory instead of the expected source/sink category. Where "IE" is used in an inventory, the Annex I Party should indicate, using the CRF completeness table, where in the inventory the emissions or removals from the displaced source/sink category have been included and the Annex I Party should explain such a deviation from the expected category;

(e) "C" (confidential) for emissions by sources and removals by sinks of greenhouse gases which could lead to the disclosure of confidential information, given the provisions of paragraph 27 above.

29. If Annex I Parties estimate and report emissions and removals from country-specific sources or sinks or of gases which are not part of the IPCC Guidelines, they should explicitly describe what source/sink categories or gases these are, as well as what methodologies, emission factors and activity data have been used for their estimation and provide the references for these data.

Key sources

30. Annex I Parties shall estimate and report the individual and cumulative percentage contributions of emissions from key source categories to their national total, with respect to both emission level and emission trend. The emissions should be expressed in terms of CO_2 equivalents using the methods provided in the IPCC good practice guidance. As indicated in paragraphs 41 and 47 below, this information should be included in table 7 of the CRF as well as the NIR using tables 7.A1 – 7.A3 of the IPCC good practice guidance adapted to the level of category disaggregation that the Annex I Party used for determining its key sources.

Verification

31. In accordance with the IPCC Guidelines, as well as for verification purposes, Annex I Parties should compare their national estimates of carbon dioxide emissions from fuel combustion with those estimates obtained using the IPCC reference approach, and report the results of this comparison in the CRF and NIR. Annex I Parties are also encouraged to report on any peer review of their inventory conducted nationally.

Uncertainties

32. Annex I Parties shall report, in the NIR, uncertainties estimated as indicated in paragraph 14 above, as well as methods used and underlying assumptions, with the purpose of helping to prioritize

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[7] Even if emissions are considered to be negligible, Parties should either report the emission estimate if calculated or use the notation key "NE".

efforts to improve the accuracy of national inventories in the future and guide decisions on methodological choice. This information should be presented using tables 6.1 and 6.2 of the IPCC good practice guidance. In addition, Annex I Parties should indicate in these tables those sources that have been identified as key sources in their inventory. If the methods used to estimate the level of uncertainty depart from the IPCC good practice guidance, these methods should be described.

Recalculations

33. Recalculations of previously submitted estimates of emissions and removals as a result of changes in methodologies, changes in the manner in which emission factors and activity data are obtained and used, or the inclusion of new sources or sinks which have existed since the base year but were not previously reported, should be reported for the base year and all subsequent years up to the year in which the recalculations are made.

34. Recalculations should be reported in the NIR, with explanatory information including justification for recalculations, and in the relevant CRF tables. Annex I Parties should also provide explanations for those cases in which they have not recalculated an estimate when such a recalculation is called for in the IPCC good practice guidance. Information on the procedures used for performing the recalculations, changes in the calculation methods, emission factors and activity data used, and the inclusion of sources or sinks not previously covered, should be reported with an indication of the relevant changes in each source or sink category where these changes have taken place. For key sources, Annex I Parties should include this information in the NIR, as indicated in paragraph 41 below.

35. Annex I Parties should report any other changes in estimates of emissions and removals, regardless of magnitude, and clearly indicate the reason for the changes compared with previously submitted inventories, e.g., error correction, statistical or editorial changes or reallocation of sources, using the corresponding CRF table, as indicated in paragraph 47 below and outlined in the annex II to these guidelines.

QA/QC

36. Annex I Parties shall report in the NIR on their QA/QC plan and give information on QA/QC procedures already implemented or to be implemented in the future.

Adjustments[8]

37. Inventories are to be reported without adjustments relating, for example, to climate variations or trade patterns of electricity. If Annex I Parties, in addition, carry out such adjustments to inventory data, they should be reported separately and in a transparent manner, with clear indications of the method followed.

2. National inventory report

38. Annex I Parties shall submit to the COP, through the secretariat, an NIR containing detailed and complete information on their inventories. The NIR should ensure transparency and contain sufficiently detailed information to enable the inventory to be reviewed. This information should cover the entire time series, from the base year[9] to the latest inventory year, and any changes to previously submitted inventories.

8 The adjustments referred to here relate, for example, to climate variations or trade patterns of electricity. They do not refer to adjustments under Article 5, paragraph 2, of the Kyoto Protocol.

9 According to the provisions of Article 4.6 of the Convention and decisions 9/CP.2 and 11/CP.4, some Parties with economies in transition are allowed to use base years other than 1990, as mentioned in paragraph 8 above.

39. Each year, an updated NIR shall be electronically submitted in its entirety to the COP, through the secretariat, in accordance with the relevant decisions of the COP; in instances where Annex I Parties have produced published hard copy versions of their NIR, they are also encouraged to submit copies to the secretariat.

40. The NIR shall include annual inventory information, submitted in accordance with paragraph 38 above.

41. The NIR should include:

(a) Descriptions, references and sources of information of the specific methodologies, assumptions, emission factors and activity data, as well as the rationale for their selection. It also should include an indication of the level of complexity (IPCC tiers) applied and a description of any national methodology used by the Annex I Party, as well as information on anticipated future improvements. For key sources, an explanation should be provided if the recommended methods from the appropriate decision tree in the IPCC good practice guidance are not used. In addition, activity data, emission factors and related information should be documented in accordance with the IPCC good practice guidance.

(b) A description of the national key sources as indicated in paragraph 30,[10] including:

(i) Reference to the key source tables in the CRF;

(ii) Information on the level of source category disaggregation used and its rationale;

(iii) Additional information relating to the methodology used for identifying key sources;

(c) With regard to possible double counting or non-counting of emissions, an indication in the corresponding sectoral part of the NIR:

(i) Whether feedstocks and non-energy use of fuels have been accounted for in the inventory, and if so, where they have been accounted for in the energy or industrial processes sector;

(ii) Whether CO_2 from agricultural soils has been estimated and if so, where it has been accounted for in the agriculture sector (under category 4.D – Agricultural soils) or in the land-use change and forestry (LUCF) sector (category 5.D – CO_2 emissions and removals from soil);

(iii) Whether emissions of CO_2 corresponding to atmospheric oxidation of CO, NMVOCs and CH_4 emissions from non-combustion and from non-biogenic processes, such as solvent use, coal mining and handling, venting and leakages of fossil fuels, have been accounted for in the inventory;

(iv) Information on source or sink categories excluded or potentially excluded, including efforts to develop estimates for future submissions;

[10] The secretariat will also perform a standardized key source determination for all Parties, based on table 7.1 of the IPCC good practice guidance. Parties may also use this approach if it is consistent with the way they prepare their inventories.

(d) Background data used to estimate emissions and removals from the LUCF sector to enhance transparency;[11]

(e) Information on how the effects of CO_2 capture from flue gases and subsequent CO_2 storage are accounted for in the inventory;

(f) Information on uncertainties, as requested in paragraph 32 above;

(g) Information on any recalculations relating to previously submitted inventory data, as requested in paragraphs 33 to 35 above, including changes in methodologies, sources of information and assumptions, as well as recalculations in response to the review process;

(h) Information on changes from previous years, not related to recalculations, including the changes in methodologies, sources of information and assumptions, as well as changes in response to the review process;

(i) Information on QA/QC as requested in paragraph 36 above, describing the QA/QC plan, and the QA/QC activities implemented for the entire inventory as well as for individual source categories, in particular key sources, and the entire inventory performed internally, as well as on the external reviews conducted, if any. Key findings on the quality of the input data, methods, processing and archiving and how they have been addressed, should be described;

(j) A description of the institutional arrangements for inventory preparation.

42. If any of the information required under paragraph 41 (a) to (h) above is provided in detail in the CRF, Annex I Parties should indicate in the NIR where in the CRF this information is provided.

43. The NIR should be reported in accordance with the outline contained in the annex I to these guidelines, ensuring that all information requested in paragraph 41 above is included.

3. Common reporting format

44. The common reporting format (CRF) is designed to ensure that Annex I Parties report quantitative data in a standardized format and to facilitate comparison of inventory data and trends among Annex I Parties. Explanation of information of a qualitative character should mainly be provided in the NIR rather than in the CRF tables. Such explanatory information should be cross-referenced to the specific section of the NIR.

45. Annex I Parties shall submit annually to the COP, through the secretariat, the information required in the CRF as contained in the annex II to these guidelines. This information shall be electronically submitted on an annual basis in its entirety to the COP, through the secretariat, in accordance with the relevant decisions of the COP.

46. The CRF is a standardized format for reporting estimates of greenhouse gas emissions and removals and other relevant information. The CRF allows for the improved handling of electronic submissions and facilitates the processing of inventory information and the preparation of useful technical analysis and synthesis documentation.

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[11] The Subsidiary Body for Scientific and Technological Advice (SBSTA) may wish to consider this issue when guidance on good practice for the land use, land-use change and forestry sector has been completed by the IPCC and, as appropriate, expand this subparagraph in any subsequent revisions of these guidelines.

47. The CRF consists of:

(a) Summary, sectoral and trend tables for all greenhouse gas emissions and removals;

(b) Sectoral background data tables for reporting implied emission factors[12] and activity data, including:

(i) IPCC worksheet 1-1 containing estimates of CO_2 emissions from fuel combustion using the IPCC reference approach and a table for comparing estimates under this reference approach with estimates under the sectoral approach, as well as providing explanations of any significant differences;[13]

(ii) Tables for reporting fossil fuel consumption for non-energy feedstocks, international bunkers and multilateral operations;

(c) Tables for reporting, inter alia, key source categories, recalculations and completeness of the inventory.

48. The CRF should be reported in accordance with the tables included in the annex II to these guidelines, ensuring that all information requested in paragraph 47 above is included. In completing these tables Annex I Parties should:

(a) Provide the full CRF for the latest inventory year and for those years for which any change in any sector has been made. For years where no changes are made, resubmission of full CRF tables is not necessary, but a reference should be made to the inventory submission in which the unchanged data were reported originally. Annex I Parties should ensure that a full and time-series consistent set of CRF tables is annually available for the entire time series from the base year onwards;

(b) Provide the CRF trend tables covering inventory years for the entire time series in one submission only, that is, in the CRF for the last inventory year;

(c) Provide completeness tables in one submission only if the information applies to all years. If the information in these tables differs for each reported year, then either the tables or information on the specific changes must be provided for each year in the CRF;

(d) Use the documentation boxes provided at the foot of the sectoral report and background data tables to provide cross-references to detailed explanations in the NIR, or any other information, as specified in those boxes.

49. Annex I Parties should provide the information requested in the additional information boxes. Where the information called for is inappropriate because of the methodological tier used by the Annex I Party, the corresponding cells should be completed using the notation key “NA”. In such cases, the Annex I Parties should cross-reference in the documentation box the relevant section in the NIR where equivalent information can be found.

50. Annex I Parties should use the notation keys, as specified in paragraph 28 above, in all tables of the CRF, to fill in the cells where no quantitative data are directly entered. Using the notation keys in

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12 The sectoral background tables were designed to allow calculation of implied emission factors. These are top-down ratios between an Annex I Party's emission estimates and activity data at the level of aggregation given by the tables. The implied emission factors are intended solely for purposes of data comparison. They will not necessarily be the emission factors actually used in the original emission estimate, unless this was a simple multiplication based on the same aggregate activity data used to calculate the implied emission factor.

13 Detailed explanations should be included in the NIR.

this way facilitates the assessment of the completeness of an inventory. Specific guidance is provided on how notation keys should be used in each CRF table where qualitative information is required.

G. Record keeping

51. Annex I Parties should gather and archive all relevant inventory information for each year, including all disaggregated emission factors, activity data and documentation on how these factors and data were generated, including expert judgement where appropriate, and how they have been aggregated for reporting in the inventory. This information should allow reconstruction of the inventory by the expert review teams, inter alia. Inventory information should be archived from the base year and should include corresponding data on the recalculations applied. The “paper trail”, which can include spreadsheets or databases used to compile inventory data, should enable estimates of emissions and removals to be traced back to the original disaggregated emission factors and activity data. Also, relevant supporting documentation related to QA/QC implementation, uncertainty evaluation, or key source analyses should be kept on file. This information should also facilitate the process of clarifying inventory data in a timely manner when the secretariat prepares annual compilations of inventories or assesses methodological issues. Annex I Parties are encouraged to collect and gather the information in a single national inventory facility or, at least, to keep the number of facilities to a minimum.

H. Systematic updating of the guidelines

52. These UNFCCC reporting guidelines on annual inventories shall be reviewed and revised, as appropriate, in accordance with decisions of the COP on this matter.

I. Language

53. The national inventory report shall be submitted in one of the official languages of the United Nations. Annex I Parties are also encouraged to submit, where relevant, a translation of the national inventory report into English.

Table 1. 1995 IPCC global warming potential (GWP) values[a] based on the effects of greenhouse gases over a 100-year time horizon

Greenhouse gas	Chemical formula	1995 IPCC GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
	Hydrofluorocarbons (HFCs)	
HFC-23	CHF_3	11 700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1 300
HFC-125	C_2HF_5	2 800
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1 000
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1 300
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3 800
HFC-227ea	C_3HF_7	2 900
HFC-236fa	$C_3H_2F_6$	6 300
HFC-254ca	$C_3H_3F_5$	560
	Perfluorocarbons	
Perfluoromethane	CF_4	6 500
Perfluoroethane	C_2F_6	9 200
Perfluoropropane	C_3F_8	7 000
Perfluorobutane	C_4F_{10}	7 000
Perfluorocyclobutane	c-C_4F_8	8 700
Perfluourpentane	C_5F_{12}	7 500
Perfluorohexane	C_6F_{14}	7 400
	Sulphur hexafluoride	
Sulphur hexafluoride	SF_6	23 900

[a] As provided by the IPCC in its second assessment report.

Annex I

STRUCTURE OF NATIONAL INVENTORY REPORT

EXECUTIVE SUMMARY

ES.1. Background information on greenhouse gas inventories and climate change (e.g., as it pertains to the national context, to provide information to the general public)
ES.2. Summary of national emission and removal related trends
ES.3. Overview of source and sink category emission estimates and trends
ES.4. Other information (e.g., indirect greenhouse gases)

Chapter 1: INTRODUCTION

1.1. Background information on greenhouse gas inventories and climate change (e.g., as it pertains to the national context, to provide information to the general public)
1.2. A description of the institutional arrangement for inventory preparation
1.3. Brief description of the process of inventory preparation (e.g., data collection, data processing, data storage)
1.4. Brief general description of methodologies and data sources used
1.5. Brief description of key source categories
1.6. Information on the QA/QC plan including verification and treatment of confidentiality issues where relevant
1.7. General uncertainty evaluation, including data on the overall uncertainty for the inventory totals
1.8. General assessment of the completeness (with reference to annex 5 of the structure of the national inventory report (NIR))

Chapter 2: TRENDS IN GREENHOUSE GAS EMISSIONS

Information should be provided in this chapter that provides an overview of emission trends, but it is not necessary to repeat information that is provided in the sector chapters and in the common reporting format (CRF) trend tables.

2.1. Description and interpretation of emission trends for aggregated greenhouse gas emissions
2.2. Description and interpretation of emission trends by gas
2.3. Description and interpretation of emission trends by source
2.4. Description and interpretation of emission trends for indirect greenhouse gases and SO_2

Chapters 3–9: *(e.g. SECTOR NAME (CRF sector number))*

The structure outlined below should be followed in each of the following sectoral chapters. The information should be reported following the IPCC sectors.

3.1. Overview of sector (e.g., quantitative overview and description)
3.2. *Source category* (CRF source category number)

For each IPCC source category (i.e., at the level of the table Summary 1.A of the CRF, or the level at which IPCC methods are described, or at the level that the Annex I Party estimates its greenhouse gas emissions) the following information should be provided:

- 3.2.1. Source category description (e.g., characteristics of sources)
- 3.2.2. Methodological issues (e.g., choice of methods/activity data/emission factors, assumptions, parameters and conventions underlying the emission and removal estimates – the rationale for their selection, any specific methodological issues (e.g. description of national methods))
- 3.2.3. Uncertainties and time-series consistency
- 3.2.4. Source-specific QA/QC and verification, if applicable
- 3.2.5. Source-specific recalculations, if applicable, including changes made in response to the review process
- 3.2.6 Source-specific planned improvements, if applicable (e.g., methodologies, activity data, emission factors, etc.), including those in response to the review process

Annex I Parties may report some of the information requested above in an aggregate form for some/several source categories if the same methodology, activity data and/or emission factors are used, in order to avoid repetition of information. For key source categories, the information should be detailed in order to enable a thorough review of the inventory.

Chapter 3: ENERGY (CRF sector 1)

In addition, the energy information should include the following:

Fuel combustion (CRF 1.A), including detailed information on:

- Comparison of the sectoral approach with the reference approach
- International bunker fuels
- Feedstocks and non-energy use of fuels
- CO_2 capture from flue gases and subsequent CO_2 storage
- Country-specific issues

Fugitive emissions from solid fuels and oil and natural gas (CRF 1.B)

Chapter 4: INDUSTRIAL PROCESSES (CRF sector 2)

Chapter 5: SOLVENT AND OTHER PRODUCT USE (CRF sector 3)

Chapter 6: AGRICULTURE (CRF sector 4)

Chapter 7: LUCF (CRF sector 5)

Chapter 8: WASTE (CRF sector 6)

Chapter 9: OTHER (CRF sector 7) (if applicable)

In addition, information previously included in the additional information and the documentation boxes of the CRF version for the trial period (FCCC/CP/1999/7) should be included and expanded in the NIR, where relevant, as specified in the appendix to this proposed structure.

Chapter 10: RECALCULATIONS AND IMPROVEMENTS

Information should be provided in this chapter that provides an overview of recalculations and improvements made to the inventory, but it is not necessary to repeat information that is provided in the sector chapters, specifically the source specific information to be provided, and in particular, Annex I Parties should cross-reference information provided in the sector chapters.

10.1. Explanations and justifications for recalculations
10.2. Implications for emission levels
10.3. Implications for emission trends, including time series consistency
10.4 Recalculations, including in response to the review process, and planned improvements to the inventory (e.g., institutional arrangements, inventory preparation)

REFERENCES

ANNEXES TO THE NATIONAL INVENTORY REPORT

Annex 1: Key sources
- Description of methodology used for identifying key sources
- Reference to the key source tables in the CRF
- Information on the level of disaggregation
- Tables 7.A1 - 7.A3 of the IPCC good practice guidance[1]

Annex 2: Detailed discussion of methodology and data for estimating CO_2 emissions from fossil fuel combustion

Annex 3: Other detailed methodological descriptions for individual source or sink categories (where relevant)

Annex 4: CO_2 reference approach and comparison with sectoral approach, and relevant information on the national energy balance

Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

Annex 6: Additional information to be considered as part of the NIR submission (where relevant) or other useful reference information

Annex 7: Tables 6.1 and 6.2 of the IPCC good practice guidance[2]

Annex 8: Other annexes - (Any other relevant information – optional).

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[1] This item has been added for consistency with the provisions in paragraph 30 of these guidelines.
[2] This item has been added for consistency with the provisions in paragraphs 32 and 41(f) of these guidelines.

Appendix A

ADDITIONAL GUIDANCE ON SECTORAL REPORTING TO BE INCLUDED IN THE CORRESPONDING SECTION OF THE NIR

This appendix provides guidance on additional information that Annex I Parties could include in their NIR in order to facilitate the review of the inventory. This list is not exhaustive. Additional information may be included in the NIR, depending on the Annex I Party's national approach for estimating greenhouse gas emissions and removals.

Energy

Fuel combustion
More specific information than that required in CRF table 1.A(a) could be provided, e.g.,

- Autoproduction of electricity
- Urban heating (in manufacturing industries, commercial and residential sectors).

Fugitive fuel emissions
Coal mining:
More specific information than that required in CRF table 1.B.1 could be provided, e.g.

- Number of active underground mines
- Number of mines with drainage (recovery) systems.

Oil and natural gas
More specific information than that required in CRF table 1.B.2 could be provided, e.g.

- Pipeline length
- Number of oil wells
- Number of gas wells
- Gas throughput[1]
- Oil throughput[1]

Industrial processes

Metal production
More specific information than is required in CRF table 2(I).A-G could be provided, e.g., data on virgin and recycled steel production.

Potential emissions of halocarbons and SF_6
In CRF table 2(II)s2, reporting of "production" refers to production of new chemicals. Recycled substances could be included in that table, but it should be ensured that double counting of emissions is avoided. Relevant explanations should be provided in the NIR.

[1] In the context of oil and gas production, throughput is a measure of the total production, such as barrels per day of oil, or cubic metres of gas per year. Specify the units of the reported values. Take into account that these values should be consistent with the activity data reported under production in table 1.B.2 of the CRF.

PFCs and SF_6 from metal production / Production of halocarbons and SF_6
The type of activity data used is to be specified in CRF tables 2(II).C-E (under column “description”). Where applying tier 1b (for 2.C Metal production), tier 2 (for 2.E Production of halocarbons and SF_6) and country-specific methods, any other relevant activity data used should be specified.

Consumption of HFCs, PFCs and SF_6
With regard to activity data reported in CRF table 2(II).F (“Amount of fluid remaining in products at decommissioning”), Annex I Parties should provide in the NIR information on the amount of the chemical recovered (recovery efficiency) and other relevant information used in the emission estimation.

CRF table 2.(II).F provides for reporting of the activity data and emission factors used to calculate actual emissions from consumption of halocarbons and SF_6 using the "bottom-up approach" (based on the total stock of equipment and estimated emission rates from this equipment). Some Annex I Parties may prefer to estimate their actual emissions following the alternative "top-down approach" (based on annual sales of equipment and/or gas). Those Annex I Parties should provide the activity data used in that CRF table and provide any other relevant information in the NIR. Data these Annex I Parties should provide include:

- The amount of fluid used to fill new products
- The amount of fluid used to service existing products
- The amount of fluid originally used to fill retiring products (the total nameplate capacity of retiring products)
- The product lifetime
- The growth rate of product sales, if this has been used to calculate the amount of fluid originally used to fill retiring products.

Alternatively, Annex I Parties may provide alternative formats with equivalent information.

Solvents and other product use

The IPCC Guidelines do not provide methodologies for the calculation of emissions of N_2O from solvent and other product use. If reporting such data in the CRF, Annex I Parties should provide additional information (activity data and emission factors) used to make these estimates in the NIR.

Agriculture

Cross-cutting
Annex I Parties should provide livestock population data in CRF table 4.A. Any further disaggregation of these data, e.g. for regions, for type (according to the classification recommended in the IPCC good practice guidance), could be provided in the NIR, where relevant**.** Consistent livestock population data should be used in the relevant CRF tables to estimate CH_4 emissions from enteric fermentation, CH_4 and N_2O emissions from manure management, N_2O emissions from soils, and N_2O emissions associated with manure production and use, as well as emissions from the use of manure as fuel and sewage-related emissions reported in the waste sector.

Enteric fermentation
More specific information than is required in CRF table 4.A could be provided, e.g., parameters relevant to the application of good practice guidance.

Manure management
More specific information than is required in CRF tables 4.B(a) and 4.B(b) could be provided, e.g., parameters relevant to the application of the IPCC good practice guidance. Information required in the additional information table may not be directly applicable to country-specific methods developed for methane conversion factor (MCF) calculations. If relevant data cannot be provided in the additional information box, information on how the MCF are derived should be described in the NIR.

Rice cultivation
More specific information than is required in CRF table 4.C could be provided. For example, when disaggregating by more than one region within a country and/or by growing season, provide additional information on disaggregation and related data in the NIR. Where available, provide activity data and scaling factors by soil type and rice cultivar in the NIR.

Agricultural soils
More specific information than is required in CRF table 4.D could be provided. For example,

- The IPCC Guidelines do not provide methodologies for the calculation of CH_4 emissions or removals by agricultural soils. If reporting such data, Annex I Parties should provide in the NIR additional information (activity data and emission factors) used to make these estimates;
- Annex I Parties which choose to account for CO_2 emissions and removals from agricultural soils under the agriculture sector (4.D Agricultural soils) should report background information on CO_2 emissions and removals estimates from agricultural soils (activity data, emissions factors) in the NIR;
- In addition to the data required in the additional information box of table 4.D, disaggregated values for $Frac_{GRAZ}$ according to animal type, and for $Frac_{BURN}$ according to crop types, should be provided in the NIR.

Prescribed burning of savannas and field burning of agricultural residues
More specific information than is required in CRF tables 4.E and 4.F could be provided. For example, the IPCC Guidelines do not provide methodologies for the calculation of CO_2 emissions from savanna burning or agricultural residues burning. If reporting such data, Annex I Parties should provide in the NIR additional information (activity data and emission factors) used to make these estimates.

Waste

Solid waste disposal and waste incineration
More specific information than is required in CRF tables 6.A and 6.C could be provided, e.g.,

- All relevant information used in the calculation should be provided in the NIR, if it is not already included in the additional information box of the CRF
- Composition of landfilled waste (%), according to paper and paperboard, food and garden waste, plastics, glass, textiles, other (specify according to inert or organic waste, respectively)
- Fraction of wastes recycled
- Fraction of wastes incinerated
- Number of solid waste disposal sites recovering CH_4.

Waste-water handling
More specific information than is required in CRF table 6.B could be provided. For example, with regard to data on N_2O from waste-water handling to be reported in CRF table 6.B, Annex I Parties using other methods for estimation of N_2O emissions from human sewage or waste-water treatment should provide in the NIR corresponding information on methods, activity data and emission factors used.

Annex II

COMMON REPORTING FORMAT[1]

Notes on the common reporting format

1. The common reporting format (CRF) is an integral part of the national inventory submission. It is designed to ensure that Annex I Parties report quantitative data in a standardized format, and to facilitate the comparison of inventory data across Annex I Parties. Details regarding any information of a non-quantitative character should be provided in the NIR.

2. The information provided in the CRF is aimed at enhancing the comparability and transparency of inventories by facilitating, inter alia, activity data and implied emission factor (IEF) cross-comparisons among Annex I Parties, and easy identification of possible mistakes, misunderstandings and omissions in the inventories.

3. As stated in these reporting guidelines, the CRF consists of summary report and sectoral report tables from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines) plus newly developed sectoral background data tables and other tables that are consistent with the IPCC Guidelines and the IPCC good practice guidance.

4. Some sectoral background tables call for the calculation of IEFs. These are top-down ratios between the Annex I Party's emissions estimate and aggregate activity data. The IEFs are intended solely for purposes of comparison. They will not necessarily be the emission factors actually used in the original emissions estimate, unless of course this was a simple multiplication based on the same aggregate activity data used to calculate the IEF.

5. Consistent with the IPCC Guidelines, memo items, such as emissions estimates from international marine and aviation bunker fuels, CO_2 emissions from biomass and emissions from multilateral operations, should be reported in the appropriate tables, but not included in the national totals.

6. Annex I Parties should use the documentation boxes at the foot of the tables to provide specific references to the relevant sections of the NIR where full details for a given sector/source category are to be provided.

7. Annex I Parties should fill in all the cells calling for emissions or removals estimates, activity data, or emission factors. Notation keys, as described in paragraph 28 of the reporting guidelines, should be used where data have not been entered.

8. In the sectoral background tables, below the source category "Other", an empty row indicates that country-specific source categories may be added. These source categories will automatically be included in the sectoral report tables.

9. Annex I Parties should complete the data in the additional information boxes. Where the information called for is inappropriate because of the methodological tier used by the Annex I Party, the corresponding cells should be completed using the indicator "NA".

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[1] The document FCCC/SBSTA/2002/L.5/Add.2, which contains the UNFCCC reporting guidelines on annual inventories, includes on pages 23 to 27 a descriptive section on agreed changes to the tables of the common reporting format . The complete tables were published separately as document FCCC/WEB/SBSTA/2002/1 prior to the eighth session of the Conference of the Parties. Because the complete common reporting format tables with the changes are now included in this document (beginning on page 25), the descriptive section has been deleted from this final version.

10. Table 5 (the land-use change and forestry sectoral report) should be completed by Annex I Parties. The corresponding sectoral background tables 5.A–D follow the IPCC Guidelines and should be completed by Annex I Parties that use IPCC default methods. Annex I Parties not using the IPCC default methods are encouraged to provide background data and descriptions for the methodologies used to estimate emissions/removals from the LUCF sector in the NIR in order to enhance transparency. Alternative formats for tables 5.A–D will be considered after the IPCC has developed the good practice guidance for the LULUCF sector.

11. Neither the order nor the notations of the columns, rows or cells should be changed in the tables as this will complicate data compilation. Any additions to the existing disaggregation of source and sink categories should be provided under "Other", if appropriate.

12. To simplify the layout of the tables and indicate clearly the specific reporting requirements for each table, only those cells that require entries by Annex I Parties have been left blank. Slight shading in cells indicates that they are expected to be filled in by software to be provided by the secretariat. However, Annex I Parties that choose not to use any software for completing the CRF would have to provide entries in those cells as well.

13. As in the current CRF, dark shading has been used in those cells that are not expected to contain any information.

List of tables

Explanatory note:

In order to avoid changes to the layout of the complex tables of the common reporting format, the tables have not been translated. The common reporting format is a standardized format to be used by Annex I Parties for electronic reporting of estimates of greenhouse gas emissions and removals and any other relevant information. Due to technical limitations, the layout of the printed version of the CRF in this document (e.g., size of tables and fonts) cannot be standardized. The list of tables in this document follows the order of tables in the electronic version of the CRF.

TABLE 1 SECTORAL REPORT FOR ENERGY
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
	(Gg)						
Total Energy							
A. Fuel Combustion Activities (Sectoral Approach)							
1. Energy Industries							
a. Public Electricity and Heat Production							
b. Petroleum Refining							
c. Manufacture of Solid Fuels and Other Energy Industries							
2. Manufacturing Industries and Construction							
a. Iron and Steel							
b. Non-Ferrous Metals							
c. Chemicals							
d. Pulp, Paper and Print							
e. Food Processing, Beverages and Tobacco							
f. Other *(as specified in table 1.A(a) sheet 2)*							
3. Transport							
a. Civil Aviation							
b. Road Transportation							
c. Railways							
d. Navigation							
e. Other Transportation *(as specified in table 1.A(a) sheet 3)*							

TABLE 1 SECTORAL REPORT FOR ENERGY
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
	(Gg)						
4. Other Sectors							
a. Commercial/Institutional							
b. Residential							
c. Agriculture/Forestry/Fisheries							
5. Other *(as specified in table 1.A(a) sheet 4)*							
a. Stationary							
b. Mobile							
B. Fugitive Emissions from Fuels							
1. Solid Fuels							
a. Coal Mining and Handling							
b. Solid Fuel Transformation							
c. Other *(as specified in table 1.B.1)*							
2. Oil and Natural Gas							
a. Oil							
b. Natural Gas							
c. Venting and Flaring							
Venting							
Flaring							
d. Other *(as specified in table 1.B.2)*							
Memo Items: [(1)]							
International Bunkers							
Aviation							
Marine							
Multilateral Operations							
CO_2 Emissions from Biomass							

[(1)] Countries are asked to report emissions from international aviation and marine bunkers and multilateral operations, as well as CO_2 emissions from biomass, under Memo Items. These emissions should not be included in the national total emissions from the energy sector. Amounts of biomass used as fuel are included in the national energy consumption but the corresponding CO_2 emissions are not included in the national total as it is assumed that the biomass is produced in a sustainable manner. If the biomass is harvested at an unsustainable rate, net CO_2 emissions are accounted for as a loss of biomass stocks in the land-use change and forestry sector.

Documentation Box: Parties should provide detailed explanations on the energy sector in Chapter 3: Energy (CRF sector 1) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 1.A(a) SECTORAL BACKGROUND DATA FOR ENERGY
Fuel Combustion Activities - Sectoral Approach
(Sheet 1 of 4)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	AGGREGATE ACTIVITY DATA		IMPLIED EMISSION FACTORS [2]			EMISSIONS			
	Consumption		CO_2	CH_4	N_2O	CO_2		CH_4	N_2O
	(TJ)	NCV/GCV[1]	(t/TJ)	(kg/TJ)			(Gg)		
1.A. Fuel Combustion									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
1.A.1. Energy Industries									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
a. Public Electricity and Heat Production									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
b. Petroleum Refining									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
c. Manufacture of Solid Fuels and Other Energy Industries									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									

Note: All footnotes for this table are given at the end of the table on sheet 4.

Note: For the coverage of fuel categories, refer to the IPCC Guidelines (Volume 1. Reporting Instructions - Common Reporting Framework, section 1.2, p. 1.19). If some derived gases (e.g. gas works, gas, coke oven gas, blast furnace gas) are considered, Parties should provide information on the allocation of these derived gases under the above fuel categories (liquid, solid, gaseous, biomass and other fuels) in the NIR (see also documentation box at the end of sheet 4 of this table).

TABLE 1.A(a) SECTORAL BACKGROUND DATA FOR ENERGY
Fuel Combustion Activities - Sectoral Approach
(Sheet 2 of 4)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	AGGREGATE ACTIVITY DATA		IMPLIED EMISSION FACTORS [2]			EMISSIONS			
	Consumption		CO_2	CH_4	N_2O		CO_2	CH_4	N_2O
	(TJ)	NCV/GCV[1]	(t/TJ)	(kg/TJ)			(Gg)		
1.A.2 Manufacturing Industries and Construction									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
a. Iron and Steel									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
b. Non-Ferrous Metals									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
c. Chemicals									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
d. Pulp, Paper and Print									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
e. Food Processing, Beverages and Tobacco									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
f. Other *(please specify)*									
(4)									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									

Note: All footnotes for this table are given at the end of the table on sheet 4.

TABLE 1.A(a) SECTORAL BACKGROUND DATA FOR ENERGY
Fuel Combustion Activities - Sectoral Approach
(Sheet 3 of 4)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	AGGREGATE ACTIVITY DATA		IMPLIED EMISSION FACTORS [2]			EMISSIONS			
	Consumption		CO_2	CH_4	N_2O		CO_2	CH_4	N_2O
	(TJ)	NCV/GCV[1]	(t/TJ)	(kg/TJ)			(Gg)		
1.A.3 Transport									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass									
Other Fuels						(3)			
a. Civil Aviation									
Aviation Gasoline									
Jet Kerosene									
b. Road Transportation									
Gasoline									
Diesel Oil									
Liquefied Petroleum Gases (LPG)									
Other Liquid Fuels *(please specify)*									
Gaseous Fuels									
Biomass						(3)			
Other Fuels *(please specify)*									
c. Railways									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Other Fuels *(please specify)*									
d. Navigation									
Residual Oil (Residual Fuel Oil)									
Gas/Diesel Oil									
Gasoline									
Other Liquid Fuels *(please specify)*									
Solid Fuels									
Gaseous Fuels									
Other Fuels *(please specify)*									
e. Other Transportation *(please specify)*									
(5)									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									

Note: All footnotes for this table are given at the end of the table on sheet 4.

TABLE 1.A(a) SECTORAL BACKGROUND DATA FOR ENERGY
Fuel Combustion Activities - Sectoral Approach
(Sheet 4 of 4)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	AGGREGATE ACTIVITY DATA		IMPLIED EMISSION FACTORS [2]			EMISSIONS			
	Consumption		CO_2	CH_4	N_2O	CO_2		CH_4	N_2O
	(TJ)	NCV/GCV[1]	(t/TJ)	(kg/TJ)			(Gg)		
1.A.4 Other Sectors									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
a. Commercial/Institutional									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
b. Residential									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
c. Agriculture/Forestry/Fisheries									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
1.A.5 Other *(Not specified elsewhere)* [6]									
a. Stationary *(please specify)*									
(7)									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									
b. Mobile *(please specify)*									
(8)									
Liquid Fuels									
Solid Fuels									
Gaseous Fuels									
Biomass						(3)			
Other Fuels									

(1) If activity data are calculated using net calorific values (NCV) as specified by the IPCC Guidelines, write NCV in this column. If gross calorific values (GCV) are used, write GCV in this column.

(2) Accurate estimation of CH_4 and N_2O emissions depends on combustion conditions, technology and emission control policy, as well as on fuel characteristics. Therefore, caution should be used when comparing the implied emission factors across countries.

(3) Although carbon dioxide emissions from biomass are reported in this table, they will not be included in the total CO_2 emissions from fuel combustion. The value for total CO_2 from biomass is recorded in Table1 sheet 2 under the Memo Items.

(4) Use this cell to list all activities covered under "f. Other".

(5) Use this cell to list all activities covered under "e. Other transportation".

(6) Include military fuel use under this category.

(7) Use this cell to list activities covered under "1.A.5.a Other - stationary".

(8) Use this cell to list activities covered under "1.A.5.b Other - mobile".

Documentation Box:
• Parties should provide detailed explanations on the fuel combustion sub-sector in the corresponding part of Chapter 3: Energy (CRF sub-sector 1.A) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• If estimates are based on GCV, use this documentation box to provide reference to the relevant section of the NIR where the information necessary to allow the calculation of the activity data based on NCV can be found.
• If some derived gases (e.g. gas works gas, coke oven gas, blast furnace gas) are considered, use this documentation box to provide a reference to the relevant section of the NIR containing the information on the allocation of these derived gases under the above fuel categories (liquid, soild, gaseous, biomass and other fuels).

TABLE 1.A(b) SECTORAL BACKGROUND DATA FOR ENERGY
CO_2 from Fuel Combustion Activities - Reference Approach (IPCC Worksheet 1-1)
(Sheet 1 of 1)

Country
Year
Submission

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor (TJ/Unit)	NCV/GCV [1]	Apparent consumption (TJ)	Carbon emission factor (t C/TJ)	Carbon content (Gg C)	Carbon stored (Gg C)	Net carbon emissions (Gg C)	Fraction of carbon oxidized	Actual CO_2 emissions (Gg CO_2)
Liquid Fossil	Primary Fuels	Crude Oil																
		Orimulsion																
		Natural Gas Liquids																
	Secondary Fuels	Gasoline																
		Jet Kerosene																
		Other Kerosene																
		Shale Oil																
		Gas / Diesel Oil																
		Residual Fuel Oil																
		Liquefied Petroleum Gas (LPG)																
		Ethane																
		Naphtha																
		Bitumen																
		Lubricants																
		Petroleum Coke																
		Refinery Feedstocks																
		Other Oil																
Other Liquid Fossil																		
Liquid Fossil Totals																		
Solid Fossil	Primary Fuels	Anthracite [2]																
		Coking Coal																
		Other Bituminous Coal																
		Sub-bituminous Coal																
		Lignite																
		Oil Shale																
		Peat																
	Secondary Fuels	BKB[3] and Patent Fuel																
		Coke Oven/Gas Coke																
Other Solid Fossil																		
Solid Fossil Totals																		
Gaseous Fossil		Natural Gas (Dry)																
Other Gaseous Fossil																		
Gaseous Fossil Totals																		
Total																		
Biomass total																		
		Solid Biomass																
		Liquid Biomass																
		Gas Biomass																

[1] To convert quantities in previous columns to energy units, use net calorific values (NCV) and write NCV in this column. If gross calorific values (GCV) are used, write GCV in this column.

[2] If data for Anthracite are not available separately, include with Other Bituminous Coal.

[3] BKB: Brown coal/peat briquettes.

Documentation Box: Parties should provide detailed explanations on the fuel combustion sub-sector, including information related to CO_2 from the Reference approach, in the corresponding part of Chapter 3: Energy (CRF sub-sector 1.A) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 1.A(c) COMPARISON OF CO_2 EMISSIONS FROM FUEL COMBUSTION
(Sheet 1 of 1)

Country
Year
Submission

FUEL TYPES	REFERENCE APPROACH			SECTORAL APPROACH [1]		DIFFERENCE [2]	
	Apparent energy consumption [3] (PJ)	Apparent energy consumption (excluding non-energy use and feedstocks) [4] (PJ)	CO_2 emissions (Gg)	Energy consumption (PJ)	CO_2 emissions (Gg)	Energy consumption (%)	CO_2 emissions (%)
Liquid Fuels (excluding international bunkers)							
Solid Fuels (excluding international bunkers) [5]							
Gaseous Fuels							
Other [5]							
Total [5]							

[1] "Sectoral approach" is used to indicate the approach (if different from the Reference approach) used by the Party to estimate CO_2 emissions from fuel combustion as reported in table 1.A(a), sheets 1-4.
[2] Difference in CO_2 emissions estimated by the Reference approach (RA) and the Sectoral approach (SA) (difference = 100% x ((RA-SA)/SA)). For calculating the difference in energy consumption between the two approaches, data as reported in the column "Apparent energy consumption (excluding non-energy use and feedstocks)" are used for the Reference approach.
[3] Apparent energy consumption data shown in this column are as in table 1.A(b).

[4] For the purposes of comparing apparent energy consumption from the Reference approach with energy consumption from the Sectoral approach, Parties should, in this column, subtract from the apparent energy consumption (Reference approach) the energy content corresponding to the fuel quantities used as feedstocks and/or for non-energy purposes, in accordance with the accounting of energy use in the Sectoral approach.

[5] Emissions from biomass are not included.

Note: The Reporting Instructions of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories require that estimates of CO_2 emissions from fuel combustion, derived using a detailed Sectoral approach, be compared to those from the Reference approach (Worksheet 1-1 of the IPCC Guidelines, Volume 2, Workbook). This comparison is to assist in verifying the Sectoral data.

Documentation Box:
• Parties should provide detailed explanations on the fuel combustion sub-sector, including information related to the comparison of CO_2 emissions calculated using the Sectoral approach with those calculated using the Reference approach, in the corresponding part of Chapter 3: Energy (CRF sub-sector 1.A) of the NIR. Use this documentation box to provide references to the relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• If the CO_2 emission estimates from the two approaches differ by more than 2 per cent, Parties should briefly explain the cause of this difference in this documentation box and provide a reference to the relevant section of the NIR where this difference is explained in more detail.

TABLE 1.A(d) SECTORAL BACKGROUND DATA FOR ENERGY
Feedstocks and Non-Energy Use of Fuels
(Sheet 1 of 1)

Country
Year
Submission

FUEL TYPE	ACTIVITY DATA AND RELATED INFORMATION		IMPLIED EMISSION FACTOR	ESTIMATE
	Fuel quantity (TJ)	Fraction of carbon stored	Carbon emission factor (t C/TJ)	Carbon stored in non-energy use of fuels (Gg C)
Naphtha [1]				
Lubricants				
Bitumen				
Coal Oils and Tars (from Coking Coal)				
Natural Gas[1]				
Gas/Diesel Oil [1]				
LPG [1]				
Ethane [1]				
Other *(please specify)*				
Total				
Total amount of C and CO_2 from feedstocks and non-energy use of fuels that is included as emitted CO_2 in the Reference approach				

Additional information [a]

CO_2 not emitted ($Gg\ CO_2$)	Subtracted from energy sector *(specify source category)*

[1] Enter data for those fuels that are used as feedstocks (fuel used as raw materials for manufacture of products such as plastics or fertilizers) or for other non-energy use (fuels not used as fuel or transformed into another fuel (e.g. bitumen for road construction, lubricants)).

[a] The fuel lines continue from the table to the left.

Documentation box: A fraction of energy carriers is stored in such products as plastics or asphalt. The non-stored fraction of the carbon in the energy carrier or product is oxidized, resulting in carbon dioxide emissions, either during use of the energy carriers in the industrial production (e.g. fertilizer production), or during use of the products (e.g. solvents, lubricants), or in both (e.g. monomers). To report associated emissions, use the above table, filling in an extra table, as shown below.

Associated CO_2 emissions (Gg)	Allocated under *(Specify source category, e.g. Waste Incineration)*

• Parties should provide detailed explanations on the fuel combustion sub-sector, including information related to feedstocks, in the corresponding part of Chapter 3: Energy (CRF sub-sector 1.A) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

• The above table is consistent with the IPCC Guidelines. Parties that take into account the emissions associated with the use and disposal of these feedstocks could continue to use their methodology, but should indicate this in this documentation box and provide a reference to the relevant section of the NIR where further explanation can be found.

TABLE 1.B.1 SECTORAL BACKGROUND DATA FOR ENERGY
Fugitive Emissions from Solid Fuels
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA	IMPLIED EMISSION FACTORS		EMISSIONS		
	Amount of fuel produced	CH_4 [1]	CO_2	CH_4		CO_2
				Recovery/Flaring [2]	Emissions [3]	
	(Mt)	(kg/t)		(Gg)		
1. B. 1. a. Coal Mining and Handling						
i. Underground Mines[4]						
Mining Activities						
Post-Mining Activities						
ii. Surface Mines[4]						
Mining Activities						
Post-Mining Activities						
1. B. 1. b. Solid Fuel Transformation						
1. B. 1. c. Other *(please specify)* [5]						

(1) The IEFs for CH_4 are estimated on the basis of gross emissions as follows: (CH_4 emissions + amounts of CH_4 flared/recovered) / activity data.

(2) Amounts of CH_4 drained (recovered), utilized or flared.

(3) Final CH_4 emissions after subtracting the amounts of CH_4 utilized or recovered.

(4) In accordance with the IPCC Guidelines, emissions from Mining Activities and Post-Mining Activities are calculated using the activity data of the amount of fuel produced for Underground Mines and Surface Mines.

(5) This category is to be used for reporting any other solid fuel-related activities resulting in fugitive emissions, such as emissions from abandoned mines and waste piles.

Note: There are no clear references to the coverage of 1.B.1.b. and 1.B.1.c. in the IPCC Guidelines. Make sure that the emissions entered here are not reported elsewhere. If they are reported under another source category, indicate this by using notation key IE and making the necessary reference in Table 9 (completeness).

Documentation box:
• Parties should provide detailed explanations on the fugitive emissions from source category 1.B.1 Solid fuels, in the corresponding part of Chapter 3: Energy (CRF source category 1.B.1) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • Regarding data on the amount of fuel produced entered in the above table, specify in this documentation box whether the fuel amount is based on the run-of-mine (ROM) production or on the saleable production. • If entries are made for "Recovery/Flaring", indicate in this documentation box whether CH_4 is flared or recovered and provide a reference to the section in the NIR where further details on recovery/flaring can be found. • If estimates are reported under 1.B.1.b. and 1.B.1.c., use this documentation box to provide information regarding activities covered under these categories and to provide a reference to the section in the NIR where the background information can be found.

TABLE 1.B.2 SECTORAL BACKGROUND DATA FOR ENERGY
Fugitive Emissions from Oil, Natural Gas and Other Sources
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA [1]			IMPLIED EMISSION FACTORS			EMISSIONS		
	Description [1]	Unit [1]	Value	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
				(kg/unit) [2]			(Gg)		
1. B. 2. a. Oil [3]									
I. Exploration	*(e.g. number of wells drilled)*								
ii. Production[4]	*(e.g. PJ of oil produced)*								
iii. Transport	*(e.g. PJ oil loaded in tankers)*								
iv. Refining / Storage	*(e.g. PJ oil refined)*								
v. Distribution of Oil Products	*(e.g. PJ oil refined)*								
vi. Other									
1. B. 2. b. Natural Gas									
i. Exploration									
ii. Production [4] / Processing	*(e.g. PJ gas produced)*								
iii. Transmission	*(e.g. PJ gas consumed)*								
iv. Distribution	*(e.g. PJ gas consumed)*								
v. Other Leakage	*(e.g. PJ gas consumed)*								
at industrial plants and power stations									
in residential and commercial sectors									
1. B. 2. c. Venting [5]									
i. Oil	*(e.g. PJ oil produced)*								
ii. Gas	*(e.g. PJ gas produced)*								
iii. Combined									
Flaring									
i. Oil	*(e.g. PJ gas consumption)*								
ii. Gas	*(e.g. PJ gas consumption)*								
iii. Combined									
1.B.2.d. Other *(please specify)* [6]									

[1] Specify the activity data used in the Description column (see examples). Specify the unit of the activity data in the Unit column using one of the following units: PJ, Tg, 10^6 m^3, 10^6 bbl/yr, km, number of sources (e.g. wells).
[2] The unit of the implied emission factor will depend on the unit of the activity data used, and is therefore not specified in this column.
[3] Use the category also to cover emissions from combined oil and gas production fields. Natural gas processing and distribution from these fields should be included under 1.B.2.b.ii and 1.B.2.b.iv, respectively.
[4] If using default emission factors, these categories will include emissions from production other than venting and flaring.
[5] If using default emission factors, emissions from Venting and Flaring from all oil and gas production should be accounted for under Venting.
[6] For example, fugitive CO_2 emissions from production of geothermal power could be reported here.

Documentation box:
• Parties should provide detailed explanations on the fugitive emissions from source category 1.B.2 Oil and natural gas, in the corresponding part of Chapter 3: Energy (CRF source category 1.B.2) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• Regarding data on the amount of fuel produced entered in this table, specify in this documentation box whether the fuel amount is based on the raw material production or on the saleable production. Note cases where more than one type of activity data is used to estimate emissions.
• Venting and Flaring: Parties using the IPCC software could report venting and flaring emissions together, indicating this in this documentation box.
• If estimates are reported under "1.B.2.d Other", use this documentation box to provide information regarding activities covered under this category and to provide a reference to the section in the NIR where background information can be found.

TABLE 1.C SECTORAL BACKGROUND DATA FOR ENERGY
International Bunkers and Multilateral Operations
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA	IMPLIED EMISSION FACTORS			EMISSIONS		
	Consumption	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
	(TJ)	(t/TJ)			(Gg)		
Aviation Bunkers							
Jet Kerosene							
Gasoline							
Marine Bunkers							
Gasoline							
Gas/Diesel Oil							
Residual Fuel Oil							
Lubricants							
Coal							
Other *(please specify)*							
Multilateral Operations [1]							

Additional information

Fuel consumption	Distribution [a] (per cent)	
	Domestic	International
Aviation		
Marine		

[a] For calculating the allocation of fuel consumption, the sums of fuel consumption for domestic navigation and aviation (Table 1.A(a)) and for international bunkers (Table 1.C) are used.

[1] Parties may choose to report or not report the activity data and implied emission factors for multilateral operations consistent with the principle of confidentiality stated in the UNFCCC reporting guidelines. In any case, Parties should report the emissions from multilateral operations, where available, under the Memo Items section of the Summary tables and in the Sectoral report table for energy.

Note: In accordance with the IPCC Guidelines, international aviation and marine bunker fuel emissions from fuel sold to ships or aircraft engaged in international transport should be excluded from national totals and reported separately for information purposes only.

Documentation box: • Parties should provide detailed explanations on the fuel combustion sub-sector, including international bunker fuels, in the corresponding part of Chapter 3: Energy (CRF sub-sector 1.A) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • Provide in this documentation box a brief explanation on how the consumption of international marine and aviation bunker fuels was estimated and separated from domestic consumption, and include a reference to the section of the NIR where the explanation is provided in more detail.

TABLE 2(I) SECTORAL REPORT FOR INDUSTRIAL PROCESSES
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs(1)		PFCs(1)		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)				(Gg)					
Total Industrial Processes													
A. Mineral Products													
1. Cement Production													
2. Lime Production													
3. Limestone and Dolomite Use													
4. Soda Ash Production and Use													
5. Asphalt Roofing													
6. Road Paving with Asphalt													
7. Other *(as specified in table 2(I)A-G)*													
B. Chemical Industry													
1. Ammonia Production													
2. Nitric Acid Production													
3. Adipic Acid Production													
4. Carbide Production													
5. Other *(as specified in table 2(I)A-G)*													
C. Metal Production													
1. Iron and Steel Production													
2. Ferroalloys Production													
3. Aluminium Production													
4. SF_6 Used in Aluminium and Magnesium Foundries													
5. Other *(as specified in table 2(I)A-G)*													

P = Potential emissions based on Tier 1 approach of the IPCC Guidelines. A = Actual emissions based on Tier 2 approach of the IPCC Guidelines. This applies only to source categories where methods exist for both tiers.

(1) The emissions of HFCs and PFCs are to be expressed as CO_2 equivalent emissions. Data on disaggregated emissions of HFCs and PFCs are to be provided in Table 2(II).

TABLE 2(I) SECTORAL REPORT FOR INDUSTRIAL PROCESSES
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
				P	A	P	A	P	A				
	(Gg)			CO_2 equivalent (Gg)						(Gg)			
D. Other Production													
1. Pulp and Paper													
2. Food and Drink[2]													
E. Production of Halocarbons and SF_6													
1. By-product Emissions													
Production of HCFC-22													
Other													
2. Fugitive Emissions													
3. Other *(as specified in table 2(II))*													
F. Consumption of Halocarbons and SF_6													
1. Refrigeration and Air Conditioning Equipment													
2. Foam Blowing													
3. Fire Extinguishers													
4. Aerosols/ Metered Dose Inhalers													
5. Solvents													
6. Other applications using ODS[3] substitutes													
7. Semiconductor Manufacture													
8. Electrical Equipment													
9. Other *(as specified in table 2(II)*													
G. Other *(as specified in tables 2(I).A-G and 2(II))*													

P = Potential emissions based on Tier 1 approach of the IPCC Guidelines. A = Actual emissions based on Tier 2 approach of the IPCC Guidelines. This applies only to source categories where methods exist for both tiers.

(1) The emissions of HFCs and PFCs are to be expressed as CO_2 equivalent emissions. Data on disaggregated emissions of HFCs and PFCs are to be provided in Table 2(II).
(2) CO_2 from Food and Drink Production (e.g. gasification of water) can be of biogenic or non-biogenic origin. Only information on CO_2 emissions of non-biogenic origin should be reported.
(3) ODS: ozone-depleting substances.

Documentation box: Parties should provide detailed explanations on the industrial processes sector in Chapter 4: Industrial processes (CRF sector 2) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 2(I).A-G SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES
Emissions of CO_2, CH_4 and N_2O
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		IMPLIED EMISSION FACTORS [2]			EMISSIONS					
	Production/Consumption quantity		CO_2	CH_4	N_2O	CO_2		CH_4		N_2O	
						Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]
	Description [1]	(kt)	(t/t)			(Gg)					
A. Mineral Products											
1. Cement Production	*(e.g. cement or clinker production)*										
2. Lime Production											
3. Limestone and Dolomite Use											
4. Soda Ash											
Soda Ash Production											
Soda Ash Use											
5. Asphalt Roofing											
6. Road Paving with Asphalt											
7. Other *(please specify)*											
Glass Production											
B. Chemical Industry											
1. Ammonia Production [5]											
2. Nitric Acid Production											
3. Adipic Acid Production											
4. Carbide Production											
Silicon Carbide											
Calcium Carbide											
5. Other *(please specify)*											
Carbon Black											
Ethylene											
Dichloroethylene											
Styrene											
Methanol											

[1] Where the IPCC Guidelines provide options for activity data, e.g. cement production or clinker production for estimating the emissions from Cement Production, specify the activity data used (as shown in the example in parenthesis) in order to make the choice of emission factor more transparent and to facilitate comparisons of implied emission factors.

[2] The implied emission factors (IEF) are estimated on the basis of gross emissions as follows: IEF = (emissions plus amounts recovered, oxidized, destroyed or transformed) / activity data.

[3] Final emissions are to be reported (after subtracting the amounts of emission recovery, oxidation, destruction or transformation).

[4] Amounts of emission recovery, oxidation, destruction or transformation.

[5] To avoid double counting, make offsetting deductions for fuel consumption (e.g. natural gas) in Ammonia Production, first for feedstock use of the fuel, and then for a sequestering use of the feedstock.

TABLE 2(I).A-G SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES
Emissions of CO_2, CH_4 and N_2O
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		IMPLIED EMISSION FACTORS [2]			EMISSIONS					
	Production/Consumption quantity		CO_2	CH_4	N_2O	CO_2		CH_4		N_2O	
						Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]
	Description [1]	(kt)	(t/t)			(Gg)					
C. Metal Production											
1. Iron and Steel Production											
Steel											
Pig Iron											
Sinter											
Coke											
Other *(please specify)*											
2. Ferroalloys Production											
3. Aluminium Production											
4. SF_6 Used in Aluminium and Magnesium Foundries											
5. Other *(please specify)*											
D. Other Production											
1. Pulp and Paper											
2. Food and Drink											
G. Other *(please specify)*											

[1] Where the IPCC Guidelines provide options for activity data, e.g. cement production or clinker production for estimating the emissions from Cement Production, specify the activity data used (as shown in the example in parenthesis) in order to make the choice of emission factor more transparent and to facilitate comparisons of implied emission factors.

[2] The implied emission factors (IEF) are estimated on the basis of gross emissions as follows: IEF = (emissions + amounts recovered, oxidized, destroyed or transformed) / activity data.

[3] Final emissions are to be reported (after subtracting the amounts of emission recovery, oxidation, destruction or transformation).

[4] Amounts of emission recovery, oxidation, destruction or transformation.

Documentation box:
• Parties should provide detailed explanations on the industrial processes sector in Chapter 4: Industrial processes (CRF sector 2) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• In relation to metal production, more specific information (e.g. data on virgin and recycled steel production) could be provided in this documentation box, or in the NIR, together with a reference to the relevant section.
• Confidentiality: Where only aggregate figures for activity data are provided, e.g. due to reasons of confidentiality, a note indicating this should be provided in this documentation box.

TABLE 2(II) SECTORAL REPORT FOR INDUSTRIAL PROCESSES - EMISSIONS OF HFCs, PFCs AND SF_6
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFC-23	HFC-32	HFC-41	HFC-43-10mee	HFC-125	HFC-134	HFC-134a	HFC-152a	HFC-143	HFC-143a	HFC-227ea	HFC-236fa	HFC-245ca	Unspecified mix of listed HFCs[(1)]	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Unspecified mix of listed PFCs[(1)]	Total PFCs	SF_6
	(t)[(2)]													CO_2 equivalent (Gg)		(t)[(2)]							CO_2 equivalent (Gg)		(t)[(2)]
Total Actual Emissions of Halocarbons (by chemical) and SF_6																									
C. Metal Production																									
Aluminium Production																									
SF_6 Used in Aluminium Foundries																									
SF_6 Used in Magnesium Foundries																									
E. Production of Halocarbons and SF_6																									
1. By-product Emissions																									
Production of HCFC-22																									
Other																									
2. Fugitive Emissions																									
3. Other *(as specified in table 2(II).C,E)*																									
F(a). Consumption of Halocarbons and SF_6 (actual emissions - Tier 2)																									
1. Refrigeration and Air Conditioning Equipment																									
2. Foam Blowing																									
3. Fire Extinguishers																									
4. Aerosols/Metered Dose Inhalers																									
5. Solvents																									
6. Other applications using ODS[(3)] substitutes																									
7. Semiconductor Manufacture																									
8. Electrical Equipment																									
9. Other *(as specified in table 2(II)F)*																									
G. Other *(please specify)*																									

Note:
1. All footnotes for this table are given at the end of the table on sheet 2.
2. Gases with GWP values not yet agreed upon by the Conference of the Parties should be reported in Table 9(b).

TABLE 2(II) SECTORAL REPORT FOR INDUSTRIAL PROCESSES - EMISSIONS OF HFCs, PFCs AND SF_6
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFC-23	HFC-32	HFC-41	HFC-43-10mee	HFC-125	HFC-134	HFC-134a	HFC-152a	HFC-143	HFC-143a	HFC-227ea	HFC-236fa	HFC-245ca	Unspecified mix of listed HFCs (1)	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Unspecified mix of listed PFCs (1)	Total PFCs	SF_6
	(t)(2)													CO_2 equivalent (Gg)		(t)(2)							CO_2 equivalent (Gg)		(t)(2)
F(p). Total Potential Emissions of Halocarbons (by chemical) and SF_6 (4)																									
Production(5)																									
Import:																									
In bulk																									
In products (6)																									
Export:																									
In bulk																									
In products (6)																									
Destroyed amount																									

	HFC-23	HFC-32	HFC-41	HFC-43-10mee	HFC-125	HFC-134	HFC-134a	HFC-152a	HFC-143	HFC-143a	HFC-227ea	HFC-236fa	HFC-245ca	Unspecified mix of listed HFCs	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Unspecified mix of listed PFCs	Total PFCs	SF_6
GWP values used	**11700**	**650**	**150**	**1300**	**2800**	**1000**	**1300**	**140**	**300**	**3800**	**2900**	**6300**	**560**			**6500**	**9200**	**7000**	**7000**	**8700**	**7500**	**7400**			**23900**
Total Actual Emissions (7) (CO_2 equivalent (Gg))																									
C. Metal Production																									
E. Production of Halocarbons and SF_6																									
F(a). Consumption of Halocarbons and SF_6																									
G. Other																									

	HFC-23	HFC-32	HFC-41	HFC-43-10mee	HFC-125	HFC-134	HFC-134a	HFC-152a	HFC-143	HFC-143a	HFC-227ea	HFC-236fa	HFC-245ca	Unspecified mix of listed HFCs	Total HFCs	CF_4	C_2F_6	C_3F_8	C_4F_{10}	$c\text{-}C_4F_8$	C_5F_{12}	C_6F_{14}	Unspecified mix of listed PFCs	Total PFCs	SF_6
Ratio of Potential/Actual Emissions from Consumption of Halocarbons and SF_6																									
Actual emissions - F(a) (Gg CO_2 eq.)																									
Potential emissions - F(p) (8) (Gg CO_2 eq.)																									
Potential/Actual emissions ratio																									

(1) In accordance with the UNFCCC reporting guidelines, HFC and PFC emissions should be reported for each relevant chemical. However, if it is not possible to report values for each chemical (i.e. mixtures, confidential data, lack of disaggregation), these columns could be used for reporting aggregate figures for HFCs and PFCs, respectively. Note that the unit used for these columns is Gg of CO_2 equivalent.

(2) Note that the units used in this table differ from those used in the rest of the Sectoral report tables, i.e. *t* instead of *Gg*.

(3) ODS: ozone-depleting substances

(4) Potential emissions of each chemical of halocarbons and SF_6 estimated using Tier 1a or Tier 1b of the IPCC Guidelines (Volume 3. Reference Manual, pp. 2.47-2.50). Where potential emission estimates are available in a disaggregated manner for the source categories F.1 to F.9, these should be reported in the NIR and a reference should be provided in the documentation box. Use table Summary 3 to indicate whether Tier 1a or Tier 1b was used.

(5) Production refers to production of new chemicals. Recycled substances could be included here, but avoid double counting of emissions. An indication as to whether recycled substances are included should be provided in the documentation box to this table.

(6) Relevant only for Tier 1b.

(7) Total actual emissions equal the sum of the actual emissions of each halocarbon and SF_6 from the source categories 2.C, 2.E, 2.F and 2.G as reported in sheet 1 of this table multiplied by the corresponding GWP values.

(8) Potential emissions of each halocarbon and SF_6 taken from row F(p) multiplied by the corresponding GWP values.

Note: As stated in the UNFCCC reporting guidelines, Parties should report actual emissions of HFCs, PFCs and SF_6, where data are available, providing disaggregated data by chemical and source category in units of mass and in CO_2 equivalent. Parties reporting actual emissions should also report potential emissions for the sources where the concept of potential emissions applies, for reasons of transparency and comparability. Gases with GWP values not yet agreed upon by the COP should be reported in Table 9 (b).

Documentation box:
• Parties should provide detailed explanations on the industrial processes sector in Chapter 4: Industrial processes (CRF sector 2) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • If estimates are reported under "2.G Other", use this documentation box to provide information regarding activities covered under this category and to provide reference to the section in the NIR where background information can be found.

TABLE 2(II). C, E SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES
Metal Production; Production of Halocarbons and SF_6
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		IMPLIED EMISSION FACTORS[2]			EMISSIONS					
			CF_4	C_2F_6	SF_6	CF_4		C_2F_6		SF_6	
						Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]
	Description [1]	(t)	(kg/t)			(t)					
C. PFCs and SF_6 from Metal Production											
PFCs from Aluminium Production											
SF_6 used in Aluminium and Magnesium Foundries											
Aluminium Foundries	*(SF_6 consumption)*										
Magnesium Foundries	*(SF_6 consumption)*										

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		IMPLIED EMISSION FACTORS[2]			EMISSIONS						
			HFC-23	SF_6	HFCs/PFCs *(as specified)*	HFC-23		SF_6		HFCs/PFCs		
						Emissions[3]	Recovery[4]	Emissions[3]	Recovery[4]	(specify chemical)	Emissions[3]	Recovery[4]
	Description [1]	(t)	(kg/t)			(t)						
E. Production of Halocarbons and SF_6												
1. By-product Emissions												
Production of HCFC-22												
Other *(specify activity)*												
2. Fugitive Emissions *(please specify activity)*												
3. Other *(please specify activity)*												

(1) Specify the activity data used as shown in the examples within parentheses.

(2) The implied emission factors (IEFs) are estimated on the basis of gross emissions as follows: IEF = (emissions + amounts recovered, oxidized, destroyed or transformed) / activity data.

(3) Final emissions are to be reported (after subtracting the amounts of emission recovery, oxidation, destruction or transformation).

(4) Amounts of emission recovery, oxidation, destruction or transformation.

Documentation box:
• Parties should provide detailed explanations on the industrial processes sector in Chapter 4: Industrial processes (CRF sector 2) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • Where only aggregate figures for activity data are provided, e.g. due to reasons of confidentiality (see footnote 1 to table 2(II)), a note indicating this should be provided in this documentation box. • Where applying Tier 1b (for source category 2.C), Tier 2 (for source category 2.E) and country-specific methods, specify any other relevant activity data used in this documentation box, including a reference to the section of the NIR where more detailed information can be found. • Use this documentation box for providing clarification on emission recovery, oxidation, destruction and/or transformation, and provide a reference to the section of the NIR where more detailed information can be found.

TABLE 2(II).F SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES
Consumption of Halocarbons and SF_6
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA *Amount of fluid*			IMPLIED EMISSION FACTORS			EMISSIONS		
	Filled into new manufactured products	In operating systems (average annual stocks)	Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	From disposal
	(t)			(% per annum)			(t)		
1. Refrigeration[(1)]									
Air Conditioning Equipment									
Domestic Refrigeration *(Specify chemical)* [(1)]									
Commercial Refrigeration									
Transport Refrigeration									
Industrial Refrigeration									
Stationary Air-Conditioning									
Mobile Air-Conditioning									
2. Foam Blowing[(1)]									
Hard Foam									
Soft Foam									

(1) Under each of the listed source categories, specify the chemical consumed (*e.g. HFC-32)* as indicated under category Domestic Refrigeration; use one row per chemical.

Note: This table provides for reporting of the activity data and emission factors used to calculate actual emissions from consumption of halocarbons and SF_6 using the "bottom-up approach" (based on the total stock of equipment and estimated emission rates from this equipment). Some Parties may prefer to estimate actual emissions following the alternative "top-down approach" (based on annual sales of equipment and/or gas). Those Parties should provide the activity data used in the current format and any other relevant information needed to understand the content of the table in the documentation box at the end of sheet 2 to this table, including a reference to the section of the NIR where further details can be found. Those Parties should provide the following data in the NIR:

1. the amount of fluid used to fill new products,
2. the amount of fluid used to service existing products,
3. the amount of fluid originally used to fill retiring products (the total nameplate capacity of retiring products),
4. the product lifetime, and
5. the growth rate of product sales, if this has been used to calculate the amount of fluid originally used to fill retiring products.

In the NIR, Parties may provide alternative formats for reporting equivalent information with a similar level of detail.

TABLE 2(II).F SECTORAL BACKGROUND DATA FOR INDUSTRIAL PROCESSES
Consumption of Halocarbons and SF_6
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA *Amount of fluid*			IMPLIED EMISSION FACTORS			EMISSIONS		
	Filled into new manufactured products	In operating systems (average annual stocks)	Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	From disposal
	(t)			(% per annum)			(t)		
3. Fire Extinguishers *Specify chemical)* [(1)]									
4, Aerosols [(1)]									
Metered Dose Inhalers									
Other									
5. Solvents [(1)]									
6. Other applications using ODS[(2)] **substitutes** [(1)]									
7. Semiconductors [(1)]									
8. Electric Equipment[(1)]									
9. Other *(please specify)* [(1)]									

(1) Under each of the listed source categories, specify the chemical consumed (e.g. HFC-32) as indicated under category Fire Extinguishers; use one row per chemical.

(2) ODS: ozone-depleting substances.

Documentation box:
• Parties should provide detailed explanations on the industrial processes sector in Chapter 4: Industrial processes (CRF sector 2) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • Where only aggregate figures for activity data are provided, e.g. due to reasons of confidentiality (see footnote 1 to table 2(II)), a note indicating this should be provided in this documentation box. • With regard to data on the amounts of fluid that remained in retired products at decommissioning, use this documentation box to provide a reference to the section of the NIR where information on the amount of the chemical recovered (recovery efficiency) and other relevant information used in the emission estimation can be found. • Parties that estimate their actual emissions following the alternative top-down approach might not be able to report emissions using this table. As indicated in the note to sheet 1 of this table, Parties should in these cases, in the NIR, provide alternative formats for reporting equivalent information with a similar level of detail. References to the relevant section of the NIR should be provided in this documentation box.

TABLE 3 SECTORAL REPORT FOR SOLVENT AND OTHER PRODUCT USE
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	N_2O	NMVOC
	(Gg)		
Total Solvent and Other Product Use			
A. Paint Application			
B. Degreasing and Dry Cleaning			
C. Chemical Products, Manufacture and Processing			
D. Other			
1. Use of N_2O for Anaesthesia			
2. N_2O from Fire Extinguishers			
3. N_2O from Aerosol Cans			
4. Other Use of N_2O			
5. Other *(as specified in table 3.A-D)*			

Note: The quantity of carbon released in the form of NMVOCs should be accounted for in both the NMVOC and the CO_2 columns. Note that these quantites of NMVOCs should be converted into CO_2 equivalent emissions before being added to the CO_2 amounts in the CO_2 column.

Documentation box:
• Parties should provide detailed explanations on the solvent and other product use sector in Chapter 5: Solvent and other product use (CRF sector 3) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • The IPCC Guidelines do not provide methodologies for the calculation of emissions of N_2O from Solvent and Other Product Use. If reporting such data, Parties should provide additional information (activity data and emission factors) used to derive these estimates in the NIR, and provide in this documentation box a reference to the section of the NIR where this information can be found.

TABLE 3.A-D SECTORAL BACKGROUND DATA FOR SOLVENT AND OTHER PRODUCT USE
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA		IMPLIED EMISSION FACTORS [(1)]	
	Description	(kt)	CO_2 (t/t)	N_2O (t/t)
A. Paint Application				
B. Degreasing and Dry Cleaning				
C. Chemical Products, Manufacture and Processing				
D. Other				
1. Use of N_2O for Anaesthesia				
2. N_2O from Fire Extinguishers				
3. N_2O from Aerosol Cans				
4. Other Use of N_2O				
5. Other *(please specify)* [(2)]				

(1) The implied emission factors will not be calculated until the corresponding emission estimates are entered directly into Table 3.

(2) Some probable sources to be reported under "other" are listed in this table. Complement the list with other relevant sources, as appropriate.

Documentation box: Parties should provide detailed explanations on the solvent and other product use sector in Chapter 5: Solvent and other product use (CRF sector 3) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 4 SECTORAL REPORT FOR AGRICULTURE
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)				
Total Agriculture					
A. Enteric Fermentation					
1. Cattle [1]					
Option A:					
Dairy Cattle					
Non-Dairy Cattle					
Option B:					
Mature Dairy Cattle					
Mature Non-Dairy Cattle					
Young Cattle					
2. Buffalo					
3. Sheep					
4. Goats					
5. Camels and Llamas					
6. Horses					
7. Mules and Asses					
8. Swine					
9. Poultry					
10. Other *(as specified in table 4.A)*					
B. Manure Management					
1. Cattle [1]					
Option A:					
Dairy Cattle					
Non-Dairy Cattle					
Option B:					
Mature Dairy Cattle					
Mature Non-Dairy Cattle					
Young Cattle					
2. Buffalo					
3. Sheep					
4. Goats					
5. Camels and Llamas					
6. Horses					
7. Mules and Asses					
8. Swine					
9. Poultry					
10. Other livestock *(as specified in table 4.B(a))*					

Note: All footnotes for this table are given at the end of the table on sheet 2.

TABLE 4 SECTORAL REPORT FOR AGRICULTURE
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)				
B. Manure Management (continued)					
11. Anaerobic Lagoons					
12. Liquid Systems					
13. Solid Storage and Dry Lot					
14. Other *(please specify)*					
C. Rice Cultivation					
1. Irrigated					
2. Rainfed					
3. Deep Water					
4. Other *(as specified in table 4.C)*					
D. Agricultural Soils [(2)]					
1. Direct Soil Emissions					
2. Pasture, Range and Paddock Manure [(3)]					
3. Indirect Emissions					
4. Other *(as specified in table 4.D)*					
E. Prescribed Burning of Savannas					
F. Field Burning of Agricultural Residues					
1 . Cereals					
2. Pulses					
3 . Tubers and Roots					
4 . Sugar Cane					
5 . Other *(as specified in table 4.F)*					
G. Other *(please specify)*					

[(1)] The sum for cattle would be calculated on the basis of entries made under either option A (dairy and non-dairy cattle) or option B (mature dairy cattle, mature non-dairy cattle and young cattle).

[(2)] See footnote 4 to Summary 1.A of this common reporting format. Parties which choose to report CO_2 emissions and removals from agricultural soils under 4.D Agricultural Soils of the sector Agriculture should report the amount (in Gg) of these emissions or removals in table Summary 1.A of the CRF. References to additional information (activity data, emissions factors) reported in the NIR should be provided in the documentation box to table 4.D. In line with the corresponding table in the IPCC Guidelines (i.e. IPCC Sectoral Report for Agriculture), this table does not include provisions for reporting CO_2 estimates.

[(3)] Direct N_2O emissions from pasture, range and paddock manure are to be reported in the "4.D Agricultural Soils" category. All other N_2O emissions from animal manure are to be reported in the "4.B Manure Management" category. See also chapter 4.4 of the IPCC good practice guidance report.

Note: The IPCC Guidelines do not provide methodologies for the calculation of CH_4 emissions and CH_4 and N_2O removals from agricultural soils, or CO_2 emissions from prescribed burning of savannas and field burning of agricultural residues. Parties that have estimated such emissions should provide, in the NIR, additional information (activity data and emission factors) used to derive these estimates and include a reference to the section of the NIR in the documentation box of the corresponding Sectoral background data tables.

Documentation box:
• Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • If estimates are reported under "4.G Other", use this documentation box to provide information regarding activities covered under this category and to provide reference to the section in the NIR where background information can be found.

TABLE 4.A SECTORAL BACKGROUND DATA FOR AGRICULTURE
Enteric Fermentation
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION			IMPLIED EMISSION FACTORS [3]
	Population size [1] (1000s)	Average gross energy intake (GE) (MJ/head/day)	Average CH_4 conversion rate (Y_m) [2] (%)	CH_4 (kg CH_4/head/yr)
1. Cattle				
Option A:				
Dairy Cattle [4]				
Non-Dairy Cattle				
Option B:				
Mature Dairy Cattle				
Mature Non-Dairy Cattle				
Young Cattle				
2. Buffalo				
3. Sheep				
4. Goats				
5. Camels and Llamas				
6. Horses				
7. Mules and Asses				
8. Swine				
9. Poultry				
10. Other *(please specify)*				

Additional information (only for those livestock types for which Ttier 2 was used) [a]

Disaggregated list of animals [b] / Indicators:		Dairy Cattle	Non-Dairy Cattle	Other *(specify)*	
Weight	(kg)				
Feeding situation [c]					
Milk yield	(kg/day)				
Work	(h/day)				
Pregnant	(%)				
Digestibility of feed	(%)				

[a] See also Tables A-1 and A-2 of the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.31-4.34). These data are relevant if Parties do not have data on average feed intake.

[b] Disaggregate to the split actually used. Add columns to the table if necessary.

[c] Specify feeding situation as pasture, stall fed, confined, open range, etc.

(1) Parties are encouraged to provide detailed livestock population data by animal type and region, if available, in the NIR, and provide reference to the relevant section in the documentation box below. Parties should use the same animal population statistics to estimate CH_4 emissions from enteric fermentation, CH_4 and N_2O from manure management, N_2O direct emissions from soil and N_2O emissions associated with manure production, as well as emissions from the use of manure as fuel, and sewage-related emissions reported in the waste sector.

(2) Y_m refers to the fraction of gross energy in feed converted to methane and should be given in per cent in this table.

(3) The implied emission factors will not be calculated until the corresponding emission estimates are entered directly into Table 4.

(4) Including data on dairy heifers, if available.

Documentation box:
• Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • Indicate in this documentation box whether the activity data used are one year-estimates or a three-year average. • Provide a reference to the relevant section in the NIR, in particular with regard to: (a) disaggregation of livestock population (e.g. according to the classification recommended in the IPCC good practice guidance), including information on whether these data are one-year estimates or a three-year average. (b) parameters relevant to the application of IPCC good practice guidance.

TABLE 4.B(a) SECTORAL BACKGROUND DATA FOR AGRICULTURE
CH_4 Emissions from Manure Management
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION							IMPLIED EMISSION FACTORS [(4)]
	Population size	Allocation by climate region [(1)]			Typical animal mass (average)	VS[(2)] daily excretion (average)	CH_4 producing potential (Bo)[(2)] (average)	CH_4
		Cool	Temperate	Warm				
	(1000s)	(%)			(kg)	(kg dm/head/day)	(m^3 CH_4/kg VS)	(kg CH_4/head/yr)
1. Cattle								
Option A:								
Dairy Cattle [(3)]								
Non-Dairy Cattle								
Option B:								
Mature Dairy Cattle								
Mature Non-Dairy Cattle								
Young Cattle								
2. Buffalo								
3. Sheep								
4. Goats								
5. Camels and Llamas								
6. Horses								
7. Mules and Asses								
8. Swine								
9. Poultry								
10. Other livestock *(please specify)*								

[(1)] Climate regions are defined in terms of annual average temperature as follows: Cool = less than 15°C; Temperate = 15 - 25°C inclusive; and Warm = greater than 25°C (see Table 4.2 of the IPCC Guidelines (Volume 3, Reference Manual, p. 4.8)).

[(2)] VS = Volatile Solids; Bo = maximum methane producing capacity for manure IIPCC Guidelines (Volume 3, Reference Manual, p.4.23 and p.4.15); dm = dry matter. Provide average values for VS and Bo where original calculations were made at a more disagregated level of these livestock categories.

[(3)] Including data on dairy heifers, if available.

[(4)] The implied emission factors will not be calculated until the corresponding emission estimates are entered directly into Table 4.

Additional information (for Tier 2) [(a)]

Animal category	Indicator	Climate region	Animal waste management system						
			Anaerobic lagoon	Liquid system	Daily spread	Solid storage	Dry lot	Pasture range paddock	Other
Dairy Cattle	Allocation (%)	Cool							
		Temperate							
		Warm							
	MCF[(b)]	Cool							
		Temperate							
		Warm							
Non-Dairy Cattle	Allocation (%)	Cool							
		Temperate							
		Warm							
	MCF[(b)]	Cool							
		Temperate							
		Warm							
Swine	Allocation (%)	Cool							
		Temperate							
		Warm							
	MCF[(b)]	Cool							
		Temperate							
		Warm							
Other livestock *(please specify)*	Allocation (%)	Cool							
		Temperate							
		Warm							
	MCF[(b)]	Cool							
		Temperate							
		Warm							

[(a)] The information required in this table may not be directly applicable to country-specific methods developed for MCF calculations. In such cases, information on MCF derivation should be described in the NIR and references to the relevant sections of the NIR should be provided in the documentation box.

[(b)] MCF = Methane Conversion Factor (IPCC Guidelines, (Volume 3. Reference Manual, p. 4.9)). If another climate region categorization is used, replace the entries in the cells with the climate regions for which the MCFs are specified.

Documentation box:
- Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of this table.
- Indicate in this documentation box whether the activity data used are one-year estimates or a three-year average.
- Provide a reference to the relevant section in the NIR, in particular with regard to:
  (a) disaggregation of livestock population (e.g. according to the classification recommended in the IPCC good practice guidance), including information on whether these data are one-year estimates or a three-year average.
  (b) parameters relevant to the application of IPCC good practice guidance;
  (c) information on how the MCF are derived, if relevant data could not be provided in the additional information box.

TABLE 4.B(b) SECTORAL BACKGROUND DATA FOR AGRICULTURE
N_2O Emissions from Manure Management
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION							
	Population size	Nitrogen excretion	Nitrogen excretion per animal waste management system (AWMS) (kg N/yr)					
	(1000s)	(kg N/head/yr)	Anaerobic lagoon	Liquid system	Daily spread	Solid storage and dry lot	Pasture range and paddock	Other
Cattle								
Option A:								
Dairy Cattle								
Non-Dairy Cattle								
Option B:								
Mature Dairy Cattle								
Mature Non-Dairy Cattle								
Young Cattle								
Sheep								
Swine								
Poultry								
Other livestock *(please specify)*								
Total per AWMS								

IMPLIED EMISSION FACTORS [(1)]	
Emission factor per animal waste management system	
(kg N_2O-N/kg N)	
Anaerobic lagoon	
Liquid system	
Solid storage and dry lot	
Other AWMS	

[(1)] The implied emission factor will not be calculated until the emissions are entered directly into Table 4.

Documentation box:

• Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

• Indicate in this documentation box whether the activity data used are one-year estimates or a three-year average.

• Provide a reference to the relevant section in the NIR, in particular with regard to:

(a) disaggregation of livestock population (e.g. according to the classification recommended in the IPCC good practice guidance), including information on whether these data are one-year estimates or a three-year average.

(b) information on other AWMS, if reported.

TABLE 4.C SECTORAL BACKGROUND DATA FOR AGRICULTURE
Rice Cultivation
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA AND OTHER RELATED INFORMATION			IMPLIED EMISSION FACTOR [1]	EMISSIONS
		Harvested area [2]	Organic amendments added[3]		CH_4	CH_4
		(10^9 m^2/yr)	type	(t/ha)	(g/m^2)	(Gg)
1. Irrigated						
Continuously Flooded						
Intermittently Flooded	Single Aeration					
	Multiple Aeration					
2. Rainfed						
Flood Prone						
Drought Prone						
3. Deep Water						
Water Depth 50-100 cm						
Water Depth > 100 cm						
4. Other *(please specify)*						
Upland Rice[4]						
Total [4]						

[1] The implied emission factor implicitly takes account of all relevant corrections for continuously flooded fields without organic amendment, the correction for the organic amendments and the effect of different soil characteristics, if considered in the calculation of methane emissions.

[2] Harvested area is the cultivated area multiplied by the number of cropping seasons per year.

[3] Specify dry weight or wet weight for organic amendments in the documentation box.

[4] These rows are included to allow comparison with international statistics. Methane emissions from upland rice are assumed to be zero.

Documentation box:
• Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • When disaggregating by more than one region within a country, and/or by growing season, provide additional information on disaggregation and related data in the NIR and provide a reference to the relevant section in the NIR. • Where available, provide activity data and scaling factors by soil type and rice cultivar in the NIR.

TABLE 4.D SECTORAL BACKGROUND DATA FOR AGRICULTURE

Agricultural Soils[1]

(Sheet 1 of 1)

Country

Year

Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION		IMPLIED EMISSION FACTORS	EMISSIONS
	Description	Value kg N/yr	kg N_2O-N/kg N [2]	N_2O (Gg)
1. Direct Soil Emissions	**N input to soils**			
1. Synthetic Fertilizers	Nitrogen input from application of synthetic fertilizers			
2. Animal Manure Applied to Soils	Nitrogen input from manure applied to soils			
3. N-fixing Crops	Nitrogen fixed by N-fixing crops			
4. Crop Residue	Nitrogen in crop residues returned to soils			
5. Cultivation of Histosols [2]	Area of cultivated organic soils (ha/yr)			
6. Other direct emissions *(please specify)*				
2. Pasture, Range and Paddock Manure	**N excretion on pasture range and paddock**			
3. Indirect Emissions				
1. Atmospheric Deposition	Volatized N from fertilizers, animal manures and other			
2. Nitrogen Leaching and Run-off	N from fertilizers, animal manures and other that is lost through leaching and run-off			
4. Other *(please specify)*				

Additional information

Fraction [a]	Description	Value
$Frac_{BURN}$	Fraction of crop residue burned	
$Frac_{FUEL}$	Fraction of livestock N excretion in excrements burned for fuel	
$Frac_{GASF}$	Fraction of synthetic fertilizer N applied to soils that volatilizes as NH_3 and NOx	
$Frac_{GASM}$	Fraction of livestock N excretion that volatilizes as NH_3 and NOx	
$Frac_{GRAZ}$	Fraction of livestock N excreted and deposited onto soil during grazing	
$Frac_{LEACH}$	Fraction of N input to soils that is lost through leaching and run-off	
$Frac_{NCRBF}$	Fraction of total above-ground biomass of N-fixing crop that is N	
$Frac_{NCRO}$	Fraction of residue dry biomass that is N	
$Frac_{R}$	Fraction of total above-ground crop biomass that is removed from the field as a crop product	
Other fractions *(please specify)*		

[a] Use the definitions for fractions as specified in the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.92 - 4.113) as elaborated by the IPCC good practice guidance (pp. 4.54 - 4.74).

[1] See footnote 4 to Summary 1.A. of this common reporting format. Parties that choose to report CO_2 emissions and removals from agricultural soils under 4.D. Agricultural Soils category should indicate the amount (in Gg) of these emissions or removals and relevant additional information (activity data, implied emissions factors) in the documentation box.

[2] To convert from N_2O-N to N_2O emissions, multiply by 44/28. Note that for cultivation of Histosols the unit of the IEF is kg N_2O-N/ha.

Documentation box:

• Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

• Provide a reference to the relevant section in the NIR, in particular with regard to:

(a) Background information on CO_2 emissions and removals estimates from agricultural soils, if accounted for under the agriculture sector;

(b) Background information on CH_4 emissions from agricultural soils, if accounted for under the agriculture sector;

(c) Disaggregated values for $Frac_{GRAZ}$ according to animal type, and for $Frac_{BURN}$ according to crop types;

(d) Full list of assumptions and fractions used.

TABLE 4.E SECTORAL BACKGROUND DATA FOR AGRICULTURE
Prescribed Burning of Savannas
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION					IMPLIED EMISSION FACTORS		EMISSIONS	
	Area of savanna burned (k ha/yr)	Average above-ground biomass density (t dm/ha)	Fraction of savanna burned	Biomass burned (Gg dm)	Nitrogen fraction in biomass	CH_4	N_2O	CH_4	N_2O
						(kg/t dm)		(Gg)	
(specify ecological zone)									

Additional information

	Living Biomass	Dead Biomass
Fraction of above-ground biomass		
Fraction oxidized		
Carbon fraction		

Documentation box: Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 4.F SECTORAL BACKGROUND DATA FOR AGRICULTURE
Field Burning of Agricultural Residues
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION								IMPLIED EMISSION FACTORS		EMISSIONS	
	Crop production	Residue/ Crop ratio	Dry matter (dm) fraction of residue	Fraction burned in fields	Fraction oxidized	Total biomass burned	C fraction of residue	N-C ratio in biomass residues	CH_4	N_2O	CH_4	N_2O
	(t)					(Gg dm)			(kg/t dm)		(Gg)	
1. Cereals												
Wheat												
Barley												
Maize												
Oats												
Rye												
Rice												
Other *(please specify)*												
2. Pulses												
Dry bean												
Peas												
Soybeans												
Other *(please specify)*												
3 Tubers and Roots												
Potatoes												
Other *(please specify)*												
4 Sugar Cane												
5 Other *(please specify)*												

Documentation box:
Parties should provide detailed explanations on the agriculture sector in Chapter 6: Agriculture (CRF sector 4) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 5 SECTORAL REPORT FOR LAND-USE CHANGE AND FORESTRY
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 emissions[(1)]	CO_2 removals[(1)]	Net CO_2 emissions/ removals [(1)]	CH_4	N_2O	NO_x	CO
	(Gg)						
Total Land-Use Change and Forestry							
A. Changes in Forest and Other Woody Biomass Stocks							
1. Tropical Forests							
2. Temperate Forests							
3. Boreal Forests							
4. Grasslands/Tundra							
5. Other *(please specify)*							
Harvested Wood [(2)]							
B. Forest and Grassland Conversion							
1. Tropical Forests							
2. Temperate Forests							
3. Boreal Forests							
4. Grasslands/Tundra							
5. Other *(please specify)*							
C. Abandonment of Managed Lands							
1. Tropical Forests							
2. Temperate Forests							
3. Boreal Forests							
4. Grasslands/Tundra							
5. Other *(please specify)*							
D. CO_2 Emissions and Removals from Soil							
Cultivation of Mineral Soils							
Cultivation of Organic Soils							
Liming of Agricultural Soils							
Forest Soils							
Other *(please specify)* [(3)]							
E. Other *(please specify)*							

(1) Note that according to the IPCC Guidelines, for purposes of reporting, the signs for removals are always (-) and for emissions (+). Net CO_2 emissions/removals are calculated as follows: net CO_2 = CO_2 emissions + CO_2 removals. Note that this result is to be reported in table Summary 1.A, where a single number is to be placed in either the CO_2 emissions or the CO_2 removals column, as appropriate.

(2) Following the IPCC Guidelines, the harvested wood should be reported under Changes in Forest and Other Woody Biomass Stocks (Volume 3. Reference Manual, p.5.17).

(3) Include emissions from soils not reported under sections A, B and C.

Note: According to the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.2, 4.87), CO_2 emissions from agricultural soils are to be included under Land-use change and forestry (LUCF). At the same time, the Summary Report 7A (Volume 1. Reporting Instructions, Tables.27) allows for reporting CO_2 emissions or removals from agricultural soils either in the Agriculture sector, under 4.D Agricultural soils or in the Land-use change and forestry sector under 5.D Emissions and removals from soil. Parties may choose either way to report emissions or removals from this source in the common reporting format, but the way they have chosen to report should be clearly indicated, by providing a brief explanation in the documentation boxes to Table 4D of the agriculture sector. Double-counting of these emissions or removals should be avoided. Parties should include these emissions or removals consistently in Table8(a) (Recalculation - Recalculated data) and Table10 (Emission trends).

Documentation box:
• Parties should provide detailed explanations on the land-use change and forestry sector in Chapter 7: Land-use change and forestry (CRF sector 5) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• If estimates are reported under "5.E Other", use this documentation box to provide information regarding activities covered under this category and to provide reference to the section in the NIR where background information can be found.

TABLE 5.A SECTORAL BACKGROUND DATA FOR LAND-USE CHANGE AND FORESTRY
Changes in Forest and Other Woody Biomass Stocks
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES			ACTIVITY DATA		IMPLIED EMISSION FACTORS	ESTIMATES
			Area of forest/biomass stocks (kha)	Average annual growth rate (t dm/ha)	Implied carbon uptake factor (t C/ha)	Carbon uptake increment (Gg C)
Tropical	Plantations	*Acacia spp.*				
		Eucalyptus spp.				
		Tectona grandis				
		Pinus spp				
		Pinus caribaea				
		Mixed Hardwoods				
		Mixed Fast-Growing Hardwoods				
		Mixed Softwoods				
	Other Forests	Moist				
		Seasonal				
		Dry				
	Other *(specify)*					
Temperate	Plantations					
	Commercial	Evergreen				
		Deciduous				
	Other *(specify)*					
Boreal						
			Number of trees (1000s of trees)	Annual growth rate (kt dm/1000 trees)	Carbon uptake factor (t C/tree)	Carbon uptake increment (Gg C)
Non-Forest Trees *(specify type)*						
					Total annual growth increment (Gg C)	
					Gg CO_2	

	Amount of biomass removed (kt dm)	Carbon emission factor (t C/t dm)	Carbon release (Gg C)
Total biomass removed in Commercial Harvest			
Traditional Fuelwood Consumed			
Total Other Wood Use			
		Total Biomass Consumption from Stocks [1] (Gg C)	
		Other Changes in Carbon Stocks [2] (Gg C)	
		Gg CO_2	

Net annual carbon uptake (+) or release (-) (Gg C)	
Net CO_2 emissions (-) or removals (+) (Gg CO_2)	

[1] Make sure that the quantity of biomass burned off-site is subtracted from this total.

[2] The net annual carbon uptake/release is determined by comparing the annual biomass growth versus annual harvest, including the decay of forest products and slash left during harvest. The IPCC Guidelines recommend default assumption that all carbon removed in wood and other biomass from forests is oxidized in the year of removal. The emissions from decay could be included under Other Changes in Carbon Stocks.

Note: Sectoral background data tables on Land-Use Change and Forestry should be filled in only by Parties using the IPCC default methodology.
Parties that use country-specific methods and models should report information on them in a transparent manner in the NIR.

Documentation box:
Parties should provide detailed explanations on the land-use change and forestry sector in Chapter 7: Land-use change and forestry (CRF sector 5) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 5.B SECTORAL BACKGROUND DATA FOR LAND-USE CHANGE AND FORESTRY
Forest and Grassland Conversion
(Sheet 1 of 1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA AND OTHER RELATED INFORMATION							IMPLIED EMISSION FACTORS					EMISSIONS				
		On site and off site burning				Decay of above-ground biomass[1]												
		Area converted annually	Annual net loss of biomass	Quantity of biomass burned		Average area converted	Average annual net loss of biomass	Average quantity of biomass left to decay	Burning				Decay	Burning				Decay
									On site			Off site		On site			Off site	
				On site	Off site				CO_2	CH_4	N_2O	CO_2	CO_2	CO_2	CH_4	N_2O	CO_2	CO_2
Vegetation types		(kha)	(kt dm)	(kt dm)	(kt dm)	(kha)	(t dm/ha)	(kt dm)	(t/ha)					(Gg)				
Tropical	Wet/Very Moist																	
	Moist, short dry season																	
	Moist, long dry season																	
	Dry																	
	Montane Moist																	
	Montane Dry																	
Tropical Savanna/Grasslands																		
Temperate	Coniferous																	
	Broadleaf																	
	Mixed Broadleaf/ Coniferous																	
Grasslands																		
Boreal	Mixed Broadleaf/ Coniferous																	
	Coniferous																	
	Forest-Tundra																	
Grasslands/Tundra																		
Other *(please specify)*																		
Total																		

[1] Activity data are by default 10-year averages. Specify the average decay time which is appropriate for the local conditions, if other than 10 years.

Emissions/Removals	On site	Off site
Immediate carbon release from burning		
Total On site and Off site (Gg C)		
Delayed emissions from decay (Gg C)		
Total annual carbon release (Gg C)		
Total annual CO_2 emissions (Gg CO_2)		

Additional information

Fractions	On site	Off site
Fraction of biomass burned (average)		
Fraction which oxidizes during burning (average)		
Carbon fraction of above-ground biomass (average)		
Fraction left to decay (average)		
Nitrogen-carbon ratio		

Note: Sectoral background data tables on Land-Use Change and Forestry should be filled in only by Parties using the IPCC default methodology. Parties that use country-specific methods and models should report information on them in a transparent manner in the NIR.

Documentation box: Parties should provide detailed explanations on the land-use change and forestry sector in Chapter 7: Land-use change and forestry (CRF sector 5) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 5.C SECTORAL BACKGROUND DATA FOR LAND-USE CHANGE AND FORESTRY
Abandonment of Managed Lands
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA AND OTHER RELATED INFORMATION						IMPLIED EMISSION FACTORS		ESTIMATES	
		Total area abandoned and regrowing (1)		Annual rate of above-ground biomass growth		Carbon fraction of above-ground biomass		Rate of above-ground biomass carbon uptake		Annual carbon uptake in above-ground biomass	
Original natural ecosystems		first 20 years (kha)	>20 years (kha)	first 20 years (t dm/ha)	>20 years (t dm/ha)	first 20 years	>20 years	first 20 years (t C/ha/yr)	>20 years (t C/ha/yr)	first 20 years (Gg C/yr)	>20 years (Gg C/yr)
Tropical	Wet/Very Moist										
	Moist, short dry season										
	Moist, long dry season										
	Dry										
	Montane Moist										
	Montane Dry										
Tropical Savanna/Grasslands											
Temperate	Mixed Broadleaf/Coniferous										
	Coniferous										
	Broadleaf										
Grasslands											
Boreal	Mixed Broadleaf/Coniferous										
	Coniferous										
	Forest-tundra										
Grasslands/Tundra											
Other *(please specify)*											

Total annual carbon uptake (Gg C)	
Total annual CO_2 removal (Gg CO_2)	

(1) If lands are regenerating to grassland, then the default assumption is that no significant changes in above-ground biomass occur.

Note: Sectoral background data tables on Land-use Change and Forestry should be filled in only by Parties using the IPCC default methodology. Parties that use country-specific methods and models should report information on them in a transparent manner in the NIR.

Documentation box: Parties should provide detailed explanations on the land-use change and forestry sector in Chapter 7: Land-use change and forestry (CRF sector 5) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 5.D SECTORAL BACKGROUND DATA FOR LAND-USE CHANGE AND FORESTRY

CO_2 Emissions and Removals from Soil

(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA	IMPLIED EMISSION FACTORS	ESTIMATES
	Land area (Mha)	Average annual rate of soil carbon uptake/removal (Mg C/ha/yr)	Net change in soil carbon in mineral soils (Tg C over 20 yr)
Cultivation of Mineral Soils [1]			
High Activity Soils			
Low Activity Soils			
Sandy			
Volcanic			
Wetland (Aquic)			
Other *(please specify)*			
	Land area (ha)	Annual loss rate (Mg C/ha/yr)	Carbon emissions from organic soils (Mg C/yr)
Cultivation of Organic Soils			
Cool Temperate			
Upland Crops			
Pasture/Forest			
Warm Temperate			
Upland Crops			
Pasture/Forest			
Tropical			
Upland Crops			
Pasture/Forest			
	Total annual amount of lime (Mg)	Carbon conversion factor	Carbon emissions from liming (Mg C)
Liming of Agricultural Soils			
Limestone $Ca(CO_3)$			
Dolomite $CaMg(CO_3)_2$			

Total annual net carbon emissions from agriculturally impacted soils (Gg C)	
Total annual net CO_2 emissions from agriculturally impacted soils (Gg CO_2)	

Additional information

Year	Climate [a]	Land-use/ management system [a]	Soil type: High activity soils	Low activity soils	Sandy	Volcanic	Wetland (Aquic)	Organic soil
			percent distribution (%)					
20 years prior	*(e.g. tropical, dry)*	*(e.g. savanna)*						
		(e.g. irrigated cropping)						
inventory year								

[a] These should represent the major types of land management systems per climate region present in the country as well as ecosystem types which were either converted to agriculture (e.g., forest, savanna, grassland) or have been derived from previous agricultural land-use (e.g., abandoned lands, reforested lands). Systems should also reflect differences in soil carbon stocks that can be related to differences in management (IPCC Guidelines, Volume 2. Workbook, Table 5-9, p. 5.26, and Appendix (pp. 5.31 - 5.38)).

[1] The information to be reported under Cultivation of Mineral Soils aggregates data per soil type over all land-use/management systems. This refers to land area data and to the emission estimates and implied emissions factors accordingly.

Note: Sectoral background data tables on Land-Use Change and Forestry should be filled in only by Parties using the IPCC default methodology. Parties that use country-specific methods and models should report information on them in a transparent manner in the NIR.

Documentation box: Parties should provide detailed explanations on the land-use change and forestry sector in Chapter 7: Land-use change and forestry (CRF sector 5) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.

TABLE 6 SECTORAL REPORT FOR WASTE
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
	(Gg)						
Total Waste							
A. Solid Waste Disposal on Land							
1. Managed Waste Disposal on Land							
2. Unmanaged Waste Disposal Sites							
3. Other *(as specified in table 6.A)*							
B. Waste Water Handling							
1. Industrial Wastewater							
2. Domestic and Commercial Waste Water							
3. Other *(as specified in table 6.B)*							
C. Waste Incineration							
D. Other *(please specify)*							

[1] CO_2 emissions from source categories Solid waste disposal on land and Waste incineration should only be included if they derive from non-biological or inorganic waste sources.

Documentation box:
• Parties should provide detailed explanations on the waste sector in Chapter 8: Waste (CRF sector 6) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table. • If estimates are reported under "6.D Other", use this documentation box to provide information regarding activities covered under this category and to provide reference to the section in the NIR where background information can be found.

TABLE 6.A SECTORAL BACKGROUND DATA FOR WASTE
Solid Waste Disposal
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION			IMPLIED EMISSION FACTOR		EMISSIONS		
	Annual MSW at the SWDS	MCF	DOC degraded	CH_4 (1)	CO_2	CH_4		CO_2 (4)
						Emissions (2)	Recovery (3)	
	(Gg)		%	(t /t MSW)		(Gg)		
1 Managed Waste Disposal on Land								
2 Unmanaged Waste Disposal Sites								
a. Deep (>5 m)								
b. Shallow (<5 m)								
3 Other *(please specify)*								

Additional information

Description	Value
Total population (1000s)(a)	
Urban population (1000s)(a)	
Waste generation rate (kg/capita/day)	
Fraction of MSW disposed to SWDS	
Fraction of DOC in MSW	
CH_4 oxidation factor (b)	
CH_4 fraction in landfill gas	
CH_4 generation rate constant (k) (c)	
Time lag considered (yr) (c)	

MSW - Municipal Solid Waste, SWDS - Solid Waste Disposal Site, MCF - Methane Correction Factor, DOC - Degradable Organic Carbon (IPCC Guidelines (Volume 3. Reference Manual, section 6.2.4)).
MSW includes household waste, yard/garden waste, commercial/market waste and organic industrial solid waste. MSW should not include inorganic industrial waste such as construction or demolition materials.

(1) The CH_4 implied emission factor (IEF) is calculated on the basis of gross CH_4 emissions, as follows: IEF = (CH_4 emissions + CH_4 recovered)/annual MSW at the SWDS.
(2) Actual emissions (after recovery).
(3) CH_4 recovered and flared or utilized.
(4) Under Solid Waste Disposal, CO_2 emissions should be reported only when the disposed waste is combusted at the disposal site as a management practice. CO_2 emissions from non-biogenic wastes are included in the total emissions, whereas the CO_2 emissions from biogenic wastes are not included in the total emissions.

(a) Specify whether total or urban population is used and the rationale for doing so.
(b) See IPCC Guidelines (Volume 3. Reference Manual, p. 6.9).
(c) Only for Parties using Tier 2 methods.

TABLE 6.C SECTORAL BACKGROUND DATA FOR WASTE
Waste Incineration
(Sheet 1 of 1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA	IMPLIED EMISSION FACTOR			EMISSIONS		
	Amount of incinerated wastes	CO_2	CH_4	N_2O	CO_2 (1)	CH_4	N_2O
	(Gg)	(kg/t waste)			(Gg)		
Waste Incineration							
a. Biogenic (1)							
b. Other (non-biogenic - *please specify*) (1), (2)							

(1) Under Solid Waste Disposal, CO_2 emissions should be reported only when the disposed waste is combusted at the disposal site as a management practice. CO_2 emissions from non-biogenic wastes are included in the total emissions, while the CO_2 emissions from biogenic wastes are not included in the total emissions.

(2) Enter under this source category all types of non-biogenic wastes, such as plastics.

Note: Only emissions from waste incineration without energy recovery are to be reported in the waste sector. Emissions from incineration with energy recovery are to be reported in the energy sector, as other fuels (see IPCC good practice guidance, page 5.23).

Documentation box:
• Parties should provide detailed explanations on the waste sector in Chapter 8: Waste (CRF sector 6) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• Parties that use country-specific models should provide a reference in the documentation box to the relevant section in the NIR where these models are described, and fill in only the relevant cells of tables 6.A and 6.C.
• Provide a reference to the relevant section in the NIR, in particular with regard to:
(a) A population size (total or urban population) used in the calculations and the rationale for doing so;
(b) The composition of landfilled waste;
(c) In relation to the amount of incinerated wastes, specify whether the reported data relate to wet or dry matter.

TABLE 6.B SECTORAL BACKGROUND DATA FOR WASTE
Waste Water Handling
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND RELATED INFORMATION[1]	IMPLIED EMISSION FACTOR		EMISSIONS		
				CH_4		N_2O [3]
	Total organic product	CH_4 [2]	N_2O[3]	Emissions [4]	Recovery [5]	
	(Gg DC[1]/yr)	(kg/kg DC)		(Gg)		
1. Industrial Waste Water						
a. Waste Water						
b. Sludge						
2. Domestic and Commercial Wastewater						
a. Waste Water						
b. Sludge						
3. Other *(please specify)*						
[6]						
a. Waste Water						
b. Sludge						
[6]						

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION			IMPLIED EMISSION FACTOR	EMISSIONS
	Population (1000s)	Protein consumption (kg/person/yr)	N fraction (kg N/kg protein)	N_2O (kg N_2O-N/kg sewage N produced)	N_2O (Gg)
N_2O from human sewage [3]					

[1] DC - degradable organic component. DC indicators are COD (Chemical Oxygen Demand) for industrial waste water and BOD (Biochemical Oxygen Demand) for Domestic/Commercial waste water/sludge (IPCC Guidelines (Volume 3. Reference Manual, pp. 6.14, 6.18)).
[2] The CH_4 implied emission factor (IEF) is calculated on the basis of gross CH_4 emissions, as follows: IEF = (CH_4 emissions + CH_4 recovered or flared) / total organic product.
[3] Parties using methods other than those from the IPCC for estimating N_2O emissions from human sewage or waste-water treatment should provide aggregate data in this table.
[4] Actual emissions (after recovery).
[5] CH_4 recovered and flared or utilized.
[6] Use these cells to specify each activity covered under "6.B.3 Other". Note that under each reported activity, data for waste water and sludge are to be reported separately.

Additional information

	Domestic	Industrial
Total waste water (m^3):		
Treated waste water (%):		

Waste-water streams:	Waste-water output (m^3)	DC (kgCOD/m^3)
Industrial waste water		
Non-ferrous		
Fertilizers		
Food and beverage		
Paper and pulp		
Organic chemicals		
Other *(specify)*		
	DC (kg BOD/1000 person/yr)	
Domestic and Commercial		
Other		

Handling systems:	Industrial waste water treated (%)	Industrial sludge treated (%)	Domestic waste water treated (%)	Domestic sludge treated (%)
Aerobic				
Anaerobic				
Other *(specify)*				

Documentation box:
• Parties should provide detailed explanations on the waste sector in Chapter 8: Waste (CRF sector 6) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and/or further details are needed to understand the content of this table.
• Regarding the estimates for N_2O from human sewage, specify whether total or urban population is used in the calculations and the rationale for doing so. Provide explanation in the documentation box.
• Parties using methods other than those from the IPCC for estimating N_2O emissions from human sewage or waste-water treatment should provide, in the NIR, corresponding information on methods, activity data and emission factors used, and should provide a reference to the relevant section of the NIR in this documentation box.

SUMMARY 1.A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A)
(Sheet 1 of 3)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
						P	A	P	A	P	A				
		(Gg)				CO_2 equivalent (Gg)						(Gg)			
Total National Emissions and Removals															
1. Energy															
A. Fuel Combustion	Reference Approach [2]														
	Sectoral Approach [2]														
1. Energy Industries															
2. Manufacturing Industries and Construction															
3. Transport															
4. Other Sectors															
5. Other															
B. Fugitive Emissions from Fuels															
1. Solid Fuels															
2. Oil and Natural Gas															
2. Industrial Processes															
A. Mineral Products															
B. Chemical Industry															
C. Metal Production															
D. Other Production [3]															
E. Production of Halocarbons and SF_6															
F. Consumption of Halocarbons and SF_6															
G. Other															

A = Actual emissions based on Tier 2 approach of the IPCC Guidelines.
P = Potential emissions based on Tier 1 approach of the IPCC Guidelines.

Note: All footnotes for this table are given at the end of the table on sheet 3.

SUMMARY 1.A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) (Sheet 2 of 3)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs [1] P	HFCs [1] A	PFCs[1] P	PFCs[1] A	SF_6 P	SF_6 A	NO_x	CO	NMVOC	SO_2
	(Gg)				CO_2 equivalent (Gg)						(Gg)			
3. Solvent and Other Product Use														
4. Agriculture														
A. Enteric Fermentation														
B. Manure Management														
C. Rice Cultivation														
D. Agricultural Soils	(4), (5)	(4), (5)												
E. Prescribed Burning of Savannas														
F. Field Burning of Agricultural Residues														
G. Other														
5. Land-Use Change and Forestry	(5)	(5)												
A. Changes in Forest and Other Woody Biomass Stocks	(5)	(5)												
B. Forest and Grassland Conversion	(5)	(5)												
C. Abandonment of Managed Lands	(5)	(5)												
D. CO_2 Emissions and Removals from Soil	(5)	(5)												
E. Other	(5)	(5)												
6. Waste														
A. Solid Waste Disposal on Land	(6)													
B. Waste-water Handling														
C. Waste Incineration	(6)													
D. Other														
7. Other *(please specify)* [7]														

Note: All footnotes for this table are given at the end of the table on sheet 3.

SUMMARY 1.A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7A) (Sheet 3 of 3)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs		PFCs		SF_6		NO_x	CO	NMVOC	SO_2
					P	A	P	A	P	A				
	(Gg)				CO_2 equivalent (Gg)						(Gg)			
Memo Items: [(8)]														
International Bunkers														
Aviation														
Marine														
Multilateral Operations														
CO_2 Emissions from Biomass														

[(1)] The emissions of HFCs and PFCs are to be expressed as CO_2 equivalent emissions. Data on disaggregated emissions of HFCs and PFCs are to be provided in Table 2(II) of this common reporting format.

[(2)] For verification purposes, countries are asked to report the results of their calculations using the Reference approach and to explain any differences with the Sectoral approach in the documentation box to Table 1.A.(c). For estimating national total emissions, the results from the Sectoral approach should be used, where possible.

[(3)] Other Production includes Pulp and Paper and Food and Drink Production.

[(4)] According to the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.2, 4.87), CO_2 emissions from agricultural soils are to be included under Land-use change and forestry (LUCF). At the same time, the Summary Report 7A (Volume 1. Reporting Instructions, Tables.27) allows for reporting CO_2 emissions or removals from agricultural soils either in the Agriculture sector, under 4.D Agricultural soils or in the Land-use change and forestry sector under 5.D Emissions and removals from soil. Parties may choose either way to report emissions or removals from this source in the common reporting format, but the way they have chosen to report should be clearly indicated, by providing a brief explanation in the documentation box to Table 4.D of the agriculture sector. Double-counting of these emissions or removals should be avoided. Parties should include these emissions or removals consistently in Table8(a) (Recalculation - Recalculated data) and Table10 (Emission trends).

[(5)] Do not provide an estimate of both CO_2 emissions and CO_2 removals. "Net" emissions (emissions - removals) of CO_2 should be estimated and a single number placed in either the CO_2 emissions or CO_2 removals column, as appropriate. Note that for the purposes of reporting, the signs for removals are always (-) and for emissions (+).

[(6)] Note that CO_2 from source categories Solid waste disposal on land and Waste incineration should only be included if it stems from non-biogenic or inorganic waste streams. Note that only emissions from waste incineration without energy recovery are to be reported in the waste sector, whereas emissions from incineration with energy recovery are to be reported in the energy sector.

[(7)] If reporting any country-specific source category under sector "7. Other", detailed explanations should be provided in Chapter 9: Other (CRF sector 7) of the NIR.

[(8)] Countries are asked to report emissions from international aviation and marine bunkers and multilateral operations, as well as CO_2 emissions from biomass, under Memo Items. These emissions should not be included in the national total emissions from the energy sector. Amounts of biomass used as fuel are included in the national energy consumption but the corresponding CO_2 emissions are not included in the national total as it is assumed that the biomass is produced in a sustainable manner. If the biomass is harvested at an unsustainable rate, net CO_2 emissions are accounted for as a loss of biomass stocks in the land-use change and forestry sector.

SUMMARY 1.B SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (IPCC TABLE 7B)
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO_2 emissions	CO_2 removals	CH_4	N_2O	HFCs[1]		PFCs[1]		SF_6		NO_x	CO	NMVOC	SO_2
						P	A	P	A	P	A				
		(Gg)				CO_2 equivalent (Gg)				(Gg)					
Total National Emissions and Removals															
1. Energy															
A. Fuel Combustion	Reference Approach[2]														
	Sectoral Approach[2]														
B. Fugitive Emissions from Fuels															
2. Industrial Processes															
3. Solvent and Other Product Use															
4. Agriculture [3]															
5. Land-Use Change and Forestry		(4)	(4)												
6. Waste															
7. Other															
Memo Items: [5]															
International Bunkers															
Aviation															
Marine															
Multilateral Operations															
CO_2 Emissions from Biomass															

A = Actual emissions based on Tier 2 approach of the IPCC Guidelines.
P = Potential emissions based on Tier 1 approach of the IPCC Guidelines.

(1) The emissions of HFCs and PFCs are to be expressed as CO_2 equivalent emissions. Data on disaggregated emissions of HFCs and PFCs are to be provided in Table 2(II) of this common reporting format.

(2) For verification purposes, countries are asked to report the results of their calculations using the Reference approach and to explain any differences with the Sectoral approach in the documentation box to Table 1.A.(c).
For estimating national total emissions, the result from the Sectoral approach should be used, where possible.

(3) According to the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.2, 4.87), CO_2 emissions from agricultural soils are to be included under Land-use change and forestry (LUCF). At the same time, the Summary Report 7A (Volume 1. Reporting Instructions, Tables.27) allows for reporting CO_2 emissions or removals from agricultural soils either in the Agriculture sector, under 4.D Agricultural soils or in the Land-use change and forestry sector under 5.D Emissions and removals from soil. Parties may choose either way to report emissions or removals from this source in the common reporting format, but the way they have chosen to report should be clearly indicated, by providing a brief explanation in the documentation box to Table 4.D of the agriculture sector. Double-counting of these emissions or removals should be avoided. Parties should include these emissions or removals consistently in Table8(a) (Recalculation - Recalculated data) and Table10 (Emission trends).

(4) Do not provide an estimate of both CO_2 emissions and CO_2 removals. "Net" emissions (emissions - removals) of CO_2 should be estimated and a single number placed in either the CO_2 emissions or CO_2 removals column, as appropriate. Note that for the purposes of reporting, the signs for removals are always (-) and for emissions (+).

(5) Countries are asked to report emissions from international aviation and marine bunkers and multilateral operations, as well as CO_2 emissions from biomass, under Memo Items. These emissions should not be included in the national total emissions from the energy sector. Amounts of biomass used as fuel are included in the national energy consumption but the corresponding CO_2 emissions are not included in the national total as it is assumed that the biomass is produced in a sustainable manner. If the biomass is harvested at an unsustainable rate, net CO_2 emissions are accounted for as a loss of biomass stocks in the land-use change and forestry sector.

SUMMARY 2 SUMMARY REPORT FOR CO_2 EQUIVALENT EMISSIONS
(Sheet 1 of 1)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs [2]	PFCs [2]	SF_6 [2]	Total
	CO_2 equivalent (Gg)						
Total (Net Emissions) [1]							
1. Energy							
A. Fuel Combustion (Sectoral Approach)							
1. Energy Industries							
2. Manufacturing Industries and Construction							
3. Transport							
4. Other Sectors							
5. Other							
B. Fugitive Emissions from Fuels							
1. Solid Fuels							
2. Oil and Natural Gas							
2. Industrial Processes							
A. Mineral Products							
B. Chemical Industry							
C. Metal Production							
D. Other Production							
E. Production of Halocarbons and SF_6							
F. Consumption of Halocarbons and SF_6 [2]							
G. Other							
3. Solvent and Other Product Use							
4. Agriculture							
A. Enteric Fermentation							
B. Manure Management							
C. Rice Cultivation							
D. Agricultural Soils[3]							
E. Prescribed Burning of Savannas							
F. Field Burning of Agricultural Residues							
G. Other							
5. Land-Use Change and Forestry[1]							
6. Waste							
A. Solid Waste Disposal on Land							
B. Waste-water Handling							
C. Waste Incineration							
D. Other							
7. Other *(as specified in Summary 1.A)*							

Memo Items: [4]							
International Bunkers							
Aviation							
Marine							
Multilateral Operations							
CO_2 Emissions from Biomass							

(1) For CO_2 emissions from Land-Use Change and Forestry the net emissions are to be reported. Note that for the purposes of reporting, the signs for removals are always (-) and for emissions (+).

(2) Actual emissions should be included in the national totals. If no actual emissions were reported, potential emissions should be included.

(3) See footnote 4 to table Summary 1.A.

(4) See footnote 8 to table Summary 1.A.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 emissions	CO_2 removals	Net CO_2 emissions / removals	CH_4	N_2O	Total emissions
Land-Use Change and Forestry	CO_2 equivalent (Gg)					
A. Changes in Forest and Other Woody Biomass Stocks						
B. Forest and Grassland Conversion						
C. Abandonment of Managed Lands						
D. CO_2 Emissions and Removals from Soil						
E. Other						
Total CO_2 Equivalent Emissions from Land-Use Change and Forestry						

Total CO_2 Equivalent Emissions without Land-Use Change and Forestry [a]	
Total CO_2 Equivalent Emissions with Land-Use Change and Forestry [a]	

(a) The information in these rows is requested to facilitate comparison of data, because Parties differ in the way they report emissions and removals from Land-Use Change and Forestry. Note that these totals will differ from the totals reported in Table 10, sheet 5 if Parties report non-CO_2 emissions from LUCF.

SUMMARY 3 SUMMARY REPORT FOR METHODS AND EMISSION FACTORS USED
(Sheet 1 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Method applied	CO_2 Emission factor	CH_4 Method applied	CH_4 Emission factor	N_2O Method applied	N_2O Emission factor	HFCs Method applied	HFCs Emission factor	PFCs Method applied	PFCs Emission factor	SF_6 Method applied	SF_6 Emission factor
1. Energy												
A. Fuel Combustion												
1. Energy Industries												
2. Manufacturing Industries and Construction												
3. Transport												
4. Other Sectors												
5. Other												
B. Fugitive Emissions from Fuels												
1. Solid Fuels												
2. Oil and Natural Gas												
2. Industrial Processes												
A. Mineral Products												
B. Chemical Industry												
C. Metal Production												
D. Other Production												
E. Production of Halocarbons and SF_6												
F. Consumption of Halocarbons and SF_6												
G. Other												

Use the following notation keys to specify the method applied:

D (IPCC default), **T1a, T1b, T1c** (IPCC Tier 1a, Tier 1b and Tier 1c, respectively), **CR** (CORINAIR),
RA (Reference Approach), **T2** (IPCC Tier 2), **CS** (Country Specific).
T1 (IPCC Tier 1), **T3** (IPCC Tier 3), **OTH** (Other)

If using more than one method within one source category, list all the relevant methods. Explanations regarding country-specific methods, other methods or any modifications to the default IPCC methods, as well as information regarding the use of different methods per source category where more than one method is indicated, should be provided in the documentation box. Also use the documentation box to explain the use of notation OTH.

Use the following notation keys to specify the emission factor used:

D (IPCC default), **CS** (Country Specific),
CR (CORINAIR), **PS** (Plant Specific).
OTH (Other)

Where a mix of emission factors has been used, list all the methods in the relevant cells and give further explanations in the documentation box. Also use the documentation box to explain the use of notation OTH.

SUMMARY 3 SUMMARY REPORT FOR METHODS AND EMISSION FACTORS USED
(Sheet 2 of 2)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Method applied	CO_2 Emission factor	CH_4 Method applied	CH_4 Emission factor	N_2O Method applied	N_2O Emission factor	HFCs Method applied	HFCs Emission factor	PFCs Method applied	PFCs Emission factor	SF_6 Method applied	SF_6 Emission factor
3. Solvent and Other Product Use												
4. Agriculture												
A. Enteric Fermentation												
B. Manure Management												
C. Rice Cultivation												
D. Agricultural Soils												
E. Prescribed Burning of Savannas												
F. Field Burning of Agricultural Residues												
G. Other												
5. Land-Use Change and Forestry												
A. Changes in Forest and Other Woody Biomass Stocks												
B. Forest and Grassland Conversion												
C. Abandonment of Managed Lands												
D. CO_2 Emissions and Removals from Soil												
E. Other												
6. Waste												
A. Solid Waste Disposal on Land												
B. Waste-water Handling												
C. Waste Incineration												
D. Other												
7. Other (as specified in Summary 1.A)												

Use the following notation keys to specify the method applied:

D (IPCC default), **T1a, T1b, T1c** (IPCC Tier 1a, Tier 1b and Tier 1c, respectively), **CR** (CORINAIR),
RA (Reference Approach), **T2** (IPCC Tier 2), **CS** (Country Specific).
T1 (IPCC Tier 1), **T3** (IPCC Tier 3), **OTH** (Other)

If using more than one method within one source category, list all the relevant methods. Explanations regarding country-specific methods, other methods or any modifications to the default IPCC methods, as well as information regarding the use of different methods per source category where more than one method is indicated, should be provided in the documentation box. Also use the documentation box to explain the use of notation OTH.

Use the following notation keys to specify the emission factor used:

D (IPCC default), **CS** (Country Specific),
CR (CORINAIR), **PS** (Plant Specific).
OTH (Other)

Where a mix of emission factors has been used, list all the methods in the relevant cells and give further explanations in the documentation box. Also use the documentation box to explain the use of notation OTH.

Documentation box:
• Parties should provide the full information on methodological issues, such as methods and emission factors used, in the relevant sections of Chapters 3 to 9 (see section 2.2 of each of Chapters 3 - 9) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of this table.
• Where a mix of methods/emission factors has been used within one source category, use this documentation box to specify those methods/emission factors for the various sub-sources where they have been applied.
• Where the notation OTH (Other) has been entered in this table, use this documentation box to specify those other methods/emission factors.

TABLE 7 SUMMARY OVERVIEW FOR KEY SOURCES
(Sheet 1 of 1)

Country
Year
Submission

KEY SOURCES	GAS	CRITERIA USED FOR KEY SOURCE IDENTIFICATION			COMMENTS
		L	T	Q	
Specify key sources according to the national level of disaggregation used:					
For example: *4.B Manure management*	*CH_4*	*X*			

Note: L = Level assessment; T = Trend assessment; Q = Qualitative assessment.

For estimating key sources Parties may chose the disaggregation level presented as an example in Table 7.1 of the IPCC good practice guidance (page 7.6), the level used in Summary 1A of the CRF or any other disaggregation level that the Party used to determine its key sources.

Documentation box:
Parties should provide the full information on methodologies used for identifying key sources and the quantitative results from the level and trend assessments (according to tables 7.A1 – 7.A3 of the IPCC good practice guidance) in Annex 1 to the NIR.

TABLE 8(a) RECALCULATION - RECALCULATED DATA Country
(Sheet 1 of 2) **Recalculated year:** Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		CO_2					CH_4					N_2O				
		Previous submission	Latest submission	Difference	Difference(1)	Impact of recalculation on total emissions (2)(3)	Previous submission	Latest submission	Difference	Difference(1)	Impact of recalculation on total emissions (2)(3)	Previous submission	Latest submission	Difference	Difference(1)	Impact of recalculation on total emissions (2)(3)
		CO_2 equivalent (Gg)			(%)	(%)	CO_2 equivalent (Gg)			(%)	(%)	CO_2 equivalent (Gg)			(%)	(%)
Total National Emissions and Removals																
1. Energy																
1.A.	Fuel Combustion Activities															
1.A.1.	Energy Industries															
1.A.2.	Manufacturing Industries and Construction															
1.A.3.	Transport															
1.A.4.	Other Sectors															
1.A.5.	Other															
1.B.	Fugitive Emissions from Fuels															
1.B.1.	Solid fuel															
1.B.2.	Oil and Natural Gas															
2. Industrial Processes																
2.A.	Mineral Products															
2.B.	Chemical Industry															
2.C.	Metal Production															
2.D.	Other Production															
2.G.	Other															
3. Solvent and Other Product Use																
4. Agriculture																
4.A.	Enteric Fermentation															
4.B.	Manure Management															
4.C.	Rice Cultivation															
4.D.	Agricultural Soils (4)															
4.E.	Prescribed Burning of Savannas															
4.F.	Field Burning of Agricultural Residues															
4.G.	Other															
5. Land-Use Change and Forestry (net) (5)																
5.A.	Changes in Forest and Other Woody Biomass Stocks															
5.B.	Forest and Grassland Conversion															
5.C.	Abandonment of Managed Lands															
5.D.	CO_2 Emissions and Removals from Soil															
5.E.	Other															

Note: All footnotes for this table are given at the end of the table on sheet 2.

TABLE 8(a) RECALCULATION - RECALCULATED DATA
(Sheet 2 of 2) **Recalculated year:**

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2					CH_4					N_2O				
	Previous submission	Latest submission	Difference	Difference[(1)]	Impact of recalculation on total emissions [(2)]	Previous submission	Latest submission	Difference	Difference[(1)]	Impact of recalculation on total emissions [(2)]	Previous submission	Latest submission	Difference	Difference[(1)]	Impact of recalculation on total emissions [(2)]
	CO_2 equivalent (Gg)			(%)	(%)	CO_2 equivalent (Gg)			(%)	(%)	CO_2 equivalent (Gg)			(%)	(%)
6. Waste															
6.A. Solid Waste Disposal on Land															
6.B. Waste-water Handling															
6.C. Waste Incineration															
6.D. Other															
7. Other *(as specified in Summary 1.A)*															
Memo Items:															
International Bunkers															
Multilateral Operations															
CO_2 Emissions from Biomass															

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFCs					PFCs					SF_6				
	Previous submission	Latest submission	Difference	Difference[(1)]	Impact of recalculation on total emissions	Previous submission	Latest submission	Difference	Difference[(1)]	Impact of recalculation on total emissions	Previous submission	Latest submission	Difference	Difference[(1)]	Impact of recalculation on total emissions
	CO_2 equivalent (Gg)			(%)	(%)	CO_2 equivalent (Gg)			(%)	(%)	CO_2 equivalent (Gg)			(%)	(%)
Total Actual Emissions															
2.C.3 Aluminium Production															
2.E. Production of Halocarbons and SF_6															
2.F. Consumption of Halocarbons and SF_6															
2.G. Other															
Potential Emissions from Consumption of HFCs/PFCs and SF_6															

	Previous submission	Latest submission	Difference	Difference[(1)]
	CO_2 equivalent (Gg)			(%)
Total CO_2 Equivalent Emissions with Land-Use Change and Forestry [(6)]				
Total CO_2 Equivalent Emissions without Land-Use Change and Forestry [(6)]				

(1) Estimate the percentage change due to recalculation with respect to the previous submission (Percentage change = 100 x [(LS-PS)/PS], where LS = Latest submission and PS = Previous submission. All cases of recalculation of the estimate of the source/sink category should be addressed and explained in Table 8(b).

(2) Total emissions refer to total aggregate GHG emissions expressed in terms of CO_2 equivalent, excluding GHGs from the LUCF sector. The impact of the recalculation on the total emissions is calculated as follows:
impact of recalculation (%) = 100 x [(source (LS) - source (PS))/total emissions (LS)], where LS = Latest submission, PS = Previous submission.

(3) The relative impact of recalculations of the LUCF sector is not considered in this table, until the IPCC completes its work on good practices for this sector and methods for estimating key sources from this sector are available.

(4) According to the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.2, 4.87), CO_2 emissions from agricultural soils are to be included under Land-use change and forestry (LUCF). At the same time, the Summary Report 7A (Volume 1. Reporting Instructions, Tables.27) allows for reporting CO_2 emissions or removals from agricultural soils either in the Agriculture sector, under 4.D Agricultural soils or in the Land-use change and forestry sector under 5.D Emissions and removals from soil. Parties may choose either way to report emissions or removals from this source in the common reporting format, but the way they have chosen to report should be clearly indicated, by providing a brief explanation in the documentation boxes to Table 4D of the agriculture sector. Double-counting of these emissions or removals should be avoided. Parties should include these emissions or removals consistently in Table8(a) (Recalculation - Recalculated data) and Table10 (Emission trends).

(5) Net CO_2 emissions/removals to be reported.

(6) The information in these rows is requested to facilitate comparison of data, because Parties differ in the way they report emissions and removals from Land-Use Change and Forestry.

Documentation box:
Parties should provide detailed information on recalculations in Chapter 10: Recalculations and improvements, and in the relevant sections of Chapters 3 to 9 (see section 2.5 of each of Chapters 3 - 9) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of this table.

TABLE 8(b) RECALCULATION - EXPLANATORY INFORMATION
(Sheet 1 of 1)

Country
Year
Submission

Specify the sector and source/sink category[1] where changes in estimates have occurred:		GHG	RECALCULATION DUE TO				
			CHANGES IN:			Addition/removal/ reallocation of source/sink categories	Other changes in data (e.g. statistical or editorial changes, correction of errors)
			Methods [2]	Emission factors [2]	Activity data [2]		

[1] Enter the identification code of the source/sink category (e.g. 1.B.1) in the first column and the name of the category (e.g. Fugitive Emissions from Solid Fuels) in the second column of the table. Note that the source categories entered in this table should match those used in Table 8(a).

[2] Explain changes in methods, emission factors and activity data that have resulted in recalculation of the estimate of the source/sink as indicated in Table 8(a). Include changes in the assumptions and coefficients in the "Methods" column.

Documentation box:
Parties should provide the full information on recalculations in Chapter 10: Recalculations and improvements, and in the relevant sections of Chapters 3 to 9 (see section 2.5 of each of chapters 3 - 9) of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of this table. References should particularly point to the sections of the NIR in which justifications of the changes as to improvements in the accuracy, completeness and consistency of the inventory are reported.

TABLE 9(a) COMPLETENESS - INFORMATION ON NOTATION KEYS
(Sheet 1 of 1)

Country
Year
Submission

Sources and sinks not estimated (NE)[1]			
GHG	**Sector[2]**	**Source/sink category [2]**	**Explanation**
CO_2			
CH_4			
N_2O			
HFCs			
PFCs			
SF_6			

Sources and sinks reported elsewhere (IE)[3]				
GHG	**Source/sink category**	**Allocation as per IPCC Guidelines**	**Allocation used by the Party**	**Explanation**
CO_2				
CH_4				
N_2O				
HFCs				
PFCs				
SF_6				

(1) Clearly indicate sources and sinks which are considered in the IPCC Guidelines but are not considered in the submitted inventory. Explain the reason for excluding these sources and sinks, in order to avoid arbitrary interpretations. An entry should be made for each source/sink category for which the notation key NE (not estimated) is entered in the sectoral tables.

(2) Indicate omitted source/sink following the IPCC source/sink category structure (e.g. sector: Waste, source category: Waste-water Handling).

(3) Clearly indicate sources and sinks in the submitted inventory that are allocated to a sector other than that indicated by the IPCC Guidelines. Show the sector indicated in the IPCC Guidelines and the sector to which the source or sink is allocated in the submitted inventory. Explain the reason for reporting these sources and sinks in a different sector. An entry should be made for each source/sink for which the notation key IE (included elsewhere) is used in the sectoral tables.

TABLE 9(b) COMPLETENESS - INFORMATION ON ADDITIONAL GREENHOUSE GASES (Sheet 1 of 1)

Country
Year
Submission

Additional GHG emissions reported[1]						
GHG	Source category	Emissions (Gg)	Estimated GWP value (100-year horizon)	Emissions CO_2 equivalent (Gg)	Reference to the source of GWP value	Explanation

(1) Parties are encouraged to provide information on emissions of greenhouse gases whose GWP values have not yet been agreed upon by the COP. Include such gases in this table if they are considered in the submitted inventory. Provide additional information on the estimation methods used.

Documentation box: Parties should provide detailed information regarding completeness of the inventory in the NIR (Chapter 1.8: General assessment of the completeness, and Annex 5). Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of this table.

TABLE 10 EMISSIONS TRENDS (CO_2)
(Sheet 1 of 5)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[1]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Change from 1990[1] to latest reported year
	(Gg)														(%)
1. Energy															
A. Fuel Combustion (Sectoral Approach)															
1. Energy Industries															
2. Manufacturing Industries and Construction															
3. Transport															
4. Other Sectors															
5. Other															
B. Fugitive Emissions from Fuels															
1. Solid Fuels															
2. Oil and Natural Gas															
2. Industrial Processes															
A. Mineral Products															
B. Chemical Industry															
C. Metal Production															
D. Other Production															
E. Production of Halocarbons and SF_6															
F. Consumption of Halocarbons and SF_6															
G. Other															
3. Solvent and Other Product Use															
4. Agriculture															
A. Enteric Fermentation															
B. Manure Management															
C. Rice Cultivation															
D. Agricultural Soils [2]															
E. Prescribed Burning of Savannas															
F. Field Burning of Agricultural Residues															
G. Other															
5. Land-Use Change and Forestry [3]															
A. Changes in Forest and Other Woody Biomass Stocks															
B. Forest and Grassland Conversion															
C. Abandonment of Managed Lands															
D. CO_2 Emissions and Removals from Soil															
E. Other															
6. Waste															
A. Solid Waste Disposal on Land															
B. Waste-water Handling															
C. Waste Incineration															
D. Other															
7. Other ***(as specified in Summary 1.A)***															
Total CO_2 emissions including net CO_2 from LUCF [4]															
Total CO_2 emissions excluding net CO_2 from LUCF [4]															
Memo Items:															
International Bunkers															
Aviation															
Marine															
Multilateral Operations															
CO_2 Emissions from Biomass															

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (CH_4)
(Sheet 2 of 5)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[(1)]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Change from 1990[(1)] to latest reported year
					(Gg)										(%)
Total CH_4 emissions															
1. Energy															
A. Fuel Combustion (Sectoral Approach)															
1. Energy Industries															
2. Manufacturing Industries and Construction															
3. Transport															
4. Other Sectors															
5. Other															
B. Fugitive Emissions from Fuels															
1. Solid Fuels															
2. Oil and Natural Gas															
2. Industrial Processes															
A. Mineral Products															
B. Chemical Industry															
C. Metal Production															
D. Other Production															
E. Production of Halocarbons and SF_6															
F. Consumption of Halocarbons and SF_6															
G. Other															
3. Solvent and Other Product Use															
4. Agriculture															
A. Enteric Fermentation															
B. Manure Management															
C. Rice Cultivation															
D. Agricultural Soils															
E. Prescribed Burning of Savannas															
F. Field Burning of Agricultural Residues															
G. Other															
5. Land-Use Change and Forestry															
A. Changes in Forest and Other Woody Biomass Stocks															
B. Forest and Grassland Conversion															
C. Abandonment of Managed Lands															
D. CO_2 Emissions and Removals from Soil															
E. Other															
6. Waste															
A. Solid Waste Disposal on Land															
B. Waste-water Handling															
C. Waste Incineration															
D. Other															
7. Other *(as specified in Summary 1.A)*															
Memo Items:															
International Bunkers															
Aviation															
Marine															
Multilateral Operations															
CO_2 Emissions from Biomass															

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSIONS TRENDS (N_2O)
(Sheet 3 of 5)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[(1)]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Change from 1990[(1)] to latest reported year
	(Gg)														(%)
Total N_2O emissions															
1. Energy															
A. Fuel Combustion (Sectoral Approach)															
1. Energy Industries															
2. Manufacturing Industries and Construction															
3. Transport															
4. Other Sectors															
5. Other															
B. Fugitive Emissions from Fuels															
1. Solid Fuels															
2. Oil and Natural Gas															
2. Industrial Processes															
A. Mineral Products															
B. Chemical Industry															
C. Metal Production															
D. Other Production															
E. Production of Halocarbons and SF_6															
F. Consumption of Halocarbons and SF_6															
G. Other															
3. Solvent and Other Product Use															
4. Agriculture															
A. Enteric Fermentation															
B. Manure Management															
C. Rice Cultivation															
D. Agricultural Soils															
E. Prescribed Burning of Savannas															
F. Field Burning of Agricultural Residues															
G. Other															
5. Land-Use Change and Forestry															
A. Changes in Forest and Other Woody Biomass Stocks															
B. Forest and Grassland Conversion															
C. Abandonment of Managed Lands															
D. CO_2 Emissions and Removals from Soil															
E. Other															
6. Waste															
A. Solid Waste Disposal on Land															
B. Waste-water Handling															
C. Waste Incineration															
D. Other															
7. Other ***(as specified in Summary 1.A)***															
Memo Items:															
International Bunkers															
Aviation															
Marine															
Multilateral Operations															
CO_2 Emissions from Biomass															

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS (HFCs, PFCs and SF_6)
(Sheet 4 of 5)

Country
Year
Submission

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[(1)]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Change from 1990[(1)] to latest reported year
	(Gg)														
Emissions of HFCs[(5)] - (Gg CO_2 equivalent)															
HFC-23															
HFC-32															
HFC-41															
HFC-43-10mee															
HFC-125															
HFC-134															
HFC-134a															
HFC-152a															
HFC-143															
HFC-143a															
HFC-227ea															
HFC-236fa															
HFC-245ca															
Unspecified mix of listed HFCs [(6)] - (Gg CO_2 equivalent)															
Emissions of PFCs[(5)] - (Gg CO_2 equivalent)															
CF_4															
C_2F_6															
C_3F_8															
C_4F_{10}															
$c\text{-}C_4F_8$															
C_5F_{12}															
C_6F_{14}															
Unspecified mix of listed PFCs [(6)] - (Gg CO_2 equivalent)															
Emissions of SF_6[(5)] - (Gg CO_2 equivalent)															
SF_6															

Chemical	GWP
HFCs	
HFC-23	11700
HFC-32	650
HFC-41	150
HFC-43-10mee	1300
HFC-125	2800
HFC-134	1000
HFC-134a	1300
HFC-152a	140
HFC-143	300
HFC-143a	3800
HFC-227ea	2900
HFC-236fa	6300
HFC-245ca	560
PFCs	
CF_4	6500
C_2F_6	9200
C_3F_8	7000
C_4F_{10}	7000
$c\text{-}C_4F_8$	8700
C_5F_{12}	7500
C_6F_{14}	7400
SF_6	23900

Note: All footnotes for this table are given at the end of the table on sheet 5.

TABLE 10 EMISSION TRENDS (SUMMARY)
(Sheet 5 of 5)

Country
Year
Submission

GREENHOUSE GAS EMISSIONS	Base year[(1)]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Change from 1990[(1)] to latest reported year
	CO_2 equivalent (Gg)														(%)
CO_2 emissions including net CO_2 from LUCF[(4)]															
CO_2 emissions excluding net CO_2 from LUCF [(4)]															
CH_4															
N_2O															
HFCs															
PFCs															
SF_6															
Total (including net CO_2 from LUCF)[(4)]															
Total (excluding net CO_2 from LUCF)[(4), (7)]															

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Base year[(1)]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Change from 1990[(1)] to latest reported year
	CO_2 equivalent (Gg)														(%)
1. Energy															
2. Industrial Processes															
3. Solvent and Other Product Use															
4. Agriculture															
5. Land-Use Change and Forestry[(8)]															
6. Waste															
7. Other															
Total (including LUCF) [(8)]															

(1) The column "Base year" should be filled in only by those Parties with economies in transition that use a base year different from 1990 in accordance with the relevant decisions of the COP. For these Parties, this different base year is used to calculate the percentage change in the final column of this table.

(2) According to the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.2, 4.87), CO_2 emissions from agricultural soils are to be included under Land-use change and forestry (LUCF). At the same time, the Summary Report 7A (Volume 1. Reporting Instructions, Tables.27) allows for reporting CO_2 emissions or removals from agricultural soils either in the Agriculture sector, under 4.D Agricultural soils or in the Land-use change and forestry sector under 5.D Emissions and removals from soil. Parties may choose either way to report emissions or removals from this source in the common reporting format, but the way they have chosen to report should be clearly indicated, by providing a brief explanation in the documentation box to Table 4.D of the agriculture sector. Double-counting of these emissions or removals should be avoided. Parties should include these emissions or removals consistently in Table8(a) (Recalculation - Recalculated data) and Table10 (Emission trends).

(3) Fill in net emissions as reported in table Summary 1.A. Please note that for the purposes of reporting, the signs for removals are always (-) and for emissions (+).

(4) The information in these rows is requested to facilitate comparison of data, because Parties differ in the way they report CO_2 emissions and removals from land-use change and forestry.

(5) Enter actual emissions estimates. If only potential emissions estimates are available, these should be reported in this table and an indication for this be provided in the documentation box. Note that only in these rows the emissions are expressed as CO_2 equivalent emissions.

(6) In accordance with the UNFCCC reporting guidelines, HFC and PFC emissions should be reported for each relevant chemical. However, if it is not possible to report values for each chemical (i.e. mixtures, confidential data, lack of disaggregation), this row could be used for reporting aggregate figures for HFCs and PFCs, respectively. Note that the unit used for this row is Gg of CO_2 equivalent and that appropriate notation keys should be entered in the cells for the individual chemicals.

(7) These totals will differ from the totals reported in table Summary 2 if Parties report non-CO_2 emissions from LUCF.

(8) Includes net CO_2, CH_4 and N_2O from LUCF.

Documentation box:
• Parties should provide detailed explanations on emissions trends in Chapter 2: Trends in greenhouse gas emissions and, as appropriate, in the corresponding Chapters 3 - 9 of the NIR. Use this documentation box to provide references to relevant sections of the NIR if any additional information and further details are needed to understand the content of this table.
• Use the documentation box to provide explanations if potential emissions are reported.

GUIDELINES FOR THE TECHNICAL REVIEW OF GREENHOUSE GAS INVENTORIES FROM PARTIES INCLUDED IN ANNEX I TO THE CONVENTION

A. Objective

1. The objective of these guidelines is to promote consistency in the review of annual greenhouse gas (GHG) inventories of Parties included in Annex I to the Convention (Annex I Parties) and to establish a process for a thorough and comprehensive technical assessment of national inventories.

B. Purposes of the technical review of greenhouse gas inventories

2. The purpose of the technical review of Annex I Parties' GHG inventories is:

(a) To ensure that the Conference of the Parties (COP) has adequate and reliable information on annual inventories and emission trends of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol;

(b) To provide the COP with an objective, consistent, transparent, thorough and comprehensive technical assessment of the annual quantitative and qualitative inventory information submitted by Annex I Parties, and a technical assessment of the implementation of Annex I Parties' commitments under Article 4, paragraph 1 (a), and Article 12, paragraph 1 (a), of the Convention;

(c) To examine, in a facilitative and open manner, the reported inventory information for consistency with the "Guidelines for the preparation of national communications by Annex I Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories"[1] and the *Revised 1996 (IPCC) Guidelines for National Greenhouse Gas Inventories*[2] as elaborated by the IPCC report entitled *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories;*[3]

(d) To assist Annex I Parties in improving the quality of their GHG inventories.

C. General approach

3. Greenhouse gas inventory submissions from all Annex I Parties will be subject to an annual technical review. The technical review process for GHG inventories, as outlined in these guidelines, comprises three stages which consider different aspects of the inventories in such a way that all of the purposes described above are achieved by the end of the process. The three stages are:

(a) Initial check of annual inventories;

(b) Synthesis and assessment of annual inventories;

(c) Review of individual annual inventories.

4. The stages of the technical review process complement each other so that, in general, for each Annex I Party, one stage is concluded before the next one is undertaken.

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1 Referred to in this document as the reporting guidelines.

2 Referred to in this document as the IPCC Guidelines.

3 Referred to in this document as the IPCC good practice guidance.

5. At all stages of the inventory review process, individual Annex I Parties under review will have the opportunity to clarify issues or provide additional information. The secretariat will send to these Annex I Parties drafts of their status report, the synthesis and assessment report and a preliminary analysis of the respective Party's inventory, and their individual inventory review report. Every effort will be made to reach agreement with each Party on the content of a report prior to its publication. In the case of a Party and the expert team being unable to agree on an issue, the Party may provide explanatory text to be included in a separate section of the report.

D. Initial check of annual inventories

1. Scope

6. The secretariat will conduct annually an initial check of the annual GHG inventory submissions from Annex I Parties in order to determine promptly whether the information provided is complete and in the correct format, and to enable subsequent review stages to take place.

7. The initial check will cover the national inventory submission, in particular, the data submitted electronically in the common reporting format (CRF), and will determine:

(a) Whether all sources, sinks and gases included in the IPCC Guidelines, as elaborated by the IPCC good practice guidance, are reported;

(b) Whether all tables of the CRF have been completed and any gaps have been explained in the CRF by use of notation keys (such as NE, NA, NO, IE, C)[4] and whether there is frequent use of these notation keys;

(c) Whether estimates for summary totals and individual source categories are provided in mass units and in terms of CO_2 equivalent using the IPCC global warming potential (GWP) values in accordance with the relevant decisions of the COP;

(d) Whether emission estimates are provided for all required years (i.e., from the base year to the latest year in the current submission);[5]

(e) Whether methodologies are indicated with notations in the CRF;

(f) Whether estimates for CO_2 emissions from fossil fuel combustion are reported using the IPCC reference approach in addition to estimates derived using national methods;

(g) Whether actual and potential emission estimates for hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride are reported by individual chemical species;

(h) Whether any recalculations are reported for the entire time series and explanatory information relating to these recalculations is provided in the CRF;

(i) Whether all emissions are reported without adjustments relating, for example, to climate variations or trade of electricity;

(j) Whether emissions from fuel used in international transportation are reported separately from national totals;

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[4] NE = not estimated, NA = not applicable, NO = not occurring, IE = included elsewhere, C = confidential.

[5] In accordance with the reporting guidelines, if there are no changes in the previously submitted inventories, the national inventory report (NIR) should reference the inventory submission where the other years constitute the time series.

(k) Whether key sources have been reported in the CRF as required by the reporting guidelines;

(l) Whether the tables on uncertainties have been reported as required by the reporting guidelines;

(m) Whether a national inventory report (NIR) has been submitted.

2. Status reports

8. The results of the initial check for each Annex I Party will be published on the UNFCCC web site as a status report, mainly in a tabular format. The status report will, inter alia:

(a) Indicate the date of receipt by the secretariat;

(b) Indicate whether the NIR and the CRF have been submitted;

(c) Determine whether the inventory information has been provided in the correct format as called for in the reporting guidelines;

(d) Determine whether the submission is complete and identify any gaps in the reported data, covering the elements listed in paragraph 7 above.

3. Timing

9. The initial check for each Annex I Party should be finalized and the status report published on the UNFCCC web site within seven weeks of the date of receipt of the submission by the secretariat. In general, the timetable for the initial check should conform to the following:

(a) The secretariat should perform the initial check and prepare a draft status report within three weeks and send it to the Party for comments;

(b) Each Party should provide comments on the draft status report within three weeks.

E. Synthesis and assessment of annual inventories

1. Scope

10. The secretariat will conduct a synthesis and assessment of Annex I Parties' greenhouse gas inventories to facilitate the consideration of inventory data and other information across Annex I Parties, and to identify issues for further consideration during the review of individual inventories.

11. The synthesis and assessment will cover the national inventory submission and previous national inventory submissions, where relevant, and will include a standardized set of data comparisons of:

(a) Implied emission factors and other inventory data across Annex I Parties to identify any irregularities or inconsistencies;

(b) Emission or removal estimates, activity data, implied emission factors and any recalculations with data from previous submissions to identify any irregularities or inconsistencies;

(c) Activity data of each Annex I Party with relevant authoritative sources, if feasible, to identify cases where there are significant differences.

12. To facilitate the analysis of the inventory data, the secretariat will, for each individual Annex I Party, identify and consider those sources that are *key sources* both in terms of their absolute

level and in terms of their trend assessment, applying the tier 1 level assessment as described in the IPCC good practice guidance. In addition, the secretariat will consider other sources (i.e., emissions from bunker fuels, emissions and removals from land-use change and forestry,[6] etc.) and non-key sources for which irregularities or inconsistencies are identified, based on their significance for specific sectors or for the whole GHG inventory.

2. Synthesis and assessment report

13. The synthesis and assessment will consist of two parts: part I and part II, which are described in paragraphs 14 and 15 below, respectively. The results of part I will be published on the UNFCCC web site as a synthesis and assessment report. Part II, containing a preliminary analysis of individual Annex I Party inventories, will be sent to the respective Party for comments. The results of part II, together with the comments provided by the respective Party, will be provided to the corresponding expert review team as input for the individual review.

Part I

14. The synthesis and assessment report (part I) will provide information to allow comparisons across Annex I Parties and to describe common methodological issues. This report will compile and compare information across Annex I Parties in a tabular and, as appropriate, graphical format, including:

(a) For *key sources*, based on the approach used by the secretariat, and other selected sources:

(i) Methodologies used in the preparation of the inventories;

(ii) Implied emission factors, default values and ranges contained in the IPCC Guidelines, as elaborated by the IPCC good practice guidance;

(iii) Reported activity data and data from authoritative sources, if possible;

(iv) Other information provided in the various CRF tables;

(b) Estimates of CO_2 emissions from fuel combustion using the IPCC reference approach compared with estimates of CO_2 emissions from fuel combustion using a national (sectoral) approach;

(c) Estimates of actual and potential emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride and the ratio between the actual and potential emissions;

(d) Inventory recalculations.

Part II

15. The preliminary analysis of individual Annex I Party inventories (part II), will be based on the information contained in the synthesis and assessment report, and will, for each individual inventory:

(a) Identify issues within source or sink categories requiring further consideration or clarification during the individual review stage;

(b) Identify any recurring problems with reporting;

(c) Examine inventory recalculations and the consistency of the time series;

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6 For land-use change and forestry, good practice guidance has not, as yet, been elaborated.

(d) Assess the availability of documentation on:

(i) National self-verification procedures or independent review in the technical review process;

(ii) The application of the IPCC good practice guidance, including estimations of uncertainties;

(e) Assess the consistency of information on methodologies and emission factors in the CRF with related information in the NIR.

3. Timing

16. The synthesis and assessment will be conducted annually and should, in general, conform to the following timetable:

(a) The secretariat will complete the synthesis and assessment report (part I), containing the elements in paragraph 14 above, within 10 weeks from the due date for submission.[7] The secretariat will incorporate all submissions and any re-submissions from Annex I Parties that were provided as a response to the status report and were received within six weeks from the due date for submissions. Annex I Parties should provide comments within three weeks of receipt of the draft synthesis and assessment report. If possible, the secretariat should complete a synthesis and assessment of the GHG inventories submitted after that date and should publish these assessments as separate documents (addenda to the synthesis and assessment report) provided that this does not delay the review process for other Annex I Parties;

(b) The preliminary analysis of individual Annex I Party inventories (part II of the synthesis and assessment), containing the elements in paragraph 15 above, will be completed at the latest four weeks prior to the scheduled individual review for the Party concerned. The secretariat will send a draft of the preliminary analysis to the Party at the latest seven weeks prior to the scheduled individual review, and the Party will provide comments within three weeks. The preliminary analysis and the Party's comments will be forwarded to the expert review team for further consideration.

F. Review of individual annual inventories

1. Scope

17. Expert review teams, coordinated by the secretariat, will conduct reviews of individual greenhouse gas inventories in order to assess whether the COP has adequate and reliable information on annual GHG inventories. The individual reviews will provide for a detailed examination of the inventory estimates, procedures and methodologies used in the preparation of inventories, covering each Annex I Party's national inventory submission, supplementary material submitted by the Party and, as appropriate, previous inventory submissions. The results of this stage of the review process will be communicated to Annex I Parties.

18. Three operational approaches may be used during this stage of the technical review, namely desk reviews, centralized reviews and in-country reviews, assuming available resources. During a desk review, inventory information of Annex I Parties will be sent to experts, who will conduct the review in their own countries. During a centralized review, the experts will meet in a single location to review the

[7] In accordance with decision 3/CP.5, the due date for submission of the GHG inventories of Annex I Parties is 15 April of each year.

inventory information of Annex I Parties. During an in-country review, experts will visit an Annex I Party to review the inventory information of this Party.

19. The review of most individual inventories of Annex I Parties will be conducted annually as a desk review or as a centralized review. In addition, the GHG inventory of each Annex I Party will be subject to an in-country visit by an expert review team once every five years. In a year when an in-country review is scheduled, a desk or centralized review of the Party's GHG inventory will not take place. In-country visits will be scheduled, planned and take place with the consent of, and close coordination with, the Party subject to review. In general, during a centralized review, up to eight GHG inventories should be reviewed; during a desk review up to five GHG inventories should be reviewed.

20. Expert review teams should pay particular attention to those areas of the inventory where problems have been identified in previous reviews, or stages of the review, or where changes have been reported by the Party. Expert review teams should not perform an individual review in cases where a NIR has not been provided.

21. Each expert review team will:

(a) Examine application of the requirements of the reporting guidelines, and the IPCC Guidelines as elaborated by the IPCC good practice guidance, and identify any departure from these requirements;

(b) Examine whether the IPCC good practice guidance was applied and documented, in particular noting the identification of key source categories, selection and use of methodologies and assumptions, development and selection of emission factors, collection and selection of activity data, reporting of recalculations and consistent time-series, reporting of uncertainties related to inventory estimates, methodologies used for estimating those uncertainties and quality assurance and quality control procedures, and identify any inconsistencies;

(c) Compare emission or removal estimates, activity data, implied emission factors and any recalculations with data from previous submissions of the Annex I Party to identify any irregularities or inconsistencies;

(d) Identify any missing sources and examine any explanatory information relating to their exclusion from the GHG inventory;

(e) Identify the reason for any differences between the Party's and the secretariat's key source determination;

(f) Assess the consistency of information in the CRF with that in the NIR;

(g) Assess the extent to which issues raised in the synthesis and assessment of annual inventories, and issues and questions raised by expert review teams in previous reports, have been addressed and resolved;

(h) Identify areas for further improvement of the inventories and note possible ways for improving the estimation and the reporting of inventory information.

22. In addition to the tasks mentioned in paragraph 21 above, expert review teams conducting in-country reviews will consider the "paper trail" of the inventory from the collection of data to the reported emission estimates and will examine procedures and institutional arrangements for inventory development and management, including quality assurance and quality control, record-keeping and documentation procedures. During subsequent desk or centralized reviews, the expert review teams will

identify any changes that may have occurred in these procedures and institutional arrangements, based on the information provided in the NIRs of Annex I Parties.

23. The expert review team may use relevant technical information in the review process, such as information from international organizations.

2. Expert review teams

General procedures

24. Each GHG inventory submission will be assigned to a single expert review team that will be responsible for performing the review in accordance with the procedures and time frames established in these guidelines. A submission by an Annex I Party will not be reviewed in two successive years by expert review teams with an identical composition.

25. Each expert review team will provide a thorough and comprehensive technical assessment of the GHG information submitted and will, under its collective responsibility, prepare a review report in accordance with the provisions of these guidelines.

26. Expert review teams will be coordinated by the secretariat which will provide administrative support, and, as appropriate, technical and methodological assistance and assistance in the use of the reporting guidelines, and these review guidelines.

27. Expert review teams will be composed of experts selected on an ad hoc basis from the UNFCCC roster of experts and will include lead reviewers. Experts will be nominated by Parties to the Convention to the roster of experts and, as appropriate, by intergovernmental organizations, in accordance with guidance provided for this purpose by the COP. Participating experts will serve in their personal capacity and will neither be nationals of the Party under review nor be nominated or funded by that Party.

28. In the conduct of the review, expert review teams shall adhere to these guidelines and work on the basis of established and published procedures, including quality assurance and control and confidentiality provisions in accordance with the relevant decisions adopted by the COP.

29. The secretariat will notify Annex I Parties about up-coming desk and centralized reviews, and ask the Annex I Parties to identify the contact person(s) through whom enquiries could be directed. Communication between the expert review teams and the Party under review should be through the lead reviewers and the designated contact person(s) of the Party. Other members of the expert review team may communicate directly with the national experts involved in the GHG inventory preparation only if a Party so agrees. Information thus obtained should be made available to other members of the team.

30. Participating experts from Parties not included in Annex I to the Convention (non-Annex I Parties) and Annex I Parties with economies in transition will be funded according to the existing procedures for participation in UNFCCC activities. Experts from other Annex I Parties will be funded by their governments.

Composition of the expert review teams

31. Participating experts shall have experience in the area of GHG inventories in general and/or in specific sectors (Energy, Industrial Processes, Solvents and Other Products Use, Agriculture, Land-Use Change and Forestry, and Waste).

32. Expert review teams may vary in size and composition, taking into account the national circumstances of the Party under review and the different expertise needs.

In general, the normal size of the expert review teams should be:

(a) Six experts for in-country visits (one expert per inventory sector[8] plus one generalist[9]);

(b) Twelve experts for desk and centralized reviews (two experts per inventory sector[8] plus two generalists[9]).

33. The secretariat will select the members of the review teams in a way that will ensure that the collective skills of the team address the areas mentioned in paragraph 31 above and that most experts in the teams have the necessary experience in the review process. The secretariat will select national inventory experts with limited or no experience of the review process and invite one of these experts to participate in each in-country review, with a maximum of five experts to participate in each centralized review. These experts with limited or no experience of the review process will work on a specific IPCC sector together with an expert with experience of the review process. Desk reviews will be conducted only by experienced experts.

34. The secretariat will select the members of the expert review teams with a view to achieving a balance between experts from Annex I Parties and non-Annex I Parties in the overall composition of the expert review teams, without compromising the selection criteria referred to in paragraph 31 above. The secretariat shall make every effort to ensure geographical balance among those experts selected from non-Annex I Parties and among those experts selected from Annex I Parties.

35. Without compromising the criteria stated in paragraphs 31 to 34 above, the formation of expert review teams should ensure, to the extent possible, that at least one member is fluent in the language of the Party under review.

Lead reviewers

36. For each expert review team, two inventory experts with substantial inventory review experience will serve as lead reviewers. One lead reviewer will be from a non-Annex I Party and one from an Annex I Party.

37. Lead reviewers should ensure that the review in which they participate is performed according to these guidelines and is performed consistently across all Annex I Parties under review by the expert review team. They should also ensure the quality and the objectivity of the technical assessments in the reviews.

38. With the support of the secretariat, lead reviewers will:

(a) Prepare a brief work plan for the review activity;

(b) Verify that the experts have all the necessary information provided by the secretariat prior to the review activity;

(c) Monitor the progress of the review activity;

(d) Ensure that there is good communication within the expert review team;

(e) Coordinate queries of the expert review team to the Party and coordinate the inclusion of the answers in the review reports;

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8 The expert(s) dealing with the Industrial Processes sector should also be responsible for the Solvents and Other Products Use sector which, in general, does not constitute a major source of GHG emissions.

9 The term “generalist” in these guidelines is used for experts who have broad knowledge of all areas of the inventory process.

(f) Provide technical advice to the ad hoc experts, if needed;

(g) Ensure that the review is performed and the review report is prepared in accordance with these guidelines;

(h) Verify that the review team gives priority to individual source categories for review in accordance with these guidelines.

3. Individual review reports

39. Under its collective responsibility, the expert review team will produce an individual inventory review report for publication in electronic format on the UNFCCC web site based on the results of the tasks listed in paragraph 21 above. The review reports should contain an objective assessment of the adherence of the inventory information to the reporting guidelines and the provisions of relevant decisions by the COP and should not contain any political judgement.

40. The report of all in-country reviews should not exceed 25–30 pages including a 2–3 page summary. For desk and centralized reviews, the report should not exceed 10 pages and should focus on particular strengths and identified problems as well as on an overall appraisal of the quality and reliability of the inventory, emission trends, actual emission factors and activity data, and on the degree of adherence to the reporting guidelines and the IPCC good practice guidance. Both types of review reports should include standardized tables, whenever possible, to increase the efficiency of communication.

4. Timing

41. The secretariat should forward all relevant information to the members of the expert review teams one month prior to the start of the review activities. Each desk or centralized review should be completed within 20 weeks and 25 weeks,[10] respectively, and each in-country review should be completed within 14 weeks. In general, the timetable for the individual review activities, assuming available resources, should conform to the following:

(a) *Desk review*: each expert review team performs individual reviews and prepares draft review reports within seven weeks (three weeks for individual reviews and four weeks for the preparation of the reports). The secretariat edits and formats the reports and sends them to the respective Annex I Party for comments. The Annex I Parties respond within four weeks. The expert review team integrates the Annex I Parties' comments within four weeks and sends the revised versions of the reports to the secretariat. The final reports are published on the UNFCCC web site within two weeks.

(b) *Centralized review*: each expert review team performs individual reviews and prepares draft review reports within ten weeks (up to eight working days for individual reviews and nine weeks for the preparation of the reports). The secretariat edits and formats the reports and sends them to the respective Annex I Party for comments. The Annex I Parties respond within four weeks. The expert review team integrates the Annex I Parties' comments within six weeks and sends the revised versions of the reports to the secretariat. The final reports are published on the UNFCCC web site within two weeks.

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[10] According to the original version of these guidelines (see FCCC/SBSTA/2002/L.5/Add.2), a total of 22 weeks was allocated for the completion of a centralized review. However, this period does not include the necessary time for editing and formatting of the review reports by the secretariat as required in paragraph 41(b). Therefore, the total time available for review has been increased from 22 to 25 weeks to be consistent with the approach taken for desk and in-country reviews.

(c) *In-country review*: each expert review team performs the individual review within one week and prepares a draft review report within three weeks. The secretariat edits and formats the report and sends it to the respective Annex I Party for comments. The Party responds within four weeks. The expert review team integrates the Party's comments within three weeks and sends the revised version of the report to the secretariat. The final report is published on the UNFCCC web site within one week.

G. Annual report of emissions and trends of greenhouse gases

42. As part of the technical review of annual national GHG inventories, the secretariat will also compile and tabulate aggregate information and trends concerning greenhouse gas emissions by sources and removals by sinks, and any other inventory information, in a stand-alone document to be published electronically on the UNFCCC web site. This document will draw information from the latest available GHG inventory submissions of all Annex I Parties and will serve to provide aggregate information to the COP on GHG emissions by sources and removals by sinks and their trends for all Annex I Parties. This document may also be used as an input to the third stage of the technical review process.

43. A summary of the document mentioned in paragraph 42 above will be published in both hard copy and electronic format for the consideration of the COP and the subsidiary bodies.[11] This summary will include trends of GHG emissions by sources and removals by sinks and an assessment of the adherence of the reported inventory information to the reporting guidelines, as well as to the provisions of relevant decisions by the COP, including information on any delays in submitting the annual inventory information.

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[11] In order to ensure the quality and timeliness of the information included in this summary, the secretariat will prepare this report for the consideration of the Convention bodies during the second sessional period scheduled for each year.

Stakeholder Meeting for the implementation of

UNEP' GLOBAL TECHNICAL ASSISTANCE PROGRAMME IN THE CHILLER SUB-SECTOR

CONCEPT NOTE

29 October 2006

BACKGROUND

The 48th meeting of the Executive Committee of the Multilateral Fund approved a Global Technical Assistance Programme in the Chiller Sub-Sector to be implemented by UNEP. The project complies with decision XVI/13 and in particular with regard to the countries which didn't receive a chillers demonstration project or any support in the chillers sector from the Multilateral Fund. Through UNEP's Compliance Assistance Programme, this project aims at providing global technical assistance to Article 5 countries in the chillers sub-sector to enable the countries to gain better understanding of the available financial and technological options in the chillers sub-sector to phase-out ODS through a close coordination with other Implementing and Bilateral Agencies working on investment projects in the chillers sector, other relevant stakeholders at the global and regional level as well as the regional teams of the Compliance Assistance Programme.

The 47th & 48th meetings of the Executive Committee approved several chillers demonstration projects within the funding window opened as per decision 45/4 covering countries in Latin America, Africa, East Europe, West Asia and South Asia & Pacific regions. Historically there were also previous approvals –under the Multilateral Fund- for chillers demonstration projects and activities (replacement & retrofitting); additionally many developed countries and some developing countries adopted national programs for phasing out the CFC-based chillers. On the other hand, most of international manufacturers developed and promoted non-CFC technologies during the last two decades. The TEAP special report on Chillers –that issued in 2004- provide a comprehensive snapshot on the technology trend as well as available information on remaining CFC-based chillers around the world. International/regional/national associations and societies are also contributing to the phase out actions through research activities, functions and thematic initiatives.

UNEP recognizes the importance of compiling all past, ongoing and future efforts in this movement and present relevant information in a useful way to the targeted stakeholders i.e. owners, policy makers, consultants and others influential parties to the chillers sector. UNEP also understands the values of coordination and appropriate planning for the sake of best results and saving of resources. Therefore, UNEP will organize a stakeholder meeting to discuss the implementation of the Global Technical Assistance Programme in the Chiller Sub-Sector.

TARGETED PARTICIPANTS

Participants to the stakeholder meeting will be representing the key partners and source of information for the implementation of the Global Technical Assistance Programme in the Chiller Sub-Sector, the proposed list includes:

- Bilateral & Implementing Agencies (Canada, Germany, France, Japan, USA, UNDP, UNIDO & World Bank);
- TEAP Chiller Task Force;
- Industry Representatives (Carrier, Trane, York, Daikin and others);
- Relevant International Associations/Organizations (ARI, ASHRAE, ICARMA, IIR) &
- Financial institutions

This meeting is being coordinated by UNEP's Compliance Assistance Programme Team (CAP) in cooperation with United States Environmental Protection Agency (US EPA).

OBJECTIVES

The stakeholder meeting will have the following objectives:

1. Discuss the project implementation approach and activities and compile feedback/proposals of participants and views on cooperation during the implementation timeframe.
2. Review the implementation time schedule of UNEP project with other Bilateral and Implementing agencies schedules in executing the demonstration projects to ensure that outputs of these projects are well reflected in the products developed by UNEP project.
3. Identify sources of information that could be used during the compilation phase of the project and means of verifying collected data.
4. Discuss the potential role of manufacturers and associations in compilation and dissemination of information during the various stages of the project.

DISCUSSION TOPICS

The topics proposed for discussions in the stakeholder meeting are:

- Detailed explanation of the project content and UNEP' view of implementation
- Plans and schedules for the chiller demonstration projects implemented by Bilateral and Implementing agencies
- Manufacturers views and experiences (focus on replacement/retrofit experience)
- Associations activities in the chiller sector
- Adequacy of the proposed activities and products in addressing countries' needs
- Role of Industry and international associations in information compilation and dissemination
- Proposed coordination plan inline with to the implementation time schedule
- Other topics (to be suggested by participants of the meeting)

DATE & VENUE

29 October 2006 from 9.00 a.m. to 5 p.m. at India Habitat Centre, New Delhi.

Chiller Replacement Projects

Presentation by World Bank
Global Chiller Workshop
29 October 2006
New Delhi, India

Objectives

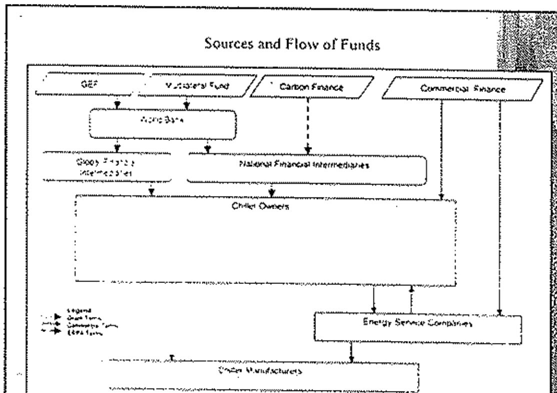
- Provide an overall strategy for all participating countries for phasing out CFCs in the chiller sector; and
- Promote utilization of more energy efficient chillers.

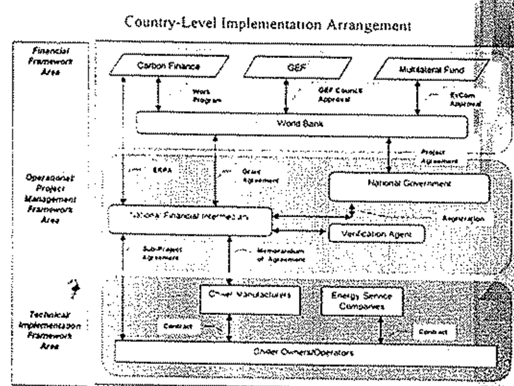
Expected Outputs

- Fulfillment of Protocol-mandated phase-out of CFC consumption;
- Accelerated transformation of the chiller sector market to one more technology-driven and responsive to energy saving opportunities;
- Free up power capacity of up to 416 MW;
- Reduce carbon dioxide emissions by up to 5.3 million MT per year for the next 17 years.

Project Description

- Deliver incentives to CFC chiller owners sufficient to overcome the well-documented techno-economic barriers;
- Stimulate the adoption by participating countries of policy and regulatory measures aimed at:
  - Fulfillment of CFC phase-out obligations;
  - Bringing private behavior in respect of energy conservation more in line with desirable social behavior; and
  - Reducing or eliminating avoidable greenhouse gas emissions.

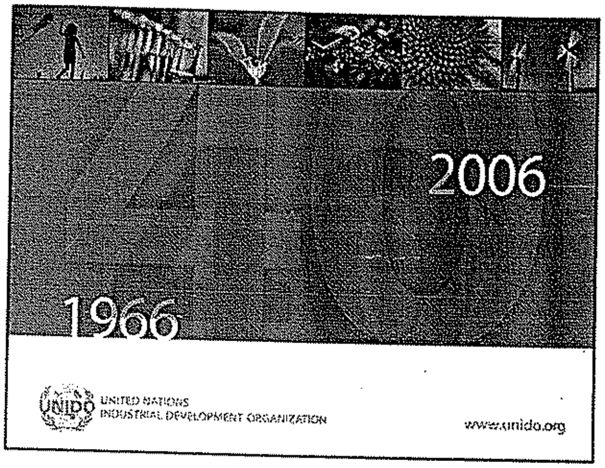




Sample Cashflow for the Overall Global Chiller Replacement Projec

Project Components

- Investment Component
  - Financial incentives to chiller owners to accelerate their chiller replacement schedules;
  - Level of incentives determined in accordance with para. (b) (ii) Decision 46/33;
- Technical Assistance Component
  - Local project implementation units (LPIU) will work with NOUs to assist chiller owners preparing decentralized refrigerant management plans;
  - Capacity building for LPIU on energy conservation and proper handling of refrigerants.
- Awareness
  - Chiller suppliers with their existing sales network will conduct, in close cooperation with LPIU and NOU, awareness activities for the targeted audience (chiller owners).



UNIDO's Chiller Programme

UNEP - USEPA Chiller meeting side event

S. M. Si Ahmed
29 October 2006, New Delhi, India

Three Regional Projects Approved

- West Asia (US$ 585,961) – Syria.
- Eastern Europe (US$ 1,069,074) - Croatia, Macedonia, Romania, and Serbia and Montenegro (Former)
- Africa (US$ 2,000,000) – Cameroon, Egypt, Namibia, Nigeria and Sudan (with possibility to include more countries in Africa)

  Under implementation by UNIDO, France, Germany and Japan

Project Activities

- Awareness Raising
- Policy advice
- Capacity Building
- Technology transfer
- Demonstration of funding approaches for replication aspects: Country based approach taking into account existing local conditions and chiller populations
- Dissemination of lessons learned

Croatia – Working through ESCOs

Role of the ESCO (Hrvatska Elektroprivreda)

- Information, advice and training on energy management issues
- Support for the implementation of energy plans
- Energy audits
- Raising awareness on energy efficiency
- Search for energy-management incentive funds at national and international level
- Financing through credit

Romania, Macedonia and Syria

Building the end users capacity in;

- evaluating the various available technology options,
- better understanding of the return on investment issue,
- preparing specifications,
- evaluating proposals,
- accessing chiller suppliers worldwide,
- available funding options

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Serbia

- Provision of subsidies for the replacement of a number of chillers instead of the partial cost pertaining to the replacement of one chiller.

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Common Limitations

- Substantial external financial resources are often required for the modification of the entire cooling plant, which creates an additional obstacle

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Africa

- Innovative approach to clearly evaluate and demonstrate the incentives and remove barriers for operators to replace CFC based chillers through coordinating inputs from engineering facilities and energy contracting providers, investors, financial institutions, government and private sector stakeholders in the region.

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Organizational and Institutional Framework

Government interventions in creating an overall framework that encourages chiller replacement

Differentiated roles ⇕ *Complementary roles*

Stakeholder involvement and willingness to respond with creativity and business generating attitude

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Potential External Funding Sources

- FGEF
- UNIDO's Investment and Technology Promotion Office (ITPO), Tokyo
- Japan Bank for International Cooperation
- African Development Bank
- Import / Export Banks (Afreximbank)
- Commercial Banks

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Main Conclusions of the Regional Workshop in Cairo

- Need to maintain momentum under the project funding conditions
- Implementing agencies were requested to take up the use of approved funds with the Multilateral Fund so that release of the funds is not conditional to any other steps at the national level
- Need to explore the CDM potential (UNIDO is currently studying the possibility of starting with a pilot country)

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Thank you

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Contact

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Programme Development
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"Utilizing the Clean Development Mechanism of the Kyoto Protocol to modernize Refrigeration Systems"

AFROC – AN EXAMPLE FOR CHILLER CDM FINANCING IN AFRICA

Juergen USINGER
GTZ Proklima

October - New Delhi

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gtz

Content

1) Introduction of AFROC Project
2) Network of AFROC
3) Possibilities on Financing and Funding
4) Possibilities on CDM Financing

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1) Introduction of the AFROC Project

Background

- Approved by the MLF: funding of a demonstration project and financing of 19 chillers in 6 African countries
- Market: ca. 600 to 1,000 chillers in the African countries
- Estimated average investment: ca. 140,000 US $ per chiller
- Incentive for significant exports of energy efficient technology system (unit and system)
- Proposed initial volume of funding: 20,000,000 US $

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1) Introduction of the AFROC Project

Phase I
- Demonstration of financial incentives and necessary infrastructure
- Technology acquisition for 19 chillers in 6 African countries
- Set up of a network and replacement policy
- Identify and remove barriers

Phase II
- Established mechanism from Phase I to replace all CFC Chillers in African countries which fulfil criteria of the Secretariat of the Montreal Protocol

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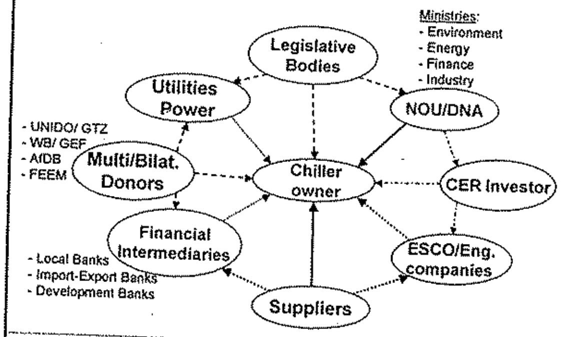
2) Network of AFROC



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3) Possibilities on Financing and Funding

Identified Barriers for chiller investments by Suppliers:

- Initial costs
- Operating costs
- Lack of awareness for new technologies
- Less knowledge on energy efficiency and environmental issues
- High customs duties

⇨ **Create conditions to remove these barriers through better access to:**

1) Capacity building / Technical assistance
2) Financial services

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3) Possibilities on Financing and Funding

Overcome Barriers by an improved framework for investments

1) Capacity building / Technical assistance

- Establishment of national network
- Coordination of Stakeholders and Funding partners
- Support in formulation and adaptation of regulations and standards
- Identification of suitable technology

⇨ Reduction of transaction costs

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3) Possibilities on Financing and Funding

Overcome Barriers by providing financial contributions

2) Interested financial institutions

- MLF: Funding of 19 chillers during Phase I
- FFEM: bilateral contribution and additional grants for TA and
- AfDB: Public and private loans, credit line; min. 3 Mio. US $
- Afreximbank: Credit lines to corporates and to local banks
- Development Bank Senegal: credit lines, guarantees
- KfW: commercial credits for energy efficiency
- CDM

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4) Possibilities on CDM Financing

1) Methodology:
- Small-scale (simplified PDD, 1 barrier sufficient, <15 GWh/year)

2) Bundling:
- Max. size 15 GWh/year; will change to 60 GWh/year
- Bundle parts must have same crediting period
- No change of composition of bundle over time

- Bundle with same technologies – one monitoring plan
- Bundle with different technology – separate monitoring and reports

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4) Possibilities on CDM Financing

CER sales from CDM are directly proportional to energy savings

$$\frac{\text{Gain from investment with CDM}}{\text{Gain from investment without CDM}} = \frac{\text{Emission factor x CER price}}{\text{Electricity price}}$$

Egypt: $\frac{0.525 \text{ CER / MWh x } 12 \text{ € / CER}}{0.027 \text{ € / kWh}}$ = 23 % higher NPV with CDM

Nigeria: 0.540 CER/MWh, 0.067 €/kWh = 9.6 %

Cameroon: 0.880 CER/MWh, 0.09 €/kWh = 11.7 %

Namibia: 0.890 CER/MWh, 0.019 €/kWh = 56 %

DAIKIN

Energy Saving Air conditioning, VRV system

K. Kanaoka
Daikin Industries Ltd.
May 23rd 2006
Side Event on Alternative Chiller Technoligies

DAIKIN

Environmental Consensus

□1987:Montreal Protocol ▷ *Protection of the Ozone Layer*

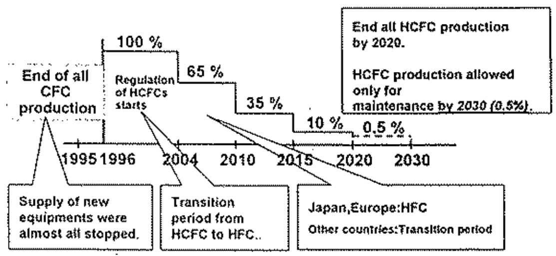
Set up to control emissions of Ozone Depleting Substances such as CFC and HCFC

□1997:Kyoto Protocol ▷ *To stop Global Warning*

DAIKIN

Protection of the Ozone Layer

CFC & HCFC Phase out Schedule



Switching to HFC of New equipments : On going

DAIKIN

CFC and/or HCFC equipments in the market

- Renovation activities → *Slow moving*
- Existing equipments can be used till the end of their lives. → *No urgency so far*
- Additional investment → *Financial burden*

Some incentives are indispensable to accelerate renovation

DAIKIN

Solution

Energy Saving ⇨ Cutting utility cost, shorten payback period

Tail.i.d.

- Soaring oil price ⇨ More than triple in a decade
- Inventing new energy saving technologies ⇨ Electricity consumption: less than half in a decade
- Reasonable price and availability of HFC equipments

DAIKIN — Corporate Data

Energy Saving Approach

Energy Saving Approach

To reduce heat transfer power
- Water : Pumps
- Air : Fans

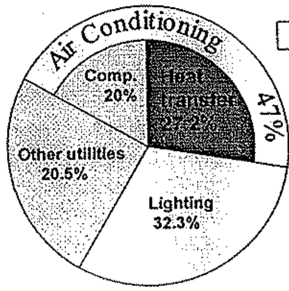
⇨ Use efficient heat transfer media

To reduce energy consumption in partial load
- Big gap between peak & actual use
- Random occupancy

⇨ Improve partial load performance

Energy saving approach

Energy consumption in office buildings



⇨ Decrease AC running cost is prime target of energy saving

⇩

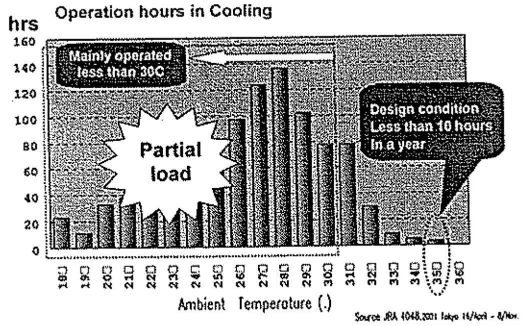
Decrease energy consumption of heat transfer, pumps & fans

Reduction of Heat Transfer Power

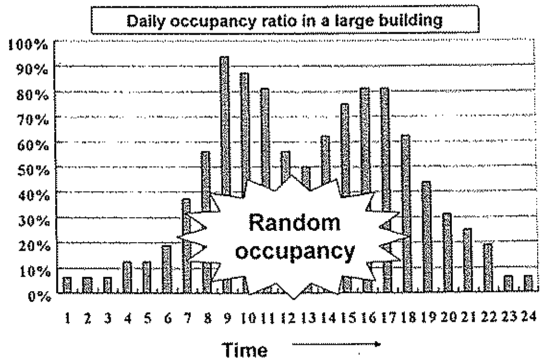
Use efficient heat transfer media

Medium	Kind of Heat	Heat Quantity
Water	sensible	21 kJ/kg
Air	sensible	10 kJ/kg
Refrigerant R410A	latent	210 kJ/kg

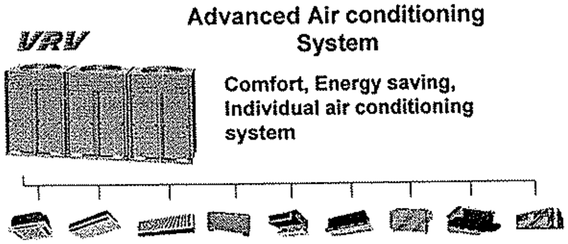
Partial load efficiency improvement



Partial load efficiency improvement



Advanced Air conditioning System

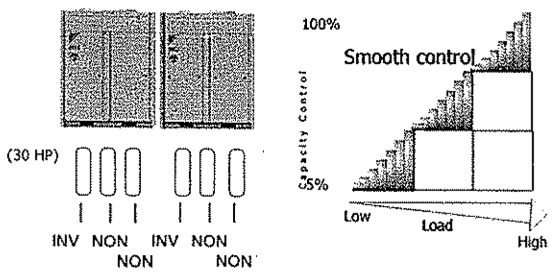


Comfort, Energy saving, Individual air conditioning system

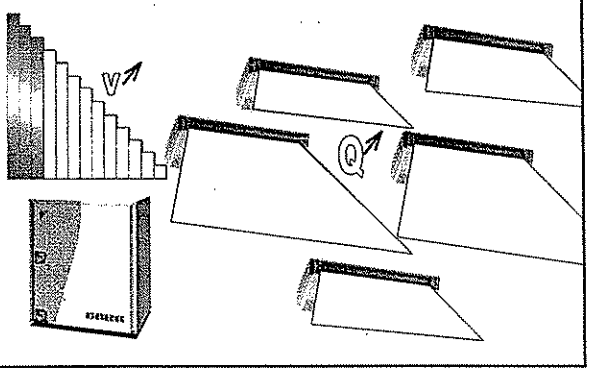
PID tempetature control in every indoor unit

40% Electricity cut

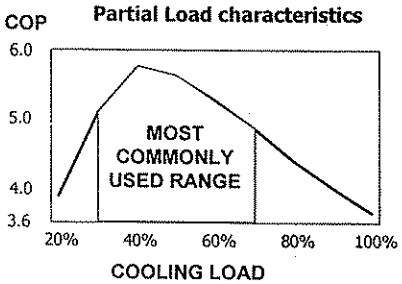
Linear Capacity Control



Inverter controlled compressor

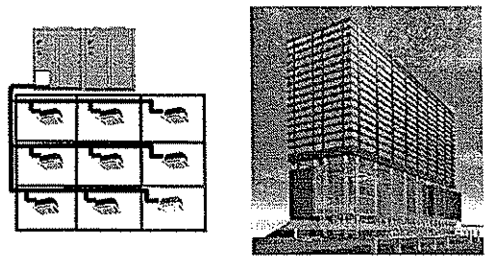


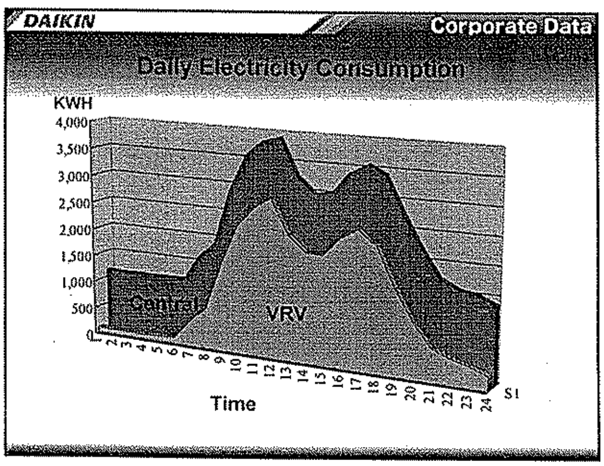
Low Energy Consumption



Individual Operation

- Ideal for Random Occupancy
- Individual temp. control





Annual power consumption

Location	System	Consumption (KW/m2/Year)	Bldg. Size (m2)
Singapore	VRV	105	10,000
Malaysia	VRV	93	800
Brazil	VRV	126	51,200
Brazil	Chiller	271	51,200

2005 New Product

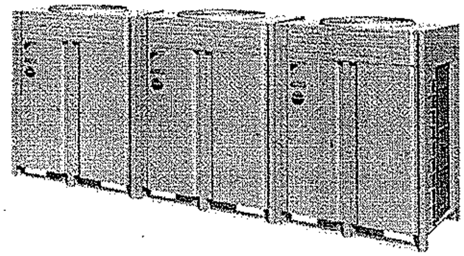
VRV II

RXYQ-MA Series Heat Pump

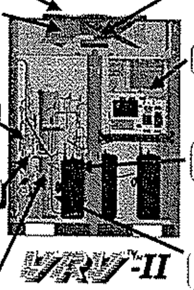
RXQ-MA Series Cooling Only

VRV

Advanced individual air conditioning system



Market Leading Technology



Aero fitting grille

Aero Spiral Fan
Airflow increase and reduction of a fan input can be achieved.

e-Pass heat exchanger
Improving heat exchange efficiency

e-Bridge circuit
Effective condenser surface is increased

Oil Balancing Circuit
Ensures balanced oil levels between compressors.

"DC" fan motor
Improved efficiency saves power.

Sine Wave DC Inverter
A smooth Sine Wave provides improved motor efficiency

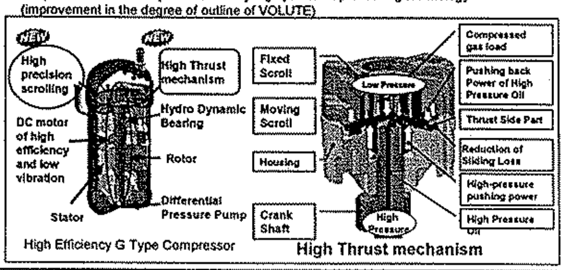
Reluctance DC compressor
Higher torque results in better efficiencies at low and medium RPM

Refrigerant Stabilization Control
Ensures balanced refrigerant flow between units

High efficiency scroll compressor

Energy Saving

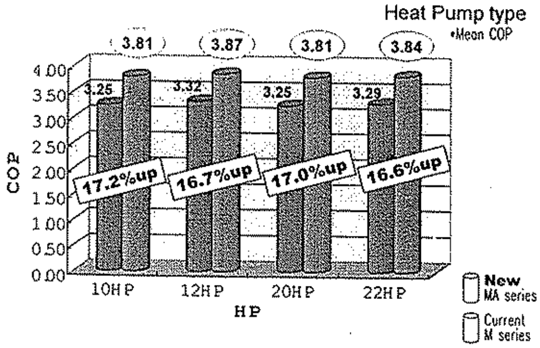
The efficient scroll G type compressor realized further energy saving
High Thrust mechanism realized a reduction of friction loss and leaks of refrigerant and high efficiency.
- Improvement in scroll performance by high precision processing technology (improvement in the degree of outline of VOLUTE)



High Efficiency G Type Compressor

High Thrust mechanism

Improvement in COP



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Transition to Non-CFC Chillers: Manufacturers' Perspective

Dave Stirpe
Executive Director
Alliance for Responsible Atmospheric Policy

New Delhi
October 29, 2006

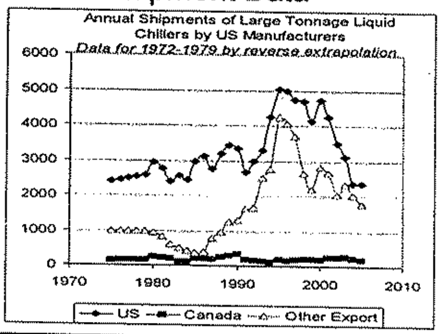
Alliance Membership List

- Air Conditioning Contractors of America
- Air-Conditioning & Refrigeration Institute
- Alliance for the Polyurethanes Industry
- American Pacific Corp.
- American Plastics Council
- Arkema
- Association of Home Appliance Manufacturers
- Bard Manufacturing Co.
- Brooks Automation
- Cap & Seal Company
- Carrier Corporation
- Copeland Corporation
- Dow Chemical U.S.A.
- Dupont
- Dupont/Dow
- E.V. Dunbar Co.
- Falcon Safety Products
- FP International
- General Electric
- General Motors
- Gilman Corporation
- H.C. Duke & Son
- Halotron
- Honeywell
- Hudson Technologies
- Ineos
- Ingersoll-Rand
- Institute of International Container Lessors
- International Pharmaceutical Aerosol Consortium
- Lennox International
- Luce, Schwab & Kase
- Maytag Corporation
- McQuay International
- Mell-Span Corporation
- National Refrigerants
- Owens Corning Specialty & Foam Products Center
- Refrigeration Service Engineers Society
- Refron
- RemTec International
- Ritchie Engineering
- Siemens Building Technology
- Solvay
- Spray Foam Alliance
- Sub-Zero
- Tech Spray
- ThermoQuest-Forma Scientific Division
- Trane Company
- Tyler Refrigeration
- Whirlpool Corporation
- Worthington Cylinder
- York International
- Zero Zone

CFC Chiller Background

- CFCs were used primarily in large centrifugal chillers
- CFC chillers in operation
  - Approximately 50,000 worldwide
  - Includes approximately 37,000 in N. America (2004 ARI survey)
- CFC chiller replacement has been slow
  - High level of activity in early 1990s
  - 58% of U.S. CFC chillers have been replaced

Large Tonnage Chillers Shipment Data



CFC Refrigerant Use - Chillers

- Age of all CFC chillers in service
  - 29,000 units (approx.) ---- 10-20 years old
  - 21,000 units (approx.) ---- 20-30 years old
- Refrigerant inventory in CFC chillers
  - 24,000 MT (approx.)
- Chillers service needs
  - Recycled and reclaimed CFCs (Article 5 and non-Article 5)
  - Virgin CFCs (Article 5)

Impediments to Chiller Replacement

- Scarce capital and economic return
  - Available capital goes to replacement projects having the fastest economic return
- Useful life of existing equipment
  - Centrifugal chillers have a long service life – estimated between 20-30 years
- Confidence in CFC service supply and regulations
  - Adequate supplies of virgin/recycled/reclaimed CFCs exist
  - Regulations in most countries allow for the continued use and servicing of CFC chillers

Incentives for Chiller Replacement

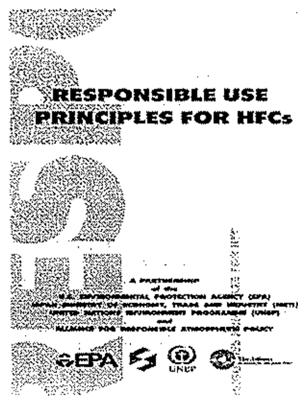
- Access to capital
  - Encourage measures to increase access to capital
    - Assistance from Multilateral Fund implementing agencies
    - Other governmental and commercial funding
- Change in current tax and incentive policies
  - Provide tax credits or accelerated depreciation
  - Institute rebate programs
- Increased awareness and leadership
  - Provide education for building owners
  - Protect the stratospheric ozone layer and the climate
  - Save energy and money; and create jobs
  - Support Montreal Protocol and Kyoto Protocol

Ozone and Climate Benefits of CFC Chiller Replacement

- New liquid centrifugal chillers use non-CFC refrigerants (lower ODP & lower GWP)
- Refrigerant emissions are negligible
  - Leak tight design – 0.5-2% annual leak rate today compared to 10-12% in 1980s
  - Venting prohibitions in many countries
  - Technician certification for equipment service and repair
- Chiller efficiencies have significantly improved -- over 30% since the 1980s
  - Indirect emissions account for 98% of a chiller's lifetime contribution to global climate change
  - Increased efficiency results in less carbon dioxide emissions from power generation

Technical and Economic Feasibility of CFC Chiller Replacement

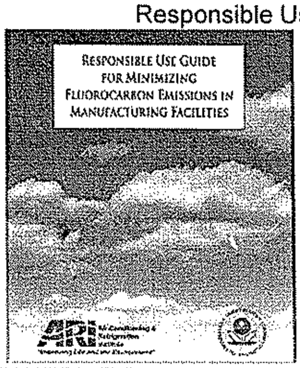
- New chillers have 3 to 5-year economic return in most locations that need cooling for more than 3 months per year
- Variable pump and cooling tower are used to optimize chiller system efficiency
- Variable speed drive (VSD) gaining popularity to dramatically improve part load energy efficiency (IPLV)



Responsible Use

- New chillers should minimize environmental impact and incorporate Responsible Use Principles
  - Contain refrigerants in tight or closed systems and containers minimizing atmospheric releases
  - Encourage monitoring after installations to minimize direct refrigerant emissions and to maintain energy efficiency
  - Train all personnel in proper refrigerant handling
  - Comply with standards on refrigerant safety, proper installation and maintenance (e.g., ASHRAE-15 and ISO- 5149)
  - Design, select, install and operate to optimize energy efficiency
  - Recover, recycle and reclaim refrigerants
  - Continue to improve equipment energy efficiency when cost effective

Air-Conditioning & Refrigeration Institute Responsible Use Guide



- Encourages refrigerant containment in air conditioning and refrigeration equipment manufacturing facilities
- Published by ARI/U.S. EPA in April 2006
- Endorsed by the International Council of Air-Conditioning and Refrigeration Manufacturers' Associations (ICARMA), the Heating, Refrigerating, & Air-Conditioning Institute of Canada (HRAI) and Australia
- ICARMA will undertake translations:
  - Spanish
  - French
  - Chinese

Can be downloaded at http://www.ari.org/

Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle

EPA420-F-05-004 February 2005

Download a PDF version of this document formatted for print. (6 pp, 54K, About PDF Files)

The U.S. Environmental Protection Agency (EPA) developed this series of four fact sheets to facilitate consistency of assumptions and practices in the calculation of emissions of greenhouse gases from transportation and mobile sources. They are intended as a reference for anyone estimating emissions benefits of mobile sources air pollution control programs.

Issue

Each EPA voluntary climate change program has used slightly different assumptions to translate the greenhouse gas (GHG) reductions associated with the program to the equivalent GHG emissions of a number of cars on the road. The result is that different numbers for the greenhouse gas emissions associated with a passenger vehicle have been used for different programs. The purpose of this fact sheet is to determine consistent assumptions and produce a number that is accepted for the annual GHG emissions associated with a passenger vehicle. The estimate calculated here is for vehicle emissions only, and does not include lifecycle emissions such as emissions associated with the production and distribution of fuel.

top of page

Recommendation

To translate GHG reductions into an equivalent number of cars off the road, annual emissions from a typical passenger vehicle should be equated to 5.5 metric tons of carbon dioxide equivalent or 1.5 metric tons of carbon equivalent.

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Key Steps to the Calculation

There are six key steps to estimate the annual greenhouse gas emissions associated with a passenger vehicle:

1. Determining the carbon dioxide (CO_2) produced per gallon of gasoline
2. Estimating the fuel economy of passenger cars and light trucks (in miles per gallon [mpg])
3. Determining the number of miles driven
4. Determining the emissions of greenhouse gases other than CO_2 (methane [CH_4], nitrous oxide [N_2O], and hydrofluorocarbons [HFCs])
5. Estimating the relative percentages of passenger cars and light trucks
6. Calculating the resulting annual greenhouse gas emissions

Note that for the purposes of this fact sheet, representative values were chosen for each of these variables, despite the fact that in practice variation does occur in these numbers.

Step 1: Determining the CO_2 produced per gallon of gasoline

A gallon of gasoline is assumed to produce 8.8 kilograms (or 19.4 pounds) of CO_2. This number is calculated from values in the Code of Federal Regulations at 40 CFR 600.113-78, which EPA uses to calculate the fuel economy of vehicles, and relies on assumptions consistent with the Intergovernmental Panel on Climate Change (IPCC) guidelines.

In particular, 40 CFR 600.113-78 gives a carbon content value of 2,421 grams (g) of carbon per gallon of gasoline, which produces 8,877 g of CO_2. (The carbon content is multiplied by the ratio of the molecular weight of CO_2 to the molecular weight of carbon: 44/12).

This number is then multiplied by an oxidation factor of 0.99, which assumes that 1 percent of the carbon remains un-oxidized.[1.] This produces a value of 8,788 g or 8.8 kg (19.4 lbs) of CO_2.

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Step 2: Estimating the fuel economy of passenger cars and light trucks (MPG estimate)

There are two sources of data which EPA has used for the average fuel economy of passenger cars and light trucks. MOBILE6.2 (EPA's computer model for estimating emissions for highway vehicles) can calculate an average fuel economy across the fleet, based on the EPA annual Fuel Economy Trends reports. For 2003, MOBILE calculates values of 23.9 miles per gallon (mpg) for passenger cars and 17.4 mpg for light trucks. These values are weighted averages (based on vehicle age data for the fleet, including vehicles up to 25 years old) of the Fuel Economy Trends sales-weighted average fuel economy of passenger cars and light trucks for each model year. MOBILE6.2 calculates an overall average fuel economy for passenger vehicles of 20.3 mpg (weighted by vehicle miles traveled [VMT] for passenger cars and light trucks).

The Federal Highway Administration's (FHWA) "Highway Statistics 2001" EXIT Disclaimer gives average values of 22.1 mpg for passenger cars and 17.6 mpg for light trucks as a fleet wide average in for the year 2001 (includes all vehicles on the road in 2001). These values are obtained by dividing vehicle miles traveled by fuel use.[2.] These values are used in the development of the "Inventory of U. S. Greenhouse Gas Emissions and Sinks."

Recommendation: Values were calculated using both sets of fuel economy numbers. Depending on the circumstances, use of one set of numbers or the other may be more appropriate. Generally EPA staff should use the MOBILE6 estimates. However, EPA uses the FHWA numbers in developing the National Inventory for Greenhouse Gas Emissions because they are consistent with the methodology used to develop the inventory. (Note that a small variation in the fuel economy number will not change the rough estimate of greenhouse gases derived here.)

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Step 3: Determining the number of miles driven

The number of miles driven per year is assumed to be 12,000 miles for all passenger vehicles. This number is based on several sources. Calculations from EPA's MOBILE6 model show an average annual mileage of roughly 10,500 miles per year for passenger cars and over 12,400 miles per year for light trucks across all vehicles in the fleet. However, these numbers include the oldest vehicles in the fleet (vehicles 25 years of age and older), which are likely not used as primary vehicles and are driven substantially less than newer vehicles. Since this calculation is for a typical vehicle, including the oldest vehicles may not be appropriate. For all vehicles up to 10 years old, MOBILE6 shows an annual average mileage of close to 12,000 miles per year for passenger cars, and over 15,000 miles per year for light trucks.

FHWA's National Highway Statistics contains values of 11,766 miles for passenger cars and 11,140 miles for light trucks across the fleet. However, as with the MOBILE6 fleet-wide estimates, these numbers include the oldest vehicles in the fleet. EPA's Commuter Model uses 1997 data from Oak Ridge Laboratories for the number of cars nationally and number of miles driven which produces a value of just over 12,000 miles per year. Due to the wide range of estimates, 12,000 miles per vehicle is used as a rough estimate for calculating the greenhouse gas emissions from a typical passenger vehicle.)

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Step 4: Determining the emissions of greenhouse gases other than CO_2 (N_2O, CH_4, and HFCs)

In addition to carbon dioxide, automobiles produce methane (CH_4) and nitrous oxide (N_2O) from the tailpipe, as well as HFC emissions from leaking air conditioners. The emissions of CH_4 and N_2O are related to vehicle miles traveled rather than fuel consumption, and the emissions of CH_4, N_2O, and HFCs are not as easily estimated from a vehicle as for CO_2.[3.] On average, CH_4, N_2O, and HFC emissions represent roughly 5 - 6 percent of the GHG emissions from passenger vehicles, while CO_2 emissions account for 94-95 percent, accounting for the global warming potential of each greenhouse gas. (These percentages are estimated from the EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2001".) To simplify this estimate, it is assumed that CH_4, N_2O, and HFCs account for 5 percent of emissions, and the CO_2 estimate was multiplied by 100/95 to incorporate the contribution of the other greenhouse gases.

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Step 5: Estimating the relative percentages of passenger cars and light trucks

Because FHWA calculates fuel economy for passenger cars and light trucks separately, it is necessary to determine the relative percentage of cars and light trucks in order to derive the greenhouse gas emissions for an average passenger vehicle. (This step is not necessary when using the MOBILE6 fuel economy data because MOBILE6 already calculates a weighted average fuel economy for all passenger vehicles.) Passenger cars are assumed to make up 63.4 percent and light trucks make up 36.6 percent of the passenger vehicle fleet. These values are derived from table 6.4 (2000 data) of the "Transportation Energy Data Book: Edition 22," EXIT Disclaimer (published by the Center for Transportation Analysis, Oak Ridge National Laboratory) which states there are 127,721,000 passenger cars on the road and 73,775,000 light trucks (less than 8500 lbs [4.]). Note that this percentage is changing over time, as light trucks now represent roughly 50 percent of annual new vehicle sales.

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Step 6: Calculating the resulting annual greenhouse gases from a typical passenger vehicle

A: Using EPA MOBILE6.2 fuel economy numbers

Metric tons of CO_2e for the average passenger vehicle =

(VMT/passenger vehicle avg. MPG) x CO_2 per gallon x (100/95) /1000 =

(12,000/20.3) x 8.8 x (100/95)/1000 =

5.48 metric tons CO_2e for the average passenger vehicle (1.49 metric tons CE)

B: Using DOT fuel economy numbers

[%LDV x (LDVVMT/LDVMPG) x CO_2 per gallon x (100/95) /1000] + [%LDT x (LDTVMT/LDTMPG) x CO_2 per gallon x (100/95) /1000] =

[0.634 x (12,000/22.1) x 8.8 x (100/95)/1000] + [0.366 x (12,000/17.6)] x 8.8 x (100/95)/1000] =

5.03 metric tons CO_2e for passenger cars and 6.32 metric tons CO_2e for light trucks (= 1.37 metric tons CE for cars and 1.72 metric tons CE for trucks) =

5.50 metric tons CO_2e for the average passenger vehicle (1.50 metric tons CE)

Recommendation: To calculate rough translations of GHG reductions into an equivalent number of cars off the road, use 5.5 metric tons of CO_2, or 1.5 metric tons of carbon equivalent. This number is rounded to the nearest tenth of a ton (using either DOT or EPA fuel economy estimates). This rough estimate will also allow for some variability in the underlying variables.

CO_2 only numbers

A: Using EPA MOBILE6.2 fuel economy numbers

Average passenger vehicle = 5.20 metric tons CO_2e (1.42 metric tons CE)

B: Using DOT fuel economy numbers

Passenger Cars = 4.78 metric tons CO_2e (1.30 metric tons CE)
Light Trucks = 6.00 metric tons CO_2e (1.64 metric tons CE)
All passenger vehicles = 5.23 metric tons CO_2e (1.43 metric tons CE)

Recommendation: For CO_2 only estimate, use 5.2 metric tons CO_2e, or 1.4 metric tons CE

Note: These calculations and the supporting data have associated variation and uncertainty. EPA may use other values in certain circumstances, and in some cases it may be appropriate to use a range of values.

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For More Information

You can access documents on greenhouse gas emissions on the Office of Transportation and Air Quality web site at:

www.epa.gov/otaq/greenhousegases.htm

For additional information on calculating emissions of greenhouse gases, please contact Ed Coe at:

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[1.] *The International Panel on Climate Change Guidelines (IPCC) recommends a fraction of carbon oxidized factor of 0.99 for all oil and oil-based products. Based on the fundamentals of internal combustion engine design and combustion, EPA is currently examining whether this fraction is higher (closer to 100 percent) for gasoline vehicles in the US.*

[2.] *U.S. Department of Transportation, Federal Highway Administration, "Highway Statistics 2000,"* EXIT Disclaimer *Washington, DC, 2001. Vehicle travel and fuel use data are kept separately for passenger cars and light trucks.*

[3.] EPA is currently examining ways to better disaggregate the HFC emissions from vehicles.

[4.] Vehicles over 8500 lbs are often not included in the light truck category. These vehicles are not required to meet CAFE standards. Examples of these vehicles include the Hummer and the Ford Excursion.

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http://www.epa.gov/OMS/climate/420f05004.htm
Print As-Is

EPA 430-R-09-004

INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS:

1990 – 2007

APRIL 15, 2009

U.S. Environmental Protection Agency
1200 Pennsylvania Ave., N.W.
Washington, DC 20460
U.S.A.

greenhouse gas to trap heat in the atmosphere relative to another gas.

The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO_2, and therefore GWP-weighted emissions are measured in teragrams (or million metric tons) of CO_2 equivalent (Tg CO_2 Eq.).[7,8] All gases in this Executive Summary are presented in units of Tg CO_2 Eq.

The UNFCCC reporting guidelines for national inventories were updated in 2006,[9] but continue to require the use of GWPs from the IPCC Second Assessment Report (SAR) (IPCC 1996). This requirement ensures that current estimates of aggregate greenhouse gas emissions for 1990 to 2007 are consistent with estimates developed prior to the publication of the IPCC Third Assessment Report (TAR) and the IPCC Fourth Assessment Report (AR4). Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values. All estimates are provided throughout the report in both CO_2 equivalents and unweighted units. A comparison of emission values using the SAR GWPs versus the TAR and AR4 GWPs can be found in Chapter 1 and, in more detail, in Annex 6.1 of this report. The GWP values used in this report are listed below in Table ES-1.

Table ES-1: Global Warming Potentials (100-Year Time Horizon) Used in this Report

Gas	GWP
CO_2	1
CH_4*	21
N_2O	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: IPCC (1996)
* The CH_4 GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

Global warming potentials are not provided for CO, NO_x, NMVOCs, SO_2, and aerosols because there is no agreed-upon method to estimate the contribution of gases that are short-lived in the atmosphere, spatially variable, or have only indirect effects on radiative forcing (IPCC 1996).

Recent Trends in U.S. Greenhouse Gas Emissions and Sinks

In 2007, total U.S. greenhouse gas emissions were 7,150.1 Tg CO_2 Eq. Overall, total U.S. emissions have risen by 17 percent from 1990 to 2007. Emissions rose from 2006 to 2007, increasing by 1.4 percent (99.0 Tg CO_2 Eq.). The following factors were primary contributors to this increase: (1) cooler winter and warmer summer conditions in 2007 than in 2006 increased the demand for heating fuels and contributed to the increase in the demand for electricity, (2) increased consumption of fossil fuels to generate electricity and (3) a significant decrease (14.2

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7 Carbon comprises 12/44ths of carbon dioxide by weight.

8 One teragram is equal to 10^{12} grams or one million metric tons.

9 See <http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf>.

land to agricultural or urban use) or can act as a sink for CO_2 (e.g., through net additions to forest biomass).

Figure ES- 5: 2007 Sources of CO_2 Emissions

As the largest source of U.S. greenhouse gas emissions, CO_2 from fossil fuel combustion has accounted for approximately 79 percent of GWP-weighted emissions since 1990, growing slowly from 77 percent of total GWP-weighted emissions in 1990 to 80 percent in 2007. Emissions of CO_2 from fossil fuel combustion increased at an average annual rate of 1.3 percent from 1990 to 2007. The fundamental factors influencing this trend include (1) a generally growing domestic economy over the last 17 years, and (2) significant overall growth in emissions from electricity generation and transportation activities. Between 1990 and 2007, CO_2 emissions from fossil fuel combustion increased from 4,708.9 Tg CO_2 Eq. to 5,735.8 Tg CO_2 Eq. —a 21.8 percent total increase over the eighteen-year period. From 2006 to 2007, these emissions increased by 100.4 Tg CO_2 Eq. (1.8 percent).

Historically, changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many long-term and short-term factors, including population and economic growth, energy price fluctuations, technological changes, and seasonal temperatures. On an annual basis, the overall consumption of fossil fuels in the United States generally fluctuates in response to changes in general economic conditions, energy prices, weather, and the availability of non-fossil alternatives. For example, in a year with increased consumption of goods and services, low fuel prices, severe summer and winter weather conditions, nuclear plant closures, and lower precipitation feeding hydroelectric dams, there would likely be proportionally greater fossil fuel consumption than a year with poor economic performance, high fuel prices, mild temperatures, and increased output from nuclear and hydroelectric plants.

Figure ES- 6: 2007 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Figure ES- 7: 2007 End-Use Sector Emissions of CO_2, CH_4, and N_2O from Fossil Fuel Combustion

The five major fuel consuming sectors contributing to CO_2 emissions from fossil fuel combustion are electricity generation, transportation, industrial, residential, and commercial. CO_2 emissions are produced by the electricity generation sector as they consume fossil fuel to provide electricity to one of the other four sectors, or "end-use" sectors. For the discussion below, electricity generation emissions have been distributed to each end-use sector on the basis of each sector's share of aggregate electricity consumption. This method of distributing emissions assumes that each end-use sector consumes electricity that is generated from the national average mix of fuels according to their carbon intensity. Emissions from electricity generation are also addressed separately after the end-use sectors have been discussed.

Note that emissions from U.S. territories are calculated separately due to a lack of specific consumption data for the individual end-use sectors.

Figure ES- 6, Figure ES- 7, and Table ES-3 summarize CO_2 emissions from fossil fuel combustion by end-use sector.

Table ES-3: CO_2 Emissions from Fossil Fuel Combustion by Fuel Consuming End-Use Sector (Tg CO_2 Eq.)

End-Use Sector	**1990**	**1995**	**2000**	**2005**	**2006**	**2007**
Transportation	**1,487.5**	**1,601.7**	**1,803.7**	**1,886.2**	**1,885.4**	**1,892.2**
Combustion	1,484.5	1,598.7	1,800.3	1,881.5	1,880.9	1,887.4
Electricity	3.0	3.0	3.4	4.7	4.5	4.8
Industrial	**1,516.8**	**1,575.5**	**1,629.6**	**1,558.5**	**1,550.7**	**1,553.4**
Combustion	834.2	862.6	844.6	828.0	844.5	845.4
Electricity	682.6	712.9	785.0	730.5	706.2	708.0
Residential	**927.1**	**993.3**	**1,128.2**	**1,207.2**	**1,145.9**	**1,198.0**
Combustion	337.7	354.4	370.4	358.0	321.9	340.6

per kilogram of HCFC-22 manufactured) and the use of thermal oxidation at some plants to reduce HFC-23 emissions.

- SF_6 emissions from electric power transmission and distribution systems decreased by 53 percent (14.1 Tg CO_2 Eq.) from 1990 to 2007, primarily because of higher purchase prices for SF_6 and efforts by industry to reduce emissions.
- PFC emissions from aluminum production decreased by 79 percent (14.7 Tg CO_2 Eq.) from 1990 to 2007, due to both industry emission reduction efforts and lower domestic aluminum production.

Overview of Sector Emissions and Trends

In accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC/UNEP/OECD/IEA 1997), and the 2003 UNFCCC Guidelines on Reporting and Review (UNFCCC 2003), Figure ES-11 and Table ES-4 aggregate emissions and sinks by these chapters. Emissions of all gases can be summed from each source category from Intergovernmental Panel on Climate Change (IPCC) guidance. Over the eighteen-year period of 1990 to 2007, total emissions in the Energy, Industrial Processes, and Agriculture sectors climbed by 976.7 Tg CO_2 Eq. (19 percent), 28.5 Tg CO_2 Eq. (9 percent), and 28.9 Tg CO_2 Eq. (8 percent), respectively. Emissions decreased in the Waste and Solvent and Other Product Use sectors by 11.5 Tg CO_2 Eq. (6 percent) and less than 0.1 Tg CO_2 Eq. (0.4 percent), respectively. Over the same period, estimates of net C sequestration in the Land Use, Land-Use Change, and Forestry sector increased by 192.5 Tg CO_2 Eq. (23 percent).

Figure ES-11: U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector

Table ES-4: Recent Trends in U.S. Greenhouse Gas Emissions and Sinks by Chapter/IPCC Sector (Tg CO_2 Eq.)

Chapter/IPCC Sector	**1990**		**1995**		**2000**		**2005**	**2006**	**2007**
Energy	5,193.6		5,520.1		6,059.9		6,169.2	6,084.4	6,170.3
Industrial Processes	325.2		345.8		356.3		337.6	343.9	353.8
Solvent and Other Product Use	4.4		4.6		4.9		4.4	4.4	4.4
Agriculture	384.2		402.0		399.4		410.8	410.3	413.1
Land Use, Land-Use Change, and Forestry (Emissions)	14.2		16.2		33.0		26.4	45.1	42.9
Waste	177.1		174.7		154.6		160.2	163.0	165.6
Total Emissions	**6,098.7**		**6,463.3**		**7,008.2**		**7,108.6**	**7,051.1**	**7,150.1**
Net CO_2 Flux from Land Use, Land-Use Change, and Forestry (Sinks)*	(841.4)		(851.0)		(717.5)		(1,122.7)	(1,050.5)	(1,062.6)
Net Emissions (Sources and Sinks)	**5,257.3**		**5,612.3**		**6,290.7**		**5,985.9**	**6,000.6**	**6,087.5**

* The net CO_2 flux total includes both emissions and sequestration, and constitutes a sink in the United States. Sinks are only included in net emissions total.
Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Energy

The Energy chapter contains emissions of all greenhouse gases resulting from stationary and mobile energy activities including fuel combustion and fugitive fuel emissions. Energy-related activities, primarily fossil fuel combustion, accounted for the vast majority of U.S. CO_2 emissions for the period of 1990 through 2007. In 2007, approximately 85 percent of the energy consumed in the United States (on a Btu basis) was produced through the combustion of fossil fuels. The remaining 15 percent came from other energy sources such as hydropower, biomass, nuclear, wind, and solar energy (see Figure ES-12). Energy-related activities are also responsible for CH_4 and N_2O emissions (35 percent and 14 percent of total U.S. emissions of each gas, respectively). Overall, emission sources in the Energy chapter account for a combined 86.3 percent of total U.S. greenhouse gas emissions in 2007.

Figure ES-12: 2007 U.S. Energy Consumption by Energy Source

Fact Sheet -- Proposed Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule

ACTION

- On September 30, 2009, EPA announced a proposal that is focused on large facilities emitting over 25,000 tons of greenhouse gases a year. These facilities would be required to obtain permits that would demonstrate they are using the best practices and technologies to minimize GHG emissions.
- The rule proposes new thresholds for greenhouse gas emissions (GHG) that define when Clean Air Act (CAA) permits under the New Source Review (NSR) and title V operating permits programs would be required for new or existing industrial facilities.
- The proposed thresholds would "tailor" the permit programs to limit which facilities would be required to obtain NSR and title V permits and would cover nearly 70 percent of the national GHG emissions that come from stationary sources, including those from the nation's largest emitters—including power plants, refineries, and cement production facilities.
- Small farms, restaurants and many other types of small facilities would not be subject to these permitting programs.
- This proposal addresses the emissions of the group of six greenhouse gases (GHGs) that may be covered by an EPA rule controlling or limiting their emissions:
    1. Carbon dioxide (CO2)
    2. Methane (CH4)
    3. Nitrous oxide (N2O)
    4. Hydrofluorocarbons (HFCs)
    5. Perfluorocarbons (PFCs)
    6. Sulfur hexafluoride (SF6)
- EPA is proposing carbon dioxide equivalent (CO2e) as the preferred metric for determining GHG emissions rates for any combination of these six GHGs, but we are requesting comment in this proposal on alternatives. Emissions of greenhouse gases are typically expressed in a common metric, so that their impacts can be directly compared, as some gases are more potent (have a higher global warming potential or GWP) than others. The international standard practice is to express GHGs in CO2e. Emissions of gases other than CO2 are translated into CO2 equivalents by using the gases' global warming potentials.
- Under the Title V operating permits program, EPA is proposing a major source emissions applicability threshold of 25,000 tons per year (tpy) of carbon dioxide CO2e for existing industrial facilities. Facilities with GHG emissions below this threshold would not be required to obtain an operating permit.
- Under the Prevention of Significant Deterioration (PSD) portion of NSR—which is a permit program designed to minimize emissions from new sources and existing sources making major modifications—EPA is proposing a:
    1. Major stationary source threshold of 25,000 tpy CO2e. This threshold level would be used to determine if a new facility or a major modification at an existing facility would trigger PSD permitting requirements.
    2. Significance level between 10,000 and 25,000 tpy CO2e. Existing major sources making modifications that result in an increase of emissions above the significance level would be required to obtain a PSD permit. EPA is requesting comment on a range of values in this proposal, with the intent of selecting a single value for the GHG significance level.

- Operating permits contain air emissions control requirements that apply to a facility, such as national emissions standards for hazardous air pollutants, new source performance standards, or best available control technologies required by a PSD permit. In general, since there are currently no such air emission control requirements, existing facilities with GHG emissions greater than 25,000 tons per year that already have operating permits would not need to immediately revise them. At the end of a 5-year period when the operating permit must be renewed, these facilities would be required to include estimates of their GHG emissions in their permit applications. Facilities may use the same data reported to EPA under the Mandatory Reporting Rule to fulfill this requirement.
- New or modified facilities with GHG emissions that trigger PSD permitting requirements would need to apply for a revision to their operating permits to incorporate the best available control technologies and energy efficiency measures to minimize GHG emissions. These controls are determined on a case-by-case basis during the PSD process.
- Under the proposed emissions thresholds, EPA estimates that 400 new sources and modifications would be subject to PSD review each year for GHG emissions. Less than 100 of these would be newly subject to PSD. In total, approximately 14,000 large sources would need to obtain operating permits for GHG emissions under the operating permits program. About 3,000 of these sources would be newly subject to CAA operating permit requirements as a result of this action. The majority of these sources are expected to be municipal solid waste landfills.
- Municipal solid waste landfills are the second largest source of human-related methane emissions in the United States, accounting for approximately 23 percent of these emissions in 2007. Landfill methane, a powerful greenhouse gas, can be captured, converted, and used as an energy source, reducing emissions and providing an important renewable energy source.
- The current thresholds for criteria pollutants such as lead, sulfur dioxide and nitrogen dioxide, are 100 and 250 tons per year (tpy). These thresholds are in effect now, and are appropriate for criteria pollutants. However, they are not feasible for GHGs. Without the tailoring rule, these lower thresholds would take effect automatically for GHGs with the adoption of any EPA rule that controls or limits GHG emissions.
- The proposed thresholds would continue to preserve the ability of the NSR and title V operating permit programs to achieve and maintain public health and environmental protection goals while avoiding an administrative burden that would prevent state and local permitting authorities from processing CAA permits efficiently.
- EPA will accept comment on this proposal for 60 days after publication in the *Federal Register.*

NEXT STEPS

- The final emissions thresholds for GHG emissions under the federal PSD and operating permits programs will take effect immediately upon promulgation of the final rule. At that time, EPA will put the new thresholds into effect in state, local and tribal agency programs that run PSD and Title V operating programs under EPA approval. Those agencies will continue to have the option to seek EPA approval for lower thresholds if they demonstrate that they can adequately implement the PSD program at the lower thresholds.
- EPA intends to evaluate ways to streamline the process for identifying GHG emissions control requirements and issuing permits. This will reduce costs and increase efficiency for both sources and for state permitting agencies, which in most cases are responsible for issuing the permits.
- Under the proposal, EPA must also re-evaluate the final GHG emissions thresholds after an initial phase, during which PSD and Title V permitting authorities will gain experience in issuing permits to GHG sources. By the end of the first phase, which is proposed to last five years, the Agency is proposing to complete a study to evaluate whether it is administratively feasible for PSD and Title V permitting authorities to adequately administer their programs at lower GHG thresholds.
- After reviewing the study results, EPA will complete a follow-on regulatory action, within one year (six years following promulgation of this rule). The follow-on rule will establish

thresholds during the second phase, by either:
1. Confirming the need to retain the GHG permitting thresholds for PSD and/or Title V at the levels promulgated with this rulemaking; or
2. Establishing different GHG threshold levels that more accurately reflect the administrative capabilities of permitting authorities to address GHGs.

- EPA believes that a five-year duration for the first phase is appropriate but the Agency requests comment on alternative time periods.
- EPA also plans to develop supporting information to assist permitting authorities as they begin to address permitting actions for GHG emissions for the first time. The guidance would first cover source categories that typically emit GHGs at levels exceeding the thresholds established through this rulemaking.
- Although EPA has not yet identified specific source categories, the Agency plans to develop sector- and source-specific guidance that would help permitting authorities and affected sources better understand GHG emissions for the selected source categories, methods for estimating those emissions, control strategies for GHG emissions, and available GHG measurement and monitoring techniques.
- This guidance also will include approaches for making Best Available Control Technology determinations as required for a PSD permit.

BACKGROUND

- On April 2, 2007, the Supreme Court found that GHGs, including carbon dioxide, are air pollutants covered by the CAA. *Massachusetts v. EPA*, 549 U.S. 497 (2007).
- The Supreme Court found that EPA was required to determine whether or not emissions of GHGs from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. In April 2009, EPA responded to the Court by proposing a finding that greenhouse gases contribute to air pollution that may endanger public health or welfare.
- EPA expects soon to take final action on the finding. The agency also expects to issue regulations under the Clean Air Act to control GHG emissions from light duty vehicles (proposal signed 9/15/09). Such an action will trigger Clean Air Act permitting requirements under the Prevention of Significant Deterioration (PSD) and Operating Permit (title V) programs for GHG emissions. This will be the first time GHGs would be subject to either of these Clean Air Act permitting programs.
- Congress established the NSR program as part of the 1977 Clean Air Act Amendments and modified it in the 1990 Amendments. NSR is a preconstruction permitting program that serves two important purposes:
  1. Ensures the maintenance of air quality standards or, where there are not air quality standards, it ensures that air quality does not significantly worsen when factories, industrial boilers, and power plants are modified or added. In areas that do not meet the national ambient air quality standards, NSR assures that new emissions do not slow progress toward cleaner air. In areas that meet the standards, especially pristine areas like national parks, NSR assures that new emissions fall within air quality standards.
  2. Ensures that state-of-the-art control technology is installed at new plants or at existing plants that are undergoing a major modification.
- New major stationary sources and major modifications at existing major stationary sources that meet emissions applicability thresholds outlined in the Clean Air Act and in existing PSD regulations must obtain a PSD permit outlining how they will control emissions. The permit requires facilities to apply best available control technology (BACT), which is determined on a case-by-case basis taking into account, among other factors, the cost and effectiveness of the control.
- The Clean Air Act Amendments of 1990 required that all states develop operating permit programs. Under these programs, known as Title V operating permits programs, every major industrial source of air pollution (and some other sources) must obtain an operating permit. The permits, which are reviewed every five years, contain all air emission control

requirements that apply to the facility, including the requirements established as part of the preconsturction permitting process.

HOW TO COMMENT

- EPA will accept comment on the proposal for 60 days after publication in the Federal Register. Comments, identified by Docket ID No. EPA-HQ-OAR-2009-0517, may be submitted by one of the following methods:
  - www.regulations.gov: Follow the online instructions for submitting comments.
  - E-mail: Comments may be sent by electronic mail (e-mail) to a-and-r-docket@epa.gov.
  - Fax: Fax your comments to: (202) 566-9744.
  - Mail: Send your comments to: EPA Docket Center, EPA West (Air Docket), Attention Docket ID No. EPA-HQ-OAR-2009-0517, U.S. Environmental Protection Agency, Mailcode: 2822T, 1200 Pennsylvania Avenue, NW, Washington, DC 20460.
  - Hand Delivery or Courier: Deliver your comments to: .S. Environmental Protection Agency, EPA West (Air Docket), 1301 Constitution Avenue, Northwest, Room 3334, Washington, DC 20004, Attention Docket ID No. EPA-HQ-OAR-2009-0517. Such deliveries are only accepted during the Docket's normal hours of operation, and special arrangements should be made for deliveries of boxed information

FOR MORE INFORMATION

- To download a copy of this notice, go to EPA's Web site at: http://www.epa.gov/nsr.
- Today's proposed action and other background information are also available electronically at http://www.regulations.gov, EPA's electronic public docket and comment system. The docket number for this action is Docket ID No. EPA-HQ-OAR-2009-0517.
- For more information on the final rule, contact Joseph Mangino at (919) 541-9778 or mangino.joseph@epa.gov.

Summary of the Science Supporting EPA's Finding That Greenhouse Gases Threaten Public Health and Welfare

For a full discussion of the rationale for EPA's proposed findings, please see the Proposal describing the findings as well the underlying Technical Support Document for a comprehensive synthesis of the science at: www.epa.gov/climatechange/endangerment.html. *All of the points in this fact sheet come from the published scientific literature, particularly from the assessments of the U.S. Climate Change Science Program, the National Research Council, and the Intergovernmental Panel on Climate Change.*

Key Points About Climate Change:

- Heat-trapping greenhouse gases are now at record-high levels in the atmosphere compared to the recent and distant past.
- These high atmospheric levels are the clear result of human emissions of carbon dioxide and other greenhouse gases.
- Warming of the climate system is now well documented, as is evident from increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Eight of the 10 warmest years on record have occurred since 2001.
- The buildup of greenhouse gases in the atmosphere is very likely the cause of the observed increase in average temperatures and other climatic changes. Most of the warming cannot be explained by natural variability such as variations in solar activity.
- Future warming over the course of the 21st century, even when assuming emissions growth will be low, is very likely to be greater than observed warming over the past century.
- The effects of climate change observed to date and/or projected to occur in the future include, but are not limited to: more frequent and intense heat waves, more wildfires, degraded air quality, more heavy downpours and flooding, increased drought, greater sea level rise, more intense storms, harm to water resources, harm to agriculture, and harm to wildlife and ecosystems.
- The changes to our climate may increase the likelihood of extreme and high-impact events such as more intense hurricanes.

Health Effects Associated With Elevated Greenhouse Gas Concentrations in the United States

Temperature Effects:

- There is evidence that extremely hot days are already increasing. Severe heat waves are projected to intensify, which can increase heat-related mortality and sickness. A possible benefit of moderate temperature increases includes fewer deaths from exposure to extreme cold.

Air Quality Changes:

- Climate change is expected to worsen regional ozone pollution, with associated risks in respiratory infection, aggravation of asthma, and premature death. The impact on particulate matter remains less certain.

Extreme Events:

- Storm impacts are likely to be more severe, especially along the Gulf and Atlantic coasts. Heavy rainfall events are expected to increase, increasing the risk of flooding, greater runoff and erosion, and thus the potential for adverse water quality effects. These projected trends can increase the number of people at risk from suffering disease and injury due to floods, storms, droughts and fires.

Climate-Sensitive Diseases:

- Potential ranges of certain diseases affected by temperature and precipitation changes, including tick-borne diseases, are expected to increase.

Welfare Effects Associated With Elevated Greenhouse Gas Concentrations in the United States

Under the Clean Air Act, "welfare" includes impacts such as effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate; damage to and deterioration of property and hazards to transportation; as well as effects on economic values and on personal comfort and well-being.

- The global sea level gradually rose in the 20th century and is currently rising at an increased rate, exacerbating storm-surge flooding and shoreline erosion.
- Rising temperatures will diminish snowpack in the Western U.S., affecting seasonal availability of water.
- Climate change will likely further constrain already over-allocated water resources in some areas of the U.S., increasing competition among agricultural, municipal, industrial, and ecological uses.
- Modest climate change, plus elevated CO_2, may bring agricultural yield increases in the near term. But, as temperatures continue to rise, these crops will increasingly begin to experience failure. Increases in regional ozone levels will also adversely impact certain crops.
- Climate change has very likely already increased the size and number of forest fires, insect outbreaks, and tree mortality in the interior West, the Southwest, and Alaska, and will continue to do so.
- Changes in climate will cause species to shift north and to higher elevations and fundamentally rearrange U.S. ecosystems.
- Ocean acidification is projected to continue, which can affect the productivity of marine life such as corals.
- Climate change impacts in certain regions of the world may exacerbate problems that raise humanitarian, trade, and national security issues for the United States.

This fact sheet is intended to assist the public to understand key aspects of the proposal. However, this fact sheet is not intended to be a substitution for the proposal itself. Visit EPA's website at the address above for more information, including the proposal, or go to www.regulations.gov to access the rulemaking docket (EPA-HQ-OAR-2009-0171) which will be opened when the proposal is published in the Federal Register. For questions that cannot be answered through the Web site or docket, call 202-343-9927.

Federal Register

Wednesday,
July 8, 2009

Part III

Environmental Protection Agency

California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emission Standards for New Motor Vehicles; Notice

ENVIRONMENTAL PROTECTION AGENCY

[FRL–8927–2]

California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emission Standards for New Motor Vehicles

SUMMARY: The Environmental Protection Agency (EPA) is granting the California Air Resources Board's (CARB's) request for a waiver of Clean Air Act preemption to enforce its greenhouse gas emission standards for model year 2009 and later new motor vehicles. This decision is under section 209(b) of the Clean Air Act (the ''Act''), as amended. This decision withdraws and replaces EPA's prior denial of the CARB's December 21, 2005 waiver request, which was published in the **Federal Register** on March 6, 2008.

DATES: Petitions for review must be filed by September 8, 2009.

ADDRESSES: EPA has established a docket for this action under Docket ID No. EPA–HQ–OAR–2006–0173. All documents and public comments in the docket are listed on the *www.regulations.gov* Web site. Publicly available docket materials are available either electronically through *www.regulations.gov* or in hard copy at the Air and Radiation Docket in the EPA Headquarters Library, EPA West Building, Room 3334, 1301 Constitution Ave., NW., Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding holidays. The telephone number for the Reading Room is (202) 566–1744. The Air and Radiation Docket and Information Center's Web site is *http://www.epa.gov/oar/docket.html.* The electronic mail (e-mail) address for the Air and Radiation Docket is: *a-and-r-Docket@epa.gov,* the telephone number is (202) 566–1742 and the fax number is (202) 566–9744.

FOR FURTHER INFORMATION CONTACT: Specific questions may be addressed to David Dickinson, Office of Transportation and Air Quality, Compliance and Innovative Strategies Division (6405J–NLD), EPA, 1200 Pennsylvania Ave., NW., Washington, DC 20460, telephone: (202) 343–9256, e-mail: *Dickinson.David@epa.gov.*

SUPPLEMENTARY INFORMATION:

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I. Executive Summary

Today, I, as Administrator of the Environmental Protection Agency, am granting California's request for a waiver of Clean Air Act preemption for California's greenhouse gas emission standards for 2009 and later model years of new motor vehicles, adopted by the California Air Resources Board on September 24, 2004. This decision withdraws and replaces EPA's previous March 6, 2008 Denial of California's waiver request.

In the March 6, 2008 Denial, EPA determined that one of the three criteria for denial of a waiver had been met, namely, that California did not need its

State standards to meet compelling and extraordinary conditions. I have reconsidered that determination, which was based on an interpretation of section 209(b)(1) of the Clean Air Act that I now reject. Based on a review of the statutory language, legislative history, and the comments received, I am returning to EPA's traditional interpretation of this provision. Applying EPA's traditional interpretation I have determined that the waiver should not be denied under this criterion. Since the March 6, 2008 Denial did not evaluate or make any determinations concerning either of the other two waiver criteria, I have evaluated those criteria and determined that the waiver should not be denied under either of them. This includes careful consideration of all of the evidence presented concerning technological feasibility of the model year 2009 and later model year standards, considering lead time and the cost of implementation.

The legal framework for this decision stems from the waiver provision first adopted by Congress in 1967, and later modified in 1977. Congress established that there would be only two programs for control of emissions from new motor vehicles—EPA emission standards adopted under the Clean Air Act and California emission standards adopted under its state law. Congress accomplished this by preempting all state and local governments from adopting or enforcing emission standards for new motor vehicles, while at the same time providing that California could receive a waiver of preemption for its emission standards and enforcement procedures. This struck an important balance that protected manufacturers from multiple and different state emission standards, and preserved a pivotal role for California in the control of emissions from new motor vehicles. Congress recognized that California could serve as a pioneer and a laboratory for the nation in setting new motor vehicle emission standards. Congress intentionally structured this waiver provision to restrict and limit EPA's ability to deny a waiver, and did this to ensure that California had broad discretion in selecting the means it determined best to protect the health and welfare of its citizens. Section 209(b) specifies that EPA must grant California a waiver if California determines that its standards are, in the aggregate, at least as protective of the public health and welfare as applicable Federal standards. EPA may deny a waiver only if it makes at least one of three findings specified under the Clean Air Act (including whether California's "protectiveness finding" noted above is arbitrary and capricious). Therefore, EPA's role upon receiving a request for waiver of preemption from California is to determine whether it is appropriate to make any of the three findings specified by the Clean Air Act and if the Agency cannot make at least one of the three findings then the waiver must be granted. The three waiver criteria are properly seen as criteria for a denial—EPA must grant the waiver unless at least one of three criteria for a denial is met. This is different from most waiver situations before the Agency, where EPA typically determines whether it is appropriate to make certain findings necessary for granting a waiver, and if the findings are not made then a waiver is denied. This reversal of the normal statutory structure embodies and is consistent with the congressional intent of providing deference to California to maintain its own new motor vehicle emissions program.

The three criteria for denial of a waiver are: First, whether California's determination that its standards are, in the aggregate, at least as protective as applicable Federal standards is arbitrary and capricious (Section 209(b)(1)(A)); second, whether California has a need for such standards to meet compelling and extraordinary conditions (Section 209(b)(1)(B)); and third, whether California's standards are consistent with Section 202(a) of the Act (Section 209(b)(1)(C)). EPA has consistently interpreted the waiver provision as placing the burden on the opponents of a waiver to demonstrate that one of the criteria for a denial has been met. In this context, since 1970, EPA has recognized its limited discretion in reviewing California waiver requests. EPA has granted over 50 waivers of preemption and has only fully denied one waiver request, the decision under reconsideration here.

In this case, California first requested that EPA waive preemption for its new motor vehicle greenhouse gas emission standards on December 21, 2005. EPA did not begin its formal consideration of the waiver request until after the *Massachusetts* v. *EPA* decision in April 2007, in which the Supreme Court determined that greenhouse gases are air pollutants within that term's meaning in the Clean Air Act. On March 6, 2008, after an administrative process that included two public hearings and a written comment period, EPA published its final decision denying California's request. EPA's waiver denial was based on the second waiver criterion, with EPA determining that California did not need its greenhouse gas standards to meet compelling and extraordinary conditions. EPA did not address the other two waiver criteria.

The reconsideration process started early this year. On January 21, 2009, California Governor Schwarzenegger sent a letter to President Obama, and the California Air Resources Board sent a letter to Administrator-designee Jackson, requesting the Agency reconsider the prior denial. After reviewing CARB's reconsideration request and the concerns raised by many different parties, EPA found that there were significant issues regarding the Agency's denial of the waiver. The denial was a substantial departure from EPA's longstanding interpretation of the Clean Air Act's waiver provision and EPA's history of granting waivers to California for its new motor vehicle emissions program. Many different parties, including California, states that have adopted or are interested in adopting California's standards, members of Congress, scientists, and other stakeholders, had expressed similar concerns about the denial of the waiver. Based on this, EPA believed there was merit to reconsidering its decision denying California's waiver request and on February 12, 2009, EPA published a **Federal Register** notice announcing its reconsideration of California's greenhouse gas waiver request. EPA held a public hearing on March 5, 2009, and received written comments through April 6, 2009.

EPA received substantial comment on each of the three waiver criteria. The entire administrative process in consideration of California's request provided the Agency with extensive legal argument and evidence, including oral testimony from three public hearings and nearly 500,000 written comments. This material has been substantive and invaluable in the Agency's review. EPA has received extensive comments from many states; federal, state and local officials; industry; environmental groups; scientists; and other stakeholders. The vast majority of comments EPA received were in support of the waiver.

After a thorough evaluation of the record, I am withdrawing EPA's March 6, 2008 Denial and have determined that the most appropriate action in response to California's greenhouse gas waiver request is to grant that request. I have determined that the waiver opponents have not met their burden of proof in order for me to deny the waiver under any of the three criteria in section 209(b)(1). The findings I have made concerning each of the criteria are summarized below.

Concerning the criterion with respect to the protectiveness of California's standards in the aggregate, I find that the opponents of the waiver have not met their burden to demonstrate that California's determination was arbitrary and capricious. This evaluation can properly by made in situations where EPA has not issued its own standards, and this finding is appropriate whether or not comparison is made to EPA's current emissions standards or the National Highway Transportation Safety Administration's (NHTSA's) fuel economy standards, and whether or not it includes an evaluation of the real-world in-use effect of California's greenhouse gas standards on its broader motor vehicle program.

With respect to the criterion concerning the need for California's state standards to meet compelling and extraordinary conditions, I have found that the March 6, 2008 Denial was based on an inappropriate interpretation of the waiver provision. The March 6, 2008 Denial determined that Congress intended to allow California to promulgate only those state standards that address pollution problems that are local or regional, and this provision was not intended to allow California to promulgate state standards designed to address global climate change problems. In the alternative, EPA found that the effects of climate change in California are not compelling and extraordinary compared to the effects in the rest of the country.

The text of section 209(b) and the legislative history, when viewed together, lead me to reject the interpretation adopted in the March 6, 2008 Denial, and to apply the traditional interpretation to the evaluation of California's greenhouse gas standards for motor vehicles. If California needs a separate motor vehicle program to address the kinds of compelling and extraordinary conditions discussed in the traditional interpretation, then Congress intended that California could have such a program. Congress also intentionally provided California the broadest possible discretion in adopting the kind of standards in its motor vehicle program that California determines are appropriate to address air pollution problems and protect the health and welfare of its citizens. The better interpretation of the text and legislative history of this provision is that Congress did not use this criterion to limit California's discretion to a certain category of air pollution problems, to the exclusion of others.

Under that interpretation, I cannot find that opponents of the waiver have demonstrated that California does not need its state standards to meet compelling and extraordinary conditions. The opponents of the waiver have not adequately demonstrated that California no longer has a need for its motor vehicle emissions program. I have also determined that even under the interpretation announced in the March 6, 2008 Denial, opponents of the waiver have not demonstrated that California does not need its greenhouse gas emission standards to meet compelling and extraordinary conditions. In addition, I have interpreted the ''compelling and extraordinary conditions'' criterion to not properly include a consideration of whether the impacts from climate change are compelling and extraordinary in California. Nevertheless, I have evaluated the comments received and evidence in the record and have determined that the opponents of the waiver have not met their burden in demonstrating why evidence such as the impacts of climate change on existing ozone conditions in California along with the cumulative impacts identified by proponents of the waiver (*e.g.,* impacts on snow melt and water resources and agricultural water supply, wildfires, coastal habitats, ecosystems, etc.) is not compelling and extraordinary.

Concerning the criterion with respect to consistency of the greenhouse gas emission standards with section 202(a), EPA has reviewed extensive comments and records received from California and from the regulated community concerning the kinds of technology needed to comply with California's standards, including costs and lead time, as well as evidence concerning the current compliance status of manufacturers. In light of the previous waiver denial, EPA specifically asked for comment on how lead time should be evaluated as part of the Agency's reconsideration. Based on all of that information, I cannot find that opponents of the waiver have demonstrated that the greenhouse gas emission standards are inconsistent with section 202(a). While I believe that a grant of the waiver for model year 2009 would not be a retroactive change in the law, to limit any potential concerns that have been raised by the manufacturers over their potential reliance upon EPA's previous waiver denial, my decision provides that CARB may not hold a manufacturer liable or responsible for any noncompliance civil penalty action caused by emission debits generated by a manufacturer for the 2009 model year.

EPA finds that those opposing the waiver request have not met the burden of demonstrating that California's regulations do not satisfy the statutory criteria of section 209(b). For this reason, I am granting California's waiver request to enforce its greenhouse gas motor vehicle emission regulations.

II. Background

A. California's Greenhouse Gas Program for New Motor Vehicles

As further explained below, CARB has adopted amendments to title 13, California Code of Regulations (CCR), sections 1900 and 1961, and established standards to regulate greenhouse gas (GHG) emissions from new passenger cars, light-duty trucks and medium-duty vehicles in a new section 1961.1.

California's GHG standards are included as part of its second generation low-emission vehicle program known as LEV II. EPA previously issued a waiver for the LEV II program and also issued a waiver for CARB's zero-emission vehicle program (known as ZEV) through the 2011 model year (MY).[1] By Resolution 04–28, CARB approved the GHG standards for motor vehicles on September 24, 2004, and California's Office of Administrative Law approved the regulations on September 15, 2005.[2]

CARB's regulation covers large-volume motor vehicle manufacturers beginning in the 2009 model year, and intermediate and small manufacturers beginning in the 2016 model year and controls greenhouse gas emissions from two categories of new motor vehicles—passenger cars and the lightest trucks (PC and LDT1) and heavier light-duty trucks and medium-duty passenger vehicles (LDT2 and MDPV). The regulations add four new greenhouse gas air contaminants (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs)) to California's existing regulations for criteria and criteria-precursor pollutants and air toxic contaminants. There are separate fleet average emission standards for the two vehicle size categories and within each category the sales-weighted average of a manufacturer's vehicles is required to comply with the standard. The regulations establish a manufacturer declining fleet average emission standard for these gases (expressed as grams of carbon dioxide equivalent per mile (''gpm'')), with separate standards for each of the two categories of passenger vehicles noted above. CARB places the declining standards into two phases: near-term standards phased in

[1] 68 FR 19811 (April 22, 2003) and 71 FR 78190 (December 26, 2006).

[2] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.2.

from the 2009 through 2012 model years, and mid-term standards, phased in from the 2013 through 2016 model years. Manufacturers may receive credits for meeting the standards before model year 2009, for surpassing the standards in later model years, and for selling alternative fuel vehicles. These credits may be banked for later use, transferred between vehicle categories, or sold to another manufacturer. If a manufacturer fails to meet the standard in a particular model year, it will begin to accrue debits. At that point it will have five years to make up for the debits, either by generating credits, or by purchasing credits from another manufacturer.

B. EPA's Consideration of CARB's Request

By letter dated December 21, 2005, CARB submitted a request (''Waiver Request'') seeking a waiver of Section 209(a)'s prohibition for its motor vehicle GHG standards.[3] On February 21, 2007, EPA notified the Executive Officer of CARB that the timing of EPA's consideration of the GHG waiver request was related to the then-pending *Massachusetts* v. *EPA* case before the United States Supreme Court. EPA stated that the decision in that case could potentially be relevant to issues EPA might address in the context of the GHG waiver proceeding. The Supreme Court issued its *Massachusetts* v. *EPA* decision on April 2, 2007, finding that greenhouse gases are air pollutants under the Clean Air Act, and that EPA is required to decide the pending rulemaking petition under section 202(a) of the Act, based on the statutory criteria of whether, in the Administrator's judgment, emissions of greenhouse gases from new motor vehicles cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare.[4]

On April 30, 2007, a **Federal Register** notice was published announcing an opportunity for hearing and comment on CARB's request.[5] EPA subsequently held two public hearings on May 22, 2007, in Washington, DC, and on May 30, 2007, in Sacramento, CA. The written comment period closed on June 15, 2007. On several occasions, EPA received requests to extend or re-open the comment period; however, the Agency did not extend the June 15, 2007 deadline. The Agency instead indicated that consistent with past waiver practice it would continue, as appropriate, to communicate with stakeholders and evaluate any comments submitted after the close of the comment period to the extent practicable. By letter dated December 19, 2007, EPA notified California Governor Schwarzenegger that EPA would be denying the waiver. On March 6, 2008, EPA published its decision denying California's waiver request (March 6, 2008 Denial).[6]

EPA's March 6, 2008 Denial was based on a finding that California did not need its GHG standards for new motor vehicles to meet compelling and extraordinary conditions. Because this finding was sufficient to deny California's waiver request, the Administrator found it unnecessary to determine whether the criteria for denial of a waiver under sections 209(b)(1)(A) and (C) had been met.

On January 21, 2009, CARB submitted a request for EPA to reconsider its March 6, 2008 Denial (''Reconsideration Request'').[7] CARB's Reconsideration Request stated its belief that EPA has the inherent authority to reconsider its previous waiver denial and EPA should do so in order to restore the Agency's interpretations and applications of the Clean Air Act to continue California's longstanding leadership role in setting emission standards. Specifically, CARB noted several bases for the reconsideration centered on EPA's misinterpretation of the Clean Air Act to set new flawed tests and misapplication of facts to those tests.

President Obama issued a Presidential Memorandum to the Administrator of the Environmental Protection Agency on January 26, 2009, stating that ''In order to ensure that the EPA carries out its responsibilities for improving air quality, you are hereby requested to assess whether the EPA's decision to deny a waiver based on California's application was appropriate in light of the Clean Air Act. I further request that, based on that assessment, the EPA initiate any appropriate action.'' [8]

Subsequently, EPA published a **Federal Register** notice on February 12, 2009, which responded to CARB's reconsideration request and announced that EPA would fully review and reconsider its March 6, 2008 Denial.[9] The February 12, 2009 notice specifically sought comment on: any new or additional information regarding the three section 209(b) waiver criteria; whether EPA's interpretation and application of section 209(b)(1)(B) in the March 6, 2008 Denial was appropriate; and, the effect of the waiver denial on whether CARB's GHG standards are consistent with section 202(a), including lead time. After holding a public hearing on March 5, 2009, the written comment period closed on April 6, 2009.

III. Analysis of Preemption Under Section 209(a) of the Clean Air Act

A. Clean Air Act Preemption Provisions

Section 209(a) of the Act provides:

> No State or any political subdivision thereof shall adopt or attempt to enforce any standard relating to the control of emissions from new motor vehicles or new motor vehicle engines subject to this part. No State shall require certification, inspection or any other approval relating to the control of emissions from any new motor vehicle or new motor vehicle engine as condition precedent to the initial retail sale, titling (if any), or registration of such motor vehicle, motor vehicle engine, or equipment.[10]

Section 209(b)(1) of the Act requires the Administrator, after an opportunity for public hearing, to waive application of the prohibitions of section 209(a) for any State that has adopted standards (other than crankcase emission standards) for the control of emissions from new motor vehicles or new motor engines prior to March 30, 1966, if the State determines that its State standards will be, in the aggregate, at least as protective of public health and welfare as applicable Federal standards.[11] However, no such waiver shall be granted by the Administrator if she finds that: (A) The protectiveness determination of the State is arbitrary and capricious; (B) the State does not need such State standards to meet compelling and extraordinary conditions; or (C) such State standards and accompanying enforcement procedures are not consistent with section 202(a) of the Act. In previous waiver decisions, EPA has stated that Congress intended EPA's review of California's decision-making be narrow. This has led EPA to reject arguments that are not specified in the statute as grounds for denying a waiver:

[3] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.

[4] *Massachusetts* v. *EPA,* 549 U.S. 497, 127 S. Ct. 1438 (2007). On April 24, 2009, EPA issued ''Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act'' at 74 FR 18885 (April 24, 2009).

[5] 72 FR 21260 (April 30, 2007).

[6] 73 FR 12156 (March 6, 2008). The State of California brought litigation against EPA in the United States Court of Appeals, DC Circuit. This litigation is held in abeyance pending further order of the court. (February 25, 2009).

[7] California Air Resources Board, EPA–HQ–OAR–2006–0173–7044.

[8] 74 FR 4905 (January 28, 2009).

[9] 74 FR 7040 (February 12, 2009).

[10] Clean Air Act section 209(a).

[11] California is the only State which meets section 209(b)(1)'s requirement for obtaining a waiver. *See* S. Rep. No. 90–403 at 632 (1967).

The law makes it clear that the waiver requests cannot be denied unless the specific findings designated in the statute can properly be made. The issue of whether a proposed California requirement is likely to result in only marginal improvement in air quality not commensurate with its cost or is otherwise an arguably unwise exercise of regulatory power is not legally pertinent to my decision under section 209, so long as the California requirement is consistent with section 202(a) and is more stringent than applicable Federal requirements in the sense that it may result in some further reduction in air pollution in California.[12]

Thus, my consideration of all the evidence submitted concerning a waiver decision is circumscribed by its relevance to those questions that I may consider under section 209(b).

B. Deference to California

In previous waiver decisions, EPA has recognized that the intent of Congress in creating a limited review based on the section 209(b)(1) criteria was to ensure that the federal government did not second-guess the wisdom of state policy. This has led EPA to state:

It is worth noting * * * I would feel constrained to approve a California approach to the problem which I might also feel unable to adopt at the federal level in my own capacity as a regulator. The whole approach of the Clean Air Act is to force the development of new types of emission control technology where that is needed by compelling the industry to ''catch up'' to some degree with newly promulgated standards. Such an approach * * * may be attended with costs, in the shaped of reduced product offering, or price or fuel economy penalties, and by risks that a wider number of vehicle classes may not be able to complete their development work in time. Since a balancing of these risks and costs against the potential benefits from reduced emissions is a central policy decision for any regulatory agency under the statutory scheme outlined above, I believe I am required to give very substantial deference to California's judgments on this score.[13]

EPA has stated that the text, structure, and history of the California waiver provision clearly indicate both a congressional intent and appropriate EPA practice of leaving the decision on ''ambiguous and controversial matters of public policy'' to California's judgment.[14]

The House Committee Report explained as part of the 1977 amendments to the Clean Air Act, where Congress had the opportunity to restrict the waiver provision, it elected instead to explain California's flexibility to adopt a complete program of motor vehicle emission controls. The amendment is intended to ratify and strengthen the California waiver provision and to affirm the underlying intent of that provision, *i.e.,* to afford California the broadest possible discretion in selecting the best means to protect the health of its citizens and the public welfare.[15]

C. Burden of Proof

In *Motor and Equip. Mfrs Assoc.* v. *EPA,* 627 F.2d 1095 (DC Cir. 1979) (*MEMA I*), the U.S. Court of Appeals stated that the Administrator's role in a section 209 proceeding is to:

consider all evidence that passes the threshold test of materiality and * * * thereafter assess such material evidence against a standard of proof to determine whether the parties favoring a denial of the waiver have shown that the factual circumstances exist in which Congress intended a denial of the waiver.[16]

The court in *MEMA I* considered the standards of proof under section 209 for the two findings necessary to grant a waiver for an ''accompanying enforcement procedure'' (as opposed to the standards themselves): (1) Protectiveness in the aggregate and (2) consistency with section 202(a) findings. The court instructed that ''the standard of proof must take account of the nature of the risk of error involved in any given decision, and it therefore varies with the finding involved. We need not decide how this standard operates in every waiver decision.'' [17]

The court upheld the Administrator's position that, to deny a waiver, there must be 'clear and compelling evidence' to show that proposed procedures undermine the protectiveness of California's standards.[18] The court noted that this standard of proof also accords with the congressional intent to provide California with the broadest possible discretion in setting regulations it finds protective of the public health and welfare.[19]

With respect to the consistency finding, the court did not articulate a standard of proof applicable to all proceedings, but found that the opponents of the waiver were unable to meet their burden of proof even if the standard were a mere preponderance of the evidence. Although *MEMA I* did not explicitly consider the standards of proof under section 209 concerning a waiver request for ''standards,'' as compared to accompanying enforcement procedures, there is nothing in the opinion to suggest that the court's analysis would not apply with equal force to such determinations. EPA's past waiver decisions have consistently made clear that: ''[E]ven in the two areas concededly reserved for Federal judgment by this legislation—the existence of compelling and extraordinary' conditions and whether the standards are technologically feasible—Congress intended that the standards of EPA review of the State decision to be a narrow one.'' [20]

Finally, opponents of the waiver bear the burden of showing that the criteria for a denial of California's waiver request has been met. As found in *MEMA I,* this obligation rests firmly with opponents of the waiver in a section 209 proceeding, holding that: ''[t]he language of the statute and it's legislative history indicate that California's regulations, and California's determinations that they must comply with the statute, when presented to the Administrator are presumed to satisfy the waiver requirements and that the burden of proving otherwise is on whoever attacks them. California must present its regulations and findings at the hearing and thereafter the parties opposing the waiver request bear the burden of persuading the Administrator that the waiver request should be denied.'' [21]

The Administrator's burden, on the other hand, is to make a reasonable evaluation of the information in the record in coming to the waiver decision. As the court in *MEMA I* stated, ''Here, too, if the Administrator ignores evidence demonstrating that the waiver should not be granted, or if he seeks to overcome that evidence with unsupported assumptions of his own, he runs the risk of having his waiver decision set aside as 'arbitrary and capricious.' '' [22] Therefore, the Administrator's burden is to act ''reasonably.'' [23]

EPA received comment suggesting that the burden of proof upon reconsideration of EPA's March 6, 2008 Denial should be reversed and placed on California.[24] It is not clear whether

[12] 36 FR 17458 (Aug. 31, 1971). Note that the more stringent standard expressed here, in 1971, was superseded by the 1977 amendments to section 209, which established that California must determine that its standards are, in the aggregate, at least as protective of public health and welfare as applicable Federal standards.

[13] 40 FR 23103–23104; *see also* LEV I Decision Document at 64.

[14] 40 FR 23104; 58 FR 4166.

[15] *MEMA I,* 627 F.2d at 1110 (citing H.R. Rep. No. 294, 95 Cong., 1st Sess. 301–02 (1977).

[16] *MEMA I,* 627 F.2d at 1122.

[17] *Id.*

[18] *Id.*

[19] *Id.*

[20] *See, e.g.,* 40 FR 21102–103 (May 28, 1975).

[21] *MEMA I,* 627 F.2d at 1121.

[22] *Id.* at 1126.

[23] *Id.* at 1126.

[24] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994 at 6–7.

the commenter is also suggesting that the entire burden of proof now shifts to California in that ''[s]uch an allocation of the burden of proof ensures that decisions in which EPA has invested time and resources are not lightly overturned, and that those decisions enjoy the finality to which they are entitled.'' Moreover, the commenter suggests that EPA carries a separate responsibility, in order to reverse its prior decision, to explain why its first decision on the waiver request is no longer the correct one. The commenter cites several cases for the proposition that ''[A]n agency changing its course * * * is obligated to supply a reasoned analysis for the change beyond that which may be required when an agency does not act in the first instance'' and that an agency must offer sufficient explanation to ensure the court that it is not ''repudiating precedent to conform with shifting political mood.''[25]

EPA believes that, regardless of the previous waiver denial, once California makes its protectiveness determination the burden of proof falls on the opponents of the waiver. This burden is inherent in the statutory requirement that EPA grant the waiver unless it makes one of the specific negative findings in section 209(b)(1).[26] This is consistent with the legislative history, which indicates that Congress intended a narrow review by EPA and to preserve the broadest possible discretion for California.[27]

As EPA explained in the previous waiver denial, the Agency did not address the section 209(b)(1)(A) and (C) criteria in its decision; therefore EPA is not in a position of reversing any interpretations or evidentiary findings. As further discussed in section VI, although commenters argue various adverse effects of the prior waiver denial on lead time, the burden remains on the opponents of the waiver to demonstrate why California's GHG standards are not consistent with section 202(a). With regard to section 209(b)(1)(B) and EPA's prior waiver denial, EPA has provided a reasoned analysis and explanation for any reversal of positions taken in this new decision. In the context of this reasoned explanation, EPA believes it is only required to demonstrate that it is aware that it is changing positions and that there are good reasons for the change in position.[28] As discussed above, the burden of proof under section 209(b)(1)(B) still falls on those who wish EPA to deny the waiver, based on the statutory structure of section 209(b)(1) and the legislative history. This requirement is not disturbed by EPA's initial denial.

IV. California's Protectiveness Determination

Section 209(b)(1)(A) of the Act requires EPA to deny a waiver if the Administrator finds that California was arbitrary and capricious in its determination that its State standards will be, in the aggregate, at least as protective of public health and welfare as applicable Federal standards. EPA recognizes that the phrase ''States standards'' means the entire California new motor vehicle emissions program. Therefore, as explained below, when evaluating California's protectiveness determination, EPA compares the California-to-Federal standards. That comparison is undertaken within the broader context of the previously waived California program, which relies upon protectiveness determinations that EPA have previously found were not arbitrary and capricious.[29]

Traditionally, EPA has evaluated the stringency of California's standards relative to comparable EPA emission standards.[30] That evaluation follows the instruction of section 209(b)(2), which states: ''If each State standard is at least as stringent as the comparable applicable Federal standard, such State standard shall be deemed to be at least as protective of health and welfare as such Federal standards for purposes of [209(b)(1)].''

To review California's protectiveness determination in light of section 209(b)(2), EPA conducts its own analysis of the newly adopted California standards to comparable applicable Federal standards. Reviewing that comparison quantitatively answers whether the new standards are more or less protective than the Federal standards. That comparison of the newly adopted California standards to the comparable applicable Federal standards is conducted in light of prior waiver determinations. That is, the California-to-Federal analysis is undertaken within the broader context of the previously waived California program, which relies upon protectiveness determinations that EPA has not found arbitrary and capricious.[31]

A finding that California's determination was arbitrary and capricious under section 209(b)(1)(A) must be based upon '''clear and compelling evidence' to show that proposed [standards] undermine the protectiveness of California's standards.''[32] Even if EPA's own analysis of comparable protectiveness or that suggested by a commenter might diverge from California's protectiveness finding, that is not a sufficient basis on its own for EPA to make a section 209(b)(1)(A) finding that California's protectiveness finding is arbitrary and capricious.[33]

California made a protectiveness determination with regard to its greenhouse gas regulations in Resolution 04–28, adopted by the California Air Resources Board on September 23, 2004.[34] Included in that Resolution were several bases to support

[25] *Id.*

[26] *MEMA I,* 627 F.2d at 1121.

[27] *MEMA I,* 627 F.2d at 1110–11, citing H.R. Rep. No. 294, 95th Cong., 1st Sess. 301–02 (1977).

[28] *Federal Communications Commission* v. *Fox Television Stations, Inc.,* 129 S.Ct. 1800, 1809 (2009).

[29] In situations where there are no Federal standards directly comparable to the specific California standards under review, the analysis then occurs against the backdrop of previous waivers which determined that the California program was at least as protective of the federal program ((LEV II + ZEV) + GHG). See 71 FR 78190 (December 28, 2006), Decision Document for Waiver of Federal Preemption for California Zero Emission Vehicle (ZEV) Standards (December 21, 2006).

[30] 36 FR 17458 (Aug. 31, 1971). (''The law makes it clear that the waiver requests cannot be denied unless the specific finding designated in the statute can properly be made. The issue of whether a proposed California requirement is likely to result in only marginal improvement in air quality not commensurate with its cost or is otherwise an arguably unwise exercise of regulatory power is not legally pertinent to my decision under section 209, so long as the California requirement is consistent with section 202(a) and is more stringent than applicable Federal requirements in the sense that it may result in some further reduction in air pollution in California.''). The ''more stringent'' standard expressed here in 1971 was superseded by the 1977 amendments to section 209, which established that California's standards must be, in the aggregate, at least as protective of public health and welfare as applicable Federal standards. The stringency standard remains, though, in section 209(b)(2).

[31] In situations where there are no Federal standards directly comparable to the specific California standards under review, the analysis then occurs against the backdrop of previous waivers which determined that the California program was at least as protective of the federal program ((LEV II + ZEV) + GHG). See 71 FR 78190 (December 28, 2006), Decision Document for Waiver of Federal Preemption for California Zero Emission Vehicle (ZEV) Standards (December 21, 2006).

[32] *MEMA I,* 627 F.2d at 1122.

[33] ''Once California has come forward with a finding that the procedures it seeks to adopt will not undermine the protectiveness of its standards, parties opposing the waiver request must show that this finding is unreasonable.'' *MEMA I,* 627 F.2d at 1124.

[34] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.107, ''Resolution 04–28, State of California, Air Resources Board, September 23, 2004'' (''BE IT FURTHER RESOLVED that the Board hereby determines that the regulations approved herein will not cause California motor vehicle emission standards, in the aggregate, to be less protective of public health and welfare than applicable federal standards.'').

California's protectiveness determination. Most generally, CARB made a broad finding that observed and projected changes in California's climate are likely to have a significant adverse impact on public health and welfare in California, and that California is attempting to address those impacts by regulating in a field for which there are no comparable federal regulations.[35] CARB also found that its greenhouse gas standards will increase the health and welfare benefits from its broader motor vehicle emissions program by directly reducing upstream emissions of criteria pollutants from decreased fuel consumption.[36] Beyond that analysis of the new regulations' impact on its broader program, CARB projected consumer response to the greenhouse gas regulations. With respect to consumer shifts due to a potential ''scrappage effect'' (the impact of increased vehicle price on fleet age) and ''rebound effect'' (the impact of lower operating costs on vehicle miles travelled), CARB found minor impacts—but net reductions—on criteria pollutant emissions.[37] Further, even assuming larger shifts in consumer demand attributable to the greenhouse gas emission standards, CARB found that the result remains a net reduction in both greenhouse gas emissions and criteria pollutant emissions.[38] That is, CARB found that the addition of its greenhouse gas emission standards to its larger motor vehicle emissions program (LEV II), which generally aligns with the federal motor vehicle emissions program (Tier II), renders the whole program to be more protective of public health and welfare. CARB noted that EPA has already determined that California was not arbitrary and capricious in its determination that the pre-existing California standards for light-duty vehicles and trucks, known as LEV II, is at least as protective as comparable Federal standards, the Tier II standards.[39] Implicit in California's greenhouse gas protectiveness determination, then, is that the inclusion of greenhouse gas standards into California's existing motor vehicle emissions program will not cause California's program to be less protective than the federal program.

A. What Are ''Applicable Federal Standards''?

EPA has received comments suggesting that the section 209(b)(1)(A) comparison to ''applicable Federal standards'' should include corporate average fuel economy (CAFE) standards promulgated, or that in the future may be promulgated, by the National Highway Traffic Safety Administration under the Energy Policy and Conservation Act of 1975 (EPCA), as amended by the Energy Independence and Security Act of 2007 (EISA).[40] That suggestion departs from EPA's traditional analysis. EPA has always interpreted ''applicable Federal standards'' as limiting EPA's inquiry to motor vehicle emission standards established by EPA under the Clean Air Act. After a thorough examination of the text and legislative history of the section 209(b) waiver provision, EPA has determined that it should continue to interpret ''applicable Federal standards'' to mean motor vehicle emission standards established by EPA under the Clean Air Act that apply to the same cars and the same air pollutants or group of air pollutants as considered in California's aggregate protectiveness finding. Additionally, EPA has determined that even if it were appropriate to take NHTSA's fuel economy standards into account as ''applicable Federal standards,'' the waiver opponents have not met their burden of proof to demonstrate that California's protectiveness determination was arbitrary and capricious. No waiver opponent has demonstrated that existing or proposed fuel economy standards are more stringent or more protective of the public health and welfare than California's greenhouse gas emission standards.

1. Are ''Applicable Federal Standards'' Limited to Clean Air Act Emission Standards or Do They Include NHTSA's Fuel Economy Standards?

Section 209(b)(1)(A) requires EPA to evaluate whether California's determination regarding the comparative level of protectiveness of its standards of the public health and welfare was ''arbitrary and capricious.'' California's standards act to improve air quality, and thus benefit the public health and welfare, by establishing limits for emissions of air pollutants from new motor vehicles and new motor vehicle engines. California is then required to compare these new motor vehicle standards in the aggregate to ''applicable Federal standards'' to determine the relative protectiveness of California's standards. Depending on whether the waiver is granted or denied, vehicle manufacturers will either have to meet California standards for those new vehicles subject to its standards and EPA standards for others, or EPA standards for all of the new vehicles.

The most straightforward reading of the comparison called for by the statute, between California and Federal standards, is an ''apples to apples'' comparison. California has standards that apply to new motor vehicles and the standards set limits for emissions of air pollutants. California would then compare its standards to the same kind of Federal standard—Federal standards that apply to the same new motor vehicles and also set limits for emissions of air pollutants. The term ''applicable'' has to refer to what the Federal standards apply to, and the most straightforward meaning is that they apply in the same way that the

[35] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.107 at 9 (''Over the last hundred years, average temperatures in California have increased 0.7% F, sea levels have risen by three to eight inches, and spring run-off has decreased 12 percent. These observed and future changes are likely to have significant adverse effects on California's water resources, many ecological systems, as well as on human health and the economy. The signs of a global warming trend continue to become more evident and much of the scientific debate is now focused on expected rates at which future changes will occur.''); California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.107 at 13 (''There are no comparable federal regulations that specifically require the control of greenhouse gas emissions from motor vehicles.'').

[36] ''The establishment of greenhouse gas emission standards will result in a reduction in upstream emissions (emission due to the production and transportation of the fuel used by the vehicle) of greenhouse gas, criteria and toxic pollutants due to reduced fuel usage.'' EPA–HQ–OAR–2006–0173–0010.107 at 8.

[37] ''Supplemental analysis of the potential response of consumers (consumer response) to the regulations was performed as part of the staff evaluation. The evaluation of consumer response indicates that the impact of vehicle price increases on fleet turnover (changes to the average age of the motor vehicle fleet) as well as the impacts of lower operating costs on vehicle miles traveled (rebound effect) by consumers have minor impacts (less than one percent of the passenger vehicle emissions inventory) on criteria pollutant emissions.'' EPA–HQ–OAR–2006–0173–0010.107 at 12.

[38] ''Taking into account the penetration of 2009 and later vehicles meeting the new standard, the proposed regulation will reduce greenhouse gas emission by an estimated 87,700 CO_2-equivelent tons per day statewide in 2020 and by 155,200 CO_2-equivelent tons per day in 2030. This translates into an 18 percent overall reduction in greenhouse gas emissions from the light duty fleet in 2020 and a 27 percent overall reduction in 2030; Taking into account the penetration of 2009 and later vehicles meeting the new standard, the proposed regulation will reduce upstream emissions of non-methane organic gases (NMOG) by 4.6 tons per day statewide in 2020 and 7.9 tons per day statewide in 2030, and will reduce upstream emissions of NO_X by 1.4 tons per day statewide in 2020 and 2.3 tons per day statewide in 2030. The regulation will provide a criteria pollutant benefit even taking into account possible pollutant increases due to consumer response.'' EPA–HQ–OAR–2006–0173–0010.107 at 15.

[39] 68 FR 19811 (April 22, 2003), Decision Document for Waiver of Federal Preemption for Low Emission Vehicle Amendments (LEV II) (April 11, 2003).

[40] Association of International Automobile Manufacturers, Inc., EPA–HQ–OAR–2006–1073–9005 at 13–14; Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994 at 16–23.

California standards apply, by setting limits on emissions of air pollutants from specified new motor vehicles. ''[A]pplicable Federal standards'' would be standards that impose a requirement on new motor vehicles and that directly establishes limits on emissions of air pollutants, as do the California standards. The ''applicable'' Federal standards are those set by EPA that directly apply by regulation to the same vehicles and, like the California regulations, set limits for the same air pollutants.

This is a straightforward and logical approach that provides clear guidance for California on what standards to compare. It avoids an open-ended inquiry into what other potential Federal standards might regulate different vehicles or regulate different aspects of the vehicles than emissions, and instead focuses the comparison on a clearly-defined and identifiable set of Federal standards that are parallel to the California standards at issue.

This interpretation also ties the comparison to the only Federal standards that are affected by the results of the comparison. If the California comparison shows it is more protective and the waiver is granted, the California standards would apply to the vehicles under section 209(b) and compliance with the California's standards will be deemed to mean compliance with the EPA standards under section 209(b)(3). If the California comparison is arbitrary and capricious and a waiver is denied, then EPA's Federal emission standards apply to those vehicles and California's standards do not. The applicability of emission standards under section 209(b) that results from the waiver decision is parallel to and fully consistent with the comparison made between the California and applicable Federal standards.

EPA has always limited its interpretation of the section 209(b) waiver provision to the scope of section 209(a)'s preemption.[41] Section 209(a) creates the explicit preemption of state emission standards, and at the same time leaves EPA to set federal emission standards, under the authority of section 202(a). Within the context of section 209, and the preemption of 209(a), section 209(b)'s waiver provision allows California the ability to set its own emission standards. Notably, section 209(b) merely gives back to California what was taken away by section 209(a)—the ability to adopt and enforce its own state emission standards. This interaction between sections 209(a) and 209(b) supports interpreting the ''applicable Federal standards'' mentioned in section 209(b)(1)(A) to mean the same types of emission standards as the emission standards that are actually set by California are preempted under section 209(a), and are the subject of a waiver request under section 209(b).

Additionally, EPA's construction of ''applicable Federal standards'' provides a single, consistent usage of that phrase in the context of the section 209(b) waiver provision. In section 209(b), the phrase ''applicable Federal standards'' appears three times. The first two instances appear in sections 209(b)(1) and 209(b)(2) and pertain to EPA's review of California's protectiveness determination and the relative stringency of California's standards, as has been discussed above. The third instance occurs in section 209(b)(3) and specifically contemplates treatment of waived California standards for the purpose of Clean Air Act compliance. Section 209(b)(3) states: ''in the case of any new motor vehicle or new motor vehicle engine to which State standards apply pursuant to a waiver granted under paragraph (1), compliance with such State standards shall be treated as compliance with applicable Federal standards *for purposes of this title.''* (Emphasis added) The reference to Title II of the Clean Air Act in section 209(b)(3) is further reason to limit the construction of ''applicable Federal standards'' to comparable Clean Air Act emission standards in sections 209(b)(1) and 209(b)(2). All three occurrences of ''applicable Federal standards'' in section 209(b) are then given the same meaning, in a context where all three occurrences function interactively to allow California to enforce its own emission standards.

The textual structure and legislative history of the waiver provision also support EPA's interpretation of ''applicable Federal standards.'' The structure of section 209(b) is notable in its focus on limiting the ability of EPA to deny a waiver and preserving ''the broadest possible discretion'' for California to construct its motor vehicle program as it deems appropriate to protect its public health and welfare.[42] Where, as in this case, California's emission standards are specified in terms of direct regulation of emissions from new motor vehicles, it is most clearly reasonable for EPA to limit its review under this criterion to those federal standards that likewise set limits for the same air pollutant emissions from the same motor vehicles. This is consistent with Congress' intent to provide California the broadest discretion and avoids limiting California's authority and frustrating this congressional intent.[43] EPA, thus, has determined it is reasonable to interpret ''applicable Federal standards'' to mean those EPA standards under the Clean Air Act that apply in the same manner as the California emission standards, regulating emissions of air pollutants from new motor vehicles.[44] Under this approach, any EPA standard that, like California's standards, sets limits for motor vehicle emissions could be considered an ''applicable Federal standard'' for the purpose of California's protectiveness determination.[45]

Applying this interpretation, Federal fuel economy standards issued by NHTSA would not be considered ''applicable Federal standards'' for purposes of this waiver criterion. In contrast to standards set limits for emissions from new motor vehicles, corporate average fuel economy (CAFE) standards set limits on fuel efficiency, to reduce fuel consumption. In contrast to EPA's and California's emission standards, which typically establish grams per mile (''gpm'') levels of acceptable pollutant emissions, CAFE standards establish ''miles per gallon'' (''mpg'') levels of acceptable fuel efficiency. Standards that set limits for emission levels and standards that set limits for fuel efficiency apply different legal requirements. The two kinds of standards can overlap significantly, in that the technology used to increase fuel efficiency will also lead to reductions in emissions of one of the GHGs—CO_2—

[41] ''The legislative history of section 209 supports the Administrator's interpretation that the waiver provision is coextensive with the preemption provision, thereby permitting the Administrator to consider waiving preemption of California's entire program of emissions control.'' *MEMA I,* 627 F.2d 1095, 1108.

[42] H.R. Rep. No. 294, 95th Cong., 1st Sess. 301–302 (1977); *MEMA I,* 627 F. 2d at 1110–11.

[43] *See MEMA I,* 627 F. 2d at 1111.

[44] *Entergy Corp.* v. *Riverkeeper, Inc.,* 129 S.Ct. 1498 (2009) (''That view governs if it is a reasonable interpretation of the statute—not necessarily the only possible interpretation, nor even the interpretation deemed *most* reasonable by the courts. *Chevron U.S.A. Inc.* v. *Natural Resources Defense Council, Inc.,* 467 U.S. 837, 8430844 (1984).'').

[45] In this waiver there are no EPA or other Federal standards that have been identified that explicitly and directly regulate emissions of GHGs from new motor vehicles. While emission standards promulgated by EPA have always been treated as applicable Federal standards because they explicitly regulate the same vehicles and air pollutants, there is the possibility that another Federal agency could have a standard that also directly and explicitly regulates emissions from some new motor vehicles. EPA is not aware of any such circumstances at this time, but reserves the right to consider in the future whether such a non-EPA Federal standard would be considered an ''applicable Federal standards'' for the purpose of a CAA waiver determination.

but they are not the same legal requirements and the regulations do not apply in the same manner.[46] Fuel economy standards do impact the levels of one GHG—CO_2—that is emitted from motor vehicles. But fuel economy standards do not set limits on emission levels of CO_2 or any other air pollutant, as do California's standards. Lacking that kind of regulation of emissions of an air pollutant, fuel economy standards are not ''applicable Federal standards.''

The difference between emission standards and fuel economy standards is highlighted by comparing the two sets of standards at issue here. California's greenhouse gas emission standards establish allowable grams per mile (''gpm'') levels for greenhouse gas emissions, including tailpipe emissions of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) as well as emissions of CO_2 and hydrofluorocarbons (HFCs) related to operation of the air conditioning system. By regulating emissions of four different greenhouse gas pollutants, the standards do more than reduce tailpipe CO_2 emissions resulting from fuel combustion. They do not directly equate to miles per gallon fuel economy reductions. Fuel economy standards, on the other hand, directly control miles per gallon (''mpg'') fuel economy levels. CO_2 reductions will occur, but they are an expected indirect effect of improved fuel economy standards because the same technology that improves fuel economy effectively reduces CO_2 emissions.

There is no doubt that a CAFE standard would clearly produce companion reductions in CO_2 as fuel economy improves, given the technology used to improve fuel economy. However, for the reasons described above EPA believes the better interpretation of section 209(b)(1)(A) is to look at whether the Federal standard is applicable to the same vehicles and air pollutants as the California standards, by considering whether they directly regulate the same vehicles and air pollutants. It is clear that a CAFE standard does not meet this test. While there is a large but non-identical overlap in effect between a CAFE standard and a GHG emission standard with respect to emissions of CO_2, the CAFE standards do not set limits on emissions of CO_2 or any other GHG. There also remain important areas where there is no overlap at all with the California standards, including the regulation of greenhouse gas pollutants other than CO_2. Instead of making an exception to its interpretation of ''applicable Federal standards'' for NHTSA's CAFE fuel economy standards, EPA believes it is more appropriate to apply its traditional interpretation, for all of the reasons discussed above. Therefore, EPA has determined that NHTSA's CAFE standards are not ''applicable Federal standards'' for purposes of this waiver criterion.

2. If EPA Did Consider CAFE Standards as ''Applicable Federal Standards,'' Are the CAFE Standards More Stringent Than California's Greenhouse Gas Emission Standards?

Even if EPA were to take fuel economy standards into consideration as ''applicable Federal standards,'' opponents of the waiver have not met their burden of proof to demonstrate that California's protectiveness determination was arbitrary and capricious. No waiver opponent has demonstrated that existing CAFE standards are more stringent or more protective of the public health and welfare than California's greenhouse gas emission standards.

EPA has consistently stated in prior waiver determinations that California's protectiveness determination must consider the ''applicable Federal standards'' in existence at the time of EPA's waiver decision.[47] Standards in existence at the time of a waiver decision have only included finalized emission standards that EPA has promulgated through its rulemaking process and pursuant to its Clean Air Act authority.

Applying that approach here, if EPA were to take NHTSA's fuel economy standards into account when reviewing California's protectiveness determination, our inquiry would be limited to those final fuel economy standards that are currently in existence at the time of the waiver decision. Although NHTSA is required by the EISA to promulgate more stringent fuel economy standards in the future, the only final fuel economy standard under EISA that is currently in existence is that for the 2011 model year.[48] Additionally, although EPA and the Department of Transportation (DOT) have issued a notice of intent to engage in a joint rulemaking, with NHTSA issuing fuel economy standards under the EISA for the 2012 through 2016 model years and EPA issuing greenhouse gas standards under the CAA for those same model years, those standards are neither proposed nor final at this time.[49] To consider CAFE standards that have been proposed or those standards that may be proposed would be speculative about what standards will be adopted, and EPA has consistently found it inappropriate to engage in that speculation with respect to either EPA's or California's future standards in prior waiver decisions.

Further, it is reasonable to limit our consideration of ''applicable Federal standards'' to those final standards that are in existence, in light of the range of options that remain for California and EPA after a decision on this waiver. If federal greenhouse gas standards are promulgated in the future, and if such standards bring this determination into question, then EPA can revisit this decision at that time. The legislative history of section 209(b) makes clear that Congress considered section 209(b) as including the authority for EPA to withdraw a waiver if circumstances occur in the future that would make this appropriate: ''Implicit in this provision is the right of the [Administrator] to withdraw the waiver at any time [if] after notice and an opportunity for public hearing he finds that the State of California no longer complies with the conditions of the waiver.[50] EPA need not decide now what action might be authorized or appropriate under section 209(b) if EPA adopts greenhouse gas emission standards in the future, as that is best decided when EPA takes such action. Additionally, the possibility that CARB may revise its standards is always present. Such a revision would be considered by EPA in a future waiver proceeding. EPA would then determine whether those changes are within-the-scope of its prior waiver or if a new, full waiver determination would need to be made, as would be required if California

[46] The Supreme Court acknowledged this ''overlap'' between fuel economy and emission standards in *Massachusetts* v. *EPA,* 127 S. Ct. at 1438. (''[T]hat DOT sets mileage standards in no way licenses EPA to shirk its environmental responsibilities. EPA has been charged with protecting the public's 'health' and 'welfare.' 42 U.S.C. 7521(a)(1), a statutory obligation wholly independent of DOT's mandate to promote energy efficiency. *See* Energy Policy and Conservation Act, section 2(5), 89 Stat. 874, 42 U.S.C. 6201(5). The two obligations may overlap, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency.'')

[47] See *e.g.,* Authorization of California's Under 25 Horsepower Utility Lawn and Garden Equipment Engine Exhaust Emission Standards (ULGE) (July 5, 1995) at 18. (''CARB's protectiveness determination must be judged on the standards that are in existence at the time EPA makes it authorization determination. However, as CARB correctly states, until EPA's rules become final no changed circumstances exist that affect CARB's protectiveness determination, and that it would be premature to make a protectiveness comparison with non-finalized federal standards.'')

[48] 74 FR 14196 (March 30, 2009).

[49] 74 FR 24007 (May 22, 2009).

[50] S. Rep. No. 403, 90th Cong. 1st Sess. (1967), at 33–34.

decided to increase the stringency of its greenhouse gas standards.

California's greenhouse gas emission standards begin with the 2009 model year and increase in stringency through the 2016 model year. For that same time period, fuel economy standards only exist for the 2009 through 2011 model years. An appropriate comparison between California's greenhouse gas standards and NHTSA's fuel economy standards, then, would compare California's standards for the 2009 and later model years to NHTSA's fuel economy standards for the 2009 through 2011 model years.

In his December 19, 2007 letter notifying California Governor Schwarzenegger that California's waiver request would be denied, former EPA Administrator Johnson stated that the EISA ''establishes an aggressive standard of 35 miles per gallon for all 50 states, as opposed to the 33.8 miles per gallon in California and a patchwork of other states.'' California prepared and documented a technical evaluation comparing federal fuel economy standards to its own standards.[51] Accounting for the differences between the two sets of standards, CARB attempted an ''apples to apples'' comparison of the standards and made several assumptions to that end. For its own standards, CARB assumed its current greenhouse gas regulations—at issue here—were in effect for the 2009 through 2016 model years and that those standards increased in stringency for the 2016 through 2020 model years (its ''Pavley 2'' standards that are not at issue in this waiver proceeding). Because EISA does not set standards, but directs NHTSA to issue standards that increase fuel economy to a minimum of 35 miles per gallon by the 2020 model year, CARB projected that the new CAFE standards would proportionally increase by 3.44 percent each year after the 2011 model year. Also, because EISA allows a fuel economy credit up to 1.2 miles per gallon for use of flexible fuel vehicles (FFVs) that can operate on high-blend ethanol, such as E85, based on manufacturer statements that they would produce large numbers of FFVs, CARB assumed maximum use of that credit. CARB also took into account differences in fleet mix in California and the other 49 states. To compare this range of years of the California greenhouse gas emission standards to the corresponding range of years of EISA fuel economy standards, CARB translated the miles per gallon standards from EISA into greenhouse gas emission rates. The rates of greenhouse gas emission reduction from each set of standards were then compared from 2009 through 2020.[52] CARB found that in California in 2016, its greenhouse gas emission standards would achieve 51.9 million metric tons of greenhouse gas emission reductions compared to 23.7 million metric tons from federal fuel economy standards. By 2020, CARB found 100.5 million metric tons of greenhouse gas emission reductions from its standards compared to 59.5 million metric tons of greenhouse gas emission reductions from the federal fuel economy standards.[53] Both sets of reductions follow a similar pattern because both sets of standards are relatively similar in stringency in the near-term (2009–2011), with California's standards ramping up in the mid-term (2012–2016), just as the proposed EISA standards begin to increase their stringency. While both sets of standards gain stringency in the long-term (2016 and beyond), California found that its standards are more stringent sooner and in the long-term and, furthermore, that its standards are more protective of its public health and welfare because they achieve greater greenhouse gas reductions.

EPA notes that this comparison requires speculation regarding what final CAFE standards will be promulgated by NHTSA for the 2012–2020 model years, and what final GHG standards may be promulgated by CARB for the 2017–2020 model years. If the comparison were truly between final, promulgated standards of California GHG-to-CAFE, it would compare California standards for the 2009 through 2016 model years to the lone NHTSA fuel economy standard for the 2011 model year, and the preexisting standards for the 2009–2010 model years. This highlights that the appropriate approach is to compare standards that are final as of the time of the waiver decision. However, California's approach indicates that its standards are more stringent than federal CAFE standards even if CAFE standards increased in the 2012 through 2016 model years. Therefore, this approach also would indicate that California's standards, reviewing only those standards that are final at this time, are more stringent in the aggregate.

No commenter has presented evidence that questions CARB's claim that its greenhouse gas emission standards are more stringent than EISA. Most commenters opposing the waiver do not focus on the comparative stringency of the two sets of standards, but instead focus on EISA's mandate for more stringent fuel economy standards as undermining the currency of California's protectiveness determination or California's ''need'' for its greenhouse gas emission standards. For example, AIAM has argued that the increased stringency of CAFE standards due to the EISA removes the basis for California's protectiveness determination.[54] Similarly, the Alliance argues that ''CARB erred in a fundamental way when it chose to ignore the impact of the federal CAFE standards generally and EISA's passage in specific on California's outdated protectiveness determination.'' [55] These arguments assume that CAFE standards are ''applicable Federal standards'' and that non-final standards may be taken into consideration at the time of a waiver determination. As explained in detail above, those assumptions are not consistent with EPA's interpretation of the section 209(b)(1)(A) criterion. Notably though, neither argument presents a factually-based analysis of the stringency of California's greenhouse gas emission standards as compared to existing fuel economy standards that undermines California's protectiveness determination.[56] Such an

[51] California Air Resources Board, Comparison of Greenhouse Gas Reductions for the United States and Canada under U.S. CAFE Standards and California Air Resources Board Greenhouse Gas Regulations, February 25, 2008, available at *http://www.arb.ca.gov/cc/ccms/reports/pavleycafe_reportfeb25_08.pdf.*

[52] The 2009 through 2020 model year standards are not a straightforward comparison of California's greenhouse gas standards to EISA standards because the years do not align. The California greenhouse gas standards at issue, here, are for the 2009 and later model years, whereas EISA was enacted in 2007 and mandates standards to reach 35 miles per gallon by the 2020 mode year, but as of yet have only been promulgated for the 2011 model year. The 2009 and 2010 MY federal fuel economy standards were pre-EISA standards. Neither California nor NHTSA has yet promulgated standards for the 2017–2020 model years: California greenhouse gas standards for those years are currently proposed in California (as ''Pavley 2'' standards), as are all the EISA standards from the 2012 through 2015 model years.

[53] California Air Resources Board, Comparison of Greenhouse Gas Reductions for the United States and Canada under U.S. CAFE Standards and California Air Resources Board Greenhouse Gas Regulations, (February 25, 2008), at 13–14.

[54] Association of International Automobile Manufacturers, Inc., EPA–HQ–OAR–2006–0173–9005 at 13–14.

[55] Alliance of Automobile Manufacturers, EPA, HQ–OAR–2006–0173–8994 at 20.

[56] The Alliance's comments received April 6, 2009 state: ''It should be noted that * * * it is also true that the fuel economy improvements required by the California GHG standards are more stringent, overall, for the industry than the CAFE standards in many jurisdictions in which the state GHG standards would apply compared to the CAFE standards. CARB does not disagree with this point. See CARB, Comparison of Greenhouse Gas Reductions for the United States and Canada Under U.S. CAFE Standards and California's Air Resources

Continued

analysis would be necessary for EPA to make a section 209(b)(1)(A) finding, if EPA were to depart from its traditional review of California's protectiveness determination and interpret ''applicable Federal standards'' to include NHTSA's fuel economy standards. As noted below, the Alliance points to an analysis of the relative stringency of the two sets of standards to find that: ''the combined vehicle-fuel program created by the EISA would result in greater life-cycle GHG reductions than the state standards that are the subject of this proceeding by the end of the decade.'' That analysis, however, is flawed for the purpose of this waiver consideration because it speculates as to NHTSA standards that are not yet finalized, or even proposed. Additionally, it infers that California's standards are more protective until 2017.[57]

Based on the above, and recognizing that federal fuel economy standards are not ''applicable Federal standards,'' EPA notes that even if the stringency of CAFE standards are considered in context of the section 209(b)(1)(A) waiver criterion, the opponents of the waiver have not presented sufficient evidence to show that California's protectiveness determination is arbitrary and capricious. No commenter has shown that California's determination was arbitrary and capricious in finding that NHTSA's fuel economy standards are not in the aggregate more protective of human health and welfare than California's greenhouse gas standards, whether one considers just the CARB and NHTSA standards that are currently finalized, or one considers possible future standards that either agency might adopt.

B. How Does EPA Evaluate Impacts on Other States?

Several comments have suggested that EPA should consider the impacts of California's greenhouse gas standards on other states.[58] At present time, thirteen other states and the District of Columbia have already adopted California's greenhouse gas emission standards pursuant to section 177 of the Act.[59] These comments raise two objections concerning other states adoption of California's greenhouse gas emission standards. First, these comments suggest that state-by-state compliance with each state's adopted set of California standards presents an unworkable compliance ''patchwork'' for automobile manufacturers.[60] Second, and related, the comments suggest that enforcement of California's greenhouse gas standards in other states will lead to ''environmental disbenefits'' in those states.[61] EPA takes no position on the merits of either argument because these arguments are outside the scope of our section 209(b)(1) waiver criteria. EPA's evaluation of California's waiver request is limited to the State of California.[62] To the extent that these comments raise issues regarding the environmental impacts of consumer shifts within California they are evaluated below.

C. Is California's Protectiveness Determination Arbitrary and Capricious?

1. Based on EPA's Traditional Analysis, Is California's Protectiveness Determination Arbitrary and Capricious?

As described above, EPA's traditional analysis has been to evaluate California's protectiveness determination by comparing the new California standards to applicable EPA emission standards for the same pollutants.[63] In the context of greenhouse gas emissions this analysis is simple. EPA has already determined that California was not arbitrary and capricious in its determination that the pre-existing California standards for light-duty vehicles and trucks, known as LEV II, is at least as protective as comparable Federal standards, known as the Tier II standards.[64] In the context of the ZEV proceeding, EPA conducted its traditional analysis to compare California's newly enacted ZEV standards to a similar lack of applicable Federal standards. At that time, California found, and EPA deemed reasonable, that the addition of the ZEV standards did not render California's LEV II program, for which a waiver had previously been granted, less protective than the Federal Tier II program. In addressing the Alliance's petition for reconsideration with respect to this issue, EPA stated that ''the words 'standards' and 'in the aggregate' in section 209(b)(1)(A) * * * . at minimum, include all the standards relating to the control of emissions for a category of vehicles (*e.g.* passenger cars, etc.) subject to CARB regulation, particularly where the standards are designed to respond to the same type of pollution.'' [65]

California's greenhouse gas standards are also an addition to its existing LEV II program. Since the greenhouse gas standards add onto California standards that have already been determined to be as least as protective, and since there are no applicable federal greenhouse gas emission standards, the point of comparison, here, is between California's greenhouse gas standards and an absence of EPA greenhouse gas emission standards. Comparing an absence of EPA greenhouse gas emission standards to the enacted set of California greenhouse gas emission standards provides a clearly rational basis for California's determination that the California greenhouse gas emission program will be more protective of human health and welfare than non-existent applicable federal standards. California directly addressed this traditional analysis in its finding that ''[t]here are no comparable federal regulations that specifically require the control of greenhouse gas emissions from motor vehicles.'' [66]

EPA received comments suggesting that this type of traditional comparison is inappropriate, even ''impossible,'' in

Board Greenhouse Gas Regulations: An Enhanced Assessment, at 8 (February 25, 2008).'' Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994 at 20, note 4.

[57] *Id.*

[58] Association of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–7176.11, p. 1–2, 24–25; National Automobile Dealers Association, EPA–HQ–OAR–2006–0173–7176.1, EPA–HQ–OAR–2006–0173–8956; NERA Economic Consulting and Sierra Research, EPA–HQ–OAR–2006–0173–9053.1.

[59] New York (6 NY Code, Rules & Regs., Part 218–8.3), Massachusetts (310 Code of Mass. Regs. 7.40(2)(a)(6)), Maryland (Code of Md. Regs. § 26.11.34), Vermont (Vt Air Poll. Ctrl Regs., Subchapter XI, 5–1106(a)(5)), Maine (06 Code of Maine Rules § 127), Connecticut (Conn. Admin. Code § 22a–174–36b), Arizona (18 A.A.C. 2), New Jersey (NJ Admin. Code §§ 7:27–29.13), New Mexico (20 NM Admin. Code, Chapter 2, Part 88), Oregon (Or. Admin. Rules § 340–257), Pennsylvania (36 Pa.B. 7424), Rhode Island (RI Air Poll. Ctrl Reg. 37.2.3), Washington (Wash. Admin. Code § 173.423–090(2), and Washington, DC (DC Law 17–0151) have adopted California's greenhouse gas emission standards. *See also http://www.pewclimate.org/what_s_being_done/in_the_states/vehicle_ghg_standard.cfm.* Four more states, including Florida, Colorado, Utah, and Montana are poised to adopt the standards.

[60] National Automobile Dealers Association, EPA–HQ–OAR–2006–0173–7176.1, EPA–HQ–OAR–2006–0173–8956.

[61] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994 at 22.

[62] These states and the District of Columbia have acted pursuant to section 177 of the Clean Air Act, which is not relevant to this proceeding, and that any issues commenters have regarding section 177 and state compliance with that statutory provision, is not appropriate for this proceeding. EPA notes that the language of section 209(b(1) refers to the ''State'' in several instances but in no instance does it refer to ''states'' or other areas of the country.

[63] See CAA section 209(b)(2).

[64] 71 FR 78190 (December 28, 2006) and Decision Document for Waiver of Federal Preemption for California Zero Emission Vehicle (ZEV) Standards (December 21, 2006); 68 FR 19811 (April 22, 2003) and Decision Document for Waiver of Federal Preemption for Low Emission Vehicle Amendments (LEV II)(April 11, 2003).

[65] EPA's August 13, 2008 Response to Petition for Administrative Reconsideration of EPA's ZEV Waiver Decision (through the 2011 Model Year) published on December 28, 2006, at 3.

[66] Id. at 13.

the absence of Federal greenhouse gas emission standards.[67] Such an argument is contrary to legislative intent and EPA's practice.[68] This is not the first time that California has enacted emission standards in the absence of Federal standards; in fact, California's pioneering role in setting mobile source emission standards is one reason the waiver provision exists.[69] Given that section 209(b)(1) is designed to allow California to have standards more stringent than Federal standards, it would make little sense to use this provision to prevent California from having such standards where the Federal government has not yet acted. Moreover, in prior decisions EPA has found that such protectiveness determinations by California in the absence of Federal standards were reasonable.[70] Indeed, California standards may be most clearly ''at least as protective'' when they are compared to the absence of Federal emission standards. This commenter further points to the ''tremendous level of current federal activity'' as the primary reason why ''it is impossible for EPA to evaluate how the GHG Regulations will compare with federal regulation in this field.'' While EPA has announced its intention to propose greenhouse gas emission standards, EPA has consistently stated that CARB's protectiveness determination must consider the Federal standards in existence at the time of EPA's waiver decision.[71]

Furthermore, waiting for future federal regulation would be contrary to the purpose of the section 209(b) waiver provision—effectively stalling California's ability to enforce its own program. CARB's protectiveness determination was made on September 23, 2004, at which time there were no federal greenhouse gas standards. CARB's determination, then, correctly compared its standards to the absence of federal emission standards. Since that time, there has been no relevant intervening ''applicable Federal standard.'' [72] Although AIAM points to the *Massachusetts* v. *EPA* decision and Executive Order 13,432, neither of those documents, nor any subsequent actions by the Federal government,[73] constitute final EPA regulation of greenhouse gas emissions for new motor vehicles that could be used as a comparable standard in this waiver proceeding.[74] The current lack of federal greenhouse gas emission standards maintains the factual basis for CARB's September 23, 2004 protectiveness determination. As noted above, if and when greenhouse gas standards are promulgated by EPA in the future, and if such standards bring this determination into question, then EPA can revisit this waiver decision at that time. Accordingly, applying its traditional comparative analysis, opponents of the waiver have not shown flaw or lack of reason in California's protectiveness determination; and we cannot find that California's protectiveness determination is arbitrary and capricious.

2. Is California's Protectiveness Determination Arbitrary and Capricious Based on the Real-World In-Use Effects of California's Greenhouse Gas Standards?

EPA received comments suggesting the need for and appropriateness of applying an alternative interpretation of section 209(b)(1)(A), based on an inquiry into the in-use effect of inclusion of greenhouse gas standards upon the broader motor vehicle emissions program.[75] EPA does not take a position as to the validity of the suggestion that the type of numerical analysis discussed above is insufficient. Noting the legislative history and text of section 209(b)(2), EPA would need a concrete factual basis to examine the in-use effect of California's greenhouse gas standards on its broader LEV II program as compared to the Federal Tier II program. We need not take a position on that matter because to the extent that the in-use effects of the greenhouse gas standards are considered, the waiver opponents do not meet their burden to show that CARB's analysis of the effects is unreasonable.

These comments suggest that consumer effects will cause California's broader LEV II motor vehicle emissions program to be less protective than the Federal Tier II emissions program.[76] In support of this analysis, the Alliance commissioned a study from Sierra Research, NERA Economic Consulting, and Air Improvement Resource, Inc. entitled ''Effectiveness of the California Light Duty Vehicle Regulations as Compared to Federal Regulations,'' which was submitted to EPA on June 15, 2007 (''June 2007 AIR/NERA/Sierra Study'').[77] CARB specifically responded to the June 2007 Study in comments it submitted to the docket on July 24, 2007 (''CARB's July Comments'').[78] Next, the Alliance submitted a response to California's response prepared by NERA Economic Consulting and Sierra Research (''October 2007 NERA/Sierra Study'').[79] Most recently, the Alliance submitted another study produced by NERA Economic Consulting and Sierra Research entitled ''Impacts of the California Greenhouse Gas Emission Standards on Motor Vehicle Sales'' (''April 2009 NERA/Sierra Study'').[80] On this issue, the Alliance also refers to a study published by the Society of Automotive Engineers entitled ''Evaluation of California Greenhouse Gas Standards and Federal Independence and Security Act—Part 2: CO_2 and GHG Impacts'' (''SAE Study'').[81] At the same time, Air Improvement Resource, Inc. has independently submitted comments which include its ''Evaluation of California Greenhouse Gas Standards and Federal Energy Independence and Security Act'' (''March 2009 AIR Study'').[82]

The Alliance has raised this issue before, in its request for reconsideration of EPA's waiver for California's ZEV

[67] Alliance of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–1455 at 3; Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–1297 at 2, 5–7, 11–12; National Automobile Dealers Association, EPA–HQ–OAR–0173–1671 at 3.

[68] The waiver provision allows California to ''act as a testing agent for various types of control and the country as a whole will be a beneficiary of this research'' (113 Cong. Rec. 32478 [1967]); ''act as a laboratory for innovation'' (*MEMA I* at 1095). *See* Decision Document for Authorization of State Standards for Utility Lawn and Garden Equipment (ULGE) (July 5, 1995).

[69] California first began regulating motor vehicle emissions in 1957, nearly a decade before Congress enacted the Motor Vehicle Air Pollution Control Act of 1965, which enabled a federal program.

[70] See *e.g.,* Authorization of California's Under 25 Horsepower Utility Lawn and Garden Equipment Engine Exhaust Emission Standards (ULGE) (July 5, 1995).

[71] *Id.* at 18.

[72] See section IV.A., regarding ''applicable Federal standards.''

[73] The Alliance similarly argues that EISA's mandate for reformed CAFE standards renders California's protectiveness determination ''obsolete'' or ''stale.'' Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994 at 21.

[74] Likewise, EPA and DOT's ''Notice of Upcoming Joint Rulemaking To Establish Vehicle GHG Emissions and CAFE Standards'' does not include any final standards which EPA can take into account as an ''applicable Federal standards.''74 FR 24007 (May 22, 2009).

[75] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–1297 at 5–12, and EPA–HQ–OAR–2006–0173–8994 at 22.

[76] *Id.*

[77] Sierra Research, Inc., EPA–HQ–OAR–2006–0173–1447, 1447.1–.5.

[78] California Air Resources Board, EPA–HQ–OAR–2006–0173–3601.

[79] NERA Economic Consulting, Inc. and Sierra Research, EPA–HQ–OAR–2006–0173–3651.

[80] NERA Economic Consulting and Sierra Research, EPA–HQ–OAR–2006–0173–9053.

[81] Thomas L. Darlington and Dennis F. Kahlbaum, Evaluation of California Greenhouse Gas Standards and Federal Independence and Security Act—Part 2: CO_2 and GHG Impacts, SAE Paper No. 2008–01–1853 (2008), Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994 at 20, note 44.

[82] Air Improvement Resources, Inc., EPA–HQ–OAR–2006–0173–13662.

standards.[83] In that reconsideration, the Alliance referred to the same June 2007 AIR/NERA/Sierra Study, saying that the California program, as a whole, was not at least as protective of public health and welfare as comparable federal standards. EPA denied the Alliance's request, in particular because the June 2007 AIR/NERA/Sierra Study was produced under the assumption that California's ZEV standards would be in effect until at least 2020 and that California's greenhouse gas standards would also be in effect. As EPA had only granted the ZEV waiver through the 2011 model year and had not granted the greenhouse gas waiver, EPA found that the study was not based upon the proper assumptions for comparing California's standards to federal standards. EPA stated at that time: ''[T]o the extent that the real-world emission effects of CARB's ZEV program (aggregated with its LEV II standards) are relevant, if at all, the Alliance fails to submit sufficiently focused information regarding these programs and their associated effect on emissions. Thus, no basis exists to reconsider EPA's December 2006 waiver decision based on the NERA/Sierra/Air report.'' [84]

In evaluating its greenhouse gas standards, California's protectiveness determination went beyond a simple numerical comparison of its greenhouse gas standards to non-existent federal greenhouse gas standards. Its protectiveness determination was also based upon its own analysis of the impact of its greenhouse gas standards on its larger program. California found that its new greenhouse gas standards would yield not only reductions in greenhouse gas emissions but also a net reduction in criteria pollutant emissions.[85] Therefore, to the extent this analysis is even relevant for an EPA waiver review opponents must present ''clear and compelling'' evidence challenging the reasonableness of this determination and California's analysis.

The June 2007 AIR/NERA/Sierra Study prepared for the Alliance presents a finding that its results ''indicate that the California Program, in the aggregate, is less protective of public health than the Federal Program with respect to emissions of ozone precursors and several other criteria pollutants.'' The study undertook consumer choice modeling to evaluate the effect of the California greenhouse gas emission standards on the new motor vehicle fleet and vehicle miles travelled (VMT) and compare those effects with fleet and VMT conditions were the Federal Program in effect in California. Its results showed that compliance with the California greenhouse gas standards would raise the cost of new motor vehicles in California, which would then lead to higher new vehicle prices, decreased new vehicle sales, increased retention of used vehicles (''scrappage effect''), increased fuel economy which would lead to increased VMT (''rebound effect''), and, finally, increased emissions of ozone precursors and several other criteria air pollutants.

On July 24, 2007, CARB submitted a response to comments received by EPA which specifically addressed the June 2007 AIR/NERA/Sierra Study.[86] First, CARB insisted that such a study should have been presented for consideration during California's rulemaking process and not later during EPA's consideration of California's waiver request. Second, CARB substantively responded to the June 2007 AIR/NERA/Sierra Study and claimed that its protectiveness determination was proper. In sum, CARB objected that the June 2007 AIR/NERA/Sierra Study is inappropriate because it is not focused on the relative stringency of emission standards, but instead presents ''a series of speculative events driven by disputed and unsupported compliance costs that would supposedly result—contrary to experience with previous reduction and automotive regulatory measures—in a substantial reduction in new motor vehicle sales (fleet turnover); and * * * Californians' theoretical desire to drive even more miles than already projected to reach increasingly distant destinations in the face of increasing traffic congestion (rebound effect).'' [87] CARB further critiqued several points of AIR/NERA/Sierra's analysis, including what it viewed as ''grossly overstated * * * highly speculative cost estimates,'' modeling errors, lack of methodological detail, and faulty assumptions. CARB asserted that its staff reviewed similar analyses and had provided its own analyses that are ''more reasonable and historically reliable'' and ''lead to dramatically different outputs.''

NERA/Sierra responded to that critique on October 29, 2007.[88] That document includes specific responses to criticisms raised by CARB and generally defends the integrity of its analyses. NERA/Sierra affirmed its conclusions that CARB's protectiveness determination is not fully supported because it understates or ignores costs, does not consider the combined effects of the ZEV mandate and GHG requirements, and does not assure compliance through technological implementation. As to the specific modeling issues raised by CARB, NERA/Sierra maintained the correctness of its modeling assumptions and estimations with regard to technology cost, fleet turnover, rebound effect, and pollutant emission effect.

NERA/Sierra also submitted an additional study on April 6, 2009, presenting many of the same methodological assertions noted above. Notably, though, this study is less methodologically clear: It does not quantify scrappage or its effects on emissions, assumes technology is applied only to meet federal CAFE

[83] Decision Document for Waiver of Federal Preemption for California Zero Emission Vehicle (ZEV) Standards (December 21, 2006) and EPA's August 13, 2008 Response to Petition for Administrative Reconsideration of EPA's ZEV Waiver Decision (through the 2011 Model Year) published on December 28, 2006.

[84] EPA's August 13, 2008 Response to Petition for Administrative Reconsideration of EPA's ZEV Waiver Decision (through the 2011 Model Year) published on December 28, 2006, at 17–18. That denial further opined: ''In light of the language of section 209(b)(1)(A) and associated legislative history, it may only be necessary to examine the applicable emission limits in determining California's ability to set more stringent standards and pursue pioneering efforts (which may or may not lead to higher costs and associated fleet turnover concerns) under section 209(b)(1)(A). Given the legislative history * * *. EPA would need a concrete basis to examine the ''real world'' or in-use effect of California's standards in comparison to applicable federal standards (in this case, a comparison of LEV II + ZEV versus Tier 2). To require CARB to justify its standards and policy goals within the context of the protectiveness criteria based on waiver opponents' complicated and controversial models that apply assumptions that are themselves controversial, and where there are no corresponding federal standards, raises questions about whether demanding this type of review conflicts with Congress' intent to allow California 'the broadest possible discretion' in fashioning its own motor vehicle program without EPA second-guessing California's policy choices.'' Id. at 12.

[85] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.107 at 15 (''Taking into account the penetration of 2009 and later vehicles meeting the new standard, the proposed regulation will reduce greenhouse gas emission by an estimated 87,700 CO_2-equivelent tons per day statewide in 2020 and by 155,200 CO_2-equivelent tons per day in 2030. This translates into an 18 percent overall reduction in greenhouse gas emissions from the light duty fleet in 2020 and a 27 percent overall reduction in 2030; Taking into account the penetration of 2009 and later vehicles meeting the new standard, the proposed regulation will reduce upstream emissions of non-methane organic gases (NMOG) by 4.6 tons per day statewide in 2020 and 7.9 tons per day statewide in 2030, and will reduce upstream emissions of NO_X by 1.4 tons per day statewide in 2020 and 2.3 tons per day statewide in 2030. The regulation will provide a criteria pollutant benefit even taking into account possible pollutant increases due to consumer response.'').

[86] California Air Resources Board, EPA–HQ–OAR–2006–0173–3601.

[87] California Air Resources Board, EPA–HQ–OAR–2006–0173–3601 at 8.

[88] NERA Economic Consulting, Inc. and Sierra Research, EPA–HQ–OAR–2006–0173–3651.

standards (and not beyond that level of stringency), and assumes that further compliance is achieved through fleet mix changes combined with restrictions on vehicle availability. It is not clear whether and how ZEV program requirements are included in this study. Most importantly, though, the April 2009 NERA/Sierra Study is outside the scope of this proceeding; it presents ''the effects on motor vehicle sales of the California Standards, assuming that they are implemented in the 13 states that have adopted California's standards.'' [89] That is, the April 2009 NERA/Sierra Study seeks to present the effect of California's greenhouse gas standards on new motor vehicle sales in those 13 states. This is inappropriate because the waiver inquiry is limited to the State of California (as noted above) and, even if this study had been limited to California, it would still be inadequate because it does not connect its findings with regard to depressed vehicle sales to increased criteria pollutant emissions.

Air Improvement Resources, Inc. (''AIR''), who had originally participated in the June 2007 AIR/NERA/Sierra Study but submitted comment independently on April 6, 2009, evaluated California's greenhouse gas standards as compared to EISA ''standards.'' As noted above, this evaluation is not relevant to EPA's section 209(b)(1)(A) inquiry because EISA ''standards'' are not ''applicable Federal standards'' for the purpose of our waiver inquiry. Nor have any fuel economy standards been promulgated beyond the 2011 model year. Those underlying inadequacies render this study unpersuasive, if not entirely irrelevant. However, it is interesting to note that the primary finding of this study is that ''the California program has lower GHG emissions until about 2016–2018.'' [90] AIR also included as an attachment an SAE Paper evaluating impacts on new vehicle fuel economy from California's greenhouse gas standards and EISA ''standards.'' The finding of this paper is that California's greenhouse gas standards will lead to higher fuel economy than EISA ''standards'' until the 2017 model year.[91] The findings of both reports are based on inconsistent assumptions that California's greenhouse gas standards will not become more stringent after the 2016 model year, (because this waiver request ends with the 2016 model year standards) but the federal fuel economy standards will become more stringent even though there are not yet any federal fuel economy standards past the 2011 model year. As stated above, EPA is not including fuel economy standards in its consideration of ''applicable Federal standards.'' But, even if EPA were to engage in that analysis, it can only consider standards in existence at the time of a waiver decision, as stated above. Since no federal fuel economy standards exist yet beyond the 2011 model year, EPA will not make predictions about later year fuel economy standards in order to take them into account here.

As discussed below, EPA has evaluated both sets of analyses (from CARB and NERA/Sierra) and makes note of the following with regard to (1) fleet turnover/delayed scrappage, (2) the rebound effect, and (3) upstream emissions impacts.[92]

a. Fleet Turnover/Delayed Scrappage

The Alliance argues that California's greenhouse gas standards will cause delayed fleet turnover and, thus, increase criteria air pollutant emissions. Delayed fleet turnover results when the prices of new vehicles increase, causing prices of existing vehicles to increase as well. A consumer's decision to scrap an existing vehicle depends upon the trade-off between the value of existing vehicle in its working condition and its scrappage value. Rising prices of existing vehicles lead some consumers to decide to delay scrapping their vehicles. An older vehicle stock on the road results in an increase in criteria air pollution.

In conducting its analysis on consumer behavior impacts in its June 2007 study, NERA/Sierra/AIR evaluated the combined impacts of the California greenhouse gas emission standards and the Zero Emission Vehicle (''ZEV'') rules. It is difficult to discern the total cost per vehicle over various model years of the greenhouse gas versus the ZEV portion of the rules and, therefore, determine how much of the consumer behavior impacts are appropriately attributable to the greenhouse gas standards. Thus, it is difficult to undertake a direct comparison of the NERA/Sierra/Air and CARB studies. According to NERA/Sierra/AIR, as a result of price increases associated with the greenhouse gas and ZEV rules in 2020, they project that new vehicle sales in California will fall by approximately 130,000 vehicles. In addition, the number of vehicles in the fleet prior to the effective date of the ZEV and GHG regulations (*i.e.,* pre-2009 model year vehicles) is more than 250,000 greater in 2020 than would otherwise be the case under a federal program.

CARB, on the other hand, only looks at the economic impacts of the California greenhouse gas standards, independent of the ZEV requirements. Without the ZEV requirements, CARB estimates that California's greenhouse gas standards will result in an increase in new vehicle prices of approximately $1,000 per vehicle (*i.e.,* $1,064 for passenger vehicles, small trucks and sport utility vehicles (SUVs) and $1,029 for certain medium-duty trucks/SUVs).[93] Using a consumer choice model, CARBITS, CARB estimated new vehicle sales from California standards would increase in the near-term, resulting in accelerated fleet turnover, but see declines in fleet turnover in the longer-term, with a loss of vehicle sales of roughly 97,000 in 2020. By 2020, CARB estimates that lost vehicle sales would lead to delayed fleet turnover. The potential increase in ozone precursor emission in California in out years (*i.e.,* 2020) from delayed fleet turnover is about 2.5 tons/day. CARB estimates that those ''disbenefits'' of fleet turnover delay are more than offset by faster turnover in the early years of the California standard and reductions in emissions associated with fuel production. The more recent April 2009 NERA/Sierra study projects the impacts of the California GHG standards on new motor vehicle sales in the thirteen states that have adopted the California standards. Since the study only examines the impacts on new vehicle sales, it does not provide estimates of ozone precursor impacts of California standards.

b. The ''Rebound Effect''

The Alliance contends that criteria air pollutant emissions will increase due to

[89] NERA Economic Consulting and Sierra Research, EPA–HQ–OAR–2006–0173–9053 at E–1.

[90] Air Improvement Resources, Inc., EPA–HQ–OAR–2006–0173–13662 at 2. Yet this analysis presumes the promulgation of fuel economy standards that have not yet been promulgated and does not accordingly presume the promulgation of further greenhouse gas standards by California, despite the fact that the Pavley law in California makes such further standards a significant possibility.

[91] Air Improvement Resources, Inc., EPA–HQ–OAR–2006–0173–13662.

[92] EPA's role in reviewing California's waiver request is limited to finding whether opponents have shown that California's protectiveness determination is arbitrary and capricious. In making its protectiveness determination, CARB included these analyses and the studies noted above have included similar analyses based on diverging assumptions. EPA has evaluated these analyses to demonstrate that CARB's protectiveness determination was not arbitrary and capricious. This evaluation is separate and distinct from any analysis that EPA would conduct in promulgating its own regulation. Nothing in this evaluation should be construed as an endorsement of CARB's or any other analysis or any particular assumption they rely upon.

[93] California Air Resources Board, EPA–HQ–OAR–2006–0173.0010.116.

the so-called vehicle ''rebound effect.'' The rebound effect for vehicle fuel economy is defined as the increase in vehicle travel resulting from a decrease in the fuel cost per vehicle miles as a consequence of an increase in fuel economy. It is projected that increasing fuel efficiency lowers the effective cost of driving to the consumer, which results in an increase in vehicle usage (holding all other factors constant). NERA developed their own econometric estimate of the California rebound effect—17%—based on California vehicle inspection data from 1983–2003. In addition, NERA re-estimated a CARB-sponsored study on the rebound effect by Small & Van Dender and NERA found the long-run rebound effect in California to be roughly 13%.

In contrast, CARB used two types of analysis to evaluate the impact of the proposed regulations on changes in vehicle miles traveled: Econometric work by Small and Van Dender and travel demand modeling (Southern California Association of Governor's (SCAG)). The study by Small & Van Dender allowed the rebound effect to vary based on changes in income and congestion. In addition, the Small & Van Dender study also analyzed the impact of higher vehicle costs on VMT. Based on the econometric modeling, projected California incomes and transportation conditions, Small and Van Dender estimated a dynamic rebound effect of approximately 3% for the State of California in 2020. A major difference between the NERA and Small and Van Dender study was the way nominal income was converted to real income. NERA tried to approximate state cost of living adjustments, but had to modify metropolitan cost of living adjustments; Small and Van Dender used the national consumer price index. Based on the difference in income calculation, NERA found that income was no longer statistically significant in explaining changes in the rebound effect. Therefore, they removed this term from their model. California also used the Southern California Association of Governor's (SCAG) travel demand model to project changes in demand travel based on declining vehicle operating costs in the context of the transportation system in the L.A. South Coast Air Basin. In contrast to the econometric study, the travel demand modeling takes into account the available transportation infrastructure. CARB examined the emission impacts of changes in both the amount and the speed of motor vehicle travel, relative to the cost of gasoline per mile traveled. Based on the vehicle classes affected by the proposed GHG regulation, the results from SCAG indicate an elasticity of VMT to fuel cost (*i.e.,* a rebound effect) of roughly 4 percent in 2020.

c. Upstream Emissions Impacts

California's greenhouse gas standards also will influence the amount of fuel going through the petroleum marketing and distribution infrastructure in California. This, in turn, will reduce the ''upstream'' criteria air pollutants from transportation, spills, and other events associated with the infrastructure. There were large differences between the CARB and NERA/Sierra estimates of upstream emissions. NERA, focusing on fuel delivery trucks and transit distances, characterized CARB's estimates as significantly flawed. However, both estimated upstream emission reductions of ROG and NO_X, with CARB estimating a 6 ton per day reduction and NERA estimating a 1.1–1.5 ton per day reduction. The table below presents the rivaling estimates presented by the CARB and NERA/Sierra analyses.

	CARB	NERA
Fleet Turnover/Scrappage Effect.	Accelerated fleet turnover in near-term; smaller delayed fleet turnover in out years (*e.g.,* 2020).	Delayed fleet turnover in near term; larger delayed fleet turnover in out years (*e.g.,* 2020).
Rebound Effect	3% in 2020	17% in 2003, 13% in 2007.
Upstream Emissions	6 tons/day reduction in ROG+NOx	1.1–1.5 tons/day reduction in ROG+NOx.

Additionally, as with our analysis of the AIR/NERA/Sierra analysis in the context of the ZEV waiver reconsideration, we note that the study included a presumption that the ZEV standards would be in effect until at least 2020, and that this assumption appears to have a significant effect on other assumptions in the analysis. However, EPA explicitly declined to approve its waiver for California's ZEV standards beyond the 2011 model year, based in part on concerns that echoed comments from the Alliance. This makes the AIR/NERA/Sierra analysis an insufficient analysis to base a denial of California's waiver request.

In evaluating the studies prepared by AIR/NERA/Sierra in light of California's protectiveness determination, EPA takes important note of CARB's response. As stated above, while CARB disagrees that these studies are properly before EPA in the waiver proceeding, it points out that even if it is proper for EPA to consider the AIR/NERA/Sierra studies, they do not provide a basis for finding that California's protectiveness determination was arbitrary and capricious. CARB maintains that the Alliance has made no attempt to show that CARB's analyses are irrational, which CARB states waiver opponents must make given the ''arbitrary and capricious'' standard.

EPA agrees that to make a section 209(b)(1)(A) finding, it is not enough for waiver opponents to provide competing analyses that they claim are based on a rational set of assumptions. Rather, they must show that California's analysis, or the assumptions California relied on to support its protectiveness determination were arbitrary and capricious. Competing analyses, each based on rational assumptions, are not sufficient to deny a waiver.[94]

As previously stated, EPA does not need to decide the validity of the suggestion that the traditional numerical analysis is insufficient and that EPA must also consider the in-use effects of the standards. Given the legislative history and text of section 209(b)(2), EPA would need a concrete factual basis to examine the in-use effect of California's greenhouse gas standards on its broader LEV II program as compared to the Federal Tier II program. We need not take a position on that matter because the waiver opponents do not meet their burden to show that CARB's analysis of the in-use effects is arbitrary and capricious.[95] Rather, they present

[94] EPA's August 13, 2008 Response to Petition for Administrative Reconsideration of EPA's ZEV Waiver Decision (through the 2011 Model Year) published on December 28, 2006, at 17, note 25.

[95] To the extent that an analysis of the in-use effects of California's greenhouse gas standards may be appropriate, then such analysis properly includes consideration of the upstream emission reduction impacts identified and linked to the standards. A holistic examination of the in-use effects of a regulation should naturally include those effects that have a plausible connection to the standards, including such consequences as indirect upstream emission reductions. The March 6, 2008 Denial stated that California may otherwise have independent authority to regulate stationary sources and therefore there was no basis to include emission reductions from such sources as part of a mobile source rulemaking. However, EPA believes that the issue under section 209(b)(1)(A) is whether

rivaling analyses—each making different assumptions so that the differences in findings can be reduced to differences in assumptions. EPA finds that the Alliance has not met its burden of proof that the greenhouse gas regulations undermine California's previous LEV II and ZEV protectiveness determinations or that California was arbitrary and capricious in its greenhouse gas protectiveness determination.

EPA, therefore, finds that opponents of the waiver have not presented clear and compelling evidence that CARB was arbitrary and capricious in finding that the real-world effect of its standards ''in the aggregate'' would not lead to greater emissions of pollutants than the federal program.

D. Section 209(b)(1)(A) Conclusion

Based on the record before me, I cannot find that CARB was arbitrary and capricious in its finding that the California motor vehicle emission standards including the greenhouse gas standards are, in the aggregate, at least as protective of public health and welfare as applicable Federal standards.

V. Does California Need Its Standards To Meet Compelling and Extraordinary Conditions?

Under section 209(b)(1)(B) of the Act, I cannot grant a waiver if I find that California ''does not need such State standards to meet compelling and extraordinary conditions.'' EPA has traditionally interpreted this provision as considering whether California needs a separate motor vehicle program to meet compelling and extraordinary conditions. However in the March 6, 2008 Denial, EPA limited this interpretation to California's motor vehicle standards that are designed to address local or regional air pollution problems. EPA determined that the traditional interpretation was not appropriate for standards designed to address a global air pollution problem and its effects and that it was appropriate to address such standards separately from the remainder of the program. EPA then proceeded to find that California did not need such standards to meet compelling and extraordinary conditions. The interpretation adopted in the March 6, 2008 Denial is now before me for reconsideration.

A. Basis of March 6, 2008 Denial

In the March 6, 2008 Denial, EPA provided its reasoning for changing its long-standing interpretation of this provision, as it pertains to California standards designed to address global air pollution. EPA described its long-standing interpretation in some detail, stating that:

> Under this approach EPA does not look at whether the specific standards at issue are needed to meet compelling and extraordinary conditions related to that air pollutant. For example, EPA reviewed this issue in detail with regard to particulate matter in a 1984 waiver decision.[96] In that waiver proceeding, California argued that EPA is restricted to considering whether California needs its own motor vehicle program to meet compelling and extraordinary conditions, and not whether any given standard is necessary to meet such conditions. Opponents of the waiver in that proceeding argued that EPA was to consider whether California needed these PM standards to meet compelling and extraordinary conditions related to PM air pollution.
>
> The Administrator agreed with California that it was appropriate to look at the program as a whole in determining compliance with section 209(b)(1)(B). One justification of the Administrator was that many of the concerns with regard to having separate state standards were based on the manufacturers' worries about having to meet more than one motor vehicle program in the country, but that once a separate California program was permitted, it should not be a greater administrative hindrance to have to meet further standards in California. The Administrator also justified this decision by noting that the language of the statute referred to ''such state standards,'' which referred back to the use of the same phrase in the criterion looking at the protectiveness of the standards in the aggregate. He also noted that the phrase referred to standards in the plural, not individual standards. He considered this interpretation to be consistent with the ability of California to have some standards that are less stringent than the federal standards, as long as, per section 209(b)(1)(A), in the aggregate its standards were at least as protective as the federal standards.
>
> The Administrator further stated that in the legislative history of section 209, the phrase ''compelling and extraordinary circumstances'' refers to ''certain general circumstances, unique to California, primarily responsible for causing its air pollution problem,'' like the numerous thermal inversions caused by its local geography and wind patterns. The Administrator also noted that Congress recognized ''the presence and growth of California's vehicle population, whose emissions were thought to be responsible for ninety percent of the air pollution in certain parts of California.''[97] EPA reasoned that the term compelling and extraordinary conditions ''do not refer to the levels of pollution directly.'' Instead, the term refers primarily to the factors that tend to produce higher levels of pollution—''geographical and climatic conditions (like thermal inversions) that, when combined with large numbers and high concentrations of automobiles, create serious air pollution problems.''[98]

The Administrator summarized that under this interpretation the question to be addressed in the second criterion is whether these ''fundamental conditions'' (*i.e.* the geographical and climate conditions and large motor vehicle population) that cause air pollution continued to exist, not whether the air pollution levels for PM were compelling and extraordinary, or the extent to which these specific PM standards will address the PM air pollution problem.[99]

However in the March 6, 2008 Denial, EPA limited this interpretation to California's motor vehicle standards that are designed to address local or regional air pollution problems. EPA determined that the traditional interpretation was not appropriate for standards designed to address a global air pollution problem and its effects.[100]

With respect to a global air pollution problem like elevated concentrations of greenhouse gases, EPA's March 6, 2008 Denial found that the text of section 209(b)(1)(B) was ambiguous and does not limit EPA to this prior interpretation. In addition, EPA noted that the legislative history supported a decision to ''examine the second criterion specifically in the context of global climate change.'' The legislative history:

> [I]ndicates that Congress was moved to allow waivers of preemption for California motor vehicle standards based on the particular effects of local conditions in California on the air pollution problems in California. Congress discussed ''the unique problems faced in California as a result of its climate and topography.'' H.R. Rep. No. 728, 90th Cong. 1st Sess., at 21 (1967). See also Statement of Cong. Holifield (CA), 113 Cong. Rec. 30942–43 (1967). Congress also noted the large effect of local vehicle pollution on such local problems. See, *e.g.,* Statement of Cong. Bell (CA) 113 Cong. Rec. 30946. In particular, Congress focused on California's

the indirect reductions of ozone pollutants from stationary sources created by the greenhouse gas emission standards for motor vehicles, can reasonably be considered by California in its determination that its standards are as protective of public health and welfare as applicable federal standards. Given that the effects are reasonably related to the regulations, if it is appropriate to consider in-use effects then it was not arbitrary and capricious for California to include such effects in this analysis.

[96] 49 FR 18887 (May 3, 1984).

[97] *Id.* at 18890.

[98] 73 FR 12156, 12159–60 (March 6, 2008).

[99] 73 FR at 12159–60.

[100] EPA recently reaffirmed that the traditional interpretation still applied for motor vehicle standards designed to address air pollution problems that are local or regional in nature. 71 FR 78190, 78192 (December 28, 2008); *see also* 71 FR 78190 and Decision Document for Waiver of Federal Preemption for California Zero Emission Vehicle Standards, at 34.

smog problem, which is especially affected by local conditions and local pollution. See Statement of Cong. Smith (CA) 113 Cong. Rec. 30940–41 (1967); Statement of Cong. Holifield (CA), id. at 30942. See also, *MEMA I,* 627 F. 2d 1095, 1109 (DC Cir., 1979) (noting the discussion of California's ''peculiar local conditions'' in the legislative history). Congress did not justify this provision based on pollution problems of a more national or global nature in justifying this provision.[101]

Relying on this, and without any further significant discussion of either congressional intent or how this new approach properly furthered the goals of section 209(b), EPA determined that it was appropriate to:

[R]eview California's GHG standards separately from the remainder of its motor vehicle emission control program for purposes of section 209(b)(1)(B). In this context it is appropriate to give meaning to this criterion by looking at whether the emissions from California motor vehicles, as well as the local climate and topography in California, are the fundamental causal factors for the air pollution problem—elevated concentrations of greenhouse gases—apart from the other parts of California's motor vehicle program, which are intended to remediate different air pollution concerns.

EPA then proceeded to apply this interpretation to the GHG standards at issue in this waiver proceeding, and found that California did not need the GHG standards under this interpretation. Having limited the meaning of this provision to situations where the air pollution problem was local or regional in nature, EPA found that California's greenhouse gas standards do not meet this criterion. EPA found that the elevated concentrations of greenhouse gases in California are similar to concentrations elsewhere in the world, and that local conditions in California such as the local topography and climate and the number of motor vehicles in California are not the determinant factors causing the elevated GHG concentrations found in California and elsewhere. Thus, the March 6, 2008 Denial found that California did not need its GHG standards to meet compelling and extraordinary conditions, and the waiver was denied.

EPA also considered an alternative interpretation, where EPA would consider ''the effects in California of this global air pollution problem in California in comparison to the rest of the country, again addressing the GHG standards separately from the rest of California's motor vehicle program.'' Under this alternative interpretation, EPA considered whether the impacts of global climate change in California were significant enough and different enough from the rest of the country such that California could be considered to need its greenhouse gas standards to meet compelling and extraordinary conditions. EPA determined that the waiver should be denied under this alternative interpretation as well.

B. Should EPA Review This Criterion Based on the Need for California's Motor Vehicle Program or the Need for the GHG Standards?

The essential first question to resolve in addressing whether California needs ''such State standards to meet compelling and extraordinary conditions'' is whether it is appropriate for EPA to evaluate this criterion based on California's need for its motor vehicle program as a whole, or to evaluate only the particular standards being addressed in this waiver proceeding.

1. Comments Supporting a Review of the Entire Program

In its initial waiver request, CARB restates its need for its own engine and vehicle programs to meet serious air pollution problems. It notes that the relevant inquiry is whether California needs its own emission control program as opposed to the need for any given standard as necessary to meet compelling and extraordinary conditions. CARB notes that in prior waivers the Administrator has determined that:

''[C]ompelling and extraordinary conditions'' does not refer to levels of pollution directly, but primarily to the factors that tend to produce them: geographical and climatic conditions that, when combined with large numbers and high concentrations of automobiles create serious air pollution problems.''

In its initial waiver request letter, CARB stated:

California, the South Coast and San Joaquin Air basins in particular, continues to experience some of the worst air quality in the nation. California's ongoing need for dramatic emission reductions generally and from passenger vehicles specifically is abundantly clear from its recent adoption of state implementation plans for the South Coast and other California air basins. The unique geographical and climatic conditions, and the tremendous growth in the vehicle population and use which moved Congress to authorize California to establish separate vehicle standards in 1967, still exist today.[102]

CARB notes that these conditions have not changed to warrant a change in confirmation by EPA and that the opponents of the waiver bear the burden on showing why California no longer has a compelling need, informed by its own circumstances and benefits that would accrue to it and other states.

EPA also received comment that the *Massachusetts* v. *EPA* holding suggests that EPA should treat greenhouse gases just like all other air pollutants when evaluating a section 209(b) waiver request for greenhouse gases. These comments suggest that once the Supreme Court clarified that greenhouse gases are Clean Air Act air pollutants, there was no room left to distinguish greenhouse gases from other air pollutants when evaluating waiver requests under section 209(b). These comments suggest that EPA ought not to treat elevated concentrations of greenhouse gases as an air pollution problem different from California's traditional air pollution problems. Likewise, the comments suggest, greenhouse gas pollutants should be treated just like other air pollutants which give rise to the need for California's motor vehicle emission program, and, therefore, be subject to EPA's traditional section 209(b)(1)(B) analysis.

Several commenters suggest that review of California's need for its motor vehicle emissions program as a whole is not only appropriate but is mandated by the statute.

2. Comments Supporting a Review of the GHG Standards Separately

Several commenters opposing the GHG waiver request have advocated that EPA should review California's GHG standards separately under the ''compelling and extraordinary conditions'' criterion. Essentially, this would require that EPA's determination be based on California's need for GHG standards in isolation of its need for its own motor vehicle emissions program.

These commenters state that the statute requires a linkage between the compelling and extraordinary conditions and the particular standards that California wishes to enforce, and that a set of standards that cannot be linked to the compelling and extraordinary conditions cannot be said to be needed to meet such conditions. The commenters note that the statute refers to ''standards''—not to a ''program''—and that such an approach would shield regulations that would not meet the criterion from any review simply by referring to other regulations that do meet the criterion. Moreover, they state that the need for such standards must be based on the particular characteristics (topography, photochemistry) that make California's conditions compelling and

[101] 73 FR at 12161.

[102] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 27.

extraordinary, whereas global climate change (and, thus, control of GHGs) is not related to such conditions.

Included among the comments suggesting that section 209(b) was intended to allow California to address local air pollution problems and not global environmental issues like climate change was an argument that the phrase ''need for such State standards to meet compelling and extraordinary conditions'' is unambiguous.[103] That lack of ambiguity, according to these comments, compels the conclusion that global warming is not the type of condition California was meant to address with its motor vehicle emissions program. These commenters further suggest that the intent of Congress was to allow California the ability to set its own standards to address the state's unique local air pollution problems and ''scientific evidence confirms that California's temperature trends are neither unique nor particularly distinct from those of at least a dozen other States.''

3. Decision

After reviewing the comments and the March 6, 2008 Denial, I believe the better approach is to review California's need for its new motor vehicle emissions program as a whole to meet compelling and extraordinary conditions, and not to apply this criterion to specific standards, or to limit it to standards designed to address only local or regional air pollution problems. The traditional approach to interpreting this provision is the best approach for considering a waiver for greenhouse standards, as well as a waiver for standards designed to address local or regional air pollution problems.[104] Therefore, I believe the interpretation that was applied in the March 6, 2008 Denial should be rejected and no longer be followed.

This traditional interpretation is the most straightforward reading of the text and legislative history of section 209(b). Congress decided in 1977 to allow California to promulgate individual standards that are not as stringent as comparable federal standards, as long as the standards are ''in the aggregate, at least as protective of public health and welfare as applicable federal standards.'' This decision by Congress requires EPA to allow California to promulgate individual standards that, in and of themselves, might not be considered needed to meet compelling and extraordinary circumstances, but are part of California's overall approach to reducing vehicle emissions to address air pollution problems.

EPA is to determine whether California's determination is arbitrary and capricious under section 209(b)(1)(A), and is to determine whether California does not need ''such State standards'' to meet compelling and extraordinary conditions. The natural reading of these provisions leads EPA to consider the same group of standards that California considered in making its protectiveness determination. While the words ''in the aggregate'' are not specifically applicable to section 209(b)(1)(B), it does refer to the need for ''such State standards,'' rather than ''each State standard'' or otherwise indicate a standard-by-standard analysis.

In addition, EPA's March 6, 2008 Denial determined that this provision was appropriately interpreted to consider California's standards as a group for standards designed to address local or regional air pollution problems, but should be interpreted in the opposite fashion for standards designed to address global air pollution problems. The text of the provision, however, draws no such distinction, and provides no indication other than Congress intended a single interpretation for this provision, not one that varied based on the kind of air pollution problem at issue.

The March 6, 2008 Denial considered the legislative history, and determined that Congress was motivated by concern over local conditions in California that lead to local or regional air pollution problems. From this, EPA determined that Congress intended to allow California to address these kinds of local or regional air pollution problems, but no others. In effect, EPA inferred from the discussion in the legislative history that Congress intended to limit California's authority in this way, and to prohibit a waiver for California standards aimed at global air pollution problems.

This ignores the main thrust of the text and legislative history of section 209(b), and improperly reads too much into an absence of discussion of global air pollution problems in the legislative history. The structure of section 209, both as adopted in 1967 and as amended in 1977, is notable in its focus on limiting the ability of EPA to deny a waiver, and thereby preserves discretion for California to construct its motor vehicle program as it deems appropriate to protect the health and welfare of its citizens. The legislative history indicates Congress quite intentionally restricted and limited EPA's review of California's standards, and its express legislative intent was to ''provide the broadest possible discretion [to California] in selecting the best means to protect the health of its citizens and the public welfare.''[105] The DC Circuit recognized that ''[t]he history of the congressional consideration of the California waiver provision, from its original enactment up through 1977, indicates that Congress intended the State to continue and expand its pioneering efforts at adopting and enforcing motor vehicle emission standards different from and in large measure more advanced than the corresponding federal program. In short, to act as a kind of laboratory for innovation. * * * For a court [to limit California's authority] despite the absence of such an indication would only frustrate the congressional intent.''[106]

In this context, it is fully consistent with the expressed intention of Congress to interpret section 209(b)(1)(B) the same way both for standards designed to address local and regional air pollution problems, and standards designed to address global air pollution problems. Congress intended to provide California the broadest possible discretion to develop its motor vehicle emissions program. Neither the text nor the legislative history of section 209(b) indicates that Congress intended to limit this broad discretion to a certain kind of air pollution problem, or to take away all discretion with respect to global air pollution problems.[107] In

[103] This comment, suggesting that the ''need for such State standards to meet compelling and extraordinary conditions,'' is made under Step 1 of the test established under *Chevron, USA., Inc.* v. *NRDC.*

[104] The traditional interpretation of section 209(b)(1)(B) is certainly not ''unambiguous precluded'' by the language of the statute. See *Entergy Corp.* v. *Riverkeeper, Inc.,* 129 S.Ct. 1498 (2009)(''That view governs if it is a reasonable interpretation of the statute—not necessarily the only possible interpretation, nor even the interpretation deemed most reasonable by the courts. *Chevron U.S.A. Inc.* v. *Natural Resources Defense Council, Inc.,* 467 U.S. 837, 843–844 (1984).'') (''It seems to us, therefore, that the phrase ''best available,'' even with the added specification ''for minimizing adverse environmental impact,'' does not unambiguously preclude cost-benefit analysis.''). *Carrow* v. *Merit Systems Protection Board,* 564 F.3d 1359 (Fed. Cir. 2009) (''[W]e are obligated to give controlling effect to [agency's] interpretation if it is reasonable and is not contrary to the unambiguously expressed intent of Congress'', citing *Entergy Corp.*).

[105] H.R. Rep. No. 294, 95th Cong., 1st Sess. 301–302 (1977). *See MEMA,* 627 F. 2d at 1110–11.

[106] *MEMA,* 627 F. 2d at 1111.

[107] This broad interpretation of section 209(b) is similar to the broad reading the Court provided to section 302(g) of the Clean Air Act when it held that the term ''air pollutant'' included greenhouse gases, rejecting among other things the argument that Congress limited the term to apply only to certain kinds of air pollution. *Massachusetts* v. *EPA,* 549 U.S. 497, 532 footnote 26.

addition, applying the traditional interpretation to greenhouse gas standards does not change the basic nature of the compromise established by Congress—California could act as the laboratory for the nation with respect to motor vehicle emission control, and manufacturers would continue to face just two sets of emissions standards—California's and EPA's.

This interpretation is directly in line with the purpose of Congress, as compared to the interpretation adopted in the March 6, 2008 Denial. The 2008 interpretation relied on the discussion in the legislative history of local conditions in California leading to air pollution problems like ozone. While this was properly read to support the view that this provision should be interpreted to address California's need for a motor vehicle program as a whole, the March 6, 2008 Denial went further and inferred that by discussing such local conditions, Congress also intended to limit California's discretion to only these kinds of local or regional air pollution problems. The March 6, 2008 Denial pointed to no particular language in the legislative history or the text of section 209(b) indicating such, instead, congressional intent to limit California's discretion was inferred from the discussion of local conditions. However, basing a limitation on such an inference is not appropriate given the express indication that Congress intended to provide California the ''broadest possible discretion'' in selecting the best means to protect the health of its citizens and the public welfare.

The text of section 209(b) and the legislative history, when viewed as a whole, leads me to conclude that the interpretation adopted in the March 6, 2008 Denial should be rejected. The better way to interpret this provision is to apply the traditional interpretation to the evaluation of California's greenhouse gas standards for motor vehicles. If California needs a separate motor vehicle program to address the kinds of compelling and extraordinary conditions discussed in the traditional interpretation, then Congress intended that California could have such a program. Congress also intentionally provided California the broadest possible discretion in adopting the kind of standards in its motor vehicle program that California determines are appropriate to address air pollution problems that exist in California, whether or not those problems are local or regional in nature, and to protect the health and welfare of its citizens. The better interpretation of the text and legislative history of this provision is that Congress did not intend this criterion to limit California's discretion to a certain category of air pollution problems, to the exclusion of others. In this context it is important to note that air pollution problems, including local or regional air pollution problems, do not occur in isolation. Ozone and PM air pollution, traditionally seen as local or regional air pollution problems, occur in a context that to some extent can involve long range transport of this air pollution or its precursors. This long-range or global aspect of ozone and PM can have an impact on local or regional levels, as part of the background in which the local or regional air pollution problem occurs. As discussed later, the effects of global concentrations of greenhouse gases can have an impact on local ozone levels. This context for air pollution problems supports the view that Congress did not draw such a line between the types of air pollution problems under this criterion, and that EPA should not implement this criterion in a narrow way restricting how California determines it should develop its motor vehicle program to protect the health and welfare of its citizens.[108]

This approach does not make section 209(b)(1)(B) a nullity, as some have suggested. EPA must still determine whether California does not need its motor vehicle program to meet the compelling and extraordinary conditions discussed in the legislative history. If that is the case, then a waiver would be denied on those grounds. As discussed below, that is not the case at this point, even though conditions in California may one day improve such that it no longer has the need for a separate motor vehicle program. The statute contemplates that such improvement is possible. In addition, the opponents of a waiver always have the ability to raise their legal, policy, and other concerns in the State administrative process, or through judicial review in State courts. Congress, however, provided EPA a much more limited role under section 209(b) in considering objections raised by opponents of a waiver.

For these reasons, I believe that the better approach for analyzing the need for ''such State standards'' to meet ''compelling and extraordinary conditions'' is to review California's need for its program, as a whole, for the class or category of vehicles being regulated, as opposed to its need for individual standards.

Having adopted this interpretation of section 209(b)(1)(B), I apply it below to determine whether EPA can find that California does not need its motor vehicle program to meet compelling and extraordinary conditions. Given the basis for EPA's March 6, 2008 Denial and the considerable debate regarding the permissible interpretations of this provision, EPA has also evaluated this criterion reviewing the greenhouse gas standards separately—using the two interpretations discussed in the March 6, 2008 Denial. In either case, EPA also cannot deny California's request for a waiver based on a finding that California does not need such standards to meet compelling and extraordinary circumstances.

C. Does California Need Its Motor Vehicle Program To Meet Compelling and Extraordinary Conditions?

As discussed above, the better interpretation of this criterion, adopted herein, is the traditional approach of evaluating California's need for a separate program to meet compelling and extraordinary conditions. Applying this approach, with due deference to California, I cannot deny the waiver.

CARB has repeatedly demonstrated the need for its motor vehicle program to address compelling and extraordinary conditions in California. In its Waiver Request letter, CARB stated:

> California—the South Coast and San Joaquin Air basins in particular—continues to experience some of the worst air quality in the nation. California's ongoing need for dramatic emission reductions generally and from passenger vehicles specifically is abundantly clear from its recent adoption of state implementation plans for the South Coast and other California air basins.[109] The unique geographical and climatic conditions, and the tremendous growth in the vehicle population and use which moved Congress to

[108] *See Massachusetts* v. *EPA, ''*While the Congresses that drafted section 202(a)(1) might not have appreciated the possibility that burning fossil fuels could lead to global warming, they did understand that without regulatory flexibility, changing circumstances and scientific developments would soon render the Clean Air Act obsolete. The broad language of section 202(a)(1) reflects an intentional effort to confer the flexibility necessary to forestall such obsolescence. See *Pennsylvania Dept. of Corrections* v. *Yeskey,* 524 U.S. 206, 212 (1998) (''[T]he fact that a statute can be applied in situations not expressly anticipated by Congress does not demonstrate ambiguity. It demonstrates breadth'' (internal quotation marks omitted)). Because greenhouse gases fit well within the Clean Air Act's capacious definition of ''air pollutant,'' we hold that EPA has the statutory authority to regulate the emission of such gases from new motor vehicles.'' 549 U.S. 497 at 532.

[109] See *e.g.* Approval and Promulgation of State Implementation Plans; California—South Coast, 64 FR 1770, 1771 (January 12, 1999). See also 69 FR 23858, 23881–90 (April 30, 2004) (designating 15 areas in California as nonattainment for the federal 8-hour ozone national ambient air quality standard).

authorize California to establish separate vehicle standards in 1967, still exist today.[110]

CARB notes in its July 14, 2007 comments that it testified at EPA's earlier hearings on this waiver request that ''since nothing has changed in the few months since EPA last easily made this determination [regarding the need for the motor vehicle emission program] on December 28, 2006 (71 FR 78190), and since California still has the ''geographical and climatic conditions that, when combined with the large numbers and high concentrations of automobiles, create serious pollution problems,'' (49 FR at 18890 (citing legislative history)), this is the end of a proper and legal EPA analysis of the extraordinary and compelling conditions waiver prong.'' [111]

EPA has not received any adverse comments suggesting that California no longer needs a separate motor vehicle emissions program to address the various conditions that lead to serious and unique air pollution problems in California.

Based on the record, I am unable to identify any change in circumstances or any evidence to suggest that the conditions that Congress identified as giving rise to serious air quality problems in California no longer exist. Therefore, using the traditional approach of reviewing the need for a separate California program to meet compelling and extraordinary conditions, I cannot deny the waiver based on this criterion.

D. Does California Need Its Motor Vehicle GHG Standards To Meet Compelling and Extraordinary Conditions?

As discussed above, EPA has also evaluated this criterion under two alternative approaches, reviewing the greenhouse gas standards separately using the two interpretations discussed in the March 6, 2008 Denial. While recognizing that they are not the interpretations adopted here by EPA, this section discusses the Agency's consideration of these alternative interpretations.

1. Are California's GHG Standards Designed in Part To Address an Air Pollution Problem That Is Local or Regional in Nature?

In the March 6, 2008 Denial, EPA interpreted this criterion as calling for a review of California's GHG standards separately from the remainder of its motor vehicle emission control program. In that context, it was determined appropriate to look at whether the emissions from California motor vehicles, as well as the local climate and topography in California, are the fundamental causal factors for the air pollution problem of greenhouse gases. This interpretation limited the meaning of this provision to situations where the motor vehicle standards at issue were designed to address an air pollution problem that was local or regional in nature, such that the local conditions in California were the fundamental causes of the air pollution problem.

The March 6, 2008 Denial applied this interpretation by focusing on elevated concentrations of greenhouse gases as the air pollution—a global air pollution problem. The March 6, 2008 Denial rejected arguments that the GHG standards should also been seen as an ozone control strategy, on the grounds that even if elevated concentrations of greenhouse gases lead to climate changes that exacerbate ozone, the causes of elevated concentrations of greenhouse gases are not solely local to California but are global in nature.

This overly narrow view fails to consider that although the factors that cause ozone are primarily local in nature and that ozone is a local or regional air pollution problem, the impacts of global climate change can nevertheless exacerbate this local air pollution problem. Whether or not local conditions are the primary cause of elevated concentrations of greenhouse gases and climate change, California has made a case that its greenhouse gas standards are linked to amelioration of California's smog problems. Reducing ozone levels in California cities and agricultural areas is expected to become harder with advancing climate change. California and many other commenters note that ''California's high ozone levels—clearly a condition Congress considered—will be exacerbated by higher temperatures from global warming.'' [112] California also notes that there is general consensus that temperature increases from climate change will exacerbate the historic climate, topography, and population factors conducive to smog formation in California, which were the driving forces behind Congress' inclusion of the waiver provision in the Clean Air Act.[113] There is a logical link between the local air pollution problem of ozone and California's desire to reduce GHGs as one way to address the adverse impact that climate change may have on local ozone conditions.[114] Given the clear deference that Congress intended to provide California on the mechanisms it chooses to use to address its air pollution problems, it would be appropriate to consider its GHG standards as designed in part to help address a local air pollution problem, and, thus, a waiver should not be denied even under the narrow interpretation employed in the March 6, 2008 Denial.

2. Do the Impacts of Climate Change in California Support a Denial of the Waiver?

As part of EPA's March 6, 2008 Denial, EPA also considered an alternative interpretation for this criterion, where EPA would consider ''the effects in California of this global air pollution problem * * * in comparison to the rest of the country, again addressing the GHG standards separately from the rest of California's motor vehicle program.'' EPA considered evidence and arguments submitted by commenters concerning whether the impacts of global climate change in California were significant enough and different enough from the rest of the country such that California could be considered to need its greenhouse gas standards to meet compelling and extraordinary conditions.[115] EPA determined in the March 6, 2008 Denial that the waiver should be denied under this approach as well.

[110] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1, at 16.

[111] California Air Resources Board, EPA–HQ–OAR–2006–0173–1686 at 7.

[112] California submits evidence that at the national scale, using global to regional air quality models, various papers demonstrate that climate change alone can worsen summertime surface ozone pollution in polluted regions of the United States including one finding that ''climate change alone will increase summertime ozone in polluted regions by 1–10 ppb over the coming decades, with the largest effects in urban areas and during pollution episodes'' and therefore ''climate change will partly offset the benefit of the emissions reductions.'' See Jacob and Winner (2009), EPA–HQ–OAR–2006–0173–9010.4. CARB also cites the 2007 Interim Report of the U.S. EPA Global Change Research Program Assessment of the Impacts of Global Change on Regional U.S. Air Quality, a draft EPA study which concludes that climate change may significantly increase ground-level ozone in areas throughout the nation. See also EPA's final April 2009 ''Assessment of the Impacts of Global Climate Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone'' which states as one of its general findings: ''[W]hile these modeling studies cannot tell us what the future will hold, they demonstrate the potential for global climate change to make U.S. air quality management more difficult, and therefore future air quality management decisions should begin to account for the impacts of climate change.'' EPA–HQ–OAR–2006–0173–9006 at 7–9.

[113] *Id.*

[114] California also submits evidence that its GHG emission regulations would result in a slight reduction of ozone precursors. EPA–HQ–OAR–2006–0173–9006 at 10.

[115] 73 FR 12156, 12164.

As discussed above, this is not the interpretation that EPA now adopts. However, even if EPA were to examine the impacts of climate change in California under this interpretation, based on a review of all the evidence in the record, I cannot deny the waiver.

a. What Test Applies Under This Alternative Approach?

In the March 6, 2008 Denial, EPA found that legislative intent called for particular circumstances in California that are ''sufficiently different'' from the nation as a whole that justify separate standards in California.

EPA received comment stating that there is no statutory foundation for a ''sufficiently different'' test. Commenters noted there is nothing in the term ''compelling and extraordinary conditions'' that requires a comparison to the rest of the country. Similarly, commenters point to EPA's 1984 PM waiver where EPA's Administrator found that ''there is no indication in the language of section 209 or the legislative history that California's pollution problem must be the worst in the country for a waiver to be granted.'' EPA also received comment that it was not reasonable for EPA to conclude that California does not face global warming impacts, including water supply, agricultural production, and wildfire seasonal impacts that present compelling and extraordinary conditions, since other states will face similar impacts. Under this rationale, since states other than California are also experiencing serious global warming impacts, California could never receive a waiver to combat climate change. Commenters find flaw in this rationale: similar impacts in other states have never before prevented California from receiving a waiver. Even though many states are faced with non-attainment ozone areas and smog problems similar to California, California has never had a waiver denied based on a finding under section 209(b)(1)(B) that it did not need its standards to meet compelling and extraordinary conditions. As such, EPA also received comment suggesting that the impacts of climate change should be reviewed within the State of California to determine their severity, and that such impacts need not be compared to impacts experienced or projected to occur elsewhere in the country.

Several commenters maintain that although the impacts of climate change in California may be compelling, they are not extraordinary when compared to the rest of the nation.[116] These commenters point to the record and the many submissions from other states, which recount the variety of impacts and risks of climate change in their respective states and claim that California is no different than any other state.

EPA does not need to resolve this issue. As discussed below, EPA has evaluated the evidence submitted concerning the observed and projected impacts of global climate change in California and other states and determined that even under the alternative approach used in the March 6, 2008 Denial, EPA cannot deny a waiver.

b. Would a Waiver Be Denied Under This Alternative Approach?

Commenters supporting the waiver maintain that California has clearly demonstrated that the impacts in California of global warming are ''compelling and extraordinary.'' Several commenters point to the impacts of global warming recited in EPA's March 6, 2008 initial denial as evidence that EPA committed an error in judgment by not finding that the extreme and various impacts of climate change in California are compelling and extraordinary in nature and that, further, California clearly satisfied the section 209(b)(1)(B) requirements.[117]

Commenters supporting the waiver, including California, have submitted an extensive array of reports and data outlining the risks and impacts of climate change on California. EPA received comment restating EPA's own statements from its March 6, 2008 Denial, including the following:

> California has the largest agricultural based economy (13% of the U.S. market value of agricultural products sold) which is heavily dependent on irrigation, has the nation's highest crop value and is the nation's leading dairy producer. There is improved information on how livestock productivity may be affected by thermal stress and through nutritional changes in forage caused by elevated CO_2 concentrations. In addition, wine is California's highest value agricultural product, and wine grapes are very sensitive to temperature changes. California has the largest state coast population, representing 25% of the U.S. oceanic coastal population. The conditions which create California's tropospheric ozone problems remain (*e.g.,* topography, regional meteorology, number of vehicles) and climate change is expected to exacerbate tropospheric ozone levels. California's water resources are already stressed due to demands from agricultural, industrial and municipal uses, and climate change is expected to introduce an additional stress to an already over-allocate system by increasing temperatures and by decreasing snowpack which is an important water source in spring and summer. California has the greatest variety of ecosystems in the U.S., and the second most threatened and endangered species (of plants and animals combined) and the most threatened and endangered animal species, representing about 21% of the U.S. total.

In addition, one commenter suggests that this summary of findings about California's special characteristics that differentiate the magnitude, intensity and range of impacts of climate change supports that assessment. Dr. Stephen Schneider of Stanford University stated that ''not only are California's conditions 'unique and arguably more severe' (*e.g.* temperature impacts from global warming are more certain for states like California) but also that no other state faces the combination of ozone exacerbation, wildfire emission's contributions, water system and coast system impacts and other impacts faced by California.'' [118] Conversely, opponents of the waiver do not contest California's claims that the impacts of climate change in California and elsewhere are substantial.[119] Instead,

[116] Association of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–9005. This comment notes the finding in *Massachusetts* v. *EPA* that the impacts of global warming are ''widely shared'' among the states.

[117] EPA has not received any comment suggesting EPA's prior inventory of evidentiary information is incorrect as set forth in its discussion of the ''Relationship of Impacts of Global Climate Change in California to the Rest of the Country'' at 73 FR 12156, 12163–12168. In addition, several new studies have been submitted to EPA, including: a recent report from the Pacific Institute examining the impacts that sea level rise would have on population, infrastructure, and property in California (this report uses projections of medium to medium-high greenhouse gas emissions scenarios indicating a 1.4 meter rise in the seal level by 2100 with 480,000 people at risk and $100 million in property at risk from a 100 year flood event); California's Climate Action Team Reports that emphasizes many of the points made in California's waiver request including the air quality impacts (''Climate change could slow progress toward attainment of health-based air quality standards and increase pollution control costs by increasing the potential for high ozone and high particulate days.'' The report itself synthesizes 37 recent reports that address a wide body of information on the range and gravity of the risks that climate change poses to California's citizens, natural resources, and economy); and the Public Policy Institute of California assessment of climate change on public health in California and cites number impacts including ''an increase in the frequency and severity of air pollution episodes'' and ''an increase in extreme heat events and associated increases in heat related morbidity and mortality.'' *See* Environmental Defense Fund, EPA–HQ–OAR–2006–0173–9025 at 15–18; *See also* California Air Resources Board, EPA–HQ–OAR–2006–0173–9006 at 7–16.

[118] Environmental Defense Fund, EPA–HQ–OAR–2006–0173–9025 at 11–12.

[119] The Association of International Automobile Manufacturers notes that although in the March 6, 2008 Denial, ''EPA found that there is ample evidence that global warming is 'compelling' in the

opponents of the waiver claim that the impacts in California are not unique or extraordinary. EPA received comment suggesting that the impacts of climate change in California are not sufficiently different from the nation as a whole to warrant a waiver.[120] Commenters note that the ''need'' requirement in section 209(b)(1)(B) authorizes the creation of regulatory standards specific to California only in cases where it is necessary to meet conditions unique to California. Commenters claim that California cannot meet this standard with respect to a global problem that does not affect California in a unique way as compared to other states. The commenters claim the impacts to coastline, ozone levels, and other impacts are not unique to California as they affect many other states as well.[121]

EPA notes that under this alternative approach the opponents of the waiver continue to bear the burden of proof to demonstrate their claims. Commenters opposing the waiver primarily focus and argue on one issue: Whether the effects of climate change in California are sufficiently different from the nation as a whole. Opponents of the waiver identify singular or multiple impacts in some other states but they largely submit conclusions—not factual evidence—as to why such adverse impacts demonstrate that California is not sufficiently different. On the other hand, California has identified a wide variety of impacts and potential impacts within California, which include exacerbation of tropospheric ozone, heat waves, sea level rise and salt water intrusion, an intensification of wildfires, disruption of water resources by, among other things, decreased snowpack levels, harm to high value agricultural production, harm to livestock production, and additional stresses to sensitive and endangered species and ecosystems. Opponents have not demonstrated that any other state, group of states, or area within the United States would face a similar or wider-range of vulnerabilities and risks. In addition, California has submitted information that climate change can impact ozone levels in California due to temperature exacerbation effects. Although other areas of the country are also projected to experience increases in temperatures which may also exacerbate local ozone levels, opponents of the waiver have not demonstrated that California's ozone levels should not be considered compelling and extraordinary conditions.

Under this alternative interpretation, the burden of proof is on the opponents of the waiver to demonstrate that the impacts of global climate change in California are either not significant enough or are not different enough from the rest of the country to be considered compelling and extraordinary conditions. The opponents of the waiver have focused their argument on the latter part of this interpretation, whether the impacts in California are sufficiently different from the rest of the country. Limiting evaluation to this issue, California has presented evidence of a wide variety of vulnerabilities, impacts and potential impacts within California, while the opponents have not demonstrated that any other state, group of states, or area within the United States would face a similar or wider-range of vulnerabilities and risks. Therefore, EPA believes that those opposing the waiver have not met their burden of proof to demonstrate that the conditions in California are not sufficiently different and that a waiver should be denied under this alternative approach.

It is important to note that nothing in this decision or this document should be construed as reflecting a judgment concerning the issues pending before EPA under section 202(a) of the Act—whether emissions of GHGs from new motor vehicles or engines cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. EPA recently proposed to make an affirmative finding under that statutory provision.[122] The issues involved in that proposal are separate and different from those involved in this decision on California's request for a waiver under section 209(b). Nothing in this decision should be construed as reflecting the Agency's judgment regarding any issue relevant to the determinations in the pending proposal under section 202(a). The statutory provisions and criteria are different, and the judgments called for under these provisions are very different in nature. For example, in evaluating the alternative section 209(b)(1)(B) interpretation, I am not evaluating how serious the impacts or potential impacts of global climate change are, either in California or the rest of the country, as the opponents of the waiver have not focused on that issue. My finding under this alternative interpretation is a narrow one, and is limited to finding that the opponents of the waiver have not met their burden of proof under this alternative interpretation of section 209(b) concerning how the impacts in California might differ from the rest of the country.

3. Must California's GHG Standards Achieve a Demonstrated Reduction in GHG Atmospheric Concentrations or Impacts Under Section 209(b)(1)(B)?

Regardless of whether EPA examines the need for California's motor vehicle emissions program or conversely the need just for the GHG emission standards, some commenters suggest

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sense that it presents serious environmental issues, the agency correctly determined that it does not present an extraordinary condition in California.'' EPA–HQ–OAR–2006–0173–9005 at 9. EPA did receive comment from Air Improvement Resources (AIR) suggesting that it might be contesting whether positive feedback from CO_2 concentrations on temperature increases (as seen in the models and data submitted to EPA by proponents of the waiver) will be seen in certain geographic areas due to an increase in cloudiness. EPA–HQ–OAR–2006–0173–13662 at 5–6. However, in its same submission it also states that while it may be true that California's cities will be disproportionately affected by increased temperatures it is by no means clear that this will be true in the future. (See p. 7). As noted in the text, the burden of proof is on the opponents of the waiver to demonstrate that the effects of climate change are not compelling or serious. Such opponents have not clearly stated the basis for making such a determination nor countered the many studies and data submitted by California and other proponents of the waiver. For purposes of this waiver proceeding, EPA is not making its own judgment with regard to the issues under section 202(a).

[120] Association of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–9005 at 9, citing 73 FR 12168—''As the discussion above indicates, global climate change has affected, and is expected to affect, the nation, indeed the world, in ways very similar to the conditions noted in California * * * These identified impacts are found to affect other parts of the United States and therefore these effects are not sufficiently different compared to the nation as a whole. California's precipitation increases are not qualitatively different from changes in other areas. Rise in sea level in the coastal parts of the United States are projected to be severe, or more severe, particularly in consequences, in the Atlantic and Gulf Regions than in the Pacific regions, which includes California. Temperature increases have occurred in most parts of the United States, and while California's temperatures have increased by more than the national average, there are other places in the United States with higher or similar increases in temperature.''

[121] *Id.* at 9–10. The Association of International Automobile Manufacturers notes that comments submitted from States supporting the waiver include statements such as ''Connecticut faces loss of its shoreline and beaches, forest die offs, destruction of shell fisheries and marine resources, * * *'' ''Global warming is having a serious impact on New Jersey's public health and economy * * *'' ''Rhode Island * * * As the most densely populated State in the country, direct impacts due to climate change, such as heat wave, increased fire frequency, increased storm intensity resulting in beach erosion, loss of property, and loss of life—pose great concerns for us,'' and other concerns expressed by states such as Pennsylvania, Maryland, and New Mexico. See also Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–1297 at 14–17 and EPA–HQ–OAR–2006–0173–0421–12 at 61–70 and General Motors Corporation, EPA–HQ–OAR–2006–0173–1596 at 6–8.

[122] See EPA's ''Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act'' at 74 FR 18886 (April 29, 2009).

that the GHG emission standards must be proven to have some mitigative effect in order for them to be needed. Some commenters suggest that to the extent that California's high ozone levels could be exacerbated by higher temperatures from global warming, there is no demonstration in the waiver record that implementation of the California GHG standards would have any perceptible impact on temperature trends in California. Opponents of the waiver have argued that California, therefore, cannot show that its GHG emission regulations will achieve a measurable and specific temperature reduction in California, and thereby mitigate the identified climate change impacts in California.[123] They maintain that California's GHG regulations will not be needed to meet a particular condition since there is no analysis suggesting that California's GHG standards will have any discernible impact on that condition or achieve any perceptible improvement in environmental conditions inside California. In terms of GHG concentrations in California's atmosphere, EPA received comment stating there is no offered proof that a reduction in GHG emissions from California vehicles would have any impact on GHG concentrations in California's atmosphere compared to the GHG concentration impacts already in the record.

In response, other commenters supporting the waiver assert that the efficacy of California's standards is not at issue in this proceeding. There is no requirement in section 209(b)(1)(B) that California prove a certain level of environmental benefit. They assert that is particularly true in this instance, where the actual and anticipated impacts of global warming are complex and historically unprecedented, and it is widely-recognized that a number of efforts by governments, private entities, and individuals globally will be required to mitigate climate change, as no single source of GHG emissions, whether from an entire state, sector of the nation's economy, or of individual countries, is completely dominant in terms of influencing atmospheric concentrations of GHGs. They claim that California need not show that the climate will in fact respond to its regulatory action; rather its obligation is to show a rational connection between the regulation it has promulgated and the problem it seeks to address.

As noted above, the Agency's inquiry under section 209(b)(1)(B) is whether California needs its own motor vehicle emission control program to meet compelling and extraordinary conditions. Under this criterion, EPA does not consider, for example, the extent to which specific PM standards will address the PM air pollution problem.[124] Under this approach, there is no need to delve into the extent to which the GHG standards at issue here would address climate change or ozone problems. That is an issue appropriately left to California's judgment.

Given the comments submitted, however, EPA has also considered an alternative interpretation, which would evaluate whether the program or standards has a rational relationship to contributing to amelioration of the air pollution problems in California. Even under this approach, EPA's inquiry would end there. California's policy judgment that an incremental, directional improvement will occur and is worth pursuing is entitled, in EPA's judgment, to great deference.[125] EPA's consistent view is that it should give deference to California's policy judgments, as it has in past waiver decisions, on California's choice of mechanism used to address air pollution problems. EPA does not second-guess the wisdom or efficacy of California's standards.[126] EPA has also considered this approach with respect to the specific GHG standards themselves, as well as California's motor vehicle emissions program.

After reviewing the arguments, I conclude that California has submitted evidence demonstrating not only the causal connection between higher temperatures from global warming and its general exacerbation of tropospheric ozone, but also the serious effects of that potential increase in ozone on the public health and welfare in California. EPA notes that several commenters have stated that while California's GHG regulations will provide only a small difference in temperatures and/or GHG concentrations, there clearly will be some reductions. These commenters note that given the numerous sources in California and around the world that contribute to GHG concentrations, no single regulation could on its own reduce GHG emissions to the levels necessary to reduce all concerns, but that every small reduction is helpful in reducing these concerns. As noted by the Supreme Court in *Massachusetts* v. *EPA,* while it is true that regulating motor vehicle GHG emissions will not by itself reverse global warming, a reduction in domestic automobile emissions would slow the pace of global emissions increase no matter what happens with regard to other emissions.[127] Moreover, there is some evidence in the record that proffers a specific level of reduction in temperature resulting from California's regulations.[128] EPA believes that under this alternative approach, opponents have not met their burden of demonstrating that California's motor vehicle program, or its GHG standards, does not have a rational relationship to contributing to amelioration of the air pollution problems in California.

E. Section 209(b)(1)(B) Conclusion

With respect to the need for California's state standards to meet compelling and extraordinary conditions, I have found that the March 6, 2008 Denial was based on a departure from the traditional interpretation of the waiver provision. An examination of the text of section 209(b) and the legislative history, when viewed together, lead to the conclusion that the best way to interpret this provision and the interpretation I adopt here, is to apply the traditional interpretation to the evaluation of California's greenhouse gas standards for motor vehicles. As such, if California needs a separate motor vehicle program to address the kinds of compelling and extraordinary conditions discussed in the traditional interpretation, then Congress intended that California could have such a program. The best interpretation of the text and legislative history of this provision is that Congress did not use this criterion to limit California's discretion to a certain category of air pollution problems, to the exclusion of others.

Under that interpretation, I cannot find that opponents of the waiver have demonstrated that California does not need its state standards to meet compelling and extraordinary conditions. The opponents of the waiver have not adequately demonstrated that

[123] However, the Alliance presented some evidence at the May 30, 2007 waiver hearing that some temperature reduction may be achieved, based on application of the Wigley equation. EPA–HQ–OAR–2006–0173–0421 at 71.

[124] 74 FR 12156, 12159–60 (March 6, 2008).

[125] *MEMA I* at 1110–11.

[126] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.

[127] *Massachusetts* v. *EPA,* 59 U.S. 497, 525–526 (2007).

[128] EPA also received comment during the second comment period indicating that a local decrease in GHGs can have a direct effect on reducing local ozone concentrations, as well as particulate matter concentrations, in California, before they mix with other greenhouse gases in the upper atmosphere. The comments that address Dr. Jacobson's testimony do not dispute these atmospheric reactions and the fact that they can increase local temperature which can increase ozone concentrations.

California no longer has a need for its motor vehicle emission program.

Separately, even applying the alternative interpretations set forth in the March 6, 2008 Denial, I cannot find that that the opponents of the waiver have demonstrated that California does not need its greenhouse gas emission standards to meet compelling and extraordinary conditions. Nor can I find that the opponents of the waiver have demonstrated that the impacts from climate change in California are not compelling and extraordinary.

Therefore, upon reconsideration of the March 6, 2008 Denial, I determine that I cannot deny the waiver request under section 209(b)(1)(B).

VI. Are the California GHG Standards Consistent With Section 202(a) of the Clean Air Act?

EPA has reviewed the information submitted to the record of this proceeding to determine whether the parties opposing this waiver request have met their burden to demonstrate that the GHG standards are not consistent with section 202(a). In its submissions, CARB has submitted information and argument that these GHG standards do provide regulated manufacturers with sufficient lead-time for the near term standards regardless of how it is measured and regardless of the waiver denial. For the mid-term standards, CARB has stated that initially, manufacturers can achieve compliance with credits from the near-term production, and subsequently can achieve compliance with refinements to existing technology and advanced technology combinations. The industry opponents of the waiver have submitted information and argument that there is insufficient leadtime for the CARB near-term standards because the already short time-frame for technology development was made even shorter by EPA's waiver denial. For the mid-term standards, the industry stated that it is likely that most large-volume manufacturers will be able to comply with the CARB standards only by ''mix-shifting'' their products to offer for sale more higher mileage vehicles to ensure meeting the CARB fleet average. The industry also submitted information and argument that the GHG standards will result in unsafe vehicles because vehicles meeting the standards will be lighter and more hazardous to occupants in accidents, and will be driven more because of higher fuel efficiency, so more accidents will occur. The industry argued that these complying vehicles are technologically infeasible because of the safety concerns. EPA's analysis of the consistency of the CARB standards with section 202(a) of the Act follows.

A. Historical Approach: The Standard of Review for Consistency With Section 202(a)

Under section 209(b)(1)(C), EPA must deny California's waiver request if the Agency finds that California standards and accompanying enforcement procedures are not consistent with section 202(a) of the Act. The scope of EPA's review under this criterion is narrow. EPA has previously stated that the determination is limited to whether those opposed to the waiver have met their burden of establishing that California's standards are technologically infeasible, or that California's test procedures impose requirements inconsistent with the Federal test procedure.[129] Previous waivers of federal preemption have stated that California's standards are not consistent with section 202(a) if there is inadequate lead time to permit the development of technology necessary to meet those requirements, giving appropriate consideration to the cost of compliance within that time.[130] California's accompanying enforcement procedures would be inconsistent with section 202(a) if the Federal and California test procedures conflict, *i.e.,* if manufacturers would be unable to meet both the California and Federal test requirements with the same test vehicle.[131]

EPA does not believe that there is any reason to review these criteria any differently for EPA's evaluation of California's greenhouse gas waiver request. There is nothing inherently different about how GHG control technologies should be reviewed when making a determination about technological feasibility or consistency of test procedures.

In the GHG waiver proceeding, automobile industry opponents of the waiver have presented evidence for EPA's consideration which they believe will require EPA to make the finding of inconsistency with section 202(a), and therefore require EPA to deny this waiver. They believe this finding should be made on one or more grounds that there is inadequate lead time provided by the CARB standards. EPA's process for evaluating lead time is discussed immediately below. The industry opponents also raise arguments based on the cost of compliance with the standards, and claims of possible significant vehicle safety problems caused, at least indirectly, by compliance with the GHG standards, which will be discussed in other parts of this section.

Regarding lead time, EPA historically has relied on two decisions from the U.S. Court of Appeals for the DC Circuit for guidance regarding the lead time requirements of section 202(a). Section 202(a) provides that an emission standard shall take effect after such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance. In *Natural Resources Defense Council* v. *EPA* (''*NRDC*''), 655 F.2d 318 (DC Cir. 1981), the court reviewed claims that EPA's particulate matter standards for diesel cars and light trucks were either too stringent or not stringent enough. In upholding the EPA standards, the court concluded:

> Given this time frame [a 1980 decision on 1985 model year standards]; we feel that there is *substantial room for deference* to the EPA's expertise in projecting the likely course of development. The essential question in this case is the pace of that development, and absent a revolution in the study of industry, defense of such a projection can never possess the inescapable logic of a mathematical deduction. We think that the EPA will have demonstrated the reasonableness of its basis for projection if it answers any theoretical objections to the [projected control technology], identifies the major steps necessary in refinement of the technology, and offers plausible reasons for believing that each of those steps can be completed in the time available.[132]

Another key case addressing the lead time requirements of section 202(a) is *International Harvester* v. *Ruckelshaus* (''*International Harvester''*), 478 F 2.d 615 (DC Cir. 1979). In *International Harvester,* the court reviewed EPA's decision to deny applications by several automobile and truck manufacturers for a one-year suspension of the 1975 emission standards for light-duty vehicles. In the suspension proceeding, the manufacturers presented data which, on its face, showed little chance of compliance with the 1975 standards, but which, at the same time, contained many uncertainties and inconsistencies regarding test procedures and parameters. In a May 1972 decision, the Administrator applied an EPA

[129] *MEMA I,* 627 F.2d at 1126.

[130] See *e.g.,* 38 FR 30136 (November 1, 1973) and 40 FR 30311 (July 18, 1975).

[131] To be consistent, the California certification test procedures need not be identical to the Federal test procedures. California procedures would be inconsistent, however, if manufacturers would be unable to meet both the state and Federal requirements with the same test vehicle in the course of the same test. See, *e.g.,* 43 FR 32182, (July 25, 1978).

[132] *Natural Resources Defense Council* v. *EPA,* 655 F.2d 318, 331. (emphasis added)

methodology to the submitted data, and concluded that ''compliance with the 1975 standards by application of present technology can probably be achieved,'' and so denied the suspension applications.[133] In reviewing the Administrator's decision, the court found that the applicants had the burden of coming forward with data showing that they could not comply with the standards, and if they did, then EPA had the burden of demonstrating that the methodology it used to predict compliance was sufficiently reliable to permit a finding of technological feasibility. In that case, EPA failed to meet this burden.

With respect to lead time, the court in *NRDC* pointed out that the court in *International Harvester* ''probed deeply into the reliability of EPA's methodology'' because of the relatively short amount of lead time involved (a May 1972 decision regarding 1975 model year vehicles, which could be produced starting in early 1974), and because ''the hardship resulting if a suspension were mistakenly denied outweigh the risk of a suspension needlessly granted.'' [134] The *NRDC* court compared the suspension proceedings with the circumstances concerning the diesel standards before it: ''The present case is quite different; 'the base hour' for commencement of production is relatively distant, and until that time the probable effect of a relaxation of the standard would be to mitigate the consequences of any strictness in the final rule, not to create new hardships.'' [135] The *NRDC* court further noted that *International Harvester* did not involve EPA's predictions of future technological advances, but an evaluation of presently available technology.

EPA also evaluates CARB's request in light of congressional intent regarding the waiver program generally. This is consistent with the motivation behind section 209(b) to foster California's role as a laboratory for motor vehicle emission control, in order ''to continue the national benefits that might flow from allowing California to continue to act as a pioneer in this field.'' [136]

For these reasons, EPA believes that California must be given substantial deference when adopting motor vehicle emission standards which may require new and/or improved technology to meet challenging levels of compliance. This deference was discussed in an early waiver decision when EPA approved the waiver request for California's 1977 model year standards:

> Even on this issue of technological feasibility I would feel constrained to approve a California approach to the problem which I might also feel unable to adopt at the Federal level in my own capacity as a regulator. The whole approach of the Clean Air Act is to force the development of new types of emission control technology where that is needed by compelling the industry to 'catch up' to some degree with newly promulgated standards. Such an approach to automotive emission control might be attended with costs, in the shape of a reduced product offering, or price or fuel economy penalties, and by risks that a wider number of vehicle classes may not be able to complete their development work in time. Since a balancing of these risks and costs against the potential benefits from reduced emissions is a central policy decision for any regulatory agency, under the statutory scheme outlined above I believe I am required to give very substantial deference to California's judgment on that score.'' [137]

EPA has traditionally considered lead time as starting with the date that the rules are adopted and become effective under California state law—not from the subsequent date of a request for a waiver or the decision on a waiver.[138] This is consistent with the structure of section 209(b), where the waiver criteria are presumed to be met absent an affirmative finding that requires EPA to deny it, which gives EPA a limited scope of review and affords deference to California. At the time that California adopts its rules, manufacturers have clear knowledge and are fully on notice of California's requirements and the date when such requirements will be implemented. In this case, the CARB GHG regulations became final and effective in 2004. This was five years before the first phase of compliance (the 2009 model year) and eight years before compliance with the ''mid-term'' standards, which include the most stringent standards (model year 2016). Because of this large amount of lead time available to manufacturers under CARB's regulatory schedule, the approach described in *NRDC* is the most appropriate under the circumstances at issue here.

EPA notes, however, that manufacturers have disputed whether ample lead time exists. Because EPA initially denied this waiver request, manufacturers have asserted that the lead time should have ''tolled'' at the time of the denial, since California could not implement and enforce standards which had not received a waiver. This tolling issue is discussed below in section VI.F.1. Additionally, if the tolling might be considered to cause a reduction in lead time for the CARB near-term standards, it could be argued that the *International Harvester* approach, involving circumstances where the lead time is short, should apply. CARB, while maintaining that the *NRDC* approach is the correct measurement here, commented that even if *International Harvester* was the correct guide, ''we believe that a combination of manufacturers' statements and plans indicated that manufacturers are already in, or with minor changes can demonstrate compliance for the 2009 and 2010 model years.'' [139] Under *International Harvester,* the burden was on the industry to demonstrate that the evidence supported the grant of an extension, then, the burden shifted to EPA to demonstrate the reasonableness of its projection. As discussed below, the manufacturers have not met their burden to show that the California standards are not technologically feasible, considering the lead time provided and cost of compliance.

Under *NRDC,* when compliance with CARB standards is phased-in over a lengthy time period, the reasonableness of a projection of technological feasibility can be based on answering any theoretical objections to the projected control technology; identifying the major steps necessary in refinement of the technology; and offering plausible reasons for believing that each of those steps can be completed in the time available.[140] EPA's review of the evidence on the technological feasibility of GHG technologies follows.

B. CARB's Assessment of the State of Development of GHG Reduction Technology and Comments Supporting CARB's Assessment

1. Development of GHG Reduction Technology

Under the terms of Assembly Bill 1493, which is the legislation that directed CARB to establish greenhouse gas emission standards, the CARB staff was directed to set those standards in a manner that would ''achieve the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles.'' CARB has

[133] *International Harvester* v. *Ruckelshaus,* 478 F.2d 615, 626.

[134] *NRDC,* 655 F.2d 318, 330.

[135] Id. The ''hardships'' referred to are hardships that would be created for manufacturers able to comply with the more stringent standards being relaxed late in the process.

[136] 40 FR 23102, 23103 (waiver decision citing views of Congressman Moss and Senator Murphy) (May 28, 1975).

[137] *Id.* at 23103.

[138] *See e.g.,* 59 FR 40625 (September 22, 1994).

[139] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006, at 23.

[140] *NRDC,* 655 F.2d 318, 331.

identified four basic areas of GHG reduction technology: (1) Engine, drivetrain and other vehicle modifications; (2) mobile air conditioning system modifications; (3) alternative fuel vehicles; and (4) exhaust catalyst improvements.

To accomplish the assessment mandated by AB 1493, CARB staff held several meetings and workshops in 2003 and 2004 on GHG vehicle technology. Those meetings brought together technology developers, researchers from the auto industry, vehicle component suppliers, academic participants, and vehicle simulation firms to discuss technologies and their potential to reduce climate change emissions from motor vehicles. CARB staff presented its preliminary findings in a draft technology and cost assessment and held a public workshop to receive comments in April 2004. Following that presentation, CARB issued a draft proposal on the methodology for developing the GHG standards and the preliminary standards themselves, in June 2004. A public workshop on this draft was held in July 2004. After considering all the comments from these sessions, CARB published its final staff proposal in the Staff Report: Initial Statement of Reasons (ISOR) in August 2004.[141]

The CARB vehicle technology results in the ISOR relied on an existing vehicle simulation study (discussed below), as well as other existing studies and research, rather than on any sort of primary development or engineering work. CARB staff acknowledged that ''because powertrain changes will be the focus for obtaining the reductions sought in this (GHG) rulemaking rather than aftertreatment technologies, staff could not reasonably build prototypes and test them in our laboratory. * * * Because building and testing prototypes is so expensive, and time consuming, even major automobile manufacturers rely on vehicle simulation firms to predict the performance of new technology either individually or in combination, and to assess their performance and emissions.'' [142] CARB further commented that the advantage of systems modeling ''is to allow a wide diversity of combinations of technologies to be modeled together and examine how they interact when simulating a vehicle operating on various driving cycles.'' [143]

The study forming the basis of the ISOR vehicle technology results was a comprehensive vehicle simulation modeling effort and a thorough cost analysis performed for the Northeast States Center for a Clean Air Future (NESCCAF), by the recognized expert companies AVL Powertrain Engineering, Martec, and Meszler Engineering Services.[144] CARB staff believed that ''the NESCAAF study is the most advanced and accurate evaluation of vehicle technologies that reduce greenhouse gas emissions yet performed.'' [145] Besides the NESCAAF study on vehicle technologies, CARB monitored a separate analysis of the GHG benefits of alternative fuel technologies, including upstream benefits and the cost associated with alternative fuel technologies, from work performed by TIAX, LLC. Finally, for air conditioning research, CARB staff met with various groups (including EPA) to develop its approach for reducing the emissions of air conditioning refrigerant and excess CO_2 emissions from air conditioning use.

After the release of the Initial Staff Report, CARB received comments on its evaluation of technological steps that could be taken to meet its GHG standards from parties who supported the CARB study, and from various industry parties who disagreed with many of the CARB conclusions. As part of its standard-setting process, CARB staff considered the comments from all parties on both sides, and responded to industry concerns in its Final Statement of Reasons (FSOR), published in August 2005.[146] CARB concluded that it had identified the necessary technology in existence at that time that could enable vehicles to meet the GHG standards; or specifically identified the projected control technologies; answered the industry objections regarding the technology; and has explained its reasons for believing that each of the steps can be completed in the time available.

2. Overview of Technologies and Their Projected Applications

The NESCAAF study identified technologies for reducing CO_2 emissions that were modeled both individually and in various technology combinations (or ''packages''). Because there were a multitude of technologies available for the CO_2 reductions, CARB realized that there needed to be engineering guidelines for choosing combinations that would be economical to the consumer. The guidelines tried to avoid combining technologies that tend to address the same categories of losses or technologies that may not complement one another from a drivability standpoint. Participants in the NESCAAF study and CARB staff then assembled a wide variety of combined technologies to evaluate through simulation modeling in order to identify those which would provide the greatest CO_2 reductions. In an effort to cover the full spectrum of CO_2 reductions that could be accomplished, CARB staff divided the results into two categories: near-term phase-in and mid-term phase-in applications. These translate to the following model year ranges: Near-term (2009–2012) and mid-term to fully phased-in (2013–2016).[147]

In the Initial Staff Report, CARB staff summarized the state of near-term technology for meeting its proposed CO_2 standards:

> The technologies explored (in the Initial Staff Report) are currently available on vehicles in various forms, or have been demonstrated by auto companies and/or vehicle suppliers in at least prototype form * * * There is near term, or off the shelf technology package in each of the vehicles classes evaluated (small and large car, minivan, small and large truck) that resulted in a reduction of CO_2 emissions of at least 15 to 20 percent from baseline values. In addition there is generally a near-term technology package in each of the vehicle classes that results in about a 25 percent CO_2 emission reduction.'' [148]

For engines, CO_2 is emitted with engine exhaust as a result of the combustion process. CARB projected that by 2009, reductions in engine CO_2 emissions would result from these primary technology drive-train changes which could be expected in all vehicle classes: Dual cam phasing, turbocharging with engine downsizing, automated manual transmissions, and

[141] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.44.

[142] *Id.* at 43.

[143] *Id.* at 58.

[144] NESCCAF undertook this study ''to help define GHG—reducing motor vehicle technologies that are expected to be feasible, commercially available and cost effective in the 2009–2015 timeframe.'' It was ''inspired by the California's legislature's passage of Assembly Bill 1493 * * *'' and it related to the Northeast U.S. because ''the results presented in this report have significant implications for states in the Northeast and elsewhere that share California's commitment to reducing transportation related GHG emissions as part of a broader effort to address the risks posed by global climate change.'' Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles, NESCCAF, p 1–1, September 2004.

[145] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.44 at 44.

[146] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.116.

[147] The NESCAAF study had a different schedule: Near-term technologies (2009–2012), mid-term (2013–2015) and long term (2015 and later). California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 27.

[148] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.44 at iii.

camless valve actuation.[149] CARB also described several other technology items that may not be present in most vehicles in the early years of the standards, but are expected to be used in later years as development continues. These include: Gasoline direct injection, engine friction reduction, aerodynamic drag and rolling resistance, more aggressive shift logic, and early torque converter lock-up. Finally, CARB staff identified two other technology choices that while offering real GHG reduction capability were not as cost effective as the other technologies, and, accordingly, were not projected to be applied in the near-term—these are hybridization and greater dieselization of the fleet.

For the later years of these standards, CARB stressed that its GHG regulations ''rely less on traditional technology-forcing than repackaging a combination of off-the-shelf technologies to meet the adopted standards.'' [150] The NESCAAF Report included, for each of the five vehicle categories, a table showing several promising technology packages, for each of the three time frames (near-, mid-, and long-term), their resulting CO_2 reductions, and expected costs.[151] Additionally, for the long-term phase of the standards (2015–2016), CARB projects that there will be increased market penetration of hybrid-electric vehicles and advanced multi-mode diesel vehicles.[152] In its December 2005 request letter, CARB discussed how improvements will occur, as it expects ''that a manufacturer would plan for a rollout of new technologies that would begin in 2009 and then build on the initial efforts with additional near and mid-term technologies that would be commensurate with previous investments.''[153]

For air conditioning systems, GHG emissions are either direct or indirect. Direct emissions are the result of normal leakage of the air conditioning refrigerant from the system over time, as well as leakages that occur because of vehicle accidents, poorly performed maintenance, or improper refrigerant recovery prior to vehicle scrappage. Air conditioning refrigerants used in vehicles today are typically a hydro-fluorocarbon (HFC), which is a very strong GHG. Indirect emissions are the additional CO_2 emissions from the engine which occur because of the added load on the engine from operation of the air conditioning system. CARB, using the modeling in the NESCAAF Report, projected that CO_2 equivalent reductions could result from these improvements in the air conditioning system: improved variable displacement compressor with revised controls, improved low-leak systems, and the use of an improved refrigerant.[154]

CARB notes that alternative fueled vehicles generally can help reduce GHG emissions by: (1) Direct reduction of GHG emissions because the alternative fuels will produce fewer GHG emissions, and (2) indirect reductions in GHG emissions because of the decreased upstream emissions. Upstream emissions are well-to-tank emissions, including the fuels' extraction, processing, distribution and marketing. The alternative fuels which result in GHG reductions are CNG, LPG, ethanol (including E85), electric, and hybrid-electric.

In its ISOR, CARB identified exhaust catalyst improvement as another technology area that could lead to GHG emission reductions, specifically the reduction of methane and nitrous oxide (N_2O). These gases are greenhouse gases just like CO_2, but their mass emissions from motor vehicles are very small compared to CO_2. CARB notes that ''although it is conceivable that these methane and N_2O emissions could be reduced by faster catalyst heating at vehicle start-up and enhanced catalysts systems with higher surface density or higher and/or revised catalyst loadings, staff is not aware of such efforts at this time (August 2004).'' [155] There were no further submissions to the record by CARB or any other party on this particular technology area.

3. CARB's Updates on Technological Development

At the time of the first set of EPA hearings on the CARB waiver request, in April 2007, CARB presented additional information to bolster its assertions on technological feasibility to highlight developments in GHG technology since CARB originally submitted its request to EPA in 2005. CARB summarized the recent developments and additional examples of real-life implementation of the technologies identified in its waiver request. In its comments following the April 2007 hearings, and its July 2007 letter responding to post-hearing comments, CARB offered additional information to bolster their GHG technology projections. Generally, CARB pointed to numerous instances in which many of the near-term and mid-term technologies have been applied in vehicles which have been produced in the years since 2004 (when the CARB standards became final) right up to mid-2007. For example, attached to additional comment letters it submitted to EPA's Docket in June and July 2007, CARB discussed the increased use of the GHG technologies discussed in the ISOR and provided summaries of GHG technology used in 2007 and 2008 model year vehicles showing increased use of all the near-term and mid-term technologies.[156] CARB also offered numerous examples, contained in manufacturer news releases and advertisements, and trade press stories, illustrating real-life adoption of the GHG technologies in both domestic and foreign manufacturers' vehicles.[157]

At its March 5, 2009 hearing following EPA's decision to reconsider its previous denial, CARB presented additional new information highlighting developments in GHG technology since the last opportunity to submit public comment on this issue. In addition, some environmental groups submitted testimony and comments in support of the CARB finding of technological feasibility of the GHG standards. This next section will summarize the technological feasibility information submitted by CARB and other parties. CARB noted that the manufacturers were employing the individual GHG-reducing technologies as well as the packages of those technologies CARB had projected as viable compliance pathways as early as 2004. CARB also noted that in addition to phasing-in technologies, as CARB had originally predicted, manufacturers were using other technologies that CARB did not rely on originally—including increased hybrid sales, downsized turbocharged engines in light truck lines, a large influx of diesel vehicle sales, and improved air conditioning systems. In some cases, the resulting reductions produced as much as 10% of the GHG reductions needed for manufacturers' fleet averages to meet the CARB standards.

CARB also cited to recent EPA studies on technological feasibility and costs for

[149] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.44 at 59–60.

[150] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 34.

[151] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 27 and 35, and OAR–2006–0173–0010.44 at 59.

[152] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 27.

[153] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 35–36.

[154] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.44 at 69–73, and EPA–HQ–OAR–2006–0173–0004.1 at 22–23.

[155] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.44 at 78–79.

[156] California Air Resources Board, EPA–HQ–OAR–2006–0173–1686, Attachments 84 and 85.

[157] California Air Resources Board, EPA–HQ–OAR–2006–0173–1686, Attachments 86 through 93 and 103, 104, 114, and California Air Resources Board, EPA–HQ–OAR–2006–0173–3601, Attachments 173–177.

GHG reductions in motor vehicles, conducted by EPA in 2007. These EPA reports were discussed in EPA's Advanced Notice of Proposed Rulemaking on Regulating Greenhouse Gas Emissions Under the Clean Air Act published on July 30, 2008.[158] The findings in these studies were very consistent with the technological feasibility, cost and lead time estimates from the CARB ISOR in 2004.

Three EPA studies were referenced by CARB. First, CARB discussed the June 2008 document ''Vehicle Technical Support Document: Evaluating Potential GHG Reduction Programs for Light-Duty Vehicles (Light-Duty Vehicle TSD).'' [159] The Light-Duty Vehicle TSD represented EPA's assessment during 2007 of how a light-duty vehicle program for GHG emission reductions under the Clean Air Act might be designed and implemented, with two program options: either (1) a fixed percentage reduction (4%) in CO_2 emissions per model year from 2011 to 2018, or (2) an annual reduction in CO_2 emissions per model year from 2011 to 2018, based on a model developed by the Department of Transportation's Volpe Center, establishing CO_2 emission standards, at the point the model projects maximum net benefits for those model years.[160] The Light-Duty Vehicle TSD collected information from a wide range of sources, including a 2002 National Academy of Sciences report, the 2004 NESCAAF report (also used by CARB), current technical literature, and information from vehicle manufacturers and automotive suppliers. CARB noted that the emission reduction potentials and costs in the EPA study were similar to the reduction potentials and costs estimated by CARB in its ISOR. In discussing the Light-duty TSD in the ANPRM, EPA also acknowledged that, based on enhancements to the Volpe Model later in 2007, the earlier EPA analysis ''tended to underestimate the benefits and/or overestimate the costs of light-duty vehicle CO_2 standards that could be established under the CAA.'' [161]

CARB also referenced the March 2008 ''EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions.'' This report presented the EPA staff assessment of costs and effectiveness of over 40 CO_2 reduction technologies in the categories of engines, transmissions, hybrids, accessories and other technologies (*e.g.,* aerodynamic improvements). EPA noted that the majority of the technologies investigated are in production and available on current vehicles, either in the U.S., Europe or Japan. As part of that report, EPA worked with an internationally recognized automotive technology firm to perform a detailed vehicle simulation modeling study of the GHG reduction effectiveness of a number of advanced automotive technologies. As noted by CARB, the EPA Report obtained technology package reductions and cost estimates very similar to those in the CARB ISOR.[162] As in the earlier Light-Duty TSD, EPA noted that the estimates in this report are conservative because they rely on data sources from one to six years old and declared that the ''automotive industry is a technology-driven industry, and new technologies are developed and introduced quickly. A number of technologies which have only recently been introduced or will be within the next year are likely to see improvements in their effectiveness and cost reductions beyond what we estimate (in this report).'' [163]

Finally, CARB referenced an EPA staff technical memorandum ''Documentation of Updated Light-duty Vehicle GHG Scenarios,'' dated June 23, 2008.[164] This memorandum summarized the staff work to update the ''4% per year'' GHG reduction scenario that was first documented in the Light-duty Vehicle TSD, by addressing some of the deficiencies of the earlier study,[165] and was discussed in the ANPRM for GHG Standards. EPA once again noted that because the updated analysis did not address all the issues identified in the earlier TSD, it continued to believe that the results of this updated analysis are conservative, tending to overestimate the costs and/or underestimate the benefits. In its most recent comment, CARB noted that the EPA lead time estimates in EPA's ANPRM cite implementation rates supportive of CARB's estimates for implementing vehicle GHG reducing technologies.[166]

CARB summarizes the reports from EPA, NESCAAF and others by declaring that ''the technologies examined are well known and most are already being implemented on today's vehicles, while the others are simply advanced versions of conventional technologies that are already being demonstrated by vehicle manufacturers and component suppliers.'' [167] To bolster this statement, CARB submitted a list of Model Year 2009 vehicles which employ GHG reduction technologies, which shows a gradual phasing-in of these technologies across all manufacturers and all product lines. CARB also submitted a list showing 2009 Model Year vehicles that comply with the CARB GHG standards; the list shows significant numbers of 2009 passenger cars and light trucks meeting the 2012 and later standards, significantly ahead of the deadlines.

With respect to the overall technological feasibility of its GHG standards, CARB believes that it has reasonably projected technological feasibility, consistent with the approach employed in the *NRDC* decision, when manufacturers have several years of lead time before compliance. CARB notes that it ''either has demonstrated that the necessary technologies presently exist to meet the established standards or we have specifically identified the projected control technologies, answered objections raised by industry regarding those technologies, and explained why we believe that each of the steps can be completed in the time available.'' [168]

In support of its conclusion, CARB submitted for the record three analyses showing that the manufacturers are employing the GHG technologies at least as fast as CARB predicted, and certainly in time for compliance with the early model years. First, CARB did an ''industry-wide'' projection using manufacturers' 2009 sales projections and worst case CO_2 values per single test vehicle, and used the 2009 projected sales as unchanged for 2010 and 2011 model years.[169] The results of this analysis show industry-wide GHG

[158] Advanced Notice of Proposed Rulemaking, Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 FR 44354 (July 30, 2008).

[159] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.5.

[160] This approach uses a computer model developed by the Department of Transportation Volpe Center called the ''CAFE Effects and Compliance Model'' (''Volpe Model'').

[161] This EPA assessment of the Light-Duty Vehicle TSD was contained in the Advanced Notice of Proposed Rulemaking, Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 FR 44354, at 44444 (July 30, 2008).

[162] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006, at 21.

[163] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.6. at 1.

[164] California Air Resources Board, EPA–HQ–OAR–2007–0173–9019.7.

[165] For example, this updated analysis included factors such as consideration of multi-year planning cycles available to manufacturers, consideration of CO_2 trading between car and truck fleets within the same manufacturer, and inclusion of plug-in hybrids as a viable technology beginning in 2012. Advanced Notice of Proposed Rulemaking, Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 FR 44354, at 44444 (July 30, 2008).

[166] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006, at 21.

[167] *Id.*

[168] *Id.* at 23.

[169] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.12.

credits for 2009 and 2010 and a debit for 2011, but an overall credit for the three-year period. CARB noted that because this was done on a worst-case testing basis, it is likely that testing with additional vehicles in each test group would show even the debiting companies in compliance.[170]

Second, CARB looked at the compliance projection for the major domestic manufacturers (Ford, GM and Chrysler) for the 2009 and 2010 model years.[171] CARB used the actual 2009 model year registration data (from Polk) and, then, applied CO_2 emissions data by vehicle model obtained from EPA, selecting the highest CO_2 emissions data for those vehicle models with multiple engines. The results showed that for the 2009 model year, GM and Ford have ample compliance margins for both PC/LDT1 and LDT2/MDV, while Chrysler has a debit for its PC/LDT1 fleet, but a wide margin for its LDT2/MDV fleet. The overall net result is compliance for all three companies. For 2010, the three companies run debits for PC/LDT1 but have compliance margins for LDT2/MDV (a small margin for GM, and substantial margins for Ford and Chrysler). Again, based on the use of accumulated credits, these companies would comply with the model years analyzed.

Third, CARB focused on just GM for the 2009 model year, using a different technique than their study directly above.[172] CARB used certification data provided by GM, projected sales based on GM's latest manufacturer update to CARB, and CO_2 results provided by EPA. Then each GM certification test group was divided by GM into sales sub-groups, each having one or several vehicle models. For each sub-group, the CO_2 emissions of the highest emitting model were multiplied with the total number of vehicles in the subgroup to calculate the sub-group's GHG value. The GHG values from all sales subgroups in a test group were summed up to represent the sales group GHG value. For the 2009 model year, under this analysis, the GM PC/LDT1 fleet over-complies by 14 grams per mile and the LDT2/MDV fleet over-complied by 27 grams per mile, generating substantial credits for 2010 and beyond.

Additional support for 2009–2011 compliance was provided by the Natural Resources Defense Council. At EPA's March 5, 2009 waiver hearing, NRDC presented testimony regarding the technological feasibility of the GHG standards for the early years of compliance. NRDC performed its analysis by using EPA fuel economy trends data for MY 2008, which predicted a national average fuel economy level without CAFE credits for flexible fuel vehicles. NRDC then converted the miles per gallon numbers to CO_2 grams per mile levels using the California sales mix and the GHG conversion established by CARB. The result is that industry accrues substantial amount of credits in 2009 and 2010, and then runs a small deficit in 2011 that can be easily made up using banked credits from the first two years.[173]

Beyond submitting results from its own recent analyses, CARB submitted a very recent (March 2009) study by Energy & Environmental Analysis (EEA) entitled ''Automakers Ability to Comply with California GHG Standards Through 2012.''[174] The EEA study notes that, if the California waiver is granted, manufacturers would be required to comply with standards for MY 2009 vehicles, which are already in production and being sold, and would have very little lead time to make changes for MY 2010 (which will start production in mid-calendar year 2009), and limited opportunity to make changes at this point for MY 2011 and 2012. EEA looked at the product plans for the ''Big Six'' manufacturers in the U.S. (GM, Ford, Chrysler, Toyota, Honda and Nissan) based on commercially available data, and from public information reported in the trade press, as well as the information submitted by the manufacturers to the Federal government in connection to the auto restructuring plans.[175] Generally, because of projected large sales of hybrids and to a lesser extent, sales of diesel vehicles, EEA projected that Toyota and Honda will meet California GHG standards through 2012, and that Nissan may have a shortfall in LDV/LDT1 for 2012, but will easily comply with LDT2/MDV in 2012, and will be able to meet the 2012 standards by trading between categories and using banked credits from prior years.

For the domestic manufacturers, EEA noted concerns about compliance with the California GHG standards, in part because these companies have Federal CAFE values which are significantly below the three Japanese companies, meaning that it will be harder for them to reach the target. Nevertheless, the EEA report noted that the product plans of these companies show the following industry-wide technology improvements coming on line in the next 4 to 5 years:

—Luxury vehicles adopting GDI across most product lines;
—4 valve OHC/DOHC engines with VVT replacing the few remaining 2-valve OHC 4 and 6 cylinder engines;
—6-speed transmissions replacing 4 or 5 speed units in most mass market vehicles
—Electric power steering replacing hydraulic units in compact and mid size cars;
—Cylinder cut-out applications to V–8 and some V–6 units;
—Variable valve lift used more widely by Japanese manufacturers;
—Introduction of several new diesel models and hybrid models by all manufacturers;
—Introduction of new small ''crossover'' SUV and car models that are one size class below the existing smallest models offered by the domestic manufacturers to compete with the Toyota Scion XD and XB models and the Honda Fit model.

To perform the GHG estimate, the EEA study used the actual fuel economy data by vehicle model for MY 2009, and used the product-plan based technology forecasts to derive fuel economy by model for MY 2010 through 2012. For sales numbers, EEA used 2008 sales data and sales for the first two months of 2009 both nationally and for California as sales indicators for the near term (MY 2009 and 2010). For 2011 and 2012, EEA used the sales forecast it had developed in the 2008 DOE study, which was a 15 million annual sales level of light duty vehicles nationally. The power train mix numbers (engine/transmission combinations) for all years were the 2008 numbers because this was the latest data available from the CAFE data base.

Using this approach, EEA found that all three domestic manufacturers are in

[170] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006 at 24.

[171] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.13. CARB limited this particular analysis to the domestic manufacturers because, in its assessment, ''the international auto companies are better positioned to comply and will unquestionably meet early model year standards.'' As summarized in the first (industry-wide) CARB analysis, although at least one international manufacturer (BMW) projected a slight debit for 2009, all the manufacturers were projected for overall compliance for the period 2009–2011.

[172] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.14.

[173] Natural Resources Defense Council, EPA–HQ–OAR–2006–0173–7176.13, at 5–6. The NRDC testimony also noted that developments in the period between the first waiver hearing (May 2007) and the new hearing strengthen the California case that the GHG standards are cost-effective and technically feasible—namely, higher gas prices, the market shift to cleaner cars and the passage of new Federal fuel economy standards.

[174] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.15.

[175] EEA completed a detailed study of product plans for the Big Six manufacturers for the U.S. Department of Energy in late 2008, and they used that study as a baseline for this report on California GHG compliance.

compliance with current and expected CAFE through 2012, with Chrysler lagging somewhat behind Ford and GM. EEA then translated these forecasts to GHG forecasts for the California vehicle class definitions, assuming no A/C improvement credits or alternative fuel credits, and no trading of credits between manufacturers, and predicted as follows:

—All manufacturers will comply with GHG requirements for 2009;
—GM and Chrysler will comply with GHG regulation in 2010 while Ford is on the edge of compliance. Ford can likely comply by either using banked credits from 2009 or with small adjustments to the power train and sales mix sold in California if necessary;
—Chrysler and GM may be able to meet 2011 GHG standards using banked credits from 2009 and 2010 and credit trading between classes. All three manufacturers could require additional efforts such as air conditioner improvements to comply with 2011 GHG requirements.
—Compliance with 2012 GHG requirements will be a challenge and may require credit trading and banked past and future credits over and above credits from air conditioner improvements and introduction of alternative fuel vehicles.
—The results appear to be very realistic based on the auto-manufacturers public statements of future fuel economy.[176]

Regarding the long-term (MY 2012 and later) outlook, CARB compared the restructuring plans submitted by the automakers to the arguments manufacturers made in this proceeding, regarding later model year feasibility. CARB stated that ''by 2015, even those manufacturers facing the most difficult challenge complying with California's standards have made statements that on their face show they plan to comply with the later model years standards, even before receiving additional credit for GHG reductions from air conditioning improvements and regardless of 2009 and 2010 credits carrying forward.'' [177] For example, CARB cited from the GM restructuring plan that the company stated that it will work to develop any changes needed to * * * meet such additional requirements as California's.[178] Further, at EPA's March 5, 2009 hearing, NRDC pointed out that the plans of both GM and Ford show MY 2012 fuel economy levels for cars and light trucks fleet average that come very close to allowing the automakers to comply with the GHG standards with little or no additional effort.[179] Additionally, CARB noted that Chrysler stated that, should this GHG waiver be granted, the company would try its best to comply using available technology; however, as a last resort it might restrict sales of certain vehicle models in California and other states adopting the California standards, out of necessity.[180] Finally, regarding Ford, NRDC stated in its testimony that Ford plans to improve the average fuel economy by 26 percent by 2012 and by 36 percent by 2015.[181]

4. Manufacturers' Comments on the Technological Feasibility of the GHG Standards

Manufacturers raised arguments regarding the feasibility of the CARB GHG standards both in the underlying rulemaking in California, and in the EPA waiver proceeding. In the CARB rulemaking, the manufacturers generally criticized some aspects of the CARB modeling work that substantiated CARB's conclusions on technological feasibility. For example, a manufacturer argued that CARB overestimated the emission reductions from the powertrain changes in many of the technology packages used in the modeling studies, such as the NESCAAF study. Because the studies assumed changes in the use of advanced transmissions and engines in such a magnitude to be unrealistic for the U.S. fleet, the manufacturer stated that the changes would require retooling of all U.S. driveline plants, perhaps more than once.[182] Manufacturers also argued that the modeling of technology packages risked ''double-counting'' emission benefits produced by the individual technologies, thus producing an unrealistic estimate of emission reductions.[183] CARB responded to these comments by stating that manufacturers were already planning to incorporate advanced transmissions and engine technologies in their vehicles, and that the gradual phase-in of the CARB standards allowed manufacturers to accomplish this during regular scheduled vehicle upgrades. CARB also noted that its modeling done by AVL specifically avoided double-counting (while some manufacturers' modeling did not).

Regarding the EPA waiver proceeding, while the manufacturers did take issue with some of the CARB modeling work during the CARB rulemaking, the manufacturers did not challenge CARB's general conclusions that the necessary technology presently exists to meet the near-term standards, that projected control technologies for future years have been identified, and that objections raised by industry have been answered. Rather, the industry offered an assessment that much of this technology is already at hand. At the first EPA hearing in March 2007, although no individual manufacturer presented testimony, the Alliance of Automobile Manufacturers discussed the progress of the industry in producing more fuel-efficient vehicles. The Alliance stated that ''every model available today is equipped with some kind of fuel efficient technology, including direct fuel injection, variable valve timing, continuously variable transmissions, cylinder deactivations, and more.'' [184] These technologies in the 2007 and 2008 MY vehicles are among those that CARB projected as being in use for the near-term GHG standards (see above discussion on ''Overview of Technologies and Their Projected Applications,'' section VI.B.2).

In comments sent to EPA after the March 2007 hearing, the industry commenters focused on whether there was adequate lead time to comply with the near-term standards, citing testimony from a CARB official (in the Vermont litigation) that some manufacturers may need up to six years to comply with the 2011 MY standards and up to 7 years to comply with the 2012 MY standards.[185] Also, the industry criticized CARB for not providing sufficient information on some technology issues for the EPA (or the public) to make an informed decision.[186] CARB responded to these

[176] California Air Resources Board, EPA–HQ–OAR–2006–0173–9019.15.

[177] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006, at 27.

[178] California Air Resources Board, EPA–HQ–OAR–2006–0173–9021.1, at 21.

[179] Natural Resources Defense Council, EPA–HQ–OAR–2006–0173–7176.13, at 4.

[180] California Air Resources Board, EPA–HQ–OAR–2006–0173–9020.2, at U116, and California Air Resources Board, EPA–HQ–OAR–2006–0173–9020.3, at 118–120.

[181] Natural Resources Defense Council, EPA–HQ–OAR–2006–0173–7176.13, at 4, citing from Ford Motor Company Business Plan, Submitted to the House Financial Services Committee, December 2, 2008.

[182] California Air Resources Board, EPA–HQ-OAR–2006–0173–0010.116, Comment 154 (at 107) and Comments 158–159(–115).

[183] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.116, Comment 162 at 117.

[184] Testimony of Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–0422, at 98.

[185] Association of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–1455.2 at 11–12. The litigation in Vermont is *Green Mountain Chrysler-Plymouth Dodge-Jeep* v. *Crombie,* 508 F. Supp, 295 (D. Vt.).

[186] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–1297.2 at 35–36.

points, stating that the CARB official also testified that most of the CARB-identified technologies are already developed and required only a few years of lead time for implementation. Additionally, based on lead time beginning at the time of the final adoption of the standards by CARB (August 2005), CARB notes that the 6 or 7 year lead time for the 2011 and 2012 model years respectively is reasonable.[187] CARB also provided, in its June 2007 and July 2007 comments, information from the Vermont litigation where various manufacturers testified that they would be able to meet the early years of the California GHG standards.[188] Concerning the list of technical issues on which the industry claimed CARB had not provided enough information to allow public comment, CARB stated that these issues were among many issues previously addressed fully both in submissions to the Docket (primarily the CARB Final Statement of Reasons) as well as in the Federal litigation.[189]

Manufacturers also presented information on technological feasibility at EPA's March 5, 2009 hearing and the subsequent comment period. At the EPA hearing, the Alliance continued to acknowledge technological advances in GHG control. The Alliance stated that ''automakers have made major contributions into developing new fuel efficient technologies and the results are now coming to dealer showrooms. More than 50 technologies offered in vehicles today reduce emissions, increase mileage and allow vehicles to run on cleaner fuels.'' [190] Regarding technological feasibility for the early years (near-term), the industry trade groups generally argued that CARB relied on manufacturer credits for these years to provide a cushion for compliance in the later years, but that the several years of lead time required for mid-term compliance combined with uncertainty resulting from the EPA waiver denial makes even the near-term lead time inadequate.[191] CARB, in its testimony and subsequent comments, presented its new analyses of compliance (for the industry in general, and for GM) that showed industry compliance is likely if not certain for the 2009 through 2011 model years (see discussion above at section VI.B.3.). Additionally, if any individual manufacturers incur a debit in any model year, the CARB regulations provide the manufacturer up to five model years afterwards to make up the debit to avoid any noncompliance penalty.

Regarding the mid-term (2012–2016) model years of the GHG standards, the industry commenters have argued that the only means by which most large-volume manufacturers will be able to meet the CARB standards is by ''mix-shifting'' their product lines to offer for sale more higher mileage vehicles to ensure meeting the CARB fleet average.[192] The Alliance stated that ''it is simply too late for manufacturers to meet all the Pavley standards for future model years through the use of technologies, if for no other reason than because approximately 18 months of the product planning and development cycle was pretermitted while the waiver was denied (assuming for purposed of this analysis that a waiver would be granted in June 2009).'' [193] As discussed earlier, CARB responded to these arguments by noting that in the restructuring plans recently submitted to the government, the manufacturers have made statements demonstrating they plan to comply with the later model years of the CARB standards, even before receiving additional credit for GHG reductions from air conditioning improvements and regardless of 2009 and 2010 credits carrying forward. Regarding the manufacturers' mix-shifting argument, EPA notes that under the narrow standard of review applied to California's technological feasibility determinations, consistency with section 202(a) does not mean that all manufacturers will be able to sell all vehicle models in California and that a reduced product offering in California resulting from California emission standards is a policy decision left to the state.[194]

C. Technological Feasibility and the Cost of Compliance

1. Historical Approach

Congress has stated that the consistency requirement of section 202(a) relates to technological feasibility.[195] Section 202(a)(2) states, in part, that any regulation promulgated under its authority ''shall take effect after such period as the Administrator finds necessary to permit the development and application of the relevant technology, considering the cost of compliance within that time.'' Section 202(a) thus requires the Administrator to first review whether adequate technology already exists, or if it does not, whether there is adequate time to develop and apply the technology before the standards go into effect.

In *MEMA I,* the court addressed the cost of compliance issue at some length in reviewing a waiver decision. According to the court:

> Section 202's cost of compliance concern, juxtaposed as it is with the requirement that the Administrator provide the requisite lead time to allow technological developments, refers to the economic costs of motor vehicle emission standards and accompanying enforcement procedures. *See* S. Rep. No. 192, 89th Cong., 1st Sass. 5–8 (1965); H.R. Rep. No. 728 90th Cong., 1st Sass. 23 (1967), *reprinted in* U.S. Code Cong. & Admin. News 1967, p. 1938. It relates to the timing of a particular emission control regulation rather than to its social implications. Congress wanted to avoid undue economic disruption in the automotive manufacturing industry and also sought to avoid *doubling or tripling* the cost of motor vehicles to purchasers. It, therefore, requires that the emission control regulations be technologically feasible within economic parameters. Therein lies the intent of the cost of compliance requirement.[196]

Previous waiver decisions are fully consistent with *MEMA I,* which indicates that the cost of compliance must reach a very high level before the EPA can deny a waiver. Therefore, past decisions indicate that the costs must be excessive to find that California's standards are inconsistent with section 202(a).[197] It should be noted that, as with other issues related to the determination of consistency with

[187] California Air Resources Board, EPA–HQ–OAR–2006–0173–3601, at 26–27.

[188] CARB referenced the industry assessments of early model year compliance from the litigation in Vermont, *Green Mountain Chrysler-Plymouth Dodge-Jeep* v. *Crombie,* 508 F. Supp, 295 (D. Vt.), California Air Resources Board, EPA–HQ–OAR–2006–0173–1686 at 20–21, California Air Resources Board, EPA–HQ–OAR–2006–0173–3601, at 27–28.

[189] The list of issues and the CARB response are discussed in the CARB July 2007 letter. EPA–HQ–OAR–2006–0173–3601, at 26.

[190] Testimony of Association of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–7177, at 108.

[191] Association of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994.1, at 24–25; Association of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–9005.2 at 4.

[192] Regarding mix-shifting, the National Automobile Dealers Association also commented that this would be costly to dealers who would lose business due to the ''scrappage effect'' (see above pp 46–49), being forced to accept smaller vehicles regardless of local consumer demand, rationing of larger vehicles, and out-of state dealers unencumbered by CARB's regulations. National Automobile Dealers Association, EPA–HQ–OAR–2006–0173–8956.1, at 8–9.

[193] Association of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994.1 at 26.

[194] 40 FR 23102, 23103 (May 28, 1975).

[195] H.R. Rep. No. 95–294, 95th Cong., 1st Sess. 301 (1977).

[196] *MEMA I* at 1118 (emphasis added). *See also id.* at 1114 n. 40 (''[T]he 'cost of compliance' criterion relates to the timing of standards and procedures.'').

[197] *See, e.g.,* 47 FR 7306, 7309 (Feb. 18, 1982), 43 FR 25735 (Jun. 14, 1978), and 46 FR 26371, 26373 (May 12, 1981).

section 202(a), the burden of proof regarding the cost issue falls upon the opponents of the grant of the waiver.

Consistent with *MEMA I,* the Agency has evaluated costs in the waiver context by looking at the actual cost of compliance in the time provided by the regulation, not the regulation's cost-effectiveness. Cost-effectiveness is a policy decision of California that is considered and made when California adopts the regulations, and EPA, historically, has deferred to these policy decisions. EPA has stated in this regard, ''the law makes it clear that the waiver request cannot be denied unless the specific findings designated in the statute can be made. The issue of whether a proposed California requirement is likely to result in only marginal improvement in air quality not commensurate with its cost or is otherwise an arguably unwise exercise of regulatory power is not legally pertinent to my decision under section 209 * * *'' [198] Thus, under the language of section 202(a)(2), EPA will look at the compliance costs for manufacturers in developing and applying the technology with the costs being broken down on a cost per vehicle or unit basis.

2. Technology Cost Information in This Proceeding

At the time of CARB's original waiver request, CARB presented the projected technology costs for the GHG vehicle standards based on cost estimates for necessary components provided by Martec, the company that did the modeling studies that produced the CARB technology assessment in its ISOR. The costs were calculated by applying a mark-up factor, determined by the Argonne National Laboratory, for the components needed for the vehicles. Additionally, CARB assumed an additional 30% discount for a limited number of components where unanticipated improvements in production processes or simplifications or consolidation in parts after additional further development would be likely.[199]

At that time, CARB stated that the average cost of control for near-term technology packages on PC/LDT1 category vehicles was estimated at $383 per vehicle, and for LDT2/MDV category vehicles was estimated at $327 per vehicle. Performing similar calculations for the mid-term technology packages, CARB put the estimates for PC/LDT1 at $1,115, and for LDT2/MDV at $1,341. CARB also presented information on the estimates of costs for the ''major 6'' manufacturers cost of compliance over the term of these standards. These figures ranged from $0 (for the three Japanese companies and GM) for the 2009 MY (*i.e.,* the fleets of these companies would comply with the 2009 standards with no changes) to the highest costs in the 2016 MY, with a $1,288–$1,341 range for the domestic manufacturers and a $272–$298 range for the Japanese manufacturers.

During the CARB GHG rulemaking, the manufacturers commented that CARB underestimated costs of individual technologies because CARB did not use the manufacturers' costs to individually develop each of the technologies, and CARB used a mark-up factor for final technology cost that was too low. The Alliance commissioned a study by Air Improvement Resources, NERA Economic Consulting, and Sierra Research (the above noted ''June 2007 AIR/NERA/Sierra Study'') that found the average vehicle cost increase to be about $3000, several times larger that the CARB estimates. In response, CARB provided a detailed critique of why the cost conclusions in this study were not reasonable. CARB found faulty technical analysis and inflated component costs.[200] In the time period since the CARB request, CARB has updated its technology cost estimates with new real-life information to show that manufacturers are continuing to implement the GHG technology packages and combinations CARB had identified at the outset—at costs in line with CARB's projections.[201]

EPA also received comments from the National Auto Dealers Association (NADA) and the National Association of Minority Automobile Dealers (NAMAD) concerning the costs of the CARB standards to its constituents, above the costs that GHG technology adds to the vehicle price to buyers. NADA notes that because of ''dire financial straits'' in the auto industry due to the economic recession, dealers are experiencing financial difficulties from vastly reduced vehicle sales (among other problems). NADA believes that if this waiver is granted, and the various other states which have adopted the GHG standards begin their own programs, the result will be a ''state-by-state patchwork approach to fuel economy that would fill their lots with more unsold vehicles.'' [202] NAMAD believes that ''dealer will lose sales if automakers have to ration delivery of large vehicles in CARB (Section 177) states to meet the fleet average, and * * * if dealers are forced to take delivery of more small cars that their customers don't want, dealers will be stuck paying the interest charges while these vehicles sit on their lots.'' [203] EPA notes the comments of NADA and NAMAD on this particular type of cost, but also notes that these comments are not relevant to the issue of whether the technology feasibility of the GHG standards are consistent with section 202(a). The comments regarding the ''patchwork'' of the GHG standards in other states are discussed below in section VII. B. 2.

3. Consistency of Certification Test Procedures

The enforcement procedures that accompany California's greenhouse gas standards would also be inconsistent with section 202(a) if the California test procedures impose testing requirements inconsistent with the Federal testing requirements. Such inconsistency means that manufacturers would be unable to meet both the California and the Federal test requirements with the same test vehicle.[204]

CARB stated in its December 2005 Waiver Request letter that there ''are no Federal test procedures that measure GHG for climate change purposes, [so] there are no potential inconsistencies precluding a manufacturer from using the same test vehicle to meet both Federal and California requirements'' and noted in its most recent (April 2009) comment letter that this was still true.[205]

EPA received no comments suggesting that CARB's GHG testing requirements pose a test procedure consistency problem with federal test procedures.

4. Safety Implications of the CARB GHG Standards

The industry raised a vehicle safety issue for consideration within the technological feasibility criterion. The industry has proffered the idea that the CARB GHG standards will result in the production of vehicles which will be unsafe for two reasons. First, they claim

[198] 36 FR 17158 (August 31, 1971). *See also* 40 FR 23102, 23104; 58 FR 4166 (January 7, 1993), LEV Waiver Decision Document at 20.

[199] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 40.

[200] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.116 at 141–155.

[201] California Air Resources Board, EPA–HQ–OAR–2006–0173–1686 at 19, and EPA–HQ–OAR–2006–0173–3601 at 28–29. CARB also notes that in the Green Mountain case, 508 F. Supp. 2d at 365–366, the Court found that the industry consultant's (T. Austin) baseline assumptions and resulting cost estimates—double that of defendants' expert—were unsupported by the evidence.

[202] National Automobile Dealers Association, EPA–HQ–OAR–2006–0173–8956.1 at 5–6.

[203] Testimony of National Association of Minority Automobile Dealers, EPA HQ–OAR–2006–0173–7177, at 126–127.

[204] *See, e.g.,* 43 FR 32182 (Jul. 25, 1978).

[205] California Air Resources Board, EPA–HQ–OAR–2006–0173–0004.1 at 42 and EPA–HQ–OAR–2006–0173–9006 at 29.

that many GHG-compliant vehicles will achieve compliance because they will be downsized, and will be inherently less safe in collisions. Second, they claim that because GHG-compliant vehicles will also have higher fuel economy than today's fleet, owners will drive more, and that additional VMT means more accidents will occur. The industry asserts that because the GHG standards will cause these problems, the resulting vehicles are technologically infeasible because of the safety concerns.

EPA takes safety into account in evaluating technology, feasibility and lead time of California emission standards. For example, when CARB in 1994 requested authorization for its original set of emission standards for small spark-ignition engines used in utility, lawn and garden equipment, the industry trade association raised safety concerns in the EPA authorization proceeding. The industry argued that compliance with the CARB standards would require the use of catalyst technology in equipment, and that current catalysts produced high exhaust and surface temperatures, and could also possibly cause sparking and flaming, so these safety issues must be addressed before this technology could become feasible, and the authorization should be denied on that basis. EPA examined these safety issues within the traditional consistency with section 202(a) criterion, with the requisite deference given to CARB and the burden placed on those arguing that safety concerns should give cause for EPA to deny the authorization. CARB responded to the industry objections by offering a detailed review of steps necessary to refine small engine catalyst technology to meet the standards while reducing the high temperature risks, as well as identifying some current small engines that met the standards without using a catalyst. After reviewing all relevant information from CARB and other commenters on the safety issues (and other technological feasibility issues) the Administrator stated he was "unable to make the finding that the CARB Tier 2 standards are not technologically feasible within the available lead time." [206]

In the California GHG proceeding, CARB has responded to the industry safety arguments, both during the underlying California rulemaking and in comments submitted to EPA in this waiver proceeding. In summary, CARB rejected the industry arguments in several ways. First, it pointed out that under the terms of AB 1493, CARB is precluded from requiring vehicle down-weighting as a means of achieving compliance. Second, CARB has laid out a broad pathway of potential technologies for achieving compliance for all vehicle types, none of which require any weight reduction of vehicles. Third, CARB notes that an industry study (Sierra 2004) shows that weight reduction is far from cost-effective and therefore becomes an unlikely compliance option. Fourth, CARB submitted reports from experts that tend to dispute any safety impacts from the GHG standards by demonstrating that any weight reduction that may be made to comply with the GHG standards need not adversely affect vehicle safety. Finally, the opponents VMT safety theory is entirely based on their flawed rebound and fleet turnover arguments (discussed above in section IV.C.2).

Regarding the safety issue, EPA notes that CARB has provided considerable evidence that its GHG standards can be met without any increase in concern regarding vehicle safety. Even accepting the industry arguments regarding the safety implications of downsizing—which are disputed by CARB, particularly for downsizing of larger vehicles—EPA cannot make the finding that the CARB standards are technologically infeasible because manufacturers may choose to use a method of compliance that is not as safe as the methods CARB has identified, particularly where there are many business reasons for manufacturers not to choose such a method. The burden, here, is on manufacturers to demonstrate that safety concerns with the technology available for compliance were unavoidable and substantial and that manufacturers would have no reasonable technological option available to them in the lead time provided for compliance. Based on the entire record, they have not made such a demonstration. Beyond this limited type of review under section 209(b), EPA's proper role is to leave for California the judgment of what greenhouse standards are appropriate in light of safety concerns raised by manufacturers.

With regard to the claim that increased VMT will increase the number of accidents, this argument is not relevant to the safety of the vehicle but to an outcome based on the possible actions or changes of driving patterns of people who own these vehicles. This argument does not go to the technological feasibility of the vehicle itself. This is a public policy argument that is left for California's discretion but is not relevant to the narrow technological feasibility analysis authorized for EPA under section 209(b).

For these reasons, EPA finds that the industry opponents of this waiver request, with respect to the vehicle safety impact of the CARB GHG standards have not met their burden of proof for EPA to find that these standards are not consistent with section 202(a) of the Act.

E. Conclusion on Technological Feasibility

After its review of the information in this proceeding, EPA has determined that CARB has demonstrated a reasonable projection that compliance with its GHG standards is reasonable, based upon the current and future availability of the described technologies in the lead-time provided and considering the cost of compliance. The industry opponents have not met the burden of producing the evidence necessary for EPA to find that California's GHG standards are not consistent with section 202(a).

With regard to motor vehicles required to meet the near-term standards for the 2009 through 2011 model years, the CARB technical information presented in this record clearly indicates that these requirements are feasible. CARB has presented the case that the industry as a whole will be able to meet these standards for this period—for the 2009 and 2010 model years—with compliance with the standards including credit generation, and for the 2011 model year—with a carry-forward of credits earned in the 2009 and 2010 model years. Within the industry, several manufacturers are not expected to need credits to comply in the 2011 model year. Moreover, California has provided several technological avenues that are currently available for meeting the 2011 MY standards without the need for credits. Manufacturers have provided no evidence that these technologies cannot be applied to meet the 2009–2011 MY standards.

For the mid-term standards, 2012 MY and beyond, CARB again identified various and reasonable technological avenues that manufacturers could use to meet the mid-term standards. CARB initially presented that the continued use of technologies identified for the near-term along with more sophisticated technologies and the expected upswing in hybrid-electric and diesel vehicles would result in industry compliance for these years. In its June 2007 comments,

[206] Decision Document, Authorization of California's Under 25 Horsepower Utility Lawn and Garden Equipment Engine Exhaust Emission Standards (ULGE) (July 5, 1995), EPA Docket A–91–01 at 61–70.

CARB noted that it expected manufacturers to use combinations of the initially introduced technologies to meet the mid-term standards and cited several examples of this already happening in several manufacturers' products. CARB also noted that in 2007, manufacturers were aggressively introducing new hybrid vehicles well ahead of the mid-term standards. For the longer term, as noted earlier, CARB states that ''by 2015, even those manufacturers facing the most difficult challenge complying with California's standards have made statements that on their face show they plan to comply with the later model years of standards, even before receiving additional credit for GHG reductions from air conditioning improvements and regardless of 2009 and 2010 credits carrying forward.'' [207]

In its comment submitted after EPA's March 5, 2009 hearing, CARB summarized the industry discussion on technological feasibility as follows:

> In our July 24, 2007 comments CARB stated ''* * * not a single manufacturer from either the Alliance or AIAM has independently presented any substantive comment concerning the principal and proper focus of the (EPA) proceeding—the technological feasibility and lead time for those manufacturers to comply with the subject greenhouse gas standards.'' Document ID No. EPA–HQ–OAR–2006–0173.3601 at 26. That statement remains true today, and stands in stark contrast to the renewed demonstration CARB has made in this reconsideration proceeding.[208]

Regarding the lead time provided by California to meet the near-term and the mid-term and later standards, the commenters have not met their burden to show that the lead time is insufficient. California provided manufacturers 4–5 years before the near-term GHG standards would go into effect and 8–9 years before the later standards, giving substantial time for development of technologies to meet the standards. The industry commenters have not shown that this lead time was insufficient, both for the near-term GHG standards, that were based on technologies already known and developed, as well as for the mid-term GHG standards, where CARB provided a reasonable pathway to be followed—answering theoretical objections, identifying major steps needed to refine technology, and offering plausible reasons for predicting successful technologies.[209]

Regarding the cost component of the technological feasibility test, EPA believes that the opponents of the waiver have not met the burden of proof to show that the GHG standards are not technologically feasible because of excessive cost. The industry cost study (from Sierra Research) from the CARB rulemaking found an average vehicle cost increase of about $3,000 to comply with the CARB standards, an increase which CARB rebutted in detail, and which was also found not credible by the district court in the Vermont litigation. Alternatively, even if the industry estimates were closer to the mark than the CARB estimates, CARB points out that Congress was concerned with standards causing a *doubling or tripling* of vehicle costs (MEMA 627 F.2d at 1118), not the cost increases that CARB has projected (ranging from under $100 for some manufacturers in near-term to a maximum of $1,100 to $1,350 for vehicles in the 2016 MY).[210]

Therefore, for the above reasons, I am unable to find that the CARB GHG motor vehicle emission standards are not technologically feasible within the available lead-time giving consideration to the cost of compliance.

F. Other Issues Related to Consistency With Section 202(a)

1. Impact of EPA's March 6, 2008 Denial on Lead Time

In EPA's February 12, 2009 **Federal Register** notice, EPA specifically sought comment on the effect of the March 6, 2008 Denial on whether CARB's GHG standards are consistent with section 202(a), including lead time.

In comments submitted for this reconsideration, the industry commenters asserted that any lead time clock that may have been running should have stopped completely and immediately upon EPA's March 6, 2008 Denial. Both the Alliance of Automobile Manufacturers and the Association of International Automobile Manufacturers noted that even CARB officials testified that manufacturers should have started development of their 2010–2012 MY product lines at the time the final standards were finalized in the 2004–2005 time frame, and that there should be a presumption that the industry could and would stop ongoing development efforts when this waiver was denied.[211] In its comments, the Alliance noted that it should not be assumed that a ''retroactive'' waiver would impose no hardship because manufacturers are able to earn credits for sales for the 2009 and 2010 MYs in advance of any waiver grant. They claim that the regulated parties would have conducted their business differently if they knew in advance that these regulations would be enforced.[212]

On the other hand, CARB urges EPA to reject the argument that the March 6, 2008 Denial tolled the lead time countdown. CARB noted that it always maintained that it intended to enforce the GHG standards from their start point for the 2009 MY, discussed how it pursued promptly all available avenues to overturn the March 6, 2008 Denial, and noted that the denial was all but guaranteed to be revisited because its waiver request was supported by both candidates for President in 2008. Additionally, CARB argues that any period the March 6, 2008 Denial was in effect was not significant compared to the four to ten years of lead time available to the manufacturers, and that technological advancements continued to appear during the denial period.

The manufacturers argue that EPA's earlier denial was reasonably relied upon by manufacturers, that the denial tolled or suspended lead time and allowed them to stop working towards compliance, which affects the adequacy of the lead-time for California's standards. This amounts to an argument that they reasonably had the opportunity to stop work towards

[207] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006 at 27.

[208] California Air Resources Board, EPA–HQ–OAR–2006–0173–9006 at 29. CARB also noted, that in the final efforts to persuade EPA to deny this waiver, waiver opponents cited policy arguments against the waiver, such as the preference for a uniform national standard to avoid a ''patchwork'' of state regulations, rather than any attack on the technological feasibility of the standards.

[209] Regarding lead time, some industry comments suggest that EPA should count lead time from the time the waiver is granted. EPA, however, believes that lead time should run from the time the rule is adopted by California. As EPA made clear in its waiver decision for California's standards regulating medium-duty motor vehicles (59 FR 48625 (Sept. 22, 1994), Decision Document at 39–41), lead time should generally be measured from the point at which California adopts its regulations. At that point, the regulations, and their obligations on regulated parties, are clear. EPA measures lead time for its regulations from the time of promulgation, which is analogous to California's adoption of its regulations. EPA review of CARB waiver requests causes no more uncertainty than judicial review of EPA regulations. In addition, California and regulated parties do not know when EPA will make a final decision on a request for waiver of preemption, so California would have little ability to evaluate lead time at the time it adopts its standards if lead time were based on a future action by another entity the timing of which is uncertain. In any case, the commenters have not shown that the amount of lead time provided from the date of the waiver is insufficient.

[210] California Air Resources Board, EPA–HQ–OAR–2006–0173–0010.14 at 80–83 and, EPA–HQ–OAR–2006–0173–0004.1 at 39–40.

[211] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994.2 at 27, and, Alliance of International Automobile Manufacturers, EPA–HQ–OAR–2006–0173–9005.2 at 16, Note 4.

[212] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173–8994.2 at 23–25, *see also* National Automobile Dealers Association, EPA–HQ–OAR–2006–0173–8956.1, at 10–12.

compliance at that point if they chose. However it does not change the basic issue before EPA: whether the manufacturers, as opponents of the waiver, demonstrated that the standards are not consistent with section 202(a) because of inadequate lead time.

Based on a review of the entire record, and even assuming the reasonableness of the manufacturers' claim that they could have reasonably stopped work towards compliance upon the March 6, 2008 Denial, the industry commenters have not shown that the lead time provided under these circumstances was insufficient. This is particularly true regarding the near-term GHG standards, which were based on technologies already known and developed. But this is also true for the mid-term GHG standards, where CARB provided a reasonable pathway to be followed—answering theoretical objections, identifying major steps needed to refine technology, and offering plausible reasons for predicting successful technologies.[213] I believe that this is borne out by the evidence submitted to the record by CARB and the NRDC, which show industry-wide compliance with the near-term GHG standards and with future-term compliance attainable using technology developments as well as early credits. Manufacturers have not come forward with evidence to show that they cannot feasibly achieve the near-term or mid-term GHG standards, based on lead time. Although the industry trade association comments generally discussed manufacturers' reliance on the EPA waiver denial to suspend or stop planning for California compliance, no manufacturer came forward and asserted that it actually stopped planning. Whatever disruptions may or may not have occurred as a result of the denial, near-term standards have clearly been shown to be feasible and mid-term standards are clearly feasible given the lead time provided, even taking account of the denial.

Regarding implementation and enforcement by CARB for the 2009 MY, manufacturers claim that approving the waiver for that year would be a retroactive grant of a waiver and would be improper. However, approval of the waiver for the 2009 MY technically would not be a retroactive action. EPA would not be determining that past conduct was or was not lawful when it occurred in the past, or rewriting past legal obligations. The legal obligation at issue is still a future obligation—compliance with the annual fleet-averaging requirements for the 2009 MY standards by the end of 2009, based on sales throughout the year. The fact that some conduct which occurred in 2009 prior to the grant of the waiver is relevant to determining compliance with the 2009 MY obligation, after the end of the model year, does not by itself make the obligation to comply with the 2009 MY standards a retroactive legal obligation. In any case, even if a waiver for the 2009 MY was considered to impose retroactive obligations, EPA has the authority in an adjudication to take such action under appropriate circumstances.[214]

Under these circumstances, all of the evidence presented to date indicates that manufacturers will be in compliance with the 2009 standards. EPA is granting the waiver for 2009 and later years. However, out of an abundance of caution, and since any delay in granting this waiver stems from EPA's prior March 2008 Denial, EPA is imposing one specific limitation designed to ensure that CARB not hold a manufacturer liable or responsible for any noncompliance civil penalty action that could be caused by emission debits generated by a manufacturer for the 2009 model year. For the 2009 model year, CARB can fully implement and enforce its regulations, including implementation of CARB's Executive Orders for 2009 model year families issued both before and after the date of today's waiver, as described below. While debits from model year 2009 may offset credits generated in later years, and reduce the amount of credits available to a manufacturer, any debits from model year 2009 may not be used as a basis for holding a manufacturer in noncompliance and no civil penalties may be assessed based on such debits. Other than that restriction, CARB may fully implement and enforce, and manufacturers may use the GHG standards program as promulgated, such that CARB may implement certification for MY 2009 motor vehicles, and may grant manufacturers credits that can be used for future obligations. This restriction on handling of any possible debits appropriately limits any potential concern raised by manufacturers over their potential reliance upon EPA's previous waiver denial.

2. Endangerment of Public Health or Welfare

a. Is it Appropriate To Review Endangerment of Public Health or Welfare Under the ''Consistency With Section 202(a)'' Criterion?

EPA has traditionally stated that a state standard would be inconsistent with section 202(a) if there is inadequate lead time to permit the development of the necessary technology, given the cost of compliance within that time, or if the Federal and State test procedures impose inconsistent certification requirements.[215] The legislative history of this provision and judicial precedent indicate that technological feasibility in the lead time provided was intended to be the primary focus of this criterion.[216]

However, several industry commenters have suggested that in the context of this waiver, it is also appropriate for EPA to include endangerment to public health or welfare in its evaluation of consistency with section 202(a). They note the language in section 202(a)(1) of the Clean Air Act that requires the Administrator to promulgate standards ''applicable to the emission of any air pollutant * * * which in his judgment cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.''

While acknowledging the limits of EPA's traditional review under the ''consistency with section 202(a)'' criterion, they note that previous waivers have generally reviewed standards designed to reduce concentrations of air pollutants, like criteria air pollutants that EPA has listed under section 108 of the CAA, for which an endangerment finding required under section 202(a)(1) has already been made. Even standards regulating PM and formaldehyde, for which EPA has granted waivers, involved pollutants that had been identified by EPA, or by Congress in the Clean Air Act, as needing regulation. Thus, the question of endangerment was not in dispute in previous waivers. By contrast, EPA has not made any final decision regarding whether emissions of GHGs from new motor vehicles cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare (this two-part

[213] EPA notes here (again) that lead time begins when California promulgates its standards, not when the waiver is granted.

[214] *Securities and Exchange Commission* v. *Chenery Corp.,* 332 U.S. 194 at 203 (''That such action might have a retroactive effect was not necessarily fatal to its validity. Every case of first impression has a retroactive effect, whether the new principle is announced by a court or by an administrative agency. But such retroactivity must be balanced against the mischief of producing a result which is contrary to a statutory design or to legal and equitable principles. If that mischief is greater than the ill effect of the retroactive application of a new standard, it is not the type of retroactivity which is condemned by law.'').

[215] 68 FR 19811, 12 (April 22, 2003).

[216] *MEMA III,* 142 F. 3d at 463; *Ford,* 606 F. 2d at 1296, n. 17, 1297; H.R.Rep, No. 728, 90th Cong, at 22–23.

test is hereafter referred to as ''endangerment''). This is a requirement for EPA to issue regulations under section 202(a).[217] Thus, the commenters state that there is an issue for review in this waiver under the consistency with section 202(a) criterion that was never relevant for EPA's review of previous waiver requests.

In contrast, CARB states that no new test of consistency with section 202(a) is warranted or permissible. CARB argues that precedent shows that nothing more than technological feasibility and test compatibility is required under section 209(b)(1)(C).

I find that in this instance, I do not need to resolve the issue of whether it is appropriate to address the issue of endangerment under the consistency with section 202(a) criterion of section 209(b). This is because in this instance, I find that even if the issue of endangerment is relevant to EPA's evaluation of consistency with section 202(a), those opposing the waiver have not met their burden of proving that California's regulations are inconsistent with section 202(a) based on that concern.

b. Parties Opposing the Waiver Have Not Met Their Burden of Showing Lack of Endangerment to Public Health or Welfare

As noted above, parties opposed to a waiver have the burden of proof to show that one of the findings under section 209(b)(1) should be made. To the extent that the two-part endangerment test is relevant to a determination of consistency with section 202(a), those opposing a waiver must affirmatively demonstrate that California's standards are inconsistent with this criterion. They have failed to do so in this instance.

Commenters who claim that EPA should deny the waiver generally base their claim on the fact that EPA has not yet determined whether greenhouse gas emissions from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, or promulgated greenhouse gas standards pursuant to section 202(a). They claim that unless and until EPA makes such a determination that authorizes regulation under section 202(a), EPA cannot grant a waiver to California. They also state that the fact that the current California waiver request pertains to global climate change emissions, rather than to conventional pollutants, means that EPA should not give California's waiver request a presumption of consistency under Section 209(b)(1)(C).

In contrast, commenters supporting the waiver request contend that EPA's lack of a determination on endangerment and lack of GHG emission regulations is not relevant to EPA's consideration of the waiver request. CARB notes in its comments that EPA may not find inconsistency on the ground that EPA must first make its own endangerment finding on GHG emissions before granting California's waiver request. CARB suggests that *Massachusetts* v. *EPA*'s contemplation of coordinated activity at the federal level is entirely irrelevant to the waiver. CARB also provides significant discussion on this issue providing evidence that, according to CARB, shows that global climate change does endanger public health and welfare.

Manufacturer suggestions that EPA should deny California's request because it has not yet made a finding of endangerment mistake the burden of proof that opponents of a waiver are obliged to meet before EPA must deny a waiver. To deny a waiver based on section 209(b)(1)(C), EPA must find that California's standards ''are not consistent with section 202(a).'' It is not enough that EPA has not made a decision on the subject of whether GHG standards are authorized under section 202(a). To deny a waiver the Administrator must affirmatively find that the standards are inconsistent with section 202(a). The initial presumption of consistency is not dependent on the pollutants being regulated, as suggested by commenters—the presumption is provided for in the statute.[218] Regarding endangerment, therefore, I believe that, to the extent it is even an appropriate criterion under section 209(b)(1)(C), it would not be appropriate to deny a waiver request unless it is affirmatively demonstrated that the pollutants being regulated do not ''cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare.''

To the extent endangerment is relevant to whether California's standards are consistent with section 202(a), this criterion should be narrowly interpreted and should require more than the fact that EPA has not yet made a final decision concerning endangerment. Denial of a waiver based on this issue should require either a previous determination by EPA on the merits that the endangerment test has not been met, or a demonstration in this proceeding by the opponents of the waiver that EPA could not find that the endangerment test is met. Lack of a final decision by EPA on this would not be sufficient to deny the waiver. Those opposing the waiver cannot simply point to an open question regarding the issue at hand—on the contrary, they must come forward with evidence demonstrating that California's standards are not consistent with section 202(a).[219]

In order to regulate emissions of a particular pollutant under section 202(a), EPA must review several issues, including whether the emissions of the pollutant from motor vehicles cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare, and whether the standards are technologically feasible within the lead time provided. EPA has to make such determinations as part of lawfully adopting GHG standards under section 202(a). However, lack of either kind of action by EPA is not by itself evidence that GHG standards are in fact inconsistent with section 202(a). The fact that EPA has not yet made either determination, in the context of its own rulemaking, is by itself not a basis to deny a waiver.

Congress understood that California may act a ''laboratory for innovation'' in the regulation of motor vehicles, and intended section 209 to allow such innovation.[220] Yet the ability of California to encourage such innovation would be greatly compromised if EPA were to determine that California could take no action under section 209 unless EPA had already made all of the necessary determinations regarding the consistency of its own standards in the context of its own regulation under section 202(a).

In similar instances where EPA reviewed California standards and EPA had not promulgated similar standards, EPA has determined that the absence of EPA standards does not by itself preclude a waiver or prevent its ability to review California's standards under section 209. Any comparisons necessary

[217] On April 24, 2009, EPA published a notice proposing to find that elevated concentrations of greenhouse gases in the atmosphere are reasonably anticipated endanger the public health and welfare of current and future generations and also proposing to find that emissions of carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons from new motor vehicles and new motor vehicle engines are contributing to this air pollution under section 202(a) of the Clean Air Act. 74 FR 18885, 18886.

[218] See *MEMA I,* 627 F. 2d at 1121 (''The language of the statute and its legislative history indicate that California's regulations, and California's determination to comply with the statute, when presented to the Administrator are presumed to satisfy the waiver requirements and that the burden of proving otherwise is on whoever attacks them.'').

[219] See *MEMA I,* 627 F. 2d at 1126.

[220] *See MEMA I,* 627 F. 2d at 1111.

under section 209 would simply take account of the absence of EPA regulations, *i.e.,* the comparison would be California standards to the absence of EPA standards. For example, under the similar procedures of section 209(e), EPA authorized California to enforce its standards on evaporative emissions for small nonroad engines despite the fact that EPA had not yet promulgated evaporative standards for such engines.[221] In any case, commenters' discussions of ''comparisons to federal standards'' in this context is more suited to review of section 209(b)(1)(A), which discusses comparisons between California and applicable federal standards. Section 209(b)(1)(C) concerns whether California standards are consistent with section 202(a). This criterion is not dependent on the existence of comparable federal standards.[222]

An additional reason for interpreting the waiver criterion this way, and not determining inconsistency with section 202(a) based on lack of an EPA final decision on an issue, is that EPA may always take action in the future that may impact the criteria for a waiver. For example, if in the future EPA promulgated standards that were more stringent than California's standards, this could implicate the ''protectiveness'' criterion of section 209(b)(1)(A). The possibility of such future events should not be used as a reason to deny a waiver now. Instead, the impact of a future EPA action should be considered if and when EPA takes action. Otherwise, the waiver could be denied now, even though in the future it could be determined that it should have been granted. This would tend to reverse the statutory presumption of the grant of waiver unless opponents demonstrate it should be denied for certain specific reasons. Instead, it would be denied because of some future possible action that may or may not occur, and may be delayed for an unspecified period of time. Basing a denial on the possibility of events that may happen in the future is not consistent with Congress' goal to preserve the broadest possible discretion to California. A more prudent approach is to take action based on the record at hand, with the possibility of reviewing such action in the future if facts change that merit such a review. As discussed above in section IV.C.1, EPA may withdraw a waiver in the future if circumstances make such action appropriate.

It is important to remember that the criterion being reviewed under section 209(b)(1)(C) is consistency with section 202(a) and not consistency with EPA standards. EPA has considerable deference within section 202(a) to promulgate the regulations it believes are most reasonable. The test for EPA under section 209(b)(1)(C) is not whether California standards are the same as the standards that EPA has promulgated or would promulgate under section 202(a), but whether the opponents of the waiver have met their burden to show, based on the record before the Agency, that the standards promulgated by California could not lawfully be promulgated in a manner consistent with section 202(a). As a prior Administrator has stated:

> I would feel constrained to approve a California approach to the problem which I might also feel unable to adopt at the federal level in my own capacity as a regulator. The whole approach of the Clean Air Act is to force the development of new types of emission control technology where that is needed by compelling the industry to ''catch up'' to some degree with newly promulgated standards. Such an approach * * * may be attended with costs, in the shape of a reduced product offering, or price or fuel economy penalties, and by risks that a wider number of vehicle classes may not be able to complete their development work in time. Since a balancing of these risks and costs against the potential benefits from reduced emissions is a central policy decision for any regulatory agency under the statutory scheme outlined above, I believe I am required to give very substantial deference to California's judgments on this score.[223]

In this case, opponents of the waiver have not met their burden of proving that EPA could not find that emissions of GHGs from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. To the contrary, while California and others have provided a great deal of evidence regarding the dangers posed by GHGs, opponents of the waiver have not provided significant evidence that emissions of GHGs from motor vehicles do not cause or contribute to air pollution that can reasonably be anticipated to endanger public health or welfare. The recent EPA proposal to find that elevated concentrations of greenhouse gases in the atmosphere are reasonably anticipated to endanger public health and welfare, and to find that emissions of carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons from new motor vehicles and new motor vehicle engines are contributing to this air pollution under section 202(a) of the Clean Air Act is further indication that opponents of the waiver did not meet their burden of proof on this issue.[224] Thus, I cannot find that those opposing the waiver have met their burden of proving that California's GHG standards are not consistent with section 202(a) for reasons of the endangerment test.[225]

G. Section 209(b)(1)(C) Conclusion

Based on its review of the information in the docket of this proceeding, I have determined that the opponents have not met their burden to demonstrate that the CARB GHG standards are not consistent with section 202(a). Therefore, I am unable to find that the CARB motor vehicle GHG emission standards are not consistent with section 202(a) of the Act.

VII. Additional Issues Raised

A. EPA's Administrative Process for Evaluating California's Waiver Request

1. Public Comment Process

Section 209(b)(1) states in part that ''The Administrator shall, after notice and opportunity for public hearing, waive application of this section * * *'' In response to this language, EPA has consistently announced in the **Federal Register** the opportunity for a public

[221] 71 FR 75536 (December 15, 2006).

[222] Commenter Alliance appears to put much weight on the existence of section 202(b)(3). That subsection was added in 1977 to ensure that where EPA provides a waiver for vehicle standards, vehicles meeting California standards can still receive a Federal certificate and be sold in California and other states where California standards are applicable. This was needed as some of the California standards may not individually be as stringent as federal standards, given the ''in the aggregate'' protectiveness provision. See discussion in *Ford* v. *EPA,* 606 F.2d 1293 (DC Cir. 1979). Without this provision, where more stringent individual federal standards applied, vehicles complying only with California standards could not receive a federal certificate of conformity. The language therefore is designed to deal with situations where federal standards exist, and may be more stringent than California's. It was not intended to add or imply any new substantive requirements regarding the existence of federal standards. Similarly, Alliance's reference to use of the word ''the'' in section 202(b)(2) is directed towards the first criterion of section 209(b), not the third. In any case, the argument raised could at most mean that section 209(b)(2) is not applicable to this waiver request. California does not rely on section 209(b)(2) in its request. Also, as noted above, EPA has long held that the absence of comparable federal standards would not automatically result in a denial of a waiver request under the ''in the aggregate'' criterion because EPA believes the appropriate comparison is between the protectiveness of the California standards as compared to the absence of the federal standards.

[223] 40 FR 23104.

[224] 74 FR 18885 (April 24, 2009).

[225] Some commenters have indicated that if EPA chooses not to deny the waiver based on lack of an endangerment finding, EPA should hold its decision in abeyance until it makes a finding. However, given the burden of proof on opponents of a waiver, and the lack of any significant evidence to the contrary in the record on this issue, I believe it is not appropriate to delay further a decision on this matter.

hearing for any waiver request received from CARB. As a general matter EPA has also offered an opportunity for written comment which has opened on the date of the **Federal Register** notice and closed on a date after the public hearing. As part of EPA's public hearings, the presiding officer has consistently stated that the hearing was being conducted in accordance with section 209(b) of the Clean Air Act and that any interested parties have the opportunity to present both oral testimony and written comments.

EPA has received comment suggesting that EPA has failed to provide any systematic procedure for commenters opposing the waiver to rebut the comments of those commenters supporting the waiver. Because opponents bear the burden of proof, this commenter believes that EPA should not treat the waiver proceeding like an informal rulemaking but instead clearly announce what evidence is admissible and applicable burdens of proof and evidentiary procedures, such as order of proof and argument that parties must follow.[226]

EPA's waiver proceedings and actions under section 209(b)(1) are informal adjudications. In a waiver proceeding, EPA receives a request from one entity (CARB) that is presenting an existing regulation established as a matter of California law. The request is for a waiver of preemption for that party, so it may adopt and enforce the specific regulations. In deciding this request, EPA interprets and applies the three specific criteria established by the Act, and under this provision EPA is required to grant the waiver unless EPA makes one of the three specified findings. EPA applies the pre-existing law, section 209(b), to a specific request covering a specific regulation or regulations, and applies the three statutory criteria to the facts of the specific request. The decision to grant or deny a waiver changes the legal rights of the party before EPA, California. If EPA grants the waiver, then CARB may enforce its state regulations. In that case, the rights and obligations of other parties, for example, the manufacturers, are affected by the operation of the state regulation that is no longer preempted. In addition, under a separate statutory provision, other States may then adopt and enforce California's' standards, under their state law. While these subsequent impacts clearly affect the legal rights and obligations of various parties, the only legal rights and obligations directly determined by EPA in the waiver proceeding are the rights of the State of California to adopt and enforce its state regulations. The other legal impacts flow from the operation of other laws, once the waiver is granted. Therefore EPA believes that its waiver proceedings and actions therein should be considered an informal adjudication rather than a rulemaking. EPA has been conducting its waiver proceedings in this manner for decades, and while Congress has amended provisions in section 209 on two separate occasions, Congress has not chosen to alter EPA's administrative requirements. Instead, Congress has expressed support for EPA's practice in applying and interpreting section 209(b).[227]

EPA disagrees with the suggestion that its waiver proceedings are governed by section 554 of the Administrative Procedure Act (APA) or any other provision of Title 5 of the United States Code, including sections 556, 557 and 558. Section 554 of the APA, regarding formal adjudications, only applies to adjudications required by statute to be determined on the record after an opportunity for an agency hearing. Section 209(b)(1) merely states that the Administrator shall provide notice and opportunity for a public hearing and does not include language stating that EPA's decision shall be on record after an opportunity for a hearing. Conversely, other provisions in the Clean Air Act, including section 205(c)(1) specifically state that EPA's actions shall be made on the record after opportunity for a hearing in accordance with sections 554 and 556 of title 5 of the United States Code. Section 205(c)(1) also requires the Administrator to issue reasonable rules for discovery and other procedures for hearings.

Any potential action on the waiver request is not subject to the requirements of APA section 558(c). Any potential action by EPA would not constitute granting a ''license'' to California. The fundamental purpose of section 209(b) is to waive application of the preemption set forth in section 209(a) of the Act, and is not a formal approval of the type contemplated in the APA. As noted previously, CARB must merely submit its regulations to EPA with a finding that its standards, in the aggregate, are as protective of public health and welfare as applicable federal standards. Unlike a license or permit applicant, the burden of proof is on the opponents of the waiver and EPA must make an affirmative finding of one of the three waiver criteria in order to deny California's waiver request. On the face of the Act, what California receives from EPA is a waiver, not a license or permit.

Contrary to commenter's claim, APA section 558 does not require the ''adversary process'' described in sections 556 and 557 for this action. APA section 558 requires the agency to ''complete proceedings required to be conducted in accordance with sections 556 and 557 of [the APA] *or* other proceedings required by law.'' 5 U.S.C. 558(c) (emphasis added). By complying with the procedural requirements of section 209(b) of the Act, EPA is complying with both the CAA and any relevant standards set in the APA.

Regardless, the approval provision in APA section 558 was not meant to establish additional procedural requirements beyond those required by law. Instead, the goal of the approval provision of the section is to ensure ''that an agency shall hear and decide licensing proceedings as quickly as possible.'' Attorney General's Manual of the APA (1947), 89. *Horn Farms* is not applicable to this situation, as the dicta statement regarding APA section 558 applied only to section 558's provisions regarding revoking a previously granted license, which is not at issue here.

EPA believes that only those actions or sections of the Clean Air Act that specifically reference section 554 or otherwise state that EPA's decision must be determined on the record after an opportunity for a hearing are subject to the formal adjudication requirements of the Administrative Procedure Act. EPA nevertheless, as part of good administrative practice, provides every interested party the opportunity to present oral testimony and provide written comment based on a **Federal Register** notice that clearly sets out the criteria by which EPA will evaluate CARB's waiver requests. EPA believes all commenters, including opponents of the waiver, have had ample opportunity to comment and meet their applicable burdens of proof. Opponents of CARB's GHG regulations and of its waiver request have had ample opportunity to present their viewpoints during the course of CARB's rulemaking and EPA's waiver proceeding. First, as noted in the March 6, 2008 Denial, in response to several requests to extend the comment period during EPA's initial consideration of CARB's waiver request EPA indicated that consistent with past waiver practice, it would continue, as appropriate, to communicate with any

[226] Alliance of Automobile Manufacturers, EPA–HQ–OAR–2006–0173.8994 at C–2 through C–4.

[227] The Committee on Interstate and Foreign Commerce that drafted the amendments to section 209 in 1977 stated that the amendment was ''intended to ratify and strengthen the California waiver provision and to affirm the underlying intent of that provision, *i.e.,* to afford California the broadest possible discretion in selecting the best means to protect the health of its citizens and the public welfare.'' (H.R. Rep. No. 294 301–302 (1977)).

stakeholders in the waiver process after the comment period ended and that it would continue to evaluate any comments submitted after the close of the comment period to the extent practicable.[228] EPA did not receive any request to extend the written comment period during the reconsideration of CARB's request. Opponents have also had the opportunity to submit lengthy comments during two separate comment periods (one of which occurred well after CARB had submitted all of their initial comments) and to testify at three separate public hearings. The regulated industry has in its possession, along with CARB, the necessary information to adequately comment on whether the GHG emission standards are technologically feasible and also what CARB has said about the protectiveness of its standards from both CARB's rulemaking phase and from earlier comments. Opponents have the same access to the necessary information in order to formulate comments in regard to the second waiver criterion at section 209(b)(1)(B).

2. EPA's Reconsideration Process

Upon receiving CARB's January 21, 2009 request for reconsideration of the March 6, 2008 waiver Denial, EPA published a notice on February 12, 2008 notifying the public that EPA was reconsidering its March 6, 2008 Denial, and was providing an additional hearing and the opportunity to submit comment on all issues relevant to the waiver, including inviting comment on certain specific criteria and questions.

EPA received comment suggesting that the February 12, 2009 notice failed to inform the public of relevant issues and contained misleading statements and, therefore, the Agency must issue a new notice before proceeding with any reconsideration of the denial.[229] This commenter notes the EPA fails to discuss the legal standards EPA believes it must meet to justify reconsideration of a major policy action including the legal standards EPA believes governs how it is to reopen a previously decided matter. EPA believes this commenter fundamentally misunderstands the purpose of the February 12, 2009 notice. EPA's February 12, 2009 notice did not constitute a final decision to change the Agency's position with regard to California's greenhouse gas waiver request, and did not implicate any arguable requirement to supply a justification for changing previous interpretations of law or evidentiary findings. The Agency set forth sufficient reason for initiating a reconsideration process, and is under no obligation to provide anything further in the Notice announcing the process. EPA clearly set forth the criteria and issues it would review in the notice for reconsideration, which covered all of the issues relevant under section 209(b). It was unnecessary to provide any further justification for its reconsideration beyond that which was supplied in the notice. Commenters have failed to disclose that any procedural error by EPA prejudiced them in any way, or that EPA's February 12, 2009 notice limited their ability to fully comment on any of the issues relevant to California's request for a waiver.

3. Is a Waiver Required Before California or Section 177 States Adopt California's Motor Vehicle Emission Standards?

Several commenters have suggested that section 209(a), which provides that no ''political subdivision shall adopt or enforce any standard,'' should be read to mean that neither California nor any Section 177 state may ''adopt'' a motor vehicle emission emissions regulation before EPA grants a waiver. Since lead time is an issue under section 209(b)(1)(C), see section VI, EPA believes it appropriate to clarify this issue especially since EPA has previously stated that lead time runs from the date of adoption of the regulation. Similarly, because of the number of states that have already adopted CARB's GHG emission standards EPA believes it appropriate to clarify this issue for purposes of section 177 as well.

EPA believes that section 209(b) on its face provides the necessary clarification as to whether California should adopt its regulations before or after receiving a waiver from EPA. Section 209(b)(1) clearly envisions EPA commencing a waiver process after California has submitted standards that have been adopted. Section 209(b)(1) states in part ''The Administrator shall, after notice and opportunity for public hearing waive application of this section to any State which *has adopted* standards * * *'' (Emphasis added). It would be illogical, if not impossible, for EPA to analyze the criteria in section 209(b) if it does not have a final regulation upon which to do the analysis. It would not be appropriate for EPA to analyze non-final documents that may or may not become final and that may or may not be revised prior to becoming final. Similarly, the courts have long interpreted the Clean Air Act to authorize pre-waiver adoption of California standards by an opt-in state.[230]

B. Scope of EPA's Waiver Review

1. Relevance of the Energy Policy and Conservation Act (EPCA) to the Waiver Decision

In EPA's initial **Federal Register** notice of California's request for a waiver, we requested comment on whether the Energy Policy and Conservation Act (EPCA) fuel economy provisions are relevant to EPA's consideration of the request and to California's authority to implement its vehicle GHG regulations.[231]

EPA received many comments regarding EPCA and its effect, or lack thereof, on this proceeding. Several commenters stated that the provisions of EPCA are not relevant to EPA's waiver determination. They note that the language of section 209(b) limits the authority of EPA to deny a waiver to three criteria and does not reference inconsistency with EPCA (or with any other statute, other than section 202(a) of the Clean Air Act) as a basis for denial. One commenter noted that EPCA was already in existence when Congress strengthened California's authority to adopt motor vehicle emission standards, and Congress indicated no intent to limit such authority based on EPCA. Some commenters noted the Supreme Court decision in *Massachusetts* v. *EPA,* which stated that EPCA does not license EPA to shirk its environmental responsibilities under the Clean Air Act.

Several commenters also provided arguments regarding their view that California's GHG standards were consistent with the provisions of EPCA.

Other commenters stated that California's standards violate EPCA. Several of these commenters noted that EPA and court precedent regarding section 209(b) indicate that EPA cannot rule on EPCA preemption under section 209(b). However, the commenters state that if EPA does consider EPCA-related issues in this waiver proceeding, it must rule that California's standards violate EPCA. One commenter states that recent court cases have created confusion regarding the scope and effect of EPA waivers. The commenters state that if EPA decides not to address the issue of EPCA preemption in this proceeding, it

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[228] 73 FR 12156, 12157 (March 6, 2008).

[229] Utility Air Regulatory Group, EPA–HQ–OAR–2006–0173–8690 at 2–5.

[230] *See Motor Vehicle Manufacturers Association* v. *New York Dept. of Environmental Conservation,* 17 F.3d 521, 533–34 (2d Cir. 1994)—''[T]he plain language of 177, coupled with common sense,'' leads to the conclusion that other states 'may adopt the [California] standards prior to the EPA's having granted a waiver, so long as [the state] makes no attempt to enforce the plan prior to the time when the waiver is actually granted.''

[231] 72 FR 12261.

needs to explicitly state that it is not addressing the issue of express preemption under EPCA or conflict with EPCA, and that those issues are best left to the courts.

As EPA has stated on numerous occasions, section 209(b) of the Clean Air Act limits our authority to deny California's requests for waivers to the three criteria therein, and EPA has refrained from denying California's requests for waivers based on any other criteria. As EPA noted in its initial decision denying California's waiver request, the decision was ''based solely on the criteria in section 209(b) of the Clean Air Act and this decision does not attempt to interpret or apply EPCA or any other statutory provision.'' [232] Where the Court of Appeals for the District of Columbia Circuit has reviewed EPA decisions declining to deny waiver requests based on criteria not found in section 209(b), the court has upheld and agreed with EPA's determination.[233]

As many of the commenters note, evaluation of whether California's GHG standards are preempted, either explicitly or implicitly, under EPCA, is not among the criteria listed under section 209(b). EPA may only deny waiver requests based on the criteria in section 209(b), and inconsistency with EPCA is not one of those criteria. In considering California's request for a waiver, I therefore have not considered whether California's standards are preempted under EPCA. As in the March 2008 decision, the decision on whether to grant the waiver is based solely on the criteria in section 209(b) of the Clean Air Act and this decision does not attempt to interpret or apply EPCA or any other statutory provision. EPA takes no position regarding whether or not California's GHG standards are preempted under EPCA.

2. Do California's GHG Emission Standards Create an Impermissible ''Patchwork''?

Under section 177 of the Act, other states may adopt California new motor vehicle emission standards under certain conditions. In this waiver proceeding EPA received comment suggesting that sections 202(a), 209(a) and 177 of the Act establish a regulatory framework designed to foster a national marketplace for vehicles while recognizing California's ability to establish its own program which can be adopted by other states. EPCA however, sets a single national fuel economy standard and is designed to prevent a fracturing of the marketplace into individual state programs. Commenters argue that manufacturers will have at least 15 different fleets they will have to balance for purposes of fuel economy and greenhouse gas emissions flowing from the fleet-average emission requirements of each state. Manufacturers also are concerned that there are significant differences between manufacturers' fleets in California and those in individual section 177 states creating unnecessary compliance burdens. The commenters suggest that the federal government should establish a single, national program for regulation of vehicle greenhouse gas standards and fuel economy.

EPA also received comment stating that to the extent the auto industry is arguing that a patchwork is created because of differences between fleet composition in different states, that argument lacks merit and is irrelevant to this waiver proceeding. Citing an EPA waiver decision from 1971, this commenter notes that claims such as the patchwork issue are not appropriate in a waiver proceeding since EPA's consideration of evidence submitted during a waiver proceeding is limited by its relevance to the three waiver criteria EPA must consider under section 209. This has led EPA to previously reject arguments that are not specified in the statute as grounds for denying a waiver.[234]

Similar to EPA's response to the EPCA claims noted above, EPA may only deny waiver requests based on the criteria in section 209(b). The actions of other states relating to the adoption of the California GHG emission standards is not a factor I may consider under section 209(b). The actions of such states are authorized under a separate section of the Act, section 177, and must conform to the requirements of that section, including identicality. Section 209(b) does not authorize me in reviewing a waiver request to consider the impact of actions or potential actions taken by other states under section 177 of the Act.[235] I therefore will not consider this claim in determining whether to grant California's waiver request.

It is important to note that on May 19, 2009, EPA and the Department of Transportation (DOT) issued a ''Notice of Upcoming Joint Rulemaking to Establish Vehicle GHG Emissions and CAFE Standards'' announcing EPA and DOT's intent to work in coordination to propose standards for control of emissions of greenhouse gases and for fuel economy, respectively. If proposed and finalized, these standards would apply to passenger cars, light-duty trucks, and medium-duty passenger vehicles (light-duty vehicles) built in model years 2012 through 2016. EPA believes that if these standards are ultimately adopted, they would represent a harmonized and consistent national policy pursuant to the separate statutory frameworks under which EPA and DOT operate.

3. What Impact Does Granting California a Waiver for Its GHG Emission Standards Have on PSD Requirements for GHGs?

Several commenters suggest that there would be a major consequence if an EPA waiver were to trigger other requirements under the Act, including Prevention of Significant Deterioration (PSD) requirements, and should it grant the waiver, EPA should state clearly that the waiver does not render GHGs ''subject to regulation'' under the Act. EPA also received comment suggesting that the question of when and how GHGs should be addressed in the PSD program or otherwise regulated under the Act should instead be addressed in separate proceedings dedicated to evaluating the complicated issues and impacts associated with those issues.

EPA agrees that these issues are not relevant to the waiver decision criteria, and are most appropriately addressed in a separate forum. EPA is not addressing these issues in today's decision.

VIII. Decision

After review of the information submitted by CARB and other parties to this Docket, I find that those opposing the waiver request have not met the burden of demonstrating that California's regulations do not satisfy any of the three statutory criteria of section 209(b). For this reason, I am granting California's waiver request to enforce its motor vehicle GHG emission regulations.

My decision will affect not only persons in California but also persons outside the State who would need to comply with California's GHG emission regulations. For this reason, I hereby determine and find that this is a final action of national applicability.

Under section 307(b)(1) of the Act, judicial review of this final action may be sought only in the United States Court of Appeals for the District of Columbia Circuit. Petitions for review must be filed by September 8, 2009.

[232] 74 FR at 12159.

[233] *See Motor and Equipment Manufacturers Ass'n* v. *Nichols,* 142 F.3d 449, 462–63, 466–67 (DC Cir. 1998), *Motor and Equipment Manufacturers Ass'n* v. *EPA,* 627 F.2d 1095, 1111, 1114–20 (DC Cir. 1979).

[234] 36 FR 17458 (August 31, 1971).

[235] 43 FR 1829, 1833 (January 12, 1978), LEV I waiver decision document at 185–186.

Under section 307(b)(2) of the Act, judicial review of this final action may not be obtained in subsequent enforcement proceedings.

As with past waiver decisions, this action is not a rule as defined by Executive Order 12866. Therefore, it is exempt from review by the Office of Management and Budget as required for rules and regulations by Executive Order 12866.

In addition, this action is not a rule as defined in the Regulatory Flexibility Act, 5 U.S.C. 601(2). Therefore, EPA has not prepared a supporting regulatory flexibility analysis addressing the impact of this action on small business entities.

The Congressional Review Act, 5 U.S.C. 801 *et seq.,* as added by the Small Business Regulatory Enforcement Fairness Act of 1996, does not apply because this action is not a rule, for purposes of 5 U.S.C. 804(3).

Dated: June 30, 2009.

Lisa P. Jackson,

Administrator.

[FR Doc. E9–15943 Filed 7–6–09; 8:45 am]

BILLING CODE 6560–50–P

8. Waste

Waste management and treatment activities are sources of greenhouse gas emissions (see Figure 8-1). Landfills accounted for approximately 23 percent of total U.S. anthropogenic methane (CH_4) emissions in 2007,[1] the second largest contribution of any CH_4 source in the United States. Additionally, wastewater treatment and composting of organic waste accounted for approximately 4 percent and less than 1 percent of U.S. CH_4 emissions, respectively. Nitrous oxide (N_2O) emissions from the discharge of wastewater treatment effluents into aquatic environments were estimated, as were N_2O emissions from the treatment process itself. N_2O emissions from composting were also estimated. Together, these waste activities account for approximately 2 percent of total U.S. N_2O emissions. Nitrogen oxide (NO_x), carbon monoxide (CO), and non-CH_4 volatile organic compounds (NMVOCs) are emitted by waste activities, and are addressed separately at the end of this chapter. A summary of greenhouse gas emissions from the Waste chapter is presented in Table 8-1 and Table 8-2.

Overall, in 2007, waste activities generated emissions of 165.6 teragrams of carbon dioxide equivalents (Tg CO_2 Eq.) or just over 2 percent of total U.S. greenhouse gas emissions.

Figure 8-1

2007 Waste Chapter Greenhouse Gas Emission Sources

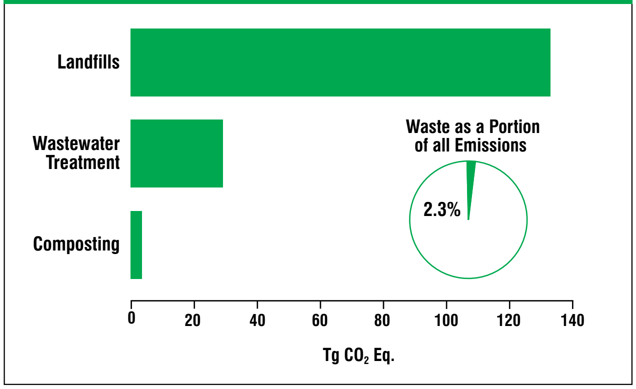


Table 8-1: Emissions from Waste (Tg CO_2 Eq.)

Gas/Source	1990	1995	2000	2005	2006	2007
CH_4	**173.0**	**169.9**	**148.8**	**153.8**	**156.5**	**158.9**
Landfills	149.2	144.3	122.3	127.8	130.4	132.9
Wastewater Treatment	23.5	24.8	25.2	24.3	24.5	24.4
Composting	0.3	0.7	1.3	1.6	1.6	1.7
N_2O	**4.0**	**4.8**	**5.8**	**6.5**	**6.6**	**6.7**
Domestic Wastewater Treatment	3.7	4.0	4.5	4.8	4.8	4.9
Composting	0.4	0.8	1.4	1.7	1.8	1.8
Total	**177.1**	**174.7**	**154.6**	**160.2**	**163.0**	**165.6**

Note: Totals may not sum due to independent rounding.

[1] Landfills also store carbon, due to incomplete degradation of organic materials such as wood products and yard trimmings, as described in the Land Use, Land-Use Change, and Forestry chapter.

per capita flow = Wastewater flow to POTW per person per day (100 gal/person/day)

conversion to m^3 = Conversion factor, ft^3 to m^3 (0.0283)

$FRAC\_CH_4$ = Proportion CH_4 in biogas (0.65)

density of CH_4 = 662 (g CH_4/m^3 CH_4)

$1/10^9$ = Conversion factor, g to Gg

U.S. population data were taken from the U.S. Census Bureau International Database (U.S. Census 2008a) and include the populations of the United States, American Samoa, Guam, Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands. Table 8-8 presents U.S. population and total BOD_5 produced for 1990 through 2007. The proportions of domestic wastewater treated onsite versus at centralized treatment plants were based on data from the 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003, and 2005 American Housing Surveys conducted by the U.S. Census Bureau (U.S. Census 2008b), with data for intervening years obtained by linear interpolation. The wastewater flow to aerobic and anaerobic systems, and the wastewater flow to POTWs that have anaerobic digesters were obtained from the 1992, 1996, 2000, and 2004 Clean Watershed Needs Survey (EPA 1992, 1996, 2000, and 2004a).[9] Data for intervening years were obtained by linear interpolation. The BOD_5 production rate (0.09 kg/capita/day) for domestic wastewater was obtained from Metcalf and Eddy (1991 and 2003). The CH_4 emission factor (0.6 kg CH_4/kg BOD_5) and the MCFs were taken from IPCC (2006). The CH_4 destruction efficiency, 99 percent, was selected based on the range of efficiencies (98 to 100 percent) recommended for flares in *AP-42 Compilation of Air Pollutant Emission Factors, Chapter 2.4* (EPA 1998), efficiencies used to establish NSPS for landfills, and in recommendations for closed flares used by the LMOP. The cubic feet of digester gas produced per person per day (1.0 ft^3/person/day) and the proportion of CH_4 in biogas (0.65) come from Metcalf and Eddy (1991).

[9] Aerobic and anaerobic treatment were determined based on unit processes in use at the facilities. Because the list of unit processes became more extensive in the 2000 and 2004 surveys, the criteria used to identify aerobic and anaerobic treatment differ slightly across the time series. Once facilities were identified as aerobic or anaerobic, they were separated by whether or not they had anaerobic digestion in place. Once these classifications were determined, the flows associated with facilities in each category were summed.

Table 8-8: U.S. Population (Millions) and Domestic Wastewater BOD_5 Produced (Gg)

Year	Population	BOD_5
1990	254	8,350
1995	271	8,895
2000	287	9,419
2001	289	9,509
2002	292	9,597
2003	295	9,685
2004	297	9,774
2005	300	9,864
2006	303	9,954
2007	306	10,043

Source: U.S. Census Bureau (2008a); Metcalf & Eddy 1991 and 2003.

The wastewater flow to a POTW (100 gal/person/day) was taken from the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (2004), "Recommended Standards for Wastewater Facilities (Ten-State Standards)."

Industrial Wastewater CH_4 Emission Estimates

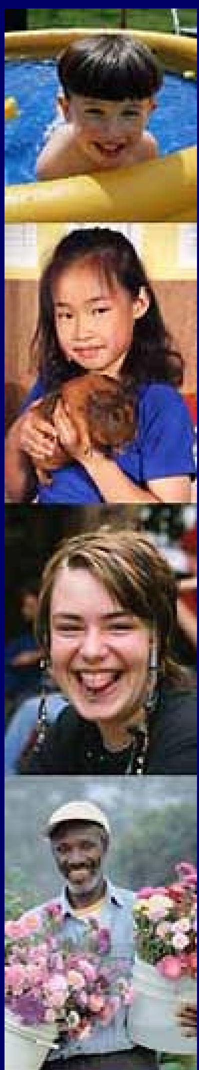
CH_4 emissions estimates from industrial wastewater were developed according to the methodology described in IPCC (2006). Industry categories that are likely to produce significant CH_4 emissions from wastewater treatment were identified. High volumes of wastewater generated and a high organic wastewater load were the main criteria. The top five industries that meet these criteria are pulp and paper manufacturing; meat and poultry processing; vegetables, fruits, and juices processing; starch-based ethanol production; and petroleum refining. Wastewater treatment emissions for these sectors for 2007 are displayed in Table 8-9.

Table 8-10 contains production data for these industries.

Table 8-9: Industrial Wastewater CH_4 Emissions by Sector for 2007

	CH_4 Emissions (Tg CO_2 Eq.)	% of Industrial Wastewater CH_4
Pulp & Paper	4.1	48%
Meat & Poultry	3.6	43%
Petroleum Refineries	0.6	7%
Fruit & Vegetables	0.1	1%
Ethanol Refineries	0.1	1%
Total	**8.5**	**100%**

California's Watersheds
People and Water
Forests and Water
Water & Recreation
Wild & Scenic Rivers
Links and Contacts
Water Projects
People & Precipitation Map
Water Use Facts



Water Use Facts

USDA Forest Service, Pacific Southwest Region

Facts About Water

- One acre foot=326,000 gallons. This covers an acre of land with a one-foot depth of water.
- Fresh water makes up only 2.8% of the water on the planet. The remaining 97.2% of the earth's water is salt water.

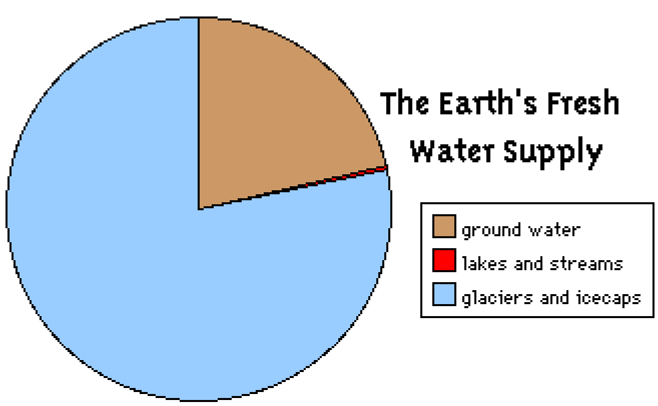
How much water do you use?

An average California household uses between one half-acre foot and one-acre foot of water each year.

Personal water use is highest in central valley cities, where a family may use as much as 300 gallons of water per person each day. Water use is as low as 50 gallons per person per day in some water-conserving coastal cities, such as San Francisco or Monterey.

How much water does it take to?

- **drink**, 1/2 gallon per person, per day
- **shower with a low-flow showerhead**, 9-12 gallons per person, per day
- **fill the bathtub**, about 36 gallons
- **cook**, 5-10 gallons per person, per day
- **wash clothes or the car**, 50 gallons per wash
- **water the lawn/yard**, 300 gallons per watering
- **flush the toilet**, 3.5 - 7 gallons, or 1.5 gallons with a water saving toilet



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PILOT VERSION

LEED for Neighborhood Development Rating System

Developed through a partnership of the Congress for New Urbanism, Natural Resources Defense Council and the U.S. Green Building Council

Congress for the New Urbanism

NRDC
The Earth's Best Defense

Minor changes, including only corrected typos and minor clarifications, have been made to this version that were not included in the February 2007 version of the LEED for Neighborhood Development rating system. In addition, an alternative version of GCT Credit 9 (Stomwater Management) is provided with this version. Prerequisite and credit requirements were not changed in any way that would affect a project's ability to achieve them.

Table of Contents

Introduction

Overview

The U.S. Green Building Council (USGBC), the Congress for the New Urbanism (CNU), and the Natural Resources Defense Council (NRDC)—three organizations that represent some of the nation's leaders among progressive design professionals, builders, developers, and the environmental community—have come together to develop a national set of standards for neighborhood location and design based on the combined principles of smart growth, new urbanism, and green building. The goal of this partnership is to establish these standards for assessing and rewarding environmentally superior development practices within the rating framework of the LEED® (Leadership in Energy and Environmental Design) Green Building Rating System™.

Unlike other LEED products that focus primarily on green building practices, with relatively few credits regarding site selection and design, LEED for Neighborhood Development places emphasis on the design and construction elements that bring buildings together into a neighborhood, and relate the neighborhood to its larger region and landscape. The work of the committee is guided by sources such as the Smart Growth Network's ten principles of smart growth, the Charter of the New Urbanism, and other LEED rating systems. LEED for Neighborhood Development creates a label, as well as guidelines for design and decision-making, to serve as an incentive for better location, design, and construction of new residential, commercial, and mixed use developments.

The existing LEED for New Construction Rating System has a proven track record of encouraging builders to utilize green building practices, such as increasing energy and water efficiency and improving indoor air quality in buildings. It is the hope of the partnership that LEED for Neighborhood Development will have a similarly positive effect in encouraging developers to revitalize existing urban areas, reduce land consumption, reduce automobile dependence, promote pedestrian activity, improve air quality, decrease polluted stormwater runoff, and build more livable, sustainable, communities for people of all income levels.

How LEED Rating Systems Work

LEED provides rating systems that are voluntary, consensus-based, market-driven, grounded in accepted energy and environmental principles, and that strike a balance between established practices and emerging concepts. LEED rating systems are developed by committees, in adherence with USGBC policies and procedures guiding the development and maintenance of rating systems. LEED for Neighborhood Development is one of a growing portfolio of rating systems serving specific market sectors.

LEED rating systems typically consist of a few prerequisites and many credits. In order to be certified, a project must meet each prerequisite. Each credit is optional, but achievement of each credit contributes to the project's point total. A minimum point total is required for certification, and higher point scores are required for silver, gold, or platinum LEED certification.

What is a "Neighborhood Development"?

The rating system is designed to certify exemplary development projects that perform well in terms of smart growth, new urbanism, and green building. Projects may constitute whole neighborhoods, fractions of neighborhoods, or multiple neighborhoods. Smaller, infill projects that are single use but complement existing neighboring uses should be able to earn certification as well as larger and mixed use developments.

The LEED for Neighborhood Development Pilot Program

Up to 120 projects in total will be selected to be a part of the pilot program. The objective of the pilot program is to ensure that the rating system is practical for application and is an effective tool for recognizing projects that incorporate smart growth, new urbanist, and green building practices. The LEED for Neighborhood Development Core Committee will assess the experience gained from the pilot program in order to revise the rating system for public comment and ballot.

LEED for Neighborhood Development's principal aim is to improve land-use patterns, neighborhood design, and technology in the United States. However, on a very limited basis, the pilot program may test the applicability of the rating system in non-United States settings as well.

In terms of eligibility for the pilot program, there is no minimum or maximum for project size and no strict definition for what would comprise a neighborhood. The only requirement is that projects must be able to meet all prerequisites and anticipate that the minimum number of points through credits to achieve certification can be earned.

Certification Process

LEED for Neighborhood Development will certify projects that may have significantly longer construction periods than single buildings, and as a result the standard LEED certification process needed to be modified. The core committee wanted to be able to provide developers of certifiable projects with some form of approval even at the early, pre-entitlement stage. They also wanted to ensure that great plans became great real-life projects. With these goals in mind, the core committee created the following three-stage certification process:

Optional Pre-review (Stage 1)

This stage is available but not required for projects at any point before the entitlement process begins. If pre-review approval of the plan is achieved, USGBC will issue a letter stating that if the project is built as proposed, it will be able to achieve LEED for Neighborhood Development certification. The purpose of this letter is to assist the developer in building a case for entitlement among land use planning authorities, as well as a case for financing and occupant commitments.

Certification of an Approved Plan (Stage 2)

This stage is available after the project has been granted any necessary approvals and entitlements to be built to plan. Any changes to the pre-reviewed plan that could potentially affect prerequisite or credit achievement would be communicated to USGBC as part of this submission. If certification of the approved plan is achieved, USGBC will issue a certificate stating that the approved plan is a LEED for Neighborhood Development Certified Plan and will list it as such on the USGBC website.

Certification of a Completed Neighborhood Development (Stage 3)

This step takes place when construction is complete or nearly complete. Any changes to the certified approved plan that could potentially affect prerequisite or credit achievement would be communicated to USGBC as part of this submission. If certification of the completed neighborhood development is achieved, USGBC will issue plaques or similar awards for public display at the project site and will list it as such on the USGBC website.

Similar to other LEED certification processes, projects will be provided with a more thorough explanation of credit topics and calculations in a reference guide. Project teams will be required to submit documentation for each credit as described in the "submittal" sections of the rating system. Pilot participants will be given submittal templates to fill out as part of documentation after they register their project. The templates will assist projects in providing the requested calculations. The submittal section included with each credit in the rating system is subject to modification during the course of the pilot program. During the pilot program, project teams are encouraged to suggest replacement documentation that clearly verifies that the requirements have been met but may be easier to access or produce than the items listed below. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

Acknowledgements

The partnership would like to thank the following funders for their support of the creation of LEED for Neighborhood Development (listed alphabetically):

The Blue Moon Fund
Centers for Disease Control
EDAW
U.S. EPA Office of Brownfields Cleanup and Redevelopment
U.S. EPA Development, Community, and Environment Division
The Johnson Foundation
National Endowment for the Arts

The pilot version of the LEED for Neighborhood Development Rating System has been made possible because of the efforts of many dedicated volunteers, staff members, consultants, and others in the USGBC, CNU, and NRDC communities. The partnership extends its deepest gratitude to all of these individuals, and especially to the LEED for Neighborhood Development Core Committee members selected by the partners, for their tireless volunteer efforts in developing this rating system. They are:

Doug Farr (Chair), Farr Associates
Kaid Benfield (Vice-Chair), Natural Resources Defense Council
Bill Browning, Browning + Bannon LLC
Victor Dover, Dover, Kohl & Partners Town Planning
Sharon Feigon, Center for Neighborhood Technology
Rebecca Flora, Green Building Alliance
Bert Gregory, Mithun Architects + Designers + Planners
Daniel Hernandez, Topology, LLC
Melissa Knott, Forest City Stapleton, Inc.
Jessica Cogan Millman, Coalition for Smarter Growth
Susan Mudd, Congress for the New Urbanism Board of Directors
John Norquist, Congress for the New Urbanism
Michael Pawlukiewicz, Urban Land Institute
Shelley Poticha, Reconnecting America
Tom Richman, Tom Richman
Elizabeth Schilling, Urban Associates
Laura Watchman, Defenders of Wildlife
Sandy Wiggins, Consilience, LLC

Project Checklist

Smart Location & Linkage — 30 Possible Points

Prereq 1	**Smart Location**	Required
Prereq 2	**Proximity to Water and Wastewater Infrastructure**	Required
Prereq 3	**Imperiled Species and Ecological Communities**	Required
Prereq 4	**Wetland and Water Body Conservation**	Required
Prereq 5	**Agricultural Land Conservation**	Required
Prereq 6	**Floodplain Avoidance**	Required
Credit 1	**Brownfield Redevelopment**	2
Credit 2	**High Priority Brownfields Redevelopment**	1
Credit 3	**Preferred Locations**	2-10
Credit 4	**Reduced Automobile Dependence**	1-8
Credit 5	**Bicycle Network**	1
Credit 6	**Housing and Jobs Proximity**	3
Credit 7	**School Proximity**	1
Credit 8	**Steep Slope Protection**	1
Credit 9	**Site Design for Habitat or Wetlands Conservation**	1
Credit 10	**Restoration of Habitat or Wetlands**	1
Credit 11	**Conservation Management of Habitat or Wetlands**	1

Neighborhood Pattern & Design — 39 Possible Points

Prereq 1	**Open Community**	Required
Prereq 2	**Compact Development**	Required
Credit 1	**Compact Development**	1-7
Credit 2	**Diversity of Uses**	1-4
Credit 3	**Diversity of Housing Types**	1-3
Credit 4	**Affordable Rental Housing**	1-2
Credit 5	**Affordable For-Sale Housing**	1-2
Credit 6	**Reduced Parking Footprint**	2
Credit 7	**Walkable Streets**	4-8
Credit 8	**Street Network**	1-2
Credit 9	**Transit Facilities**	1
Credit 10	**Transportation Demand Management**	2
Credit 11	**Access to Surrounding Vicinity**	1
Credit 12	**Access to Public Spaces**	1
Credit 13	**Access to Active Public Spaces**	1
Credit 14	**Universal Accessibility**	1
Credit 15	**Community Outreach and Involvement**	1
Credit 16	**Local Food Production**	1

Green Construction & Technology — 31 Possible Points

Prereq 1	**Construction Activity Pollution Prevention**	Required
Credit 1	**Certified Green Buildings**	1-3
Credit 2	**Energy Efficiency in Buildings**	1-3
Credit 3	**Reduced Water Use**	1-3
Credit 4	**Building Reuse and Adaptive Reuse**	1-2
Credit 5	**Reuse of Historic Buildings**	1

Credit 6	**Minimize Site Disturbance through Site Design**	1
Credit 7	**Minimize Site Disturbance during Construction**	1
Credit 8	**Contaminant Reduction in Brownfields Remediation**	1
Credit 9	**Stormwater Management**	1-5
Credit 10	**Heat Island Reduction**	1
Credit 11	**Solar Orientation**	1
Credit 12	**On-Site Energy Generation**	1
Credit 13	**On-Site Renewable Energy Sources**	1
Credit 14	**District Heating and Cooling**	1
Credit 15	**Infrastructure Energy Efficiency**	1
Credit 16	**Wastewater Management**	1
Credit 17	**Recycled Content in Infrastructure**	1
Credit 18	**Construction Waste Management**	1
Credit 19	**Comprehensive Waste Management**	1
Credit 20	**Light Pollution Reduction**	1

Innovation & Design Process — 6 Possible Points

Credit 1	**Innovation in Design**	1-5
Credit 2	**LEED Accredited Professional**	1

Project Totals — 106 Possible Points

Certification Levels:

Certified 40-49 points
Silver 50-59 points
Gold 60-79 points
Platinum 80-106 points

Smart Location & Linkage

SLL Prerequisite 1: Smart Location

Required

Intent

Encourage development within and near existing communities or public transportation infrastructure. Reduce vehicle trips and miles traveled and support walking as a transportation choice.

Requirements

OPTION 1

Locate the **project** on an **infill site**;

OR

OPTION 2

Locate the project near existing or planned **adequate transit service** so that at least 50% of dwelling units and business entrances within the project are within ¼ mile **walk distance** of bus or streetcar stops or within ½ mile walk distance of bus rapid transit stops, light or heavy passenger rail stations and ferry terminals. In the case of planned service, show that the relevant transit agency has committed in a legally binding warrant that **adequate transit service** will be provided at or before the beginning of the transit agency's first service year after 50% of the dwelling units and/or businesses within the project are occupied and has identified all funding necessary to do so;

OR

OPTION 3

Locate the project near existing neighborhood shops, services, and facilities so that the **project boundary** is within ¼ mile walk distance of at least four, or within ½ mile walk distance of at least 6, of the **diverse uses** defined in Appendix A. Uses may not be counted in two categories, e.g an office building may be counted only once even if it is also a major employment center. A mixed use building containing several uses as distinct enterprises would count each as a separate use, but no more than half of the minimum number of diverse uses can be situated in a single building. A single retail store of any type (such as a big box retail store that sells both clothing and household goods) may only be counted once even if it sells products associated with multiple use types;

OR

OPTION 4

Locate the project within a region served by a Metropolitan Planning Organization (MPO) and within a transportation analysis zone for which MPO research demonstrates that the average annual home-based and/or non-home-based rate of **Vehicle Miles Traveled (VMT)** per capita is lower than the average annual rate of the metropolitan region as a whole. The research must be derived from transportation surveys conducted within ten years of the date of submission for LEED for Neighborhood Development certification;

OR

OPTION 5

Locate the project within a region served by a Metropolitan Planning Organization (MPO) and demonstrate through peer-reviewed analysis that the average annual home-based and/or non-home-based rate of Vehicle Miles Traveled (VMT) per capita of the project will be lower than the average annual rate shown by MPO research for the metropolitan region as a whole. The MPO research must be derived from transportation surveys conducted within ten years of the date of submission for LEED for Neighborhood Development certification. The analysis prepared for the project must be conducted by a qualified transportation professional and reviewed and supported by a second qualified transportation professional who is not affiliated with either the sponsor of the project or the first analyst.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1:

- ❑ A map of the vicinity demonstrating that the project is located on an infill site.

Option 2:

- ❑ A site and/or vicinity map showing all dwelling units and relevant building entrances, transit stops, and walking routes to those stops.
- ❑ A table of walk distances between each dwelling unit or business entrance and the closest transit stop, and a calculation of the percentage of dwelling units and business entrances that lie within the specified distances.
- ❑ Schedules or a brief narrative indicating the frequency and type of transit available.
- ❑ For planned transit routes, provide documents from the relevant transit authority indicating when service will be instituted and the source of funding.

Option 3:

- ❑ A site and/or vicinity map showing the project's boundary and walking routes to any uses listed in Appendix A.

- ❑ A table of walk distances between the project boundary and each relevant use listed in Appendix A.

Option 4:

- ❑ Excerpts of relevant MPO research.

Option 5:

- ❑ Confirmation of which MPO the project is located within.
- ❑ VMT analysis, with relevant conclusions highlighted, and the sources of peer-review listed.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2
If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2
If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Prerequisite 2: Proximity to Water and Wastewater Infrastructure

Required

Intent

Encourage new development within and near existing communities in order to reduce multiple environmental impacts caused by sprawl. Conserve natural and financial resources required for construction and maintenance of infrastructure.

Requirements

OPTION 1

Locate the **project** on a site served by existing water and wastewater infrastructure. Replacement or other on-location improvements to existing infrastructure are considered *existing* for the purpose of achieving this option;

OR

OPTION 2

Locate the project within a legally adopted planned water and wastewater service area and provide new water and wastewater infrastructure for the project.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site and/or vicinity map indicating the location of existing water and wastewater infrastructure.

Option 2

- ❑ A map showing the planned water and wastewater service areas, and/or a letter from the relevant public authority stating that the project site lies within planned water and wastewater service areas.
- ❑ A brief narrative explaining the new infrastructure that the project team or sponsor commits to providing or funding if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Prerequisite 3: Imperiled Species and Ecological Communities Required

Intent

Protect imperiled species and ecological communities.

Requirements

Check with the state Natural Heritage Program, and any local wildlife agencies to determine if species listed under the federal Endangered Species Act, the state's endangered species act, or species or ecological communities classified by NatureServe as G1 (critically imperiled) or G2 (imperiled), have been found on the site or have a high likelihood of occurring on the site due to the presence of suitable habitat and nearby occurrences. If no such species have been found or have a high likelihood of being present, the prerequisite is achieved. If any such species have been found or have a high likelihood of being present, meet the requirements of Option 1 or Option 2 set forth below.

OPTION 1

Comply with an approved Habitat Conservation Plan (HCP) under the Endangered Species Act for each identified species or ecological community;

OR

OPTION 2

If no approved HCP exists for an identified species or ecological community, then coordinate with the state's Natural Heritage Program or fish and wildlife agency to perform adequate surveys of imperiled species and ecological communities. If a survey finds that an imperiled species or ecological community is present, the project applicant shall do the following:

a. Work with a qualified biologist, a non-governmental conservation organization or the appropriate state, regional or local agency to identify and map the geographic extent of the habitat and identify an appropriate buffer of no less than 100 feet around the habitat that ensures the protection of the imperiled species or ecological community.

b. Protect the habitat and buffer or setback area from development in perpetuity by donating or selling the land or a conservation easement on the land to an accredited land trust or relevant public agency.

c. Work with ecologists to analyze the threats from development of the proposed project and develop a management plan that eliminates or significantly mitigates the identified threats.

Additional Notes

G1 species are critically imperiled; at very high risk of extinction globally due to extreme rarity (often five or fewer populations), very steep declines, or other factors.

G2 species are imperiled; at high risk of extinction globally due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

NatureServe (www.natureserve.org) is a non-profit conservation organization that provides the scientific information and tools needed to help guide effective conservation action. It represents an international network of biological inventories—known as natural heritage programs or conservation data centers—operating in all 50 U.S. states, Canada, Latin America and the Caribbean. "G1" and "G2" are part of a classification system developed in the early 1970s by the Nature Conservancy's network of natural heritage programs in every state. NatureServe currently maintains the network of natural heritage program, the classification system, and the data on biodiversity. NatureServe uses a number of criteria in assessing the status of species, including the number of populations, the size of populations, the viability of the species occurrences, the trends in population numbers, and the threats to species.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ Results of inquiries to the state Natural Heritage Program and any local wildlife agencies as to whether listed endangered species or G1 or G2 ecological communities occur or have a high likelihood of occurring on the project site.

Option 1

- ❑ A map showing the geographic extent of the HCP and the project's location within it.
- ❑ A brief narrative describing how the project will meet the requirements of the HCP.

Option 2

- ❑ Information about the site received from the relevant natural heritage program or agency.
- ❑ The results of site surveys.
- ❑ If imperiled species or ecological communities are found, submit a) a site plan which delineates imperiled species habitat in relation to the project; b) a letter from the

accredited land trust or relevant public agency stating that a transfer of land rights for the habitat and buffer has taken place or will take place if the project is built, such that these areas will be protected in perpetuity; and c) a brief narrative explaining how imperiled species and ecological communities will be protected.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Prerequisite 4: Wetland and Water Body Conservation
Required

Intent

Conserve water quality, natural hydrology and habitat and preserve biodiversity through conservation of water bodies or wetlands.

Requirements

OPTION 1 – FOR SITES WITH NO WETLANDS OR WATER BODIES

Locate the **project** on a site that includes no **wetlands**, **water bodies**, or land within 100 feet of these areas;

OR

OPTION 2 – FOR PREVIOUSLY DEVELOPED SITES WITH WETLANDS/WATER BODIES

Locate the project on a **previously developed site** where the area within a 1 mile radius from the perimeter of the site has either a) an average **street grid density** of at least 30 centerline miles per square mile, or b) an average built **density** of at least 30 dwelling units per acre for any residential components and 1.5 **FAR** for any non-residential components. If local, state, and federal regulations permit impacts to any on-site wetlands, water bodies, or buffer land that is within 100 feet of these areas, such impacts must be compensated by on-site or off-site wetland restoration of equal or greater amounts;

OR

OPTION 3 – FOR ALL OTHER SITES

If the project is located on a site that includes wetlands, water bodies, or land within 100 feet of these areas, and if local, state, and federal regulations permit impacts to any on-site wetlands, water bodies, or buffer land that is within 100 feet of these areas, limit any impacts to less than the percentage of these areas reflected in either one of the two following tables, and compensate by on-site or off-site wetland restoration of equal or greater amounts. The portion of the site that is impacted must incorporate stormwater best management practices within the impacted area to infiltrate, re-use, or evapotranspirate at least 90% of the average annual rainfall or 1” of rainfall from 75% of the **development footprint** within the impacted area.

Street grid density within a 1 mile radius from the perimeter of the site boundary	Percentage of on-site impacts allowed
>20	15
10-20	10
<10	5

Residential **density** (DU/acre)	Non-residential density (**FAR**)	Percentage of on-site impacts allowed
>20	>1.0	15
10-20	.75 - 1.0	10
< 10	< .75	5

For all Options, minor development within the buffer may be undertaken in order to enhance appreciation for wetlands and water bodies. Such development may only include minor path-ways, limited pruning and tree removal for safety, habitat management activities, educational structures not exceeding 200 square feet, and small clearings for picnic tables, benches, and non-motorized recreational water crafts.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site and/or vicinity map demonstrating that there are no wetlands, water bodies, or land within 100 feet of these areas.

  OR

- ❑ Declaration that there are no wetlands or water bodies.

Options 2 and 3

- ❑ A site and/or vicinity map showing a) any previously developed areas of the site; b) the street grid density or built density of the area within a 1 mile radius of the perimeter of the project site; and c) the construction impact zone; and d) the location of any wetlands, water bodies, or land within 100 feet of these areas.
- ❑ A calculation of either street grid density or built density within a 1 mile radius of the perimeter of the project site.
- ❑ If on-site impacts occur, a brief narrative describing the planned compensating wetland restoration activities, including the size of the impacted wetlands and of the restored wetlands. For Option 3, also include a narrative describing the stormwater best management practices employed and the amount of rainfall that will be captured.

Option 3

- ❑ A site plan indicating the portion of the site that is impacted, and the location of any BMPs.

- ❑ A written commitment to incorporate BMPs within the impacted area to meet the requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

Options 2 and 3

- ❑ If wetland restoration activities took place, either a photograph, diagram, or a brief description of the resulting areas.

Option 3

- ❑ For portions of the site where BMPs were required, a calculation of either 90% of the average annual rainfall or 1" of rainfall that occurs on the project's development footprint and other effectively impervious areas.
- ❑ A calculation of the percentage of the development footprint for which runoff is infiltrated, re-used, or evapotranspirated.

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Smart Location & Linkage

SLL Prerequisite 5: Agricultural Land Conservation
Required

Intent

Preserve irreplaceable agricultural resources by protecting prime and unique farmland and forest lands from development.

Requirements

OPTION 1

Locate the **project** such that the site contains no more than 25% **prime soils**, **unique soils**, or soils of state significance as identified in a state Natural Resources Conservation Service soil survey;

OR

OPTION 2

Locate the project such that it meets the requirements specified in Options 1, 2, or 3, of SLL Prerequisite 1;

OR

OPTION 3

Locate the project such that it is within a designated receiving area for development rights under a publicly administered farmland protection program that provides for the transfer of development rights from lands designated for conservation to lands designated for development;

OR

OPTION 4 – FOR REGIONS WITH AN ABUNDANCE OF PRIME AGRICULTURAL LAND

If the project is located within a metropolitan or micropolitan statistical area for which 75% or more of the total vacant land, including **infill sites**, is covered by prime soils, unique soils, or soils of state significance, and is on an **adjacent site**, then the prerequisite is not applicable. If the project does not lie in an established metropolitan or micropolitan statistical area, then the county boundary may serve for the purposes of the calculation.

Additional Notes

The Natural Resources Conservation Service (NRCS) is responsible for identifying prime and unique soils, and they make detailed soil surveys and maps available for every county in the United States. NRCS data are available for download to GIS mapping programs.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site and/or vicinity map indicating the location of any prime or unique soils on the site.

  OR

- ❑ Declaration that there are no prime or unique soils on the site.
- ❑ If any prime, unique, or state significant soils occur on the site, a calculation of the percentage of the site area that they cover.

Option 2

- ❑ No additional documentation necessary.

Option 3

- ❑ A brief description and/or map indicating the receiving area for development rights.

Option 4

- ❑ Data and/or a map showing that 75% of the total vacant land in the metropolitan or micropolitan statistical area (or county) is covered by prime soils, unique soils, or soils of state significance.
- ❑ A site and/or vicinity map showing that the project site is an adjacent site.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Smart Location & Linkage

SLL Prerequisite 6: Floodplain Avoidance
Required

Intent

Protect life and property, promote open space and habitat conservation, and enhance water quality and natural hydrological systems.

Requirement

OPTION 1- FOR SITES WITH NO 100-YR FLOODPLAINS

Locate on a site that does not contain any land within the 100-year floodplain as defined and mapped by the Federal Emergency Management Agency or state or local floodplain management entity, whichever has been done most recently;

OR

OPTION 2- FOR INFILL AND PREVIOUSLY DEVELOPED SITES

Locate the **project** on an **infill site** or a **previously developed site** and follow the National Flood Insurance Program (NFIP) requirements for developing any portions of the site that lie within the 100-year floodplain as defined and mapped by the Federal Emergency Management Agency or state or local floodplain management entity, whichever has been done most recently;

OR

OPTION 3- FOR ALL OTHER SITES

For projects where part(s) of the site is located within the 100-year floodplain as defined and mapped by the Federal Emergency Management Agency or state or local floodplain management entity, whichever has been done most recently, develop only on portions of the site that are not in the 100-year floodplain or on portions that have been previously developed. Previously developed portions in the floodplain must be developed according to the NFIP requirements.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site and/or vicinity map indicating that the site contains no land within the 100-year floodplain.

  OR

- ❑ Declaration that the site contains no land within the 100-year floodplain.

Option 2

- ❑ A site and/or vicinity map indicating that the project is an infill site or areas that are previously developed.
- ❑ If any portion of the site lies within the 100-year floodplain, submit a brief narrative describing how the NFIP requirements will be met for that portion.

Option 3

- ❑ A site and/or vicinity map indicating where new development will take place, areas that are previously developed, and the boundaries of the 100-year floodplain.
- ❑ If any portion of the site that is being redeveloped lies within the 100-year floodplain, submit a brief narrative describing how the NFIP requirements will be met for that portion.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 1: Brownfields Redevelopment
2 Points

Intent

Encourage the reuse of land by developing sites where development is complicated by environmental contamination, reducing pressure on undeveloped land.

Requirements

Locate **project** on a site, part or all of which is documented as contaminated (by means of an ASTM E1903-97 Phase II Environmental Site Assessment or a local Voluntary Cleanup Program) OR on a site defined as a **brownfield** by a local, state or federal government agency;

AND

Remediate site contamination such that the controlling public authority approves the protective measures and/or clean-up as effective, safe, and appropriate for the future use of the site.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- Confirmation of whether any part of the project site was determined contaminated by means of an ASTM E1903-97 Phase II Environmental Site Assessment or defined as a brownfield by a local, state, or federal agency.
- Narrative describing the site contamination and remediation efforts undertaken or to be undertaken by the project.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Confirmation from the controlling public authority that it has approved the remediation as effective, safe, and appropriate for the future use of the site.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Smart Location & Linkage

SLL Credit 2: High Priority Brownfields Redevelopment
1 Point

Intent

Encourage the cleanup of contaminated **brownfields** sites in areas targeted for redevelopment.

Requirements

Earn SLL Credit 1: Brownfields Redevelopment, using a site that is in one of the following areas:

- Federal Empowerment Zone
- Federal Enterprise Community
- Federal Renewal Community
- Communities with Official Recognition (OR) from the Department of Justice for their Weed and Seed Strategy
- Qualified Low-Income Communities (LICs) as defined by the New Markets Tax Credit (NMTC) Program of the U.S. Department of the Treasury - Community Development Financial Institutions Fund (CDIF).

Brownfield sites in areas identified by state level equivalent programs to those listed above will also qualify.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ Documentation demonstrating that the site lies within one of the listed zones or communities.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 3: Preferred Locations
2 to 10 Points

Intent

Encourage development within existing communities and developed places to reduce multiple environmental harms associated with sprawl. Reduce development pressure beyond the limits of existing development. Conserve natural and financial resources required for construction and maintenance of infrastructure.

Requirements

Locate the **project** in one of the following locations that also earn at least one point for **street grid density** according to the calculation below:

- An **infill site** that is also a **previously developed site** (6 points)
- An infill site that is not a previously developed site (4 points)
- An **adjacent site** that is also a previously developed site (3 points)
- A previously developed site that is not an adjacent or infill site (2 points)
- An adjacent site that is not a previously developed site (1 point)

AND

Calculate the street grid density (in street centerline miles per square mile) within a 1 mile radius from the perimeter of the site boundary. Points are added to the above points according to the following street grid density:

- 40 centerline miles per square mile or greater (4 points)
- 30-39 centerline miles per square mile (3 points)
- 20-29 centerline miles per square mile (2 points)
- 10-19 centerline miles per square mile (1 point)

No points are available under this credit for sites that are not either 1) an adjacent site, 2) an infill site, or 3) a previously developed site.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A map of the vicinity demonstrating that the project is located on one or more of the following: 1) an infill site; 2) an adjacent site; or 3) a previously developed site.
- ❑ A map of the vicinity showing the street grid density of the area within a 1 mile radius of the perimeter of the project site.
- ❑ A calculation of the street grid density within a 1 mile radius of the perimeter of the project site.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 4: Reduced Automobile Dependence
1 to 8 Points

Intent

Encourage development in locations that exhibit superior performance in providing transportation choices or otherwise reducing motor vehicle use.

Requirements

OPTION 1

Locate **project** on a site with transit service of 20 or more easily accessible transit rides per week day. The number of points available for increasing transit service is indicated in the table below. The total number of rides available during weekdays is defined as the number of buses or streetcars stopping within a ¼ mile **walk distance** of at least 50% of the project's dwellings and business entrances, and the number of bus rapid transit buses, light rail trains, heavy passenger rail, and ferries stopping within a ½ mile walk distance of at least 50% of the project's dwellings and business entrances;

Total rides available per weekday	Points earned
20 – 59	2
60 – 99	3
100 – 224	4
225 – 349	5
350 – 499	6
500 or more	7

OR

OPTION 2

Locate project within a region served by a Metropolitan Planning Organization AND within a transportation analysis zone where annual **Vehicle Miles Traveled (VMT)** per capita or single occupancy vehicle (SOV) driving mode share has been demonstrated by MPO research derived from a household transportation survey to be no more than 80% of the average of the metropolitan region as a whole. The research must be derived from transportation surveys conducted within ten years of the date of submission for LEED for Neighborhood Development certification. Additional credit may be awarded for increasing levels of performance, as indicated;

Percent of average regional per capita VMT or SOV mode share	Points earned
71% to 80%	2
61% to 70%	3
51% to 60%	4
41% to 50%	5
31% to 40%	6
30% or less	7

OR

OPTION 3

Locate the project such that 50% of the dwelling units and business entrances are within a ¼ mile walk distance of at least one vehicle that is available through a vehicle-sharing program, and publicize the availability and benefits of the vehicle-sharing program to project occupants. If the project will add more than 100 dwelling units and/or employees to the neighborhood, at least one additional vehicle for every 100 dwelling units and/or employees must be available and the parking space must be dedicated as part of the project. Where new vehicle locations are created, a vehicle share program must commit to providing a vehicle to the location for at least three years. (1 point)

Points earned under Options 1 and 2 may not be combined. A point from Option 3 may be earned independently, or be added to those earned under Options 1 and 2 for a maximum of 8 points.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site and/or vicinity map showing all relevant dwelling units and building entrances, transit stops, and walking routes to those stops.
- ❑ Schedules or a brief narrative indicating the frequency and type of transit available.
- ❑ A list of transit stops that lie within the specified walk distance of 50% of the project's dwelling units and business entrances.

- ❑ A calculation showing the total rides available per weekday.

Option 2

- ❑ Excerpts of relevant MPO research.

Option 3

- ❑ A site and/or vicinity map showing all relevant building entrances, shared vehicles, and walking routes to those vehicles.
- ❑ A table of walk distances between each dwelling unit and/or business entrance and the closest shared vehicle, and a calculation of the percentage of dwelling units and business entrances that lie within the specified distances.
- ❑ A brief narrative describing how the availability of the vehicle-sharing program will be publicized to project occupants.
- ❑ If the project adds more than 100 dwelling units or employees to the neighborhood, submit calculations showing how many additional vehicles are required and indicate on the site plan where any required parking spaces are dedicated within the project.
- ❑ If a new vehicle location is created to meet the requirements, submit a letter from the vehicle-sharing program stating its commitment to provide a vehicle at that location for at least 3 years.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

<u>Case 3B: Change since Stage 2</u>

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 5: Bicycle Network
1 Point

Intent

To promote bicycling and transportation efficiency.

Requirements

Design or locate the **project** such that 50% of the dwelling units and business entrances are within 3 miles of at least four or more of the diverse uses listed in Appendix A using an existing **biking network** and/or a biking network that will be completed as part of the project (3 mile distance is measured along the biking network, not as a straight radius);

AND

For any non-residential buildings and multifamily residential buildings that are part of the project, provide bicycle parking spaces or storage for a capacity of no less than 15% of the off-street parking space capacity provided for cars for those buildings.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site and/or vicinity map indicating the relevant building entrances, diverse uses listed in Appendix A, and biking network.
- ❑ A table of biking distances between each dwelling unit or business entrance and each relevant use listed in Appendix A, and a calculation of the percentage of dwelling units and business entrances that lie within the specified distance.
- ❑ If non-residential buildings or multifamily residential buildings are included in the project, submit a calculation of the required bicycle parking spaces and indicate their location on the site plan.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 6: Housing and Jobs Proximity
3 Points

Intent

Encourage balanced communities with a diversity of uses and employment opportunities. Reduce energy consumption and pollution from motor vehicles by providing opportunities for shorter vehicle trips and/or use of alternative modes of transportation.

Requirements

OPTION 1

Include a residential component equaling at least 25% of the **project**'s total building square footage, and locate and/or design the project such that the center is within a 1/2 mile **walk distance** of a number of **pre-project** jobs equal to or greater than 50% of the number of dwelling units in the project;

OR

OPTION 2

Include a non-residential component equaling at least 25% of the project's total building square footage, and locate on an **infill** site whose center is within a ½ mile walk distance of an existing and operational rail transit stop, and within a ½ mile walk distance of a number of existing dwelling units equal to or greater than 50% of the number of new jobs created as part of the project.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A calculation demonstrating that at least 25% of the project's built square footage is residential.

- ❑ A site and/or vicinity map showing the location of relevant dwelling units within the project, nearby pre-project jobs, and walking routes to those jobs.
- ❑ A calculation showing that the number of pre-project jobs is equal to or greater than 50% of the number of dwelling units.

Option 2

- ❑ A calculation demonstrating that at least 25% of the project's built square footage is non-residential.
- ❑ A site and/or vicinity map demonstrating that the project site is an infill site, and indicating the location of the relevant rail transit stop, existing dwelling units, new jobs created as part of the project, and walking routes to the transit stop and dwelling units.
- ❑ A calculation showing that the number of pre-project jobs is equal to or greater than 50% of the number of dwelling units.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 7: School Proximity
1 Point

Intent

Promote public health through physical activity by facilitating walking to school. Promote community interaction and engagement.

Requirements

Include a residential component in the **project** that constitutes at least 25% of the project's total building square footage; and locate or design the project so that at least 50% of the project's dwelling units are within ½ mile **walk distance** of an existing or planned school.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A calculation demonstrating that at least 25% of the project's square footage is residential.
- ❑ A site and/or vicinity map showing the relevant school, dwelling units, and walking routes.
- ❑ A table of walk distances between each dwelling unit the relevant school, and a calculation of the percentage of dwelling units that lies within the specified distance.
- ❑ If the school is planned rather than existing, submit a letter signed by the school district or academic institution confirming that a school will be constructed at the identified location.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1
If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2
If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2
If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 8: Steep Slope Protection
1 Point

Intent

Minimize erosion to protect habitat and reduce stress on natural water systems by preserving steep slopes in a natural, vegetated state.

Requirements

OPTION 1

Avoid disturbing portions of **project** sites that have **pre-project** slopes greater than 15%;

OR

OPTION 2- FOR **PREVIOUSLY DEVELOPED SITES** ONLY

On portions of project sites with pre-project slopes greater than 15%:

a. treat any fractions of the site that have not been previously developed by complying with the requirements for sites that are not previously developed set forth in Option 3;

   OR

b. restore **native plants** or **adapted plants** to 100% of any **previously developed** slopes over 40%; 60% of any previously developed slopes between 25%-40%; and 40% of any previously developed slopes between 15%-25%;

OR

OPTION 3

On portions of project sites with pre-project slopes greater than 15% that are <u>not</u> previously developed sites:

- do not disturb slopes greater than 40% and do not disturb portions of the project site within 50 feet of the top of the slope, and 75 feet from the **toe of the slope**;
- limit development to no more than 40% of slopes between 25%-40%, and to no more than 60% of slopes between 15%-25%.
- locate development such that the percentage of the **development footprint** that is on pre-project slopes less than 15% is greater than the percentage of **buildable land** that has pre-project slopes less than 15%.

For all three options, those portions of project sites with slopes up to 20 feet in elevation (toe to top) that are more then 30 feet in any direction from another slope greater than 15% are exempt from the requirements, although more restrictive local regulations may apply.

For Options 2 and 3, develop **CC&Rs**, development agreements, or other binding documents that will protect the specified steep slope areas in perpetuity.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ Topographic drawings of the project site indicating slopes, any areas that are previously developed, and the areas planned for development or redevelopment.

Option 1

- ❑ Declaration that there are no pre-project slopes greater than 15%.

Option 2a

- ❑ Calculations showing that portions of the site that have not been previously developed are complying with the percentage requirements set forth in Option 3.

Option 2b

- ❑ A site plan indicating areas planned for restoration (or indicate these areas on the topographic drawings).
- ❑ A list of plants to be used.

Option 3

- ❑ Calculations showing that the site is complying with the percentage requirements.

Options 2a and 3

- ❑ A copy of, or a written commitment to create, any necessary CC&Rs, development agreements, or other binding documents that will restrict development around slopes according to the relevant credit requirements. If jurisdictional regulations provide for these restrictions, a copy of the relevant passages can be substituted.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For Options 2a and 3, if written commitments to create copies of the required agreements were submitted previously, submit a copy of the actual agreement(s).
- ❑ For Option 2b, either a photograph, diagram, or a brief description of the restored areas.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Smart Location & Linkage

SLL Credit 9: Site Design for Habitat or Wetland Conservation
1 Point

Intent

Conserve native wildlife habitat, wetlands and water bodies.

Requirements

OPTION 1

Work with the state's Natural Heritage Program, a local fish or wildlife agency, or the state fish and wildlife agency to determine if significant habitat occurs on the site. If significant habitat is found, do not disturb that significant habitat or portions of the site within an appropriate buffer around the habitat. The geographic extent of the habitat and the appropriate buffer shall be identified by a qualified biologist, a non-governmental conservation organization or the appropriate state, regional or local agency. Protect significant habitat and its identified buffers from development in perpetuity by donating or selling the land or a conservation easement on the land to an accredited land trust or relevant public agency. Significant habitat for this credit includes:

- Habitat for species that are listed or are candidates for listing under state or federal endangered species acts, or for those classified as G1, G2, G3 and/or S1 and S2 species by NatureServe (see note below about G and S classification); and
- Locally or regionally significant habitat, or patches of natural vegetation at least 150 acres in size (irrespective of whether some of the 150 acres lies outside the **project boundary**); and
- Habitat flagged for conservation under a regional or state conservation or green infrastructure plan;

OR

OPTION 2

If the project is located on a **previously developed site**, use **native plants** for 90% of vegetation, and use no **invasive plants** on any part of the site;

OR

OPTION 3 – FOR SITES WITH WETLANDS AND/OR WATER BODIES

Design the project to conserve 100% of all **water bodies** and **wetlands** on the site; and conduct an assessment, or compile existing assessments, showing the extent to which water bodies and/or wetlands on the site perform the following functions: 1) water quality maintenance, 2) wildlife habitat protection, and 3) hydrologic function maintenance, including flood protection. Assign appropriate buffers (not less than 100 feet) around the development footprint throughout the site based upon the functions provided, contiguous soils and slopes, and contiguous land uses; and protect wetlands, water bodies, and their buffers from development in perpetuity by donating or selling the land or a conservation easement on the land to an accredited land trust or relevant public agency.

Additional Notes

G1 species are critically imperiled; at very high risk of extinction globally due to extreme rarity (often five or fewer populations), very steep declines, or other factors.

G2 species are imperiled; at high risk of extinction globally due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

G3 species are vulnerable; at moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

S1 species are critically imperiled in the state because of extreme rarity (often five or fewer occurrences) or because of some factor such as very steep declines making it especially vulnerable to extirpation from the state

S2 species are imperiled in the state because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state.

See notes under SLL Prerequisite 3: Imperiled Species and Ecological Communities" for more information about NatureServe and this classification system.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A brief description of the efforts to determine if significant habitat occurs on the project site, including information about the site received from the relevant natural heritage program or agency.
- ❑ A brief narrative summarizing the results of the efforts to determine whether significant habitat occurs on the project site.
- ❑ If significant habitat is found, submit a) a site plan which delineates significant habitat and buffers in relation to the project; and b) a letter from the accredited land trust or

relevant public agency stating that a transfer of land rights for the habitat and buffer has taken place or will take place if the project is built, such that these areas will be protected in perpetuity.

Option 2

- ❑ A site plan indicating areas that were previously developed.
- ❑ A list of plants to be used.

Option 3

- ❑ A site plan which delineates any water bodies, wetlands, and/or buffers in relation to the development footprint.
- ❑ A summary of the assessment of water body and wetland functions.
- ❑ A letter from the accredited land trust or relevant public agency stating that a transfer of land rights for the habitat and buffer has taken place or will take place if the project is built, such that these areas will be protected in perpetuity.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Smart Location & Linkage

SLL Credit 10: Restoration of Habitat or Wetlands
1 Point

Intent

Restore wildlife habitat and wetlands that have been harmed by previous human activities.

Requirements

Using only **native plants**, restore native habitat or **pre-development water bodies** or **wetlands** on the **project** site in an area equal to or greater than 10% of the **development footprint** and remove any invasive species on the site. Protect such areas from development in perpetuity by donating or selling the land or a conservation easement on the land to an accredited land trust or relevant public agency.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan showing areas of restoration.
- ❑ A list of plants to be used.
- ❑ A calculation comparing the size of the restored areas to the size of the development footprint.
- ❑ A letter from the accredited land trust or relevant public agency stating that a transfer of land rights for the habitat or wetlands and water bodies has taken place or will take place if the project is built, such that these areas will be protected in perpetuity.
- ❑ Declaration that any invasive species on the project were removed.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Either a photograph, diagram, or a brief description of the restored areas.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Smart Location & Linkage

SLL Credit 11: Conservation Management of Habitat or Wetlands
1 Point

Intent

Conserve native wildlife habitat, wetlands and water bodies.

Requirements

OPTION 1 – FOR SITES WITH HABITAT

Create a long-term (at least 10-year) management plan for on-site native habitats and their buffers and create a guaranteed funding source for management. Involve at least one person from a natural resources agency, a natural resources consulting firm, or an academic ecologist in writing the management plan and conducting or evaluating the ongoing management. The plan should include biological objectives consistent with habitat conservation, and it should identify a) procedures, including personnel to carry them out, for maintaining the conservation areas; b) estimated implementation costs and funding sources; and c) threats that the **project** poses for habitat within conservation areas (e.g., introduction of exotic species, intrusion of residents in habitat areas) and measures to substantially reduce those threats;

OR

OPTION 2 – FOR SITES WITH WETLANDS AND WATER BODIES

Create a long-term (at least 10-year) management plan for any on-site **wetlands**, **water bodies** and their buffers and a guaranteed funding source for management. Involve at least one person from a natural resources agency, a natural resources consulting firm, or an academic ecologist in writing the management plan and conducting or evaluating the ongoing management. The plan should include biological objectives consistent with wetland and water body conservation, and it should identify a) procedures, including personnel to carry them out, for maintaining the conservation areas; and b) estimated implementation costs and funding sources.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A copy or summary of the management plan, including identification of preparers, or a written commitment to create a management plan if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ If a written commitment to create a management plan was submitted at previous stages, submit a copy or summary of the completed management plan.

<u>Case 3B: Change since Stage 2</u>

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Neighborhood Pattern & Design

NPD Prerequisite 1: Open Community

Required

Intent

Promote communities that are physically connected to each other. Foster community and connectedness beyond the development.

Requirements

Designate all streets and sidewalks that are built as part of the **project** or serving the project directly as available for general public use and not gated. Gated areas and enclaves are NOT considered available for public use, with the exception of education and health care campuses where gates are used for security purposes.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site and/or vicinity map indicating that all streets and sidewalks are available for general public use.

  OR

- ❑ Declaration that all streets and sidewalks are available for general public use.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate “No change since Stage 1” on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Prerequisite 2: Compact Development

Required

Intent

Conserve land. Promote livability, transportation efficiency, and walkability.

Requirements

Build any residential components of the **project** at an average **density** of seven or more dwelling units per acre of **buildable land** available for residential uses;

AND

Build any non-residential components of the project at an average density of 0.50 **FAR** or greater per acre of buildable land available for non-residential uses.

If the project location is serviced by a transit agency which has specified minimum service densities that are greater than the densities required by this prerequisite, then the project must meet the transit agency's minimum service densities instead.

The specified average density must be achieved by the point in the project's construction at which 50% of dwelling units are built, or within five years of the date that the first building is occupied, whichever is longer.

Additional Notes

The density of a mixed-use building is calculated by: 1) determining the total square footage of all residential and non-residential uses; 2) calculating the percentages of the total square footage that the residential and non-residential components each represent; 3) applying those percentages to the building parcel to determine the proportionate share of land area for each component; and 4) calculating residential density as the number of dwelling units per acre using the residential share of the building parcel, and calculating non-residential density as FAR using the non-residential share of the land area divided by total non-residential square footage. For example, a mixed-use building of ten dwellings at 1,500 sq.ft. each, and 25,000 sq.ft. of retail, on one acre of land would have a residential density of 26 DU/acre and a non-residential density of 0.92 FAR. Densities of individual mixed use buildings that are not being averaged with other single-use buildings must meet either the residential density minimum or the non-residential density minimum, but need not meet both.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The *certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.*

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating densities.

  OR

- ❑ A table of calculations of the densities of any residential components, non-residential components, and mixed use buildings.
- ❑ A statement indicating whether any transit agency has specified minimum service densities higher than densities required by this prerequisite for the area where the project is located.
- ❑ A statement indicating the expected timeline for project construction and (for projects that have a residential component) which components of the project will be completed when 50% of the dwelling units are built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

- ❑ If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 1: Compact Development
1 to 7 Points

Intent

Conserve land. Promote community livability, transportation efficiency, and walkability.

Requirements

Design and build the **project** to achieve the densities shown in the table below.

Residential **Density** (DU/acre)	Non-residential Density (**FAR**)	Points Available
10 to 20	0.75 to 1.0	1
> 20 and ≤ 30	> 1.0 and ≤ 1.5	2
> 30 and ≤ 40	> 1.5 and ≤ 2.0	3
> 40 and ≤ 50	> 2.0 and ≤ 2.5	4
> 50 and ≤ 60	> 2.5 and ≤ 3.0	5
> 60 and ≤ 70	> 3.0 and ≤ 3.5	6
> 70	> 3.5	7

The specified density must be achieved by the point in the project's construction at which 50% of dwelling units are built, or within five years of the date that the first building is occupied, whichever is longer.

Additional Notes

The scoring of the density of a mixed-use project is calculated by a weighted average: 1) determining the total square footage of all residential and non-residential uses; 2) calculating the percentages of the total square footage that the residential and non-residential components each represent; 3) determining the density of each component as measured in dwelling units per acre and FAR respectively; 4) determining how many points the residential and non-residential component each earns separately according to the table above; 5) if the points are different, multiply the point value of the residential component by the percentage of the total square footage it represents (as determined in step 2) and multiply the point value of the non-residential component by the percentage of the total square footage it represents (as determined in step 2); 6) add the two scores together. For example; a project that is 75% residential at an average density of 65 DU/acre and 25% non-residential at an FAR of 0.8 would earn 4 points:
(.75 x 6) + (.25 x 1) = 4.25, which is rounded to 4.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The *certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.*

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating densities.

  OR

- ❑ A table of calculations of the densities of any residential components, non-residential components, and mixed use buildings.
- ❑ For mixed-use projects, submit a calculation showing the points earned by the weighted average of residential and non-residential.
- ❑ A statement indicating the expected timeline for project construction and (for projects which have a residential component) which components of the project will be completed when 50% of the dwelling units are built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>
If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

<u>Case 3B: Change since Stage 2</u>
If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 2: Diversity of Uses
1 to 4 Points

Intent

Promote community livability, transportation efficiency, and walkability.

Requirements

Include a residential component in the **project** that constitutes at least 25% of the project's total building square footage; and design or locate the project such that at least 50% of the dwelling units are within ½ mile **walk distance** of at least two (1 point), four (2 points), seven (3 points) or ten (4 points) of the **diverse uses** defined in Appendix A. Uses may either be in nearby areas or be built within the development.

Verify that a pedestrian can reach the uses via routes that do not necessitate crossing any streets that have speed limits of greater than 25 miles per hour, unless those crossings have vehicle traffic controls such as signals and stop signs with crosswalks.

The specified number of uses must be in place by the time certain percentages of occupancy are in place, as indicated in the following table:

Number of uses	Percentage of project occupancy at which uses need to be in place
Two uses (1 point)	20%
Four uses (2 points)	30%
Seven uses (3 points)	40%
Ten uses (4 points)	50%

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A calculation demonstrating that at least 25% of the project's built square footage is residential.
- ❑ A site and/or vicinity map of the vicinity showing the project's dwelling units and walking routes to any of the relevant uses defined in Appendix A.
- ❑ A table of walk distances between each dwelling unit and relevant uses defined in Appendix A, and calculation of the percentage of dwelling units that lie within the specified distance.
- ❑ For any streets with speed limits greater than 25 miles per hour that intersect with walking routes to the relevant uses defined in Appendix A, verify that vehicle traffic controls exist or will be installed at all walking route intersections.
- ❑ A statement indicating the expected timeline for project construction and which uses will be in place at the time the relevant percentages of occupancy are in place.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 3: Diversity of Housing Types
1 to 3 Points

Intent

To enable citizens from a wide range of economic levels and age groups to live within a community.

Requirements

Include a sufficient variety of housing sizes and types in the **project** such that the total variety of housing within the project, or within a ¼ mile of the center of the project, achieves at least 0.5 according to the following calculation, which is based on the Simpson Diversity Index using the housing categories below.

The Simpson Diversity Index score is calculated with the following equation:

Score = $1 - \sum (n/N)^2$,

where n = the total number of dwellings in a single category, and
N = the total number of dwellings in all categories.

Score on the Simpson Diversity Index	Points Earned
≥ 0.5 and < 0.6	1
≥ 0.6 and < 0.7	2
≥ 0.7	3

Housing categories are defined for the purposes of this calculation in LEED for Neighborhood Development as:

(1) Detached residential large - (greater than 1200 sq. ft.)
(2) Detached residential small - (less than 1200 sq. ft.)
(3) Duplex or townhouse - large (greater than 1200 sq. ft.)
(4) Duplex or townhouse - small (less than 1200 sq. ft.)
(5) Multifamily dwelling in a building with no elevator - large (greater than 750 sq. ft.)
(6) Multifamily dwelling in a building with no elevator - small (less than 750 sq. ft.)
(7) Multifamily dwelling in a building with elevator four stories or fewer - large (greater than 750 sq. ft.)
(8) Multifamily dwelling in a building with elevator four stories or fewer - small (less than 750 sq. ft.)
(9) Multifamily dwelling in a building with elevator more than four stories and fewer than nine stories - large (greater than 750 sq. ft.)
(10) Multifamily dwelling in a building with more than four stories and fewer than nine stories - small (less than 750 sq. ft.)
(11) Multifamily dwelling in a building with elevator nine stories or more - large (greater than 750 sq. ft.)
(12) Multifamily dwelling in a building with nine stories or more - small (less than 750 sq. ft.)

(13) Live/work large (greater than 1200 sq. ft.)
(14) Live/work small (less than 1200 sq. ft.)
(15) Accessory Unit – large (greater than 1200 sq. ft.)
(16) Accessory Unit – small (less than 1200 sq. ft.)

Townhouse and live/work units may be ground related and/or within a multifamily or mixed-use building. Double counting is prohibited. Each dwelling may be classified in only one category.

Additional Notes

This credit was adapted from Laurance Aurbach's TND Design Rating Standards Version 2.1, June 2005.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site and/or vicinity map showing the location of different types of housing, either 1) within the project; or 2) within ¼ mile of the center of the project.
- ❑ The number of dwelling units in each category, the total number of dwelling units, and the results of the Simpson Diversity Index calculation.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 4: Affordable Rental Housing
1 to 2 Points

Intent

To enable citizens from a wide range of economic levels and age groups to live within a community.

Requirements

Include a proportion of rental units priced for households earning below **area median income** such that:

OPTION 1

At least 15% of total rental units are priced for households up to 50% of area median income and units are maintained at affordable levels for a minimum of fifteen years (1 point);

OR

OPTION 2

At least 30% of total rental units are priced for households up to 80% of area median income and units are maintained at affordable levels for a minimum of fifteen years (1 point);

OR

OPTION 3

At least 15% of total rental units are priced for households up to 50% of area median income and an additional 15% of total rental units are priced for households at up to 80% of area median income and units are maintained at affordable levels for a minimum of fifteen years (2 points).

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ Confirmation of current HUD data regarding the area median income and the resulting maximum monthly rents.
- ❑ A table showing the number of affordable and market rate housing units, the rental prices of any affordable units, and a calculation of the percentage of rental units that are priced within the specified range.
- ❑ A copy of, or a written commitment to create a regulatory and operating agreement, deed restrictions, or other recorded document evidencing that the units will be maintained at the specified affordable levels for a minimum of fifteen years.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 5: Affordable For-Sale Housing
1 to 2 Points

Intent

To enable citizens from a wide range of economic levels and age groups to live within a community.

Requirements

Include a proportion of for-sale housing affordable to households at or slightly above the **area median income** such that:

OPTION 1

At least 10% of for-sale housing is priced for households up to 80% of the area median income (1 point);

OR

OPTION 2

At least 20% of for-sale housing is priced for households up to 120% of the area median income (1 point);

OR

OPTION 3

At least 10% of for-sale housing is priced for households up to 80% of the area median income and an additional 10% of for-sale housing is priced for households at up to 120% of the area median income (2 points).

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ Confirmation of current HUD data regarding the area median income and the resulting maximum housing sale price(s).
- ❑ A table showing the number of affordable and market rate housing units, the sale prices of any affordable units, and a calculation of the percentage of for-sale units that are priced within the specified range.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 6: Reduced Parking Footprint
2 Points

Intent

Design parking to increase the pedestrian orientation of projects and to minimize the adverse environmental effects of parking facilities.

Requirements

For any non-residential buildings and multifamily residential buildings that are part of the project, locate all off-street surface parking lots at the side or rear of buildings, leaving building frontages and streetscapes free of surface parking lots;

AND

Use no more than 20% of the total **development footprint** area for surface parking facilities, with no individual surface parking lot larger than 2 acres. For the purposes of this credit, surface parking facilities include ground-level garages unless they are under or over space intended for human occupancy. Underground or multi-story parking facilities can be used to provide additional capacity, and on-street parking spaces are exempt from this limitation;

AND

For any non-residential buildings and multifamily residential buildings that are part of the **project**, provide bicycle and/or carpool parking spaces equivalent to 10% of the total automobile parking for each non-residential and multifamily building on the site. Signage indicating carpool parking spots should be provided, and bicycle parking should be within 200 yards of the entrance to the building that it services. The 10% carpool/bicycle space requirement can be met with any combination of bicycle and carpool parking.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating the location of all surface, underground, or multi-story parking facilities, including relevant carpool and bicycle spaces and carpool signage. For bicycle spaces provided for non-residential buildings, indicate the distance between the spaces and the entrance of the building they serve.
- ❑ The percentage of total development footprint that is used for surface parking facilities.
- ❑ The size of each individual parking lot that is part of the project.
- ❑ For any non-residential or multifamily residential buildings, submit the number of conventional automobile parking spaces, carpool spaces, and bicycle parking spaces that will be provided.
- ❑ Confirm that signage will be provided for any carpool spaces.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 7: Walkable Streets
4 to 8 Points

Intent

Provide appealing and comfortable pedestrian street environments in order to promote pedestrian activity. Promote public health though increased physical activity.

Requirements

Design and build the **project** such that all of the following are achieved (4 points):

a. A principal **functional entry** of each building has a front façade that faces a public space such as a street, square, park, paseo, or plaza.
b. A minimum of 30% of all street frontages located *within* the project, if any, are planned for development that complies with the minimum building-height-to-street-width proportions of 1:3; and where building sites are planned along streets *bordering* the project, a minimum of 15% of the total street frontage of such sites contains (or is dedicated to) development that will produce a building-height-to-street-width proportion of 1:3. Street frontages are to be measured in linear feet.
c. Continuous sidewalks or equivalent provisions for walking are provided along both sides of all streets within the **project**. New sidewalks must be at least 4 feet wide. Equivalent provisions for walking include ***woonerfs*** and footpaths.
d. All streets along exclusively residential blocks within the **project**, whether new or existing, are designed for a maximum speed of 20 mph.
e. All streets along non-residential or mixed use blocks within the project, whether new or existing, are designed for a maximum speed of 25 mph.

If the above measures are achieved, the project may earn additional points as follows: 1 point for designing and building the project such that any three measures on the list below are accomplished (up to 4 additional points):

f. The front façades of at least 80% of all buildings are no more than 25 feet from front property line.
g. The front facades of at least 50% of all buildings are no more than 18 feet from the front property line.
h. The front facades of at least 50% of mixed-use and non-residential buildings are contiguous to the sidewalk.
i. Functional building entries occur every 75 feet, on average, along non-residential or mixed use blocks.
j. All ground-level non-residential interior spaces that face a public space have transparent glass on at least 33% of the ground-level façade.
k. No blank (without doors or windows) walls longer than 50 feet occur along sidewalks. Walls with public art installations such as murals may be exempted.
l. Any ground-level storefront windows must be kept open and visible (unshuttered) at night, and this must be stipulated to future owners in **CC&Rs** or other binding documents.

m. On-street parking is provided on 70% of both sides of all new streets. The percentage of on-street parking shall be measured by comparing the length of street designated for parking to the total length of the curb around the perimeter of each block, including curb cuts, driveways, and intersection radii.
n. Street trees occur between the vehicle travel way and sidewalk at intervals of no greater than 40 feet;
o. At least 50% of ground-floor dwelling units have an elevated finished floor no less than 24 inches above the sidewalk grade.
p. In non-residential or mixed use projects, 50% or more of the total number of office buildings include ground floor retail; and all businesses and/or other community services on the ground floor are accessible directly from sidewalks along a public space such as a street, square, or plaza.
q. Trees or other structures provide shade within five years of project occupancy over at least half the length of sidewalks included within or contiguous to the project. The estimated crown diameter (the width of the shade if the sun is directly above the tree) is used to calculate the shaded area.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ To achieve the base 4 points, submit a site plan or plans indicating the following:
  - (a) the principal functional entries of all buildings and any streets or other public spaces.
  - (b) any street frontages planned for development with a minimum building height- to-street-width proportion of 1:3.
  - (c) the location and width of sidewalks or equivalent provisions for walking.
  - (d/e) the location of residential and non-residential uses, and the speed for which each street within the project will be designed.
- ❑ To achieve the base 4 points, submit the following additional documentation:
  - (b) a calculation showing the percentage of street frontage within the project that will meet the minimum building height-to-street-width proportion of 1:3; and the same percentage for street frontage on the borders of the project.
- ❑ To achieve additional points, submit a site plan or plans indicating the following (as appropriate to the measures attempted):

(f/g) the distance between the front façades of buildings and the front property lines.

(h) the location of any mixed-use or non-residential buildings and the distance between their front façades and the sidewalk.

(i) the location of functional entries along non-residential or mixed use blocks.

(j) the location of all ground-level non-residential uses along public spaces, the length of the use that will border the public space (in linear feet), and which of them will have transparent glass on the ground-level façade.

(k) the location and length of any blank walls along sidewalks.

(l) the location of any ground-level storefront windows that will be kept open and visible (unshuttered) at night.

(m) the location and length of any on-street parking.

(n) the location of any street trees and the distance between them.

(o) the location of any ground-floor dwelling units, and which of them will have an elevated finished floor.

(p) the location of any office buildings, which of them will have ground floor retail, and the location of entries to any ground-level business or community service from sidewalks or other public spaces.

(q) the location and length of sidewalks, and the location and length of shade that will be generated by trees or other structures.

- ❑ To achieve additional points, submit the following additional documentation (as appropriate to the measures attempted):

(f) a calculation showing the percentage of building front façades that will be no more than 25 feet from the front property line.

(g) a calculation showing the percentage of building front façades that will be no more than 18 feet from the front property line.

(h) a calculation showing the percentage of mixed-use and non-residential building front façades that will be contiguous to the sidewalk.

(i) a calculation showing the average of the distances between functional building entries along non-residential or mixed-use blocks.

(j) a calculation showing the percentage of ground-level non-residential interior spaces that will face a public space that will have transparent glass on the ground-level façade.

(l) a copy of, or a written commitment to create, any necessary CC&Rs, development agreements, or other binding documents that will ensure that ground-level storefront windows are kept open and visible (unshuttered) at night.

(m) a calculation showing the percentage of street length that will have on-street parking.

(o) a calculation showing the percentage of ground-floor dwelling units that will have an elevated finished floor.

(p) a calculation showing the percentage of office buildings that will have ground floor retail.

(q) a calculation showing the percentage of sidewalks that will be shaded.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For projects attempting the measure described in (l), if a written commitment to create the required agreements was submitted previously, submit a copy of the actual agreement(s).

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Neighborhood Pattern & Design

NPD Credit 8: Street Network

1 to 2 Points

Intent

Encourage the design of projects that incorporate high levels of internal connectivity and the location of projects in existing communities in order to conserve land, promote multimodal transportation and promote public health through increased physical activity.

Requirements

If new cul-de-sacs are created as part of the **project**, include a pedestrian or bicycle through-connection in at least 50% of any new cul-de-sacs. If topographical conditions prohibit such connections, these are not included in the calculation.

AND meet the requirements under one of the following Options:

OPTION 1 – FOR PROJECTS SMALLER THAN 7 ACRES

Locate the project such that the **street grid density** within a ¼ mile radius from the center of the project falls within one of the ranges listed in the table below, OR design the project such that the project's street grid density falls within one of the ranges listed in the table below.

OR

OPTION 2 – FOR PROJECTS 7 ACRES OR LARGER

Design the project such that the project's average street grid density falls within one of the ranges listed in the table below.

Street grid density (centerline miles/sq.mi.)	Points Earned
20 – 29	1
>30	2

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ A site plan indicating the location of any cul-de-sacs and pedestrian or bicycle through-connections.

Option 1

- ❑ A site plan and map of the vicinity showing the street grid density of the area within a ¼ mile radius of the center of the project site.
- ❑ A calculation of the street grid density within a ¼ mile radius of the center of the project site.

Option 2

- ❑ A site plan showing the street grid density of the project site.
- ❑ A calculation of the street grid density of the project site.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

<u>Case 3B: Change since Stage 2</u>

If project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 9: Transit Facilities

1 Point

Intent

Encourage transit use and reduce driving by creating safe and comfortable transit facilities.

Requirements

Provide covered and at least partially enclosed shelters, adequate to buffer wind and rain, with at least one bench at each transit stop within the **project boundaries**. Shelters shall be illuminated to five average maintained footcandles (light levels may be reduced after hours). Existing external lighting can contribute to this level, but any new lighting shall meet light pollution requirements in GCT Credit 20, and designed to not directly illuminate any windows of residential properties.

AND

Provide kiosks, bulletin boards, and/or signs devoted to providing local transit information as part of the project, including basic schedule and route information at each transit stop that borders or falls within the **project**.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan showing the location of any transit stops within the project boundaries and any kiosks, bulletin boards, or signs with local transit information that will be provided as part of the project.
- ❑ A brief narrative listing the facilities for each transit stop that will be provided, including shelters, benches, and the mechanism for achieving the minimum light levels.
- ❑ A brief narrative describing the transit information that will be posted at kiosks, bulletin boards, or signs.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 10: Transportation Demand Management
2 Points

Intent

Reduce energy consumption and pollution from motor vehicles by encouraging use of public transit.

Requirements

OPTION 1

Create and implement a comprehensive transportation demand management (TDM) program for the **project** aimed at reducing **weekday peak period** trips by at least 20% compared to the forecasted trip generation for the project without the TDM strategies; and fund for a minimum of two years following **buildout** of the project (1 point);

OR

OPTION 2

Provide transit passes valid for at least one year, subsidized to be half of regular price or cheaper, to each resident and employee locating within the project during the first three years of project occupancy (or longer). Publicize the fact that subsidized transit passes are available to the eligible residents and employees (1 point);

OR

OPTION 3

Provide transit service (with vans, shuttles, buses) to rail, ferry, or other major transit facilities and/or another major destination such as a retail or employment center, with service no less frequent than five rides per weekday peak period. The service must begin when the project is 20% occupied or sooner, and must be guaranteed for at least two years beyond project buildout (1 point).

No more than 2 points can be earned under this credit.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A narrative describing the TDM program, including the strategies used, the estimated resulting trip reduction percentage, and the estimated cost of the program for two years following buildout of the project.
- ❑ A written commitment to fund the TDM program for two years following buildout of the project if the project is built.

Option 2

- ❑ A narrative describing the type of transit available, the mechanism for publicizing and distributing subsidized transit passes, the regular and subsidized prices of passes, and the estimated number of new residents and employees that will receive subsidized transit passes.
- ❑ A written commitment to provide a legally binding guarantee that passes will be provided to meet the requirements, if the project is built.

Option 3

- ❑ A map of the vicinity indicating the routes of new transit service that will be provided as part of the project.
- ❑ A description of the type of transit, and a schedule of service to be provided by as part of the project.
- ❑ A timeline of estimated project occupancy as compared with the estimated start date of transit service provided as part of the project.
- ❑ A written commitment to provide a legally binding guarantee that such service will be provided for at least two years beyond project buildout, if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>
❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For Options 2 or 3, if a copy of the legally binding guarantee has not yet been submitted, submit a copy of this guarantee.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Neighborhood Pattern & Design

NPD Credit 11: Access to Surrounding Vicinity
1 Point

Intent

Provide direct and safe connections, for pedestrians and bicyclists as well as drivers, to local destinations and neighborhood centers. Promote public health by facilitating walking and bicycling.

Requirements

Design and build **projects** such that there is at least one through-street at the **project boundary** every 800 feet, or at existing abutting street intervals, whichever distance is smaller. This does not apply to connections that cannot physically be made; e.g. **wetlands**, rivers, railroads, extreme topography, natural gas lines, pipeline easements, highways, expressways and other limited-access roads.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site and/or vicinity map showing the project boundary, existing abutting street intervals, the through-streets at the project boundary, and the distances between through-streets.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 12: Access to Public Spaces
1 Point

Intent

To provide a variety of open spaces close to work and home to encourage walking, physical activity and time spent outdoors.

Requirements

Locate and/or design **project** so that a park, green plaza or square at least 1/6 acre in area, and at least 150' in width, lies within 1/6 mile **walk distance** of the 90% of the dwelling units and business entrances in the project. Parks less than 1 acre must also have a proportion no narrower than 1 unit of width to 4 units of length;

AND

For projects larger than 7 acres only, locate and/or design the project so that taken together all of the parks in the project shall average at least 1/2 acre in size.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site and/or vicinity map showing 1) the location of all residential units and non-residential building entrances; 2) the location, size, and proportions of all relevant parks; and 3) the walking routes between the project's buildings and relevant parks.
- ❑ A table of walk distances between each dwelling unit or non-residential building entrance and the closest relevant public space, and a calculation of the percentage of dwelling units and non-residential building entrances that lie within the specified distance.
- ❑ For projects larger than 7 acres, submit a calculation of the average size of parks (in acres) in the project.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 13: Access to Active Spaces
1 Point

Intent

To provide a variety of open spaces close to work and home to encourage walking, physical activity and time spent outdoors.

Requirements

OPTION 1

Locate and/or design the **project** so that an active open space facility (e.g., general playfields, soccer, baseball, basketball and other sports fields) of at least 1 acre lies within ½ mile **walk distance** of 90% of the dwelling units and business entrances in the project;

OR

OPTION 2

Locate and/or design the project so that at least 50% of dwelling units and business entrances are located within ¼ mile walk distance of a multi-use trail or Class I bikeway of at least 3 miles in length;

OR

OPTION 3

Locate and/or design the project so that at least 90% of all dwelling units and business entrances in the project are located within ¼ mile walk distance of a public recreation center or gym with outdoor facilities or a park with active recreational facilities.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site and/or vicinity map showing 1) the location of all residential units and non-residential building entrances; 2) the location and size of all relevant active open space facilities; and 3) the walking routes between the project's buildings and relevant facilities.
- ❑ A table of walk distances between each dwelling unit or non-residential building entrance and the closest relevant active open space facility, and a calculation of the percentage of dwelling units and non-residential building entrances that lie within the specified distance.

Option 2

- ❑ A site and/or vicinity map showing 1) the location of all buildings; 2) the location and length of the relevant trail; and 3) the walking routes between the project's buildings and relevant trail.
- ❑ A table of walk distances between each building and the closest relevant trail, and a calculation of the percentage of building that lie within the specified distance.

Option 3

- ❑ A site and/or vicinity map showing 1) the location of all residential units and non-residential building entrances; 2) the location of all relevant recreation centers and gyms with outdoor facilities, and parks with active recreational facilities; and 3) the walking routes between the project's buildings and relevant recreation centers, gyms, and parks.
- ❑ A table of walk distances between each dwelling unit or non-residential building entrance and the closest relevant recreation center, gym, or park, and a calculation of the percentage of dwelling units and non-residential building entrances that lie within the specified distance.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Neighborhood Pattern & Design

NPD Credit 14: Universal Accessibility
1 Point

Intent

Enable the widest spectrum of people, regardless of age or ability, to more easily participate in their community life by increasing the proportion of areas that are usable by people of diverse abilities.

Requirements

For **projects** with residential components:

For each residential unit type developed, design 20% (and not less than one) of each type to comply with the accessible design provisions of the Fair Housing Amendments Act (FHAA) and Section 504 of the Rehabilitation Act (Rehabilitation Act), as applicable. Separate residential unit types include: single-family, duplex, triplex, multi-unit row or townhouses, and mixed-use buildings that include residential units. (Compliance for multi-family buildings of four or more units is already a regulatory requirement.). All paths of travel between residential units and other buildings within the project shall comply with the accessible design provisions of the FHAA and Rehabilitation Act, as applicable;

AND

For projects with common-use or recreational facilities constructed as part of the project:
- For any residential areas, apply the accessible design provisions of the FHAA and the Rehabilitation Act to facilities and rights-of-way; and
- For any non-residential areas, apply the accessible design provisions of the American Disabilities Act (ADA) to facilities and rights-of-way.

Projects that include only non-residential components and public right-of-ways will not be able to achieve this credit, since they are already required by law to comply with applicable accessibility regulations. However, if non-residential projects include any common-use or recreational facilities not covered by accessibility regulations, they will be able to achieve the credit.

Regarding residential accessibility design provisions, an accessible entrance can be located at the front, side or back of the residential unit, which may sometimes be determined by the topography of the site.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A brief narrative identifying the universal design or universal accessibility features of the project, and identifying any applicable provisions of the FHAA, Rehabilitation Act, and the ADA.
- ❑ For projects with residential components, submit a site plan indicating the location of any units and paths of travel that comply with the applicable provisions of the FHAA and the Rehabilitation Act, and a calculation showing the percentage of each type of residential unit that complies with the applicable provisions.
- ❑ For projects with common-use or recreational facilities constructed as part of the project, submit a site plan indicating the location of these facilities, including rights-of-way in residential areas.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For projects with residential components, submit a list of street addresses for any residential units that comply with the applicable provisions of the FHAA and the Rehabilitation Act

<u>Case 3B: Change since Stage 2</u>

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Neighborhood Pattern & Design

NPD Credit 15: Community Outreach and Involvement
1 Point

Intent

To encourage community participation in the project design and planning and involve the people who live in a community in deciding how it should be improved or how it should change over time.

Requirements

Meet with immediate neighbors and local public officials to solicit input on the proposed **project** during the pre-conceptual design phase,

AND

Host an open community meeting during conceptual design phase to solicit input on the proposed project,

AND

Modify the project design as a direct result of community input, or if modifications are not made, explain why community input did not generate design improvements,

AND

Work directly with community associations and/or other social networks of the community to advertise public meetings and generate comments on project design,

AND

Establish ongoing means for communication between the developer and the community throughout the design, construction, and in cases where the developer maintains control of part or the entire project, post-construction.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ For projects that have not yet undertaken community outreach and involvement but intend to, submit a written commitment to meet the requirements of the credit and a brief description as to how and when the activities are expected to take place.
- ❑ For projects that have already undertaken community outreach and involvement, submit the following:

  1) some documentation that at least one public meeting was held (examples could include meeting fliers, agenda, minutes, invitation letters, photographs of the meeting, copies of meeting sign-in sheets);

  2) a brief narrative and/or illustration demonstrating how community input influenced changes to the design or an explanation of why changes were not made;

  3) at least one letter of support from a community association and/or social network stating that the project team worked directly to engage with the association or network to advertise and generate comments on the project;

  4) a brief narrative describing the ongoing means of communication between developers and community during design, construction, and in cases where the developer maintains control of part or the entire project, after construction.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ If community outreach and involvement efforts had not taken place at the time of previous stages of certification, submit documentation of these efforts.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Neighborhood Pattern & Design

NPD Credit 16: Local Food Production
1 Point

Intent

Promote community-based and local food production to minimize the environmental impacts from transporting food long distances and increase direct access to fresh foods.

Requirements

Establish **CC&Rs** or other forms of deed restrictions that do not prohibit areas for growing produce, including greenhouses, on any portion or area of residential front yards, rear yards, side yards, balconies, patios or rooftops. Greenhouses, but not gardens, may be prohibited in front yard areas that face the street.

AND

Meet the requirements under one of the following Options:

OPTION 1 – NEIGHBORHOOD FARMS AND GARDENS

Dedicate permanent and viable growing space and/or related facilities (such as greenhouses) within the **project** at the square footage areas specified below. Provide fencing, watering systems, soil and/or garden bed enhancements (such as raised beds), secure storage space for garden tools, solar access, and pedestrian access for these spaces. Ensure that the spaces are owned and managed by an entity that can include occupants of the project in its decision-making, such as a community group, a homeowners association, or a public body.

Project **density** (dwelling unit/acre)	Required growing space (sq ft per dwelling unit)
7 to 14	200
> 14 and ≤ 22	100
> 22 and ≤ 28	80
> 28 and ≤ 35	70
> 35	60

OR

OPTION 2 – COMMUNITY SUPPORTED AGRICULTURE

Purchase shares in a **Community Supported Agriculture (CSA)** program located within 150 miles of the project site for at least 80% of the households within the project for two years. Shares must be delivered to within ¼ mile of the project on a regular schedule, which shall not be less than twice per month at least four months of the year.

OR

OPTION 3 – PROXIMITY TO FARMERS' MARKET

Locate and/or design project such that the center is within ¼ mile of an established farmer's market (that has been operating for at least two years), with at least three producer vendors, and that operates at least once a week for at least 5 months of the year.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ A copy of, or a written commitment to create, any necessary CC&Rs, development agreements, deed restrictions, or other binding documents that will establish that areas for growing produce are not prohibited as specified.

Option 1

- ❑ A site plan showing the location and size of dedicated space for growing and/or related facilities.
- ❑ A calculation showing the required growing space based on density.
- ❑ A written commitment to provide the items specified if the project is built.
- ❑ A brief narrative explaining what entity will serve to own and manage the growing spaces and facilities.

Option 2

- ❑ Identification of available CSA programs that can deliver to within ¼ mile of the project site according to the specified schedule, and an estimated cost for purchasing shares for 80% of the project's households for two years.
- ❑ A written commitment to purchase shares for 80% of the project's households for two years, if the project is built.

Option 3

- ❑ A map showing the location of the relevant farmers' market in relation to the project.

- ❑ A brief narrative describing the number of producer vendors and the market's schedule of operation.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ If a written commitment to create the required agreements regarding the allowance of growing spaces and facilities was submitted previously, submit a copy of the actual agreement(s).
- ❑ For Option 1, if a written commitment to provide the items specified was submitted previously, submit confirmation that the items were provided.
- ❑ For Option 2, if a written commitment to purchase shares for 80% of the project's households for two years, submit confirmation that the shares were purchased.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Prerequisite 1: Construction Activity Pollution Prevention Required

Intent

Reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation.

Requirements

Create and implement an Erosion and Sedimentation Control (ESC) Plan for all construction activities associated with the **project**. The ESC Plan shall list the Best Management Practices (BMPs) employed and describe how the BMPs accomplish the following objectives:

- Prevent loss of soil during construction by stormwater runoff and/or wind erosion, including protecting topsoil by stockpiling for reuse.
- Prevent sedimentation of any impacted stormwater conveyance systems or receiving streams.
- Prevent polluting the air with dust and particulate matter.

The BMPs shall be selected from the 2003 EPA Construction General Permit (CGP) OR local erosion and sedimentation control standards and codes, whichever is more stringent.

Note: Many projects are already mandated to comply with the CGP. These requirements are intended to integrate consideration of these measures into site planning and to ensure that all projects seeking LEED certification implement these measures, regardless of size.

Additional Notes

Information on the CGP is available at: http://cfpub.epa.gov/npdes/stormwater/cgp.cfm.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating where erosion and sedimentation control will be necessary during construction.
- ❑ A written commitment that an ESC plan will be created and implemented if the project is built, or confirmation that local code requires the same provisions.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A summary of the ESC Plan, including a list of BMPs that will be used and confirmation of whether they were selected from the EPA CGP or local standards and codes.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to prerequisite requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Copies of photographs or drawings to document the erosion and sedimentation control measures implemented on the site, or a representative sample thereof.
- ❑ A brief narrative describing the erosion and sedimentation control measures implemented on the project.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 1: LEED Certified Green Buildings

1 to 3 Points

Intent

Encourage the design and construction of buildings to utilize green building practices.

Requirements

OPTION 1 – FOR **PROJECTS** WITH 5 OR FEWER **HABITABLE BUILDINGS**

Design, construct, or retrofit one building as part of the project to be certified under one of the following LEED building rating systems: LEED for New Construction, LEED for Existing Buildings, LEED for Homes, LEED for Core & Shell, LEED for Schools, or any Application Guides of these rating systems (1 point). Additional points (no more than 3 total) may be earned for each additional certified building that is part of the project;

OR

OPTION 2 – FOR PROJECTS WITH 6 OR MORE HABITABLE BUILDINGS

Design, construct, or retrofit a percentage of the square footage of buildings that are part of the project to be certified under one of the LEED building rating programs listed above. Points are available as follows:

Percent of square footage of project's buildings LEED certified	Points
20% to 30%	1
> 30% to 40%	2
> 40%	3

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to certify the relevant buildings under a LEED building rating system if the project is built.

Option 2

- ❑ A calculation showing the percentage of square footage that will be LEED certified.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ Confirmation that the relevant buildings have been registered under a LEED building rating system. (If buildings are submitting for Design Review, the results of this review may be submitted, but are not required.)

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Confirmation that the relevant buildings have been certified under a LEED building rating system.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 2: Energy Efficiency in Buildings
1 to 3 Points

Intent

Encourage the design and construction of energy efficient buildings to reduce air, water, and land pollution and environmental impacts from energy production and consumption.

Requirements

1 POINT CAN BE EARNED AS FOLLOWS:

Design and construct at least 90% of all buildings in the **project** such that they meet one of the following requirements according to the appropriate category:

Category 1: For non-residential buildings and residential buildings over 3 stories:

WHOLE BUILDING ENERGY SIMULATION

Demonstrate a minimum 10% improvement in the proposed building performance rating compared to the baseline building performance rating per ASHRAE/ IESNA Standard 90.1-2004 (without addenda) by a whole building project simulation using the Building performance Rating Method in Appendix G of the Standard. Appendix G requires that this energy analysis include ALL of the energy costs within and associated with the building project. To achieve this point, the proposed design:

- must comply with the mandatory provisions (Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4) in Standard 90.1-2004 (without addenda);
- must include all the energy costs within and associated with the building project; and
- must be compared against a baseline building that complies with Appendix G to Standard 90.1-2004 (without addenda). The default process energy cost is 25% of the total energy cost for the baseline building. For buildings where the process energy cost is less than 25% of the baseline building energy cost, the LEED submittal must include supporting documentation substantiating that process energy inputs are appropriate.

For the purposes of this analysis, process energy is considered to include, but is not limited to, office and general miscellaneous equipment, computers, elevators and escalators, kitchen cooking and refrigeration, laundry washing and drying, lighting exempt from the lighting power allowance (e.g. lighting integral to medical equipment) and other (e.g. waterfall pumps). Regulated (non-process) energy includes lighting (such as for the interior, parking garage, surface parking, façade, or building grounds, except as noted above), HVAC (such as for space heating, space cooling, fans, pumps, toilet exhaust, parking garage ventilation, kitchen hood exhaust, etc.), and service water heating for domestic or space heating purposes.

For this credit, process loads shall be identical for both the baseline building performance rating and for the proposed building performance rating. However, project teams may follow the Exceptional Calculation Method (ASHRAE 90.1-2004 G2.5) to document measures that reduce process loads. Documentation of process load energy savings shall include a list of the assumptions made for both the base and proposed design, and theoretical or empirical information supporting these assumptions.

OR

PRESCRIPTIVE COMPLIANCE PATH A

Comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide for Small Office Buildings or the ASHRAE Advanced Energy Design Guide for Small Retail Buildings, as appropriate to building type. The following restrictions apply:

- Buildings must be under 20,000 square feet.
- Buildings must be office or retail occupancy.
- Project teams must fully comply with all applicable criteria as established in the Advanced Energy Design Guide for the climate zone in which the building is located.

OR

PRESCRIPTIVE COMPLIANCE PATH B

Comply with the Basic Criteria and Prescriptive Measures of the Advanced Buildings Benchmark™ Version 1.1 with the exception of the following sections: 1.7 Monitoring and Trend-logging, 1.11 Indoor Air Quality, and 1.14 networked Computer Monitor Control. The following restrictions apply:

- Project teams must fully comply with all applicable criteria as established in Advanced Buildings Benchmark for the climate zone in which the building is located.

Category 2: For residential buildings 3 stories or fewer:

Qualify as an ENERGY STAR Home by either a performance path (through a **HERS Index** rating) or a prescriptive path (Builder Option Package or BOP).

2 POINTS CAN BE EARNED AS FOLLOWS:

Design and construct at least 90% of all buildings in the project such that they meet one of the following requirements according to the appropriate category:

Category 1: For non-residential buildings and residential buildings over 3 stories:

WHOLE BUILDING ENERGY SIMULATION

Demonstrate a minimum 15% improvement in the proposed building performance rating compared to the baseline described above in WHOLE BUILDING ENERGY SIMULATION of Category 1.

OR

PRESCRIPTIVE COMPLIANCE PATH A

Comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide for Small Office Buildings or the ASHRAE Advanced Energy Design Guide for Small Retail Buildings, as described above in PRESCRIPTIVE COMPLIANCE PATH A of Category 1.

Category 2: For residential buildings 3 stories or fewer:

Qualify as an ENERGY STAR Home by either a performance path (through a HERS Index rating) or a prescriptive path (Builder Option Package or BOP).

3 POINTS CAN BE EARNED AS FOLLOWS:

Design and construct at least 90% of all buildings in the project such that they meet one of the following requirements according to the appropriate category:

Category 1: For non-residential buildings and residential buildings over 3 stories:

WHOLE BUILDING ENERGY SIMULATION

Demonstrate a minimum 20% improvement in the proposed building performance rating compared to the baseline described above in WHOLE BUILDING ENERGY SIMULATION of Category 1.

OR

PRESCRIPTIVE COMPLIANCE PATH A

Comply with the prescriptive measures of the ASHRAE Advanced Energy Design Guide for Small Office Buildings or the ASHRAE Advanced Energy Design Guide for Small Retail Buildings, as described above in PRESCRIPTIVE COMPLIANCE PATH A of Category 1.

Category 2: For residential buildings 3 stories or fewer:

Exceed the ENERGY STAR for Homes requirements by achieving a minimum **HERS Index** of at least 80 for **IECC** Climate Zones 1-5 (generally the southern United States), or at least 75 for IECC Climate Zones 6-8 (generally the northern United States).

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to meet the requirements of the credit as appropriate to the number of points attempted if the project is built, including a table listing each building and what compliance path is planned for the building, and a calculation showing the percentage of buildings that will be meeting the relevant requirements.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ For Category 1 buildings, submit a statement of the project team's capacity and/or qualifications to design and construct the relevant buildings according to the compliance path chosen, and/or a description of the services that will be contracted to do so.
- ❑ For Category 2 buildings, submit the name of the HERS provider to be used or a brief narrative explaining how the project team will ensure that homebuilders will have the necessary capacity and/or qualifications to meet the requirements.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For Category 1 buildings using WHOLE BUILDING ENERGY SIMULATION, submit confirmation that, for a representative sample of buildings, whole building energy simulation was completed and the specified percentage of improvement in energy performance was achieved. (The LEED submittal template may provide additional calculations that are too lengthy to repeat here.)

- ❑ For Category 1 buildings using PRESCRIPTIVE COMPLIANCE PATH A, submit confirmation that, for a representative sample of buildings, the prescriptive measures of the appropriate ASHRAE Advanced Energy Design Guide were met. (The LEED submittal template may provide additional calculations that are too lengthy to repeat here.)
- ❑ For Category 1 buildings using PRESCRIPTIVE COMPLIANCE PATH B, submit confirmation that, for a representative sample of buildings, the prescriptive measures of the Advanced Buildings Benchmark™ were met. (The LEED submittal template may provide additional calculations that are too lengthy to repeat here.)
- ❑ For Category 2 buildings attempting 1 or 2 points, submit the ENERGY STAR for Homes certificate.
- ❑ For Category 2 buildings attempting 3 points, submit the HERS performance test results.

<u>Case 3B: Change since Stage 2</u>
If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 3: Reduced Water Use
1 to 3 Points

Intent

Minimize water use in buildings and for landscape irrigation to reduce the impact to natural water resources and reduce the burden on municipal water supply and wastewater systems.

Requirements

OPTION 1 – INDOOR (1 to 2 points)

Design and construct at least 90% of all buildings in the **project** such that they meet one of the following requirements according to the appropriate category (1 point):

Category 1: For non-residential buildings and residential buildings over 3 stories:

Employ strategies that in aggregate use 20% less water than the water use baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements. Calculations are based on estimated occupant usage and shall include only the following fixtures (as applicable to the building): water closets, urinals, lavatory faucets, showers, and kitchen faucets.

Category 2: For residential buildings 3 stories or fewer:

Comply with 2 out of 3 of the following requirements:

- The average flow rate for all lavatory faucets must be ≤ 2.0 GPM.
- The average flow rate for all shower heads must be ≤ 2.0 GPM.
- The average flow rate for all toilets, including dual-flush toilets, must be ≤ 1.3 GPF.

2 POINTS CAN BE EARNED AS FOLLOWS:

Design and construct at least 90% of all buildings in the project such that they meet one of the following requirements according to the appropriate category:

Category 1: For non-residential buildings and residential buildings over 3 stories:

Employ strategies that in aggregate use 30% less water than the water use baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements. Calculations are based on estimated occupant usage and shall include only the following fixtures (as applicable to the building): water closets, urinals, lavatory faucets, showers, and kitchen faucets.

Category 2: For residential buildings 3 stories or fewer:

Comply with all of the following requirements:

- The average flow rate for all lavatory faucets must be ≤ 2.0 GPM.
- The average flow rate for all shower heads must be ≤ 2.0 GPM.
- The average flow rate for all toilets, including dual-flush toilets, must be ≤ 1.3 GPF.

OR

OPTION 2 – OUTDOOR (1 point)

For irrigation, use only captured rainwater, recycled wastewater, recycled **graywater**, or water treated and conveyed by a public agency specifically for non-potable uses.

OR

Install landscaping that does not require permanent irrigation systems. Temporary irrigation systems used for plant establishment are allowed only if removed within one year of installation.

A point from Option 2 may be earned independently, or be added to those earned under Options 1, for a maximum of 3 points.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ An estimate of baseline indoor water use based on the type and number of buildings in the project.
- ❑ A written commitment to employ indoor water use reduction strategies to meet the requirements of the credit as appropriate to the number of points attempted if the project is built.

Option 2

- ❑ A site plan indicating areas of outdoor water use.
- ❑ A written commitment to employ outdoor water use reduction strategies to meet the requirements of the credit, including a list of strategies planned.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

Option 1

- ❑ For Category 1 buildings, submit: 1) a narrative describing the strategies that were used in the buildings to reduce water use; 2) a table showing each building's water use compared to the baseline fixture performance requirements of the Energy Policy Act of 1992; and 3) a calculation of the aggregate percentage of reduced water use for each building.
- ❑ For Category 2 buildings, submit a table showing the fixtures that were incorporated into each building that meet the flow rate specifications.

Option 2

- ❑ The total non-potable water supply in gallons available for irrigation purposes.
- ❑ A brief narrative describing the landscaping and irrigation design strategies employed by the project.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 4: Building Reuse and Adaptive Reuse
1 to 2 Points

Intent

Extend the life cycle of existing building stock, conserve resources, reduce waste, and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Incorporate into the **project** the reuse of one building that maintains at least 50% (based on surface area) of the existing building structure (including structural floor and roof decking) and envelope (including exterior skin and framing, and excluding window assemblies and non-structural roofing material). Hazardous materials that are remediated as a part of the project scope shall be excluded from the calculation of the percentage maintained (1 point).

For projects reusing portions of two or more existing buildings, 1 additional point can be earned by incorporating into the project the reuse that achieves the greater of the following:

- 50% of 1 existing building plus an equivalent amount reused among one or more buildings (based on surface area, as defined above); or
- 20% of the existing building stock (based on surface area, as defined above)

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to maintain the percentage of building structure(s) to meet the requirements of the credit as appropriate to the number of points attempted if the project is built.
- ❑ For projects attempting to earn 2 points, confirmation of which compliance path the project will use and calculations demonstrating that it is the greater of the two.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A table of the existing and reused areas in square feet of each structural/envelope element, and a calculation of the percentage of existing buildings reused.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 5: Reuse of Historic Buildings
1 Point

Intent

Encourage use of historic buildings in a manner that preserves their historic materials and character.

Requirements

Incorporate into the **project** one or more buildings that have been:

- designated, listed, or identified by a local government as a historic or contributing structure in a locally designated historic district pursuant to a local preservation ordinance;
  OR
- designated, listed, or identified as a historic or contributing structure in a historic district under a state historic register or on the National Register of Historic Places;

AND

Rehabilitate the building(s) in accordance with local or federal standards for rehabilitation, and:

- obtain confirmation from the municipality, and/or the local historic preservation commission that the plan(s) for rehabilitation meet the local standards for an historic rehabilitation,
  OR
- obtain confirmation from a State Historic Preservation Office or the National Park Service that the rehabilitation satisfies the Secretary of the Interior's "Standards for Rehabilitation."

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A document from the local government, the State Historic Preservation Officer, or the National Park Service stating the name and address of the property, its historic designation or status, and the date of designation. Other acceptable documents include a copy of the notice in the *Federal Register* or a verifiable copy of the web page of a state or national register that demonstrates the designation.

- ❑ A written commitment to incorporate and rehabilitate at least one historic building to meet the requirements of the credit if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A document from the municipality, and/or the local historic preservation commission stating that the building(s) has complied with local requirements for a historic rehabilitation, including the name and address of the property or properties, and the date compliance was determined, or a document from the State Historic Preservation officer or the National Park Service, stating that the building(s) has complied with the Secretary of the Interior's "Standards for Rehabilitation," including the name and address of the certified property or properties and the date compliance was determined.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 6: Minimize Site Disturbance Through Site Design
1 Point

Intent

Preserve existing tree canopy, native vegetation and pervious surfaces while encouraging high **density**, smart growth communities.

Requirements

OPTION 1

Locate the **development footprint** on areas that are 100% **previously developed** and for which the zone of construction impact is 100% previously developed;

OR

OPTION 2

Depending on the density of the **project**, do not develop or disturb a proportion of the land that has not been previously developed on the site, exclusive of any land excluded from development by law or required to be preserved as a prerequisite of LEED for Neighborhood Development, and stipulate in **CC&Rs** or other binding development documents that the undisturbed area will be protected from development in perpetuity. Densities and minimum percentages are as follows (mixed use projects should use the lowest applicable density or calculate a weighted average per the methodology in NPD Credit 1: Compact Development):

Residential Density (DU/acre)	Non-Residential Density (**FAR**)	Minimum percentage of previously undeveloped site area to leave undisturbed
< 15	< .50	20%
15-21	.50 – 1.00	15%
> 21	> 1.0	10%

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ A site plan indicating the location of any areas that are previously developed, the development footprint of the project, and the zone of construction impact.

Option 2

- ❑ A calculation showing the residential and/or non-residential density of the project.
- ❑ A calculation of the percentage of the previously undeveloped areas that will be left undisturbed.
- ❑ A copy of, or a written commitment to create, any necessary CC&Rs, development agreements, or other binding documents that will protect the undisturbed area according to the relevant credit requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For Option 2, if a written commitment to create the required agreements was submitted previously, submit a copy of the actual agreement(s).

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 7: Minimize Site Disturbance During Construction
1 Point

Intent

Conserve existing natural areas and protect trees to provide habitat and promote biodiversity.

Requirements

OPTION 1

Locate the **development footprint** on areas that are 100% **previously developed** and for which the zone of construction impact is 100% previously developed;

OR

OPTION 2

For portions of the site that are not previously developed: identify limits of disturbance through the creation of construction impact zones; and limit all site disturbance to 40 feet beyond the building perimeter; 10 feet beyond surface walkways, patios, surface parking and utilities less than 12 inches in diameter; 15 feet beyond primary roadway curbs and main utility branch trenches; and 25 feet beyond constructed areas with permeable surfaces (such as pervious paving areas, stormwater detention facilities and playing fields) that require additional staging areas in order to limit compaction in the constructed area.

OR

OPTION 3 – AVAILABLE FOR SITES WITH TREES ONLY

Survey the site to identify:

- trees in good or excellent condition as determined by a certified arborist,
- any Heritage or Champion trees of special importance to the community as defined by a jurisdictional City, County or State Forester because of their age, size, type, historical association or horticultural value,
- the caliper of all trees at 4'6" above ground (diameter at breast height or D.B.H.), and
- any invasive species of tree present on the site, and whether those species threaten the health of other trees to be preserved on the site, as determined by a certified arborist.

Preserve the following on the site that are also identified as in good or excellent condition:

- all Heritage or Champion Trees identified,
- a minimum of 75% of all non-invasive trees (including the above) over 18" in caliper (D.B.H.), and
- a minimum of 25% of all non-invasive trees (including the above) that are over 12" in caliper (D.B.H.) if deciduous, and 6" in caliper (D.B.H.) if conifer.

Develop a plan, in consultation with and approved by a certified arborist, for the health of the trees, including fertilization and pruning, and construction tree protection plans and specifications which are to include protection fencing located at the drip line of each tree, and specifying that if trenching or other disturbance is necessary within the drip line, this work must be done by hand. If a certified arborist has determined that the health of the trees to be preserved is threatened by invasive vegetation, develop a plan for invasive vegetation removal and restoration.

Stipulate in **CC&Rs** or other binding development documents that the preserved trees will be protected from development in perpetuity.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Options 1 and 2

- ❑ A site plan indicating the location of any areas that are previously developed, the development footprint of the project, and the zone of construction impact.

Option 3

- ❑ A site plan showing the locations of existing trees, and indicating which will be preserved.
- ❑ A summary of the survey conducted, highlighting the type and quantity of trees found, any Heritage or Champion trees, any trees with a caliper greater than 18”, and any invasive tree species present on the site.
- ❑ A list or summary of the trees to be preserved.
- ❑ A calculation of the percentage of non-invasive trees with a caliper greater than 12” or 6” (as appropriate to type) that will be preserved.
- ❑ A copy or summary of the maintenance plan developed in consultation with a certified arborist.
- ❑ A copy of, or a written commitment to create, any necessary CC&Rs, development agreements, or other binding documents that will protect the preserved trees according to the relevant credit requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2
If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ For Option 3, if a written commitment to create the required agreements was submitted previously, submit a copy of the actual agreement(s).

Case 3B: Change since Stage 2
If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 8: Contaminant Reduction in Brownfields Remediation
1 Point

Intent

Encourage **brownfields** cleanup methods that reduce contaminant volume or toxicity and thereby minimize long-term remediation or monitoring burdens.

Requirements

Earn SLL Credit 1: Contaminated Brownfields Redevelopment;

AND

Use cleanup method(s) for 100% of the remediation that treat, reduce or eliminate the volume or toxicity of contaminated material found on the site.

Cleanup methods which include only capping or translocation of contaminated material to an off-site location will not achieve this credit.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating the areas of contamination.
- ❑ A written commitment to meet the requirements of the credit if the project is built, and a brief narrative describing the types of contamination and the cleanup methods to be used.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A brief narrative and/or technical drawings demonstrating the cleanup methods used.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 9: Stormwater Management
1 to 5 Points

JUNE 2007 VERSION

Note: Projects can use this version or the February 2007 version found in Appendix B.

Intent

Reduce adverse impacts on water resources by mimicking the natural hydrology of the region on the project site, including groundwater recharge. Reduce pollutant loadings from stormwater discharges, reduce peak flow rates to minimize stream channel erosion, and maintain or restore chemical, physical, and biological integrity of downstream waterways.

Requirements

OPTION 1 – FOR **PREVIOUSLY DEVELOPED SITES**

Implement a comprehensive stormwater management plan for the **project** that infiltrates, re-uses, or evapotranspirates the below-specified amount of rainfall from the project's **development footprint** and other areas that have been graded so as to be effectively impervious.

Points achievable	Arid Watersheds (less than 20" of rain/year)	Semi-arid Watersheds (between 20"-40" rain/year)	Humid Watersheds (at least 40" rain/year)
1 point	0.15"	0.225"	0.3"
2 points	0.3"	0.45"	0.6"
3 points	0.45"	0.675"	0.9"
4 points	0.6"	0.9"	1.2"
5 points	0.75"	1.125"	1.5"

OPTION 2 – FOR ALL OTHER SITES

Implement a comprehensive stormwater management plan for the project that infiltrates, re-uses, or evapotranspirates the below-specified amount of rainfall from the project's **development footprint** and other areas that have been graded so as to be effectively impervious.

Points achievable	Arid Watersheds (less than 20" of rain/year)	Semi-arid Watersheds (between 20"-40" rain/year)	Humid Watersheds (at least 40" rain/year)
1 point	0.3"	0.45"	0.6"
2 points	0.6"	0.9"	1.2"
3 points	0.9"	1.35"	1.8"

4 points	1.2”	1.8”	2.4”
5 points	1.5”	2.25”	3.0”

Notes: a) The stormwater management plan should identify practices to be employed, such as permeable pavements, rainwater harvesting systems or green roofs.
b) For the purposes of the calculations in this credit, the development footprint will include typically impervious surfaces included in the definition of “development footprint,” such as roofs and pavements, even though the surfaces may be made pervious as part of the stormwater management plan.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ A site plan indicating the project’s development footprint, and the location of any planned stormwater management technologies or BMPs.
- ❑ A written commitment to develop and implement a comprehensive stormwater management plan to meet the requirements if the project is built.
- ❑ Confirmation of type of watershed.

Option 1

- ❑ A site plan indicating previously developed areas (this can be done as part of the site plan listed above).

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate “No change since Stage 1” on project checklist, and submit the following additional documentation:

All Options

- ❑ A summary of the stomwater management plan, highlighting the technologies or BMPs used on the site.

- ❑ A statement of the project team's capacity and/or qualifications to implement the plan, and/or a description of the services that will be contracted to do so.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>
If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A calculation of either 90% of the average annual rainfall or 1" of rainfall that occurs on the project's development footprint and other effectively impervious areas.
- ❑ A calculation of the percentage of the development footprint for which runoff will be infiltrated, re-used, or evapotranspirated.

<u>Case 3B: Change since Stage 2</u>
If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 10: Heat Island Reduction
1 Point

Intent

Reduce heat islands to minimize impact on microclimate and human and wildlife habitat.

Requirements

OPTION 1 – NON-ROOF

Provide any combination of the following strategies for 50% of the non-roof impervious site landscape (including roads, sidewalks, courtyards, parking lots, and driveways):

- Shade (within five years of occupancy)
- Paving materials with a Solar Reflectance Index (SRI) of at least 29
- Open grid pavement system

OR

Place a minimum of 50% of off-street parking spaces under cover (defined as underground, under deck, under roof, or under a building). Any roof used to shade or cover parking must have an SRI of at least 29;

OR

OPTION 2 – ROOF

Use roofing materials that have a Solar Reflectance Index (SRI) equal to or greater than the values in the table below for a minimum of 75% of the roof surface of all buildings within the **project**; or install a "green" (vegetated) roof for at least 50% of the roof area of all buildings within the project. Combinations of SRI compliant and vegetated roof can be used provided that they collectively cover 75% of the roof area of all buildings.

Roof Type	Slope	SRI
Low-Sloped Roof	≤ 2:12	78
Steep-Sloped Roof	≥ 2:12	29

Additional Notes

Shaded areas for the purposes of this credit will include areas shaded by trees, other landscape features, but not awnings, buildings, or other structural features.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site plan indicating the location of any non-roof areas that will be employing the heat island reduction technologies or strategies listed in the requirements.
- ❑ A written commitment to employ sufficient non-roof heat island reduction strategies to meet the requirements, if the project is built.

Option 2

- ❑ A site plan indicating the location of any green roofs or roof areas that will have an SRI greater than or equal to those specified in the requirements.
- ❑ A written commitment to include a sufficient percentage of green roofs, or roofs with the specified SRI value to meet the requirements, if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

Option 1

- ❑ A table of strategies to be used and area covered by each, and a calculation of the percentage of non-roof impervious site landscape that will employ heat island reduction strategies.

Option 2

- ❑ A table of roof types to be used and roof area covered for each, and a calculation of the percentage of roof area that will be green roofs or roofs with the specified SRI value.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Green Construction & Technology

GCT Credit 11: Solar Orientation
1 Point

Intent

Achieve enhanced energy efficiency by creating the optimum conditions for the use of passive and active solar strategies.

Requirements

OPTION 1 – BLOCK DESIGN (AVAILABLE FOR **PROJECTS** EARNING AT LEAST 2 POINTS UNDER NPD CREDIT 1: COMPACT DEVELOPMENT)

Locate project on existing blocks, or design and orient project, such that for 75% or more of the project's blocks, one axis of each block is within 15 degrees of geographical east/west, and the east/west length of each block is at least as long, or longer, as the north/south length of the block.

OR

OPTION 2 – BUILDING DESIGN (AVAILABLE FOR ALL PROJECTS)

Design and orient 75% or more of the **project**'s buildings such that one axis of each building is at least 1.5 times longer than the other, and such that the longer axis is within 15 degrees of the geographical east/west axis. The length to width ratio shall be applied only to the length of walls enclosing conditioned spaces; walls enclosing unconditioned spaces such as garages, arcades, or porches cannot contribute to credit achievement. South-facing vertical surfaces of buildings counting towards credit achievement must not be more than 25% shaded at time of initial occupancy (measured at noon on December 21st).

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

Option 1

- ❑ A site plan indicating the axis of all relevant blocks, and their degree relation to the geographical east/west axis.
- ❑ A calculation of the percentage of blocks that have a long (or equal-length) axis within 15 degrees of geographical east/west axis.

Option 2

- ❑ A site plan indicating: 1) the axis of all relevant buildings and their degree relation to the geographical east/west axis; and 2) the length to width proportion of each relevant building.
- ❑ A cross section drawing showing any shading that would impact solar access for relevant buildings.
- ❑ A calculation of the percentage of buildings that the required proportions and their long axis within 15 degrees of geographical east/west axis.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>
If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

Option 2

- ❑ Drawings, diagrams, or photographs demonstrating the solar access for each relevant building, or a representative sample thereof.

<u>Case 3B: Change since Stage 2</u>
If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 12: On-Site Energy Generation
1 Point

Intent

Reduce air, water, and land pollution from energy consumption and production by increasing the efficiency of the power delivery system. Increase the reliability of power.

Requirements

OPTION 1 – (PRESCRIPTIVE) ELECTRICAL BASELINE

Develop on-site energy generation system(s) with peak electrical generating capacity of at least 5% of the **project**'s specified electrical service load.

OPTION 2 – (PERFORMANCE) TOTAL ENERGY BASELINE

Develop on-site energy generation system(s) with capacity of at least 5% of the project's annual electrical and thermal energy consumption, as established through an accepted building energy performance simulation tool.

For both options, total CO_2 emissions shall be less than or equal to national average of CO_2 emissions for grid supplied electricity, which shall be calculated as the sum of 1545 lb per MWh produced by the on-site power generation system and 145 lb per MMBtu of thermal energy produced by the on-site power generation system.

For both options, calculations for total on-site energy can include future site or building-integrated systems stipulated through **CC&Rs** or other binding documents.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to develop on-site energy generation system(s) to meet the requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A brief narrative describing the planned on-site energy generation system(s), including an estimate of the total project specified electrical service load or energy use, confirmation of which compliance path will be used, the type(s) of on-site energy system(s) to be used, and estimates of CO_2 emissions compared to the national average of grid supplied electricity.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

All Options

- ❑ A list of on-site energy generating system(s) used and the generation capacity of each.
- ❑ A calculation of total CO_2 emissions of the system compared to the national average for grid supplied electricity, as described in the requirements.

Option 1

- ❑ The total electrical service load of the project and a calculation showing the percentage that is generated by on-site system(s).

Option 2

- ❑ The total annual electrical and thermal energy consumption of the project, a calculation showing the percentage that is generated by on-site system(s), and confirmation of the building energy performance simulation tool used.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 13: On-Site Renewable Energy Sources
1 Point

Intent

Encourage on-site renewable energy self-supply in order to reduce environmental and economic impacts associated with fossil fuel energy use.

Requirements

OPTION 1 – (PRESCRIPTIVE) ELECTRICAL BASELINE

Design and incorporate the use of shared on-site nonpolluting renewable energy generation technologies such as solar, wind, geothermal, small scale/micro hydroelectric, and biomass with peak electrical generating capacity of at least 5% of the **project's** specified electrical service load.

OPTION 2 – (PERFORMANCE) TOTAL ENERGY BASELINE

Design and incorporate the use of shared on-site nonpolluting renewable energy generation technologies such as solar, wind, geothermal, small scale/micro hydroelectric, and biomass with peak electrical generating capacity of at least 5% of the project's annual electrical and thermal energy consumption, as established through an accepted building energy performance simulation tool.

For both options, calculations for total on-site energy can include future site or building-integrated systems stipulated through **CC&Rs** or other binding documents.

Additional Notes

Eligible Renewable Energy Systems

- **Electrical Systems:** Photovoltaic (PV), wind, hydro, wave, tidal, and bio-fuel based electrical production systems deployed at the project site.

- **Geothermal Energy Systems:** Geothermal energy systems using deep-earth water or steam sources (and not using vapor compression systems for heat transfer) deployed at the project site. These systems may either produce electric power or provide thermal energy for primary use at the building.
- **Solar Thermal Systems:** Active solar thermal energy systems that employ collection panels; heat transfer mechanical components, such as pumps or fans, and a defined heat storage system, such as a hot water tank or thermo-siphon solar and storage tank "batch heaters" deployed at the site.

Ineligible on-site renewable energy systems include geo-exchange systems (ground source heat pumps) and renewable or green-power from off-site sources. Eligible bio-fuels include untreated wood waste including mill residues, agricultural crops or waste, animal waste and other organic waste and landfill gas. Electrical production based on the following bio-fuels are excluded from eligibility for this credit:

combustion of municipal solid waste, forestry biomass waste, other than mill residue, wood that has been coated with paints, plastics, or formica and wood that has been treated for preservation with materials containing halogens, chlorine compounds, halide compounds, chromated copper arsenate (CCA), or arsenic. If more than 1% of the wood fuel has been treated with these compounds, the energy system shall be considered ineligible for this credit.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to develop on-site renewable energy generation system(s) to meet the requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A brief narrative describing the planned on-site renewable energy generation system(s), including an estimate of the specified electrical service load or total project energy use, confirmation of which compliance path will be used, and the type(s) of on-site energy system(s) to be used.

Case 2B: Change since Stage 1
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)
Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

All Options

- ❑ A list of on-site renewable energy generating system(s) used and the generation capacity of each.

Option 1

- ❑ The total electrical service load of the project and a calculation showing the percentage that is generated by on-site renewable energy system(s).

Option 2

- ❑ The total annual electrical and thermal energy consumption of the project, a calculation showing the percentage that is generated by on-site renewable energy system(s), and confirmation of the building energy performance simulation tool used.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 14: District Heating & Cooling
1 Point

Intent

Reduce air, water, and land pollution resulting from energy consumption in buildings by employing energy efficient district technologies.

Requirements

Design and incorporate into the **project** a district heating and/or cooling system for space conditioning of all buildings in the project (at least 2 buildings total) such that at least 80% of the project total square footage is connected, and at least 80% of the project total peak heating or cooling load is connected.

The efficiency of each component of the system which is regulated by ASHRAE / IESNA 90.1-2004 must have an overall efficiency performance at least 10% better than specified by the ASHRAE 90.1 - 2004 Prescriptive Requirements. Additionally, pumping power must not exceed 2.5% of the thermal energy output (with one kWh of electricity equal to 3,413 Btu). Combined Heat and Power (CHP) district systems can achieve this credit by demonstrating equivalency relative to the above criteria.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to develop a district heating and/or cooling system to meet the requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A brief narrative describing the planned district heating or cooling system, including an estimate of the total project heating or cooling load, and which buildings will be connected.
- ❑ A list of components of the system that are regulated by ASHRAE / IESNA 90.1-2004, and the estimated efficiency of each compared to the relevant standard.
- ❑ Submit an estimate of pumping power as a percentage of thermal energy output.

<u>Case 2B: Change since Stage 1</u>

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 3A: No change since Stage 2</u>

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ The heating or cooling generation capacity of the system.
- ❑ The total heating or cooling load of the project, and a calculation showing the percentage that is generated by the district heating or cooling system.
- ❑ A calculation showing the percentage of the project total square footage that is connected.
- ❑ The efficiency of each component which is regulated by ASHRAE / IESNA 90.1-2004 compared to the relative standard.
- ❑ Submit the calculation of pumping power as a percentage of thermal energy output.

<u>Case 3B: Change since Stage 2</u>

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 15: Infrastructure Energy Efficiency
1 Point

Intent

Reduce air, water, and land pollution from energy consumption.

Requirements

Design or purchase any traffic lights, street lights, water and wastewater pumps and treatment systems that are included as part of the **project** to achieve a 15% annual energy reduction beyond an estimated baseline energy use for this infrastructure. If any traffic lights are installed as part of the project, use light emitting diode (LED) technology.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to meet the requirements for any of the specified infrastructure items used in the project if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A list of the relevant infrastructure items to be used in the project.
- ❑ An estimate of the baseline energy use for these items.
- ❑ A brief narrative explaining how the 15% reduction in annual energy use will be achieved and demonstrated.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A brief narrative and/or other documentation specified by the project beforehand (see Case 2A) demonstrating that the 15% reduction in energy use was achieved.
- ❑ Confirmation that LED technology was used for any traffic lights.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 16: Wastewater Management
1 Point

Intent

Reduce pollution from wastewater and encourage water reuse.

Requirements

Design and construct the **project** to divert at least 50% of the wastewater generated by the project, and reuse wastewater to replace the use of potable water. Provide for on-site wastewater treatment to a quality defined by state and local regulations for the proposed reuse.

50% of the wastewater is calculated by determining the total wastewater flow using conventional design practices in gallons per day and demonstrating that 50% of that volume enters an alternative, on-site process.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to divert, treat as necessary, and reuse wastewater on site to meet the requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ An estimate of the amount of wastewater to be generated by the project.

- ❑ A brief narrative describing the technologies to be used for diversion and treatment, the estimated percentage of wastewater to be diverted, and the on-site reuses for the diverted wastewater.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Applicable drawings from the construction documents that show the technologies used to divert, treat, and reuse wastewater.
- ❑ A calculation of the amount of wastewater generated by the project.
- ❑ A calculation of the amount of wastewater diverted, treated, and reused on site.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 17: Recycled Content in Infrastructure
1 Point

Intent

Use recycled materials to reduce the environmental impact of extraction and processing of virgin materials.

Requirements

Use the indicated recycled materials in all the following applications, if present in the **project**.

For roadways, parking lots, sidewalks, and curbs (above-ground structured parking and underground parking are exempt from this requirement):

- Any aggregate base and aggregate subbase shall be at least 90% by volume recycled aggregate materials such as crushed Portland cement concrete and asphalt concrete.
- Any asphalt base shall be a minimum 15% by volume recycled asphalt pavement.
- Any asphalt concrete pavement shall:
  - be a minimum 15% by volume recycled asphalt pavement, OR
  - be a minimum 75% by volume rubberized asphalt concrete from crumb rubber from scrap tires (crumb rubber modifier), OR
  - include a minimum of 5% (of total weight) of **pre-consumer** or **post-consumer** asphalt roofing shingles.
- Any Portland cement concrete pavement shall contain:
  - recycled mineral admixtures (such as coal fly ash, ground granulated blast furnace slag, rice hull ash, silica fume, or other pozzolanic industrial byproduct) to reduce by at least 25% the concrete mix's typical Portland cement content, AND
  - a minimum of 10% by volume reclaimed concrete material aggregate.

Piping made of Portland cement concrete shall contain recycled mineral admixtures (such as coal fly ash, ground granulated blast furnace slag, rice hull ash, silica fume, or other pozzolanic industrial byproduct) to reduce by at least 25% the concrete mix's typical Portland cement content.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to meet the requirements for recycled content in the specified applications, if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A table of each material used on the project that is being tracked for recycled content, including the type of material and recycled content.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 18: Construction Waste Management
1 Point

Intent

Divert construction and demolition debris from disposal in landfills and incinerators. Redirect recyclable recovered resources back to the manufacturing process. Redirect reusable materials to appropriate sites.

Requirements

Recycle and/or salvage at least 50% of non-hazardous construction and demolition debris. Develop and implement a construction waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be stored on-site or commingled. Excavated soil and land-clearing debris do not contribute to this credit. Calculations can be done by weight or volume, but must be consistent throughout.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A written commitment to recycle and/or salvage demolition debris to meet the requirements if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A summary of the construction waste management plan.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A table of the demolition debris, including a general description of each category of waste generated, the quantity in tons or cubic yards, and the location of receiving agent (recycler/landfill) for waste.
- ❑ A calculation showing the total percentage of material diverted from landfill disposal.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 19: Comprehensive Waste Management
1 Point

Intent

Reduce the waste hauled to and disposed of in landfills. Promote proper disposal of office and household hazardous waste streams.

Requirements

Meet at least two of the following three requirements and publicize the availability and benefits of the drop-off point(s), station(s), or services:

1) Include at least one drop-off point as part of the **project** available to all project occupants for office or household potentially hazardous wastes such as paints, solvents, oil, batteries; OR locate project in a local government jurisdiction that provides services for collecting these materials. If a plan for post-collection disposal or use does not exist, establish one.

2) Include at least one recycling or reuse station as part of the project available to all project occupants dedicated to the separation, collection, and storage of materials for recycling including, at a minimum, paper, corrugated cardboard, glass, plastics and metals; OR locate project in a local government jurisdiction that provides recycling services for these materials. If a plan for post-collection use does not exist, establish one.

3) Include at least one compost station as part of the project available to all project occupants dedicated to the collection and composting of food wastes; OR locate project in a local government jurisdiction that provides services for composting materials. If a plan for post-collection use does not exist, establish one.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)

Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating the location of the drop-off points or stations and a written commitment to provide them if the project is built, or confirmation that the project site is located in a jurisdiction that provides services for collecting these materials, and a schedule or summary of those services.
- ❑ A written commitment to publicize the availability and benefits of the drop-off points or stations to project occupants if the project is built.
- ❑ Confirmation that a plan for post-collection disposal or reuse of materials exists, or a written commitment to create one if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ If the collection services will be provided as part of the project (rather than by the local jurisdiction), submit a brief narrative describing how the stations will be operated and any necessary plans for post-collection disposal or reuse of materials.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Confirmation that the collection services are available to project occupants, and that any necessary plan for post-collection disposal or reuse of materials have been implemented.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Green Construction & Technology

GCT Credit 20: Light Pollution Reduction
1 Point

Intent

Minimize light trespass from site, reduce sky-glow to increase night sky access, improve nighttime visibility through glare reduction, and reduce development impact on nocturnal environments.

Requirements

For exterior lighting in **shared portions of the project**, only light areas as required for safety and comfort. Do not exceed 80% of the lighting power densities for exterior areas and 50% for building facades and landscape features as defined in ASHRAE/IESNA Standard 90.1-2004, Exterior Lighting Section, without addenda;

AND

Stipulate **CC&Rs** or other binding documents that require continued adherence to these standards.

All **projects** shall be classified under the following zones, as defined in IESNA RP-33, and shall follow all of the requirements for that specific zone:

LZ1 — Dark (Park and Rural Settings)
Design exterior lighting so that all site and building mounted luminaires produce a maximum initial illuminance value no greater than 0.01 horizontal and vertical footcandles at the site boundary and beyond. Document that 0% of the total initial designed fixture lumens are emitted at an angle of 90 degrees or higher from nadir (straight down).

LZ2 — Low (Residential areas)
Design exterior lighting so that all site and building mounted luminaires produce a maximum initial illuminance value no greater than 0.10 horizontal and vertical footcandles at the site boundary and no greater than 0.01 horizontal footcandles 10 feet beyond the site boundary. Document that no more than 2% of the total initial designed fixture lumens are emitted at an angle of 90 degrees or higher from nadir (straight down). For site boundaries that abut public rights-of-way, light trespass requirements may be met relative to the curb line instead of the site boundary.

LZ3 — Medium (Commercial/Industrial, High-Density Residential)
Design exterior lighting so that all site and building mounted luminaires produce a maximum initial illuminance value no greater than 0.20 horizontal and vertical footcandles at the site boundary and no greater than 0.01 horizontal footcandles 15 feet beyond the site. Document that no more than 5% of the total initial designed fixture lumens are emitted at an angle of 90 degrees or higher from nadir (straight down). For site boundaries that abut public rights-of-way, light trespass requirements may be met relative to the curb line instead of the site boundary.

LZ4 — High (Major City Centers, Entertainment Districts)

Design exterior lighting so that all site and building mounted luminaires produce a maximum initial illuminance value no greater than 0.60 horizontal and vertical footcandles at the site boundary and no greater than 0.01 horizontal footcandles 15 feet beyond the site. Document that no more than 10% of the total initial designed site lumens are emitted at an angle of 90 degrees or higher from nadir (straight down). For site boundaries that abut public rights-of-way, light trespass requirements may be met relative to the curb line instead of the site boundary.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ A site plan indicating shared portions of the project, and relevant sources of lighting.
- ❑ Confirmation of which LZ (lighting zone) the project is located in.
- ❑ A written commitment to reduce light pollution from shared portions of the project to meet the requirements if the project is built.
- ❑ A copy of, or a written commitment to create, any necessary CC&Rs, development agreements, or other binding documents that will require continued adherence to these standards.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

- ❑ A brief summary of the lighting design strategies that will be used to reduce light pollution from shared portions of the project.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

<u>Case 2C: Did not submit at Stage 1</u>

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ Applicable lighting drawings from the construction documents that show the design strategies and/or technologies used to reduce light pollution from shared portions of the project.
- ❑ If a written commitment to create copies of the required agreements was submitted previously, submit a copy of the actual agreement(s).

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Innovation & Design Process

ID Credit 1: Innovation and Exemplary Performance
1 to 5 Points

Intent

To provide projects the opportunity to be awarded points for exceptional performance above the requirements set by the LEED for Neighborhood Development Rating System and/or innovative performance in green building, smart growth, or new urbanist categories not specifically addressed by the LEED for Neighborhood Development Rating System.

Requirements

In writing, identify the intent of the proposed innovation credit, the proposed requirement for compliance, the proposed submittals to demonstrate compliance, and the design approach and strategies that might be used to meet the requirements. (1 point each, up to 5 possible)

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ The specific title for the ID credit, a statement of the credit intent, and a statement of credit requirements.
- ❑ A narrative (and site plan if necessary) describing the project's approach to achievement of the credit, including a description of the quantifiable benefits of the credit proposal.
- ❑ A written commitment to meet the requirements (stated by the project team as part of the submission requirement above) if the project is built.

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate “No change since Stage 1” on project checklist.

Case 2B: Change since Stage 1
If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2
If project conditions remain unchanged with respect to credit requirements, indicate “No change since Stage 2” on project checklist, and submit the following additional post-construction documentation:

- ❑ Copies of any specific construction drawings or exhibits that will serve to illustrate the project’s approach to this credit. (Note: this may not be applicable to all ID credit proposals.)

Case 3B: Change since Stage 2
If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

Innovation & Design Process

ID Credit 2: LEED Accredited Professional
1 Point

Intent

To support and encourage the planning and design integration required by a LEED for Neighborhood Development green neighborhood project and to streamline the application and certification process.

Requirements

At least one principal member of the **project** design team shall be a LEED Accredited Professional.

OR

At least one principal member of the project design team shall be a professional who is credentialed with regard to smart growth as determined by the Natural Resources Defense Council in consultation with Smart Growth America.

OR

At least one principal member of the project design team shall be a professional who is credentialed with regard to new urbanism as determined by the Congress for the New Urbanism.

OR

This point may be used instead as an additional point available under ID Credit 1: Innovation and Exemplary Performance, for performance not related to professional team member experience.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

- ❑ The name, place of employment, and a brief description of the project role for the individual.

- ❑ Confirmation of whether the individual is a LEED Accredited Professional, credentialed with regard to smart growth, or credentialed with regard to new urbanism.

For STAGE 2 Submissions (Certification of Approved Plan)

Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 2A: No change since Stage 1

If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, no additional documentation is required. Indicate "No change since Stage 1" on project checklist.

Case 2B: Change since Stage 1

If the project submitted at Stage 1, and project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist.

Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2.

Definitions

Adapted (or introduced) Plants – Plants that reliably grow well in a given habitat with minimal attention from humans in the form of winter protection, pest protection, water irrigation, or fertilization once root systems are established in the soil. Adapted plants are low maintenance but not invasive.

Adaptive reuse – Conversion of an existing building that is functionally obsolete for its designed purpose to an updated purpose.

Adequate transit service – During **weekday peak periods**, at least four buses (including bus rapid transit), streetcars or light rail trains per hour OR at least 5 heavy passenger rail or ferries per weekday peak period.

Adjacent site – A site having at least 25% of its perimeter bordering land that has been **previously developed.** For the puposes of this definition**,** a street or roadway does not constitute previously developed land. Any fraction of the perimeter that borders waterfront will be excluded from the calculation.

Area median income – The median, or middle, income of a county as defined and available from the U.S. Department of Housing and Urban Development.

Biking network – A continuous network consisting of one or more of the following: bicycle lanes or trails at least 5 feet wide or roads designed for a speed of 10 miles per hour or slower.

Block – Land bounded by the project boundary, dedicated transportation or utility rights-of-way, waterfront, and/or comparable land division features.

Brownfield – Real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminate. (U.S. EPA)

Buildable land – The portion of the site where construction can occur. When used in **density** calculations, the calculation for buildable land excludes: public streets and other public rights of way, and land excluded from development by law or other prerequisites of LEED for Neighborhood Development.

Buildout – The time at which all **habitable buildings** on the project are complete and ready for occupancy.

Class I Bikeway - Class I bikeways are defined as bicycle or multi-use facilities that are completely separate from the vehicular right-of-way. The standard Class I bikeway has pavement that is 8 feet wide however the exact design requirements for Class I bikeways differ from jurisdiction to jurisdiction.

Community Supported Agriculture (CSA) – A farm operation for which a community of individuals who pledge support so that the farmland becomes, either legally or informally, the community's farm. The growers and consumers provide mutual support, sharing the risks and benefits of food production. Consumers receive portions of the farm's harvest throughout the growing season.

Covenants, Conditions and Restrictions (CC&Rs) – Limitations that may be placed on a property and its use, and which are made a condition of holding title or lease.

Density – Density is the amount of building structures constructed on the project site, measured for residential buildings as dwelling units per acre of **buildable land** available for residential uses, and for non-residential buildings as the floor area ratio per acre of buildable land area available for non-residential uses.

Development footprint – The total land area of a **project** site covered by buildings, streets, parking areas, and other typically impermeable surfaces constructed as part of the project.

Floor Area Ratio (FAR) – The measure of the **density** of non-residential land use. It is the total non-residential building floor area divided by the total **buildable land** area available for non-residential uses. For example, on a site with 10,000 square feet of buildable land area, an FAR of 1.0 would be 10,000 square feet of built building floor area. On the same site, an FAR of 1.5 would be 15,000 square feet of built floor area; an FAR of 2.0 would be 20,000 built square feet and an FAR of 0.5 would be 5,000 built square feet.

Functional entry – An entryway that is designed to be used by pedestrians and is open during regular business hours. This does not include any door that is exclusively designated as an emergency exit, or a garage door that is not designed as an entrance for pedestrians.

Graywater – Untreated household waste water which has not come into contact with toilet waste. Gray water includes used water from bathtubs, showers, bathroom wash basins, and water from clothes-washer and laundry tubs. It shall not include waste water from kitchen sinks or dishwashers. Some states and local authorities allow kitchen sink wastewater to be included in graywater. Project teams should comply with graywater definitions as established by the authority having jurisdiction in their areas. (Uniform Plumbing Code)

Habitable building – A structure that is intended for living, working, or other types of occupancy. Habitable structures do not include buildings such as garages and pump stations.

HERS Index – A scoring system established by the Residential Energy Services Network (RESNET) in which a home built to the specifications of the HERS Reference Home (based on the 2006 International Energy Conservation Code) scores a HERS Index of 100, while a net zero energy home scores a HERS Index of 0. The lower a home's HERS Index, the more energy efficient it is in comparison to the HERS Reference Home.

Infill site – A site having at least 75% of its perimeter bordering sites that have been **previously developed**. For the puposes of this definition, a street or roadway does not constitute previously developed land. Any fraction of the perimeter that borders waterfront will be excluded from the calculation.

IECC – International Energy Conservation Code

Invasive Plants – Plants that may be either indigenous or non-indigenous species or strains that are characteristically adaptable, aggressive, have a high reproductive capacity and tend to overrun the ecosystems in which they inhabit.

Native (or indigenous) Plants – Plants that have adapted to a given area during a defined time period and are not invasive. In America, the term often refers to plants growing in a region prior to the time of settlement by people of European descent.

Neighborhood – An area of dwellings and/or work places and their immediate environment that residents and/or employees identify with in terms of social and economic attitudes, lifestyles, and institutions.

Post-consumer – Generated by households or by commercial, industrial and institutional facilities in their role as end-users of a product, which can no longer be used for its intended purpose.

Pre-consumer – Diverted from the waste stream during the manufacturing process. It does not include the reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.

Pre-development – Before any development occurred on the site. Pre-development conditions describe the natural conditions of the site prior to any human alteration, i.e. development of roads, buildings, etc.

Previously developed – Having pre-existing paving, construction, or altered landscapes. This does not apply to altered landscapes resulting from current agricultural use, forestry use, or use as preserved natural area.

Previously developed site – A site consisting of at least 75% **previously developed** land**.**

Pre-project – Before the **project** was initiated, but not necessarily before any development or disturbance took place on the site. Pre-project conditions describe site conditions as the current developer or project applicant found them.

Prime soils – Soils with chemical, hydrographic and topological properties that make them especially suited to the production of crops. The Natural Resources Conservation Agency is responsible for identifying prime soils, and they make detailed soil surveys and maps available for every county in the United States. All of the NRCS data are available for download to GIS mapping programs.

Project – The land and construction that constitutes the basis for LEED for Neighborhood Development application.

Project boundary – The outermost property line of the **project**. Projects located on publicly-owned campuses that do not have internal property lines shall delineate a sphere of influence line to be used in place of "property line." The phrase 'project site' is equivalent to the land inside the project boundary.

School – An institution for the academic instruction of children or adults, technical trade school, arts school, college, or university.

Shared portions of the project – Areas of the **project** that are publicly-owned, such as streets and parks, and land and facilities that are held under common ownership by entities such as a condominium association, land trust, or privately owned corporations.

Street grid density – The density of the street network as measured in centerline miles per square mile. Areas that shall be excluded from the calculation are water bodies, parks, recreational facilities, public campus facilities (such as universities), areas preserved from development because of local, state, or federal law, land preserved from development from the prerequisites of LEED for Neighborhood Development, land that cannot be developed due to a unique topographic or geologic condition (such as steep slopes).

Toe of the slope – Where there is a distinct break between a 40% slope and lesser slopes.

Unique soils – Soils with chemical, hydrographic and topological properties that make them especially suited to specific crops. The Natural Resources Conservation Agency is responsible for identifying unique soils, and they make detailed soil surveys and maps available for every county in the United States. All of the NRCS data are available for download to GIS mapping programs.

Walk distance – The distance that a pedestrian must travel between destinations without obstruction, in a safe and comfortable environment such as on sidewalks, footpaths or other pedestrian facilities.

Water bodies – The surface water of a stream, creek, river, lake, estuary, bay, or ocean.

Weekday peak periods –Weekdays between 5:30 a.m. to 10:30 a.m. and 3:30 p.m. to 8:30 p.m. The period of time during the weekday commute when traffic congestion is the greatest.

Wetlands – Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." http://www.wetlands.com/regs/tlpge02e.htm (1987 Army Corps of Engineers Manual)

Vehicle Miles Traveled (VMT) – The number of miles traveled by motor vehicles in a specified period of time, such as a day or a year, by a number of motorists in absolute or per capita terms.

Woonerf – A Dutch word that means "street for living." In practice, it is common space shared by pedestrians, bicyclists, and low-speed motor vehicles. They are usually streets raised to the same grade as curbs and sidewalks. Vehicles are slowed by placing trees, planters, parking areas, and other obstacles in the street, so that motorists travel at walking speed.

Appendix A: List of Diverse Uses

Bank
Child care facility (licensed)
Community/civic center
Convenience store
Hair care
Hardware store
Health club or outdoor recreation facility
Laundry/dry cleaner
Library
Medical/dental office
Pharmacy (stand-alone)
Place of worship
Police/fire station
Post office
Restaurant
School
Senior care facility
Supermarket
Theater

Appendix B:

GCT Credit 9: Stormwater Management

1 to 5 Points

FEBRUARY 2007 VERSION

Note: Projects can use this version or the June 2007 version found in the GCT Section.

Intent

Reduce pollution and hydrologic instability from stormwater, prevent flooding, and promote aquifer recharge.

Requirements

OPTION 1 – FOR **PREVIOUSLY DEVELOPED SITES** OF ANY SIZE AND **INFILL SITES** OF LESS THAN 7 ACRES

Implement a comprehensive stormwater management plan for the **project** that infiltrates, re-uses, or evapotranspirates runoff from 90% of the average annual rainfall or 1” of rainfall from a percentage of the project’s **development footprint** and other areas that have been graded so as to be effectively impervious, as listed below.

Minimum 15% of the development footprint	(1 point)
Minimum 30% of the development footprint	(2 points)
Minimum 45% of the development footprint	(3 points)
Minimum 60% of the development footprint	(4 points)
Minimum 75% of the development footprint	(5 points)

OPTION 2 – FOR ALL OTHER SITES

Implement a comprehensive stormwater management plan for the project that infiltrates, re-uses, or evapotranspirates runoff from 90% of the average annual rainfall or 1” of rainfall from a percentage of the project’s **development footprint** as listed below.

Minimum 20% of the development footprint	(1 point)
Minimum 40% of the development footprint	(2 points)
Minimum 60% of the development footprint	(3 points)
Minimum 80% of the development footprint	(4 points)
Minimum 100% of the development footprint	(5 points)

Notes: a) The stormwater management plan should identify practices to be employed, such as permeable pavements, rainwater harvesting systems or green roofs.
b) For the purposes of this calculations in this credit, the development footprint will include typically impervious surfaces included in the definition of “development

footprint," such as roofs and pavements, even though the surfaces may be made pervious as part of the stormwater management plan.

Submittals

During the pilot program, project teams are encouraged to suggest replacement documentation that may be easier to access or produce than the items listed below, but still clearly verifies that the requirements have been met. The certification reviewers will evaluate the adequacy of the potential replacement documentation on a case-by-case basis.

- ❑ Provide the LEED submittal template, signed by the responsible party, declaring that the requirements have been met, and the following:

For STAGE 1 Submissions (Pre-review)
Submitting for Stage 1 is optional. If it is skipped, these items will be required at Stage 2.

All Options

- ❑ A site plan indicating the project's development footprint, and the location of any planned stormwater management technologies or BMPs.
- ❑ A written commitment to develop and implement a comprehensive stormwater management plan to meet the requirements if the project is built.

Option 1

- ❑ A site plan indicating the size of the project and any previously developed areas (this can be done as part of the site plan listed above).

For STAGE 2 Submissions (Certification of Approved Plan)
Stage 2 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

<u>Case 2A: No change since Stage 1</u>
If the project submitted at Stage 1, and project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 1" on project checklist, and submit the following additional documentation:

All Options

- ❑ A summary of the stomwater management plan, highlighting the technologies or BMPs used on the site.
- ❑ A statement of the project team's capacity and/or qualifications to implement the plan, and/or a description of the services that will be contracted to do so.

<u>Case 2B: Change since Stage 1</u>
If the project submitted at Stage 1, and project conditions have changed with respect to prerequisite requirements:

- ❑ Submit updated versions of the relevant documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

Case 2C: Did not submit at Stage 1

- ❑ Submit the documentation required at Stage 1 and the additional item(s) listed above in Case 2A.

For STAGE 3 Submissions (Certification of Completed Neighborhood Development)

Stage 3 must be completed. If a project is already built, Stage 2 and 3 documentation may be submitted simultaneously.

Case 3A: No change since Stage 2

If project conditions remain unchanged with respect to credit requirements, indicate "No change since Stage 2" on project checklist, and submit the following additional post-construction documentation:

- ❑ A calculation of either 90% of the average annual rainfall or 1" of rainfall that occurs on the project's development footprint and other effectively impervious areas.
- ❑ A calculation of the percentage of the development footprint for which runoff will be infiltrated, re-used, or evapotranspirated.

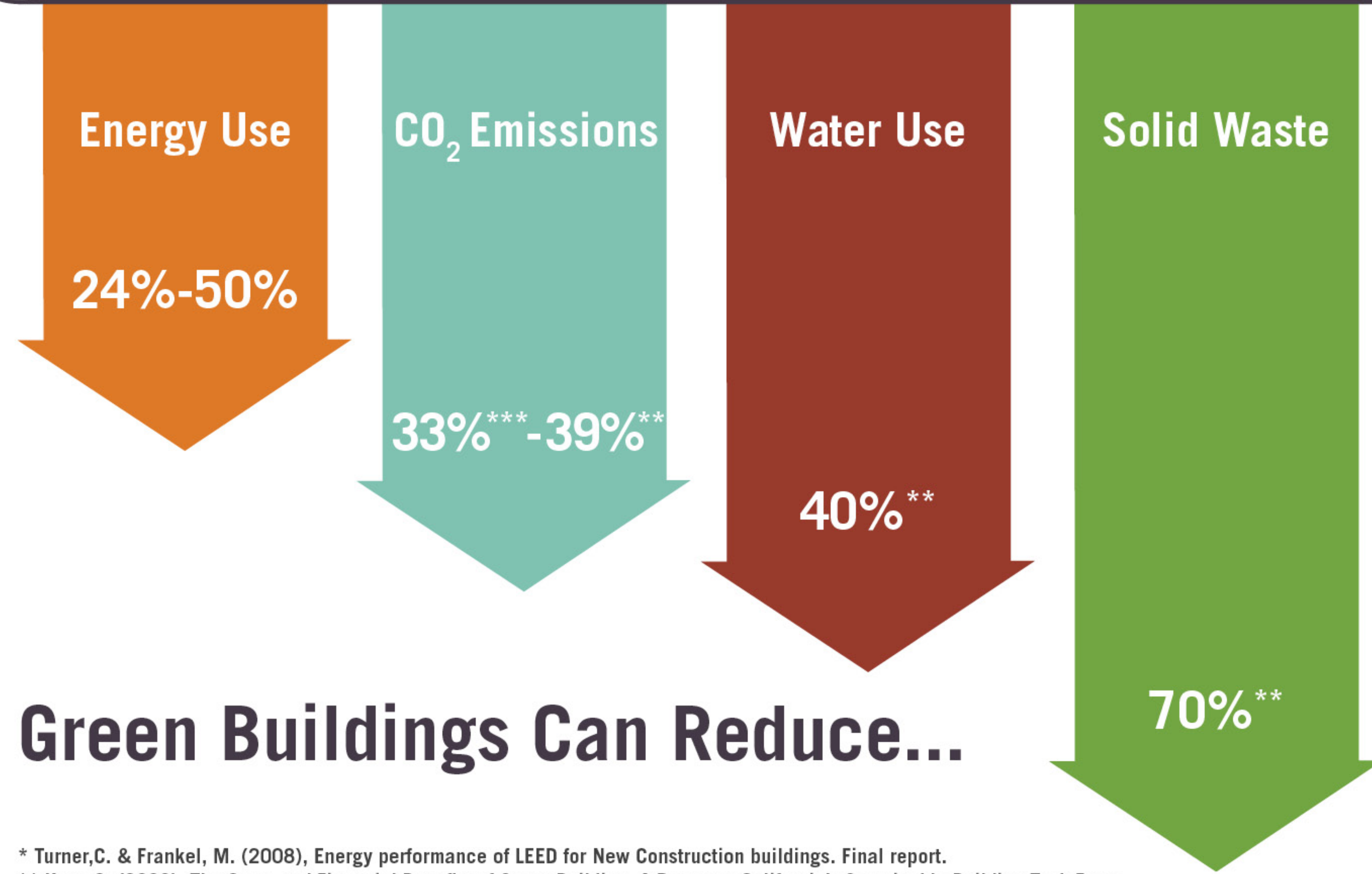
Case 3B: Change since Stage 2

If project conditions have changed with respect to credit requirements:

- ❑ Submit updated versions of the relevant documentation submitted at Stage 2 and the additional item(s) listed above in Case 3A.

LEED FOR NEIGHBORHOOD DEVELOPMENT

Green Infrastructure & Buildings



Green Buildings Can Reduce...

* Turner,C. & Frankel, M. (2008), Energy performance of LEED for New Construction buildings. Final report.
** Kats, G. (2003). The Costs and Financial Benefits of Green Building. A Report to California's Sustainable Building Task Force.
*** GSA Public Buildings Service (2008). Assessing green building performance. A post occupancy evaluation of 12 GSA buildings.

Water Q&A: Water use at home

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(1) Q: Where does our household water come from?

A: All of the water that we use in our homes comes from either a ground-water source, such as a well, or from a surface-water source, such a river, lake, or reservoir. In the U.S. in 2000, about 240 million of the 285 million people in the United States got their home water delivered by a public supplier, such as the county water department. At other homes, people provide water for themselves from sources, such as a well, a cistern, a pond, or a stream.

(2) Q: Where does it go after we are done with it?

A: Water leaving our homes generally goes either into a septic tank in the back yard where it evaporates or seeps back into the ground, or is sent to a sewage-treatment plant through a sewer system. In 1995, the last year for which consumptive-use data was compiled, about 26 percent of the water coming from our homes was "consumptively used." That is, it was evaporated or transpired from yards. The other 74 percent was discharged to septic tanks or sewage-treatment plants, where it was cleaned and sent into streams, or sometimes reused for other purposes, such as watering golf courses and parks.

(3) Q: How much water does the average person use at home per day?

A: Estimates vary, but each person uses about 80-100 gallons of water per day. Are you surprised that the largest use of household water is to flush the toilet, and after that, to take showers and baths? That is why, in these days of water conservation, we are starting to see toilets and showers that use less water than before. Many local governments now have laws that specify that water faucets, toilets, and showers only allow a certain amount of water flow per minute. In fact, if you look real close at the head of a faucet, you might see something like "1.5 gpm,", which means that the faucet head will allow water to flow at a maximum of 1.5 gallons per minute.

(4) Q: How is water supplied to our homes?

A: In a modern society such as ours, much work goes into supplying our houses with water. Many years ago when everyone lived in rural areas, they would have to get their own water from rivers or from local wells.

Nowadays, most people in the U.S. live in towns and cities, and communities have installed an organized structure called a public water-supply system to provide water to homes (and to some businesses and industries, too). Now, even many rural areas have similar systems. In 2000, the U.S. had a population of about 285 million. About 240 million people had their water delivered from a public-supply system, and about 45 million people supplied their own water (over 90 percent of these people use water from their own wells).

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(5) Q: How is the water I drink made safe?

A: Different treatment is used depending on the source of your water. Ground water taken from wells has been filtered through rocks, so it is usually quite free of particles. It can still contain chemicals and organic matter that must be taken out, though. If your water comes from a surface-water source, such as a river, some work must be done to get rid of particulate matter. In this case filters are used to screen out large particles, and at a minimum, chlorine is added to kill dangerous bacteria and microorganisms. Some systems have additional water treatment, such as adding chemicals to make matter bunch up (flocculate) and fall out of solution and adding chemicals to make the water less corrosive to metal.

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(6) Q: Is it true that water coming out of sewage treatment plants is used for other purposes?

A: Yes, it is called reclaimed wastewater, though its use is limited. Before you start to feel ill, no, it is not used further down the line as drinking water. It is most often used for irrigation and for water parks and golf courses. In the U.S. in 1995 (the last year for which wastewater-treatment data was compiled) about 44,400 wastewater-treatment plants sent about 44,600 million gallons per day of treated water back into the environment. About 983 million gallons per day was used again (reclaimed) after treatment, mainly as irrigation water.

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(7) Q: I live on a hill, how does water get to my house?

A: Let's assume that you get your water from the local water department through pipes buried below the streets. In other words, you don't have your own well in your back yard. Chances are that you get your water through the magic of gravity or pumps. Cities and towns build those big water towers on top of the highest hills and then fill them with water. So even if you live on a hill, there's a good chance the water tower is higher than your house. Water goes down a large pipe from the tower and through an intricate network of pipes that eventually reaches your house.

A: In other words, when I have a big storm over my house, just how much rain am I getting? Let's say your house sits on a one-half acre lot. And let's say you get a storm that drops 1 inch of rain. You've just received 13,577 gallons of water on your yard! A big bath holds about 50 gallons of water, so if you could save that inch of water that fell you could take a daily bath for 271 days! (Careful now, that 13,577 gallons of water weighs over 56 tons ... so don't put it in your bathtub all at once).
Let's expand that to a city. Atlanta, Ga. has corporate boundaries that cover about 84,100 acres (U.S. Census Bureau). A 1-inch rainstorm deposits 27,154 gallons on one acre, so during this storm Atlanta receives 2.28 billion gallons of water.

Don't miss our Challenge Question, where you can find out how much water falls during a rainstorm.

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(9) Q: Does a little leak in my house really waste water?

A: It's not the little leak that wastes water -- it is the little leak that keeps on leaking that wastes water. And the fact that the leak is so little means that maybe you ignore it. So, how can a little leak turn into a big waste?

Many of our toilets have a constant leak -- somewhere around 22 gallons per day. This translates into about 8,000 gallons per year of wasted water, water that could be saved. Or think of a leaky water line coming into your house. If it leaks 1 gallon of water every 10 minutes that means that you are losing (and paying for) 144 gallons per day, or 52,560 gallons per year.

Use our leak calculator to see how much a leaking faucet wastes.

Related Topics

Water Questions and Answers:
Water at home ◆ Water use ◆ Measuring water ◆ Other Q&As ◆ Floods ◆ Droughts

Accessibility FOIA Privacy Policies and Notices

Assessment of HCFC-Based Air Conditioning Equipment and Emerging Alternative Technologies

Final Report

Prepared for

The World Bank
Montreal Protocol Operations
Environment Department
1818 H Street, NW
Washington, DC 20433 USA

Prepared by

ICF International
1725 Eye Street, NW
Washington, DC 20006 USA

September 2007

Prepared prior to the HCFC Adjustments agreed upon at the 19th Meeting of the Parties (MOP) to the Montreal Protocol.

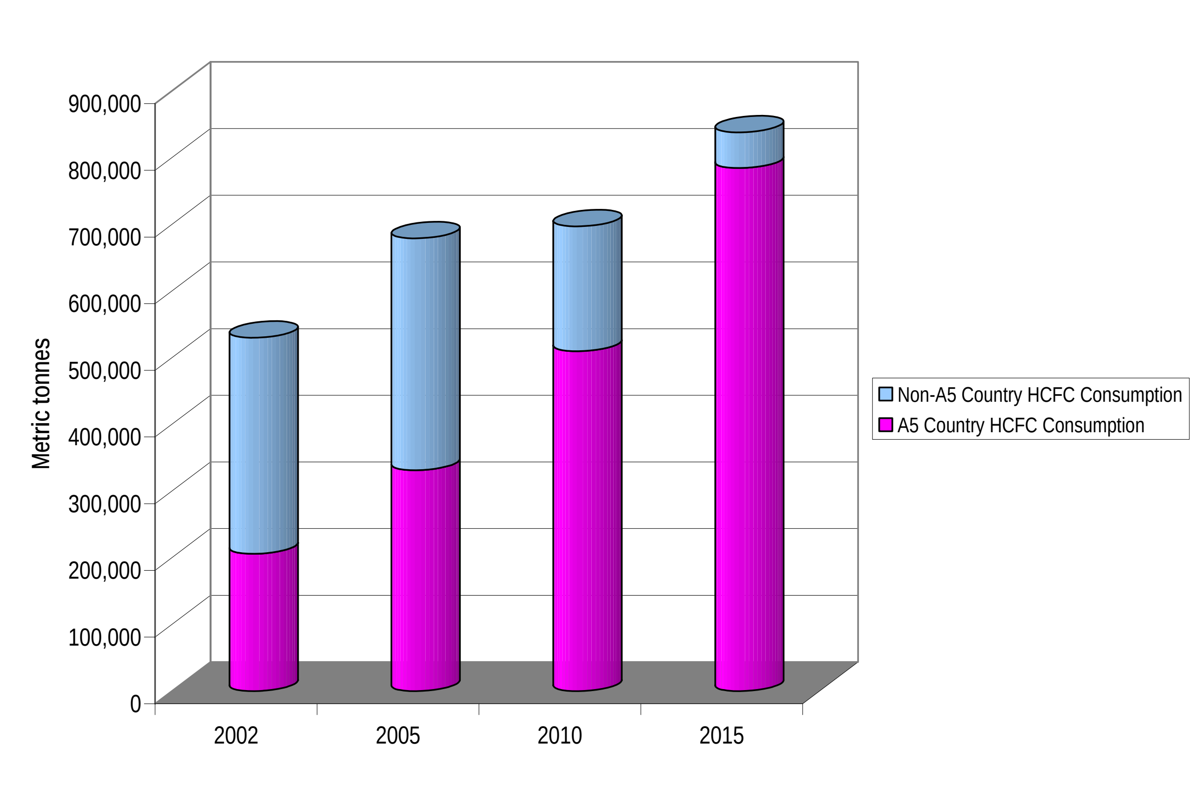
Table of Contents

1. Introduction

The production and consumption of ozone-depleting hydrochlorofluorocarbons (HCFCs)—used as refrigerants, blowing agents, solvents, aerosols, and fire suppressants—are increasing rapidly in developing countries, even as they are being gradually phased out in developed countries under the current phaseout requirements for non-A5 countries, as articulated under the Montreal Protocol and subsequent adjustments and amendments. From 2005 to 2015, although consumption of HCFCs in developed countries will be reduced by approximately 85%, global consumption will increase by more than 20%, as consumption in developing countries increases by more than 135% during that same period (US EPA 2007a).

Indeed, because the cap on the consumption of HCFCs in developing countries does not enter into effect until 2016, annual consumption growth rates from 2005 to 2015 are impossible to know with certainty, but available reported information indicates a value of 9% (ICF estimates).[1] Assuming this growth rate of 9%, Exhibit 1 graphically presents the projected increase in demand for HCFCs in developing (Article 5 or A5) countries compared to the projected decrease in demand in developed (non-Article 5 or non-A5) countries.

Exhibit 1: Historical and Projected Consumption of HCFCs in A5 and non-A5 Countries



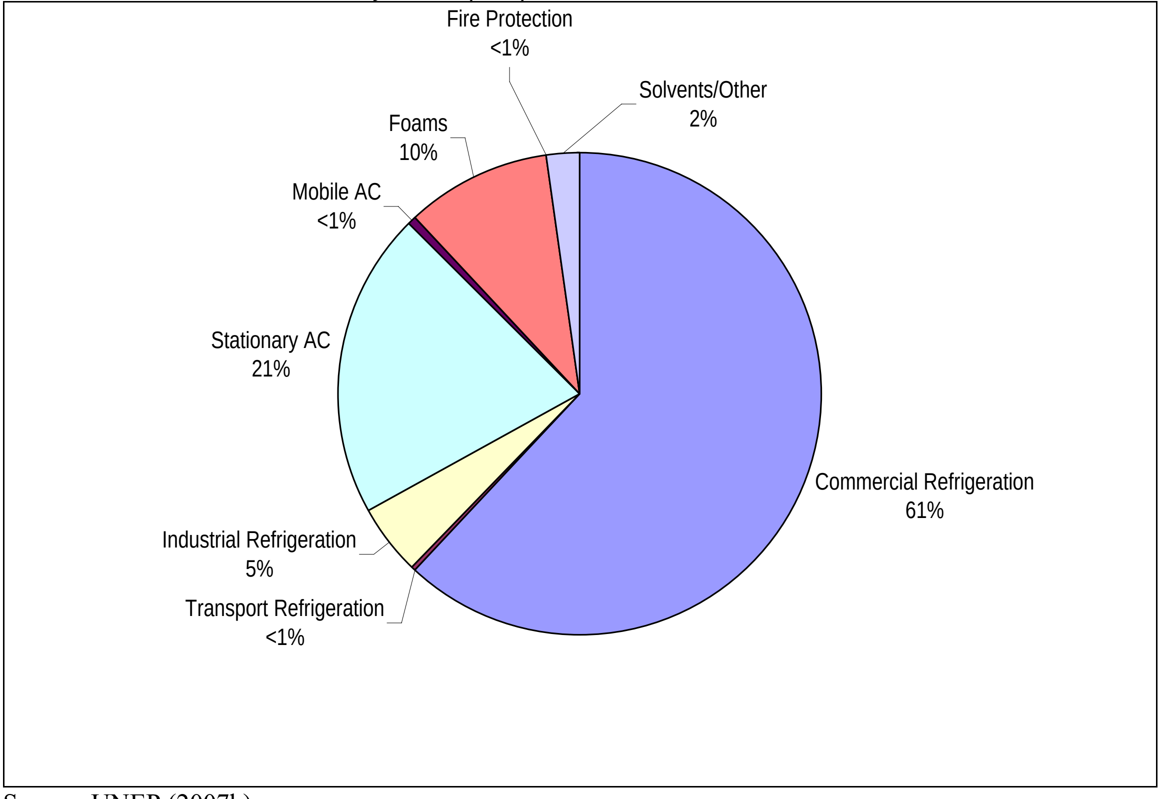
Source: US EPA (2007a).

[1] This growth rate was developed by ICF through an effort to harmonize existing projections used by Parties in assessing and negotiating an expedited HCFC phaseout schedule, and is based primarily on actual and projected consumption and production estimates provided by A5 countries through the *Study on the Strategy for the Long Term Management of HCFCs in China and HCFC Surveys in Nine Article 5 Countries*. Other proposed annual growth rates range from 10.9% (World Bank 2006) to 5.9% (IPCC/TEAP 2005) to about 5% (UNEP 2007a). The TEAP XVIII/12 report (UNEP 2007b) based its baseline calculations on the growth rates developed in the SROC (average rate of 5.9%), but recognized that the SROC demand growth is relatively conservative (i.e., low growth compared to other assessments).

Moreover, because the Protocol does not require developing countries to reduce consumption until 2040, global HCFC consumption could remain excessively high for the next 35 years, undermining the phaseout efforts of developed countries and threatening the recovery of the ozone layer and posing threats to human health and the environment from excess UV radiation. These projected high levels of HCFC consumption will also have impacts on global climate change, through both direct and indirect processes. From this standpoint, an accelerated phase-out of HCFCs in developed and developing countries is imperative.

Any proposed accelerated phase-out schedule must take into account the costs of early retirement of HCFC equipment, particularly in the stationary AC sector, which currently represents the second largest source (about 20%) of total A5 HCFC demand, as shown in Exhibit 2 (US EPA 2007a, UNEP 2007b). Moreover, because large AC systems (chillers) have long lifetimes and high replacement costs, and because the import/export of smaller AC equipment significantly affect Article 5 economies, a technical assessment of the stationary air-conditioning market in Article 5 countries is needed to gain an understanding of the impacts and costs associated with an expedited HCFC phaseout.

Exhibit 2: Total A5 HCFC Demand by Sector (2005)



Source: UNEP (2007b)

The purpose of this report is to provide the international community with an understanding of where and how much HCFCs will be installed within the stationary AC sector in Article 5 countries under a business-as-usual scenario, and what it will take to achieve phaseout. To this end, the report assesses current and projected A5 consumption of HCFCs in stationary AC applications, as well as the feasibility and likelihood of using non-ODS refrigerants in this sector through 2015 and beyond. The report also provides broad analysis of the costs of transitions to alternative refrigerants in existing and new equipment and identifies barriers associated with (a) the replacement and servicing of HCFC-based chillers and (b) the conversion of manufacturing facilities reliant on HCFC refrigerant for the production of smaller AC equipment in A5 countries.

The remainder of the report is organized as follows:

- Section 2 provides background information on ODS consumption, focusing on the commercial and residential air-conditioning sector in A5 countries;
- Section 3 provides an overview of the methodology used to prepare this report;
- Section 4 characterizes the chiller sector in A5 countries, providing estimated number of units installed by chiller type and refrigerant type, summarizing available alternatives, and projecting future refrigerant transitions;
- Section 5 characterizes the residential and small commercial air-conditioning market in A5 countries, providing estimated number of units installed by refrigerant type, summarizing available alternatives, and projecting future refrigerant transitions;
- Section 6 summarizes the results from Sections 4 and 5 and discusses the implications for A5 phaseout in terms of the cost to replace/service HCFC chillers and convert AC equipment manufacturing facilities reliant on HCFC refrigerant;
- Section 7 presents the references used in this report;
- Appendix 1 presents the questionnaires used in collecting information from industry and government sources;
- Appendix 2 provides a list of major chiller and air conditioning equipment manufacturers; and
- Appendix 3 presents detailed results on projected AC stocks by equipment type, refrigerant type, and A5 region.

2. Background: HCFC Consumption in Article 5 Countries

Currently, 191 nations are Parties to the Montreal Protocol, a landmark international agreement to restore the Earth's deteriorating stratospheric ozone layer. The global success of this effort to protect the environment requires the elimination of emissions to the atmosphere of ozone-depleting substances (ODS). Chlorofluorocarbons (CFCs)—used as refrigerants, blowing agents, solvents, and aerosols—are some of the most damaging ODS, and their phaseout in non-A5 countries was implemented in 1996. Hydrochlorofluorocarbons (HCFCs), used in part as replacements for CFCs, also deplete the stratospheric ozone layer and are controlled under the Montreal Protocol as Annex C Group 1 substances. In non-A5 countries, HCFC consumption is being reduced progressively to reach complete phaseout in 2030. In A5 countries, CFCs are scheduled for complete phaseout in 2010, while HCFCs are scheduled for complete phaseout in 2040 (with a freeze in 2016 at 2015 consumption levels).

While ODS have a wide variety of applications, the most common uses for CFCs and HCFCs are in the refrigeration and air conditioning (AC) sectors. In 2005, an estimated 75% of total global demand for CFCs and HCFCs was in the refrigeration/AC sector (UNEP 2007b). Exhibit 3 presents the most common CFC and HCFC refrigerants and their ODPs.

Exhibit 3: Common CFC and HCFC Refrigerants and their ODPs

Chemical Name	ODP
CFC-11 (CCl_3F)	1
CFC-12 (CCl_2F_2)	1
HCFC-22 (CHF_2Cl)	0.055
HCFC-123 ($C_2HF_3Cl_2$)	0.02
HCFC-124 (C_2HF_4Cl)*	0.022
HCFC-142b (CH_3CF_2Cl)*	0.065

*Used in blends only.

As a result of the global CFC phaseout underway, CFCs used in the refrigeration/AC and other sectors have declined steadily over time (see Exhibit 4 and Exhibit 5). By 2005, CFCs comprised only about 23% of ODS demand in the refrigeration/AC sector in A5 countries, and 21% in non-A5 countries (where CFC phaseout began earlier). As the CFC phaseout continues to progress, demand for CFCs is expected to decrease to less than 2% of A5 demand for ODS in the refrigeration/AC sector in 2015, and approximately 7% of non-A5 demand. (UNEP 2007b)

At the same time, the demand for HCFCs in the refrigeration/AC and other sectors has risen and will continue to rise steadily as market growth spurs demand (see Exhibit 4 and Exhibit 5). Indeed, by 2005, annual consumption of HCFCs had more than doubled in A5 countries relative to consumption in 1999, reaching 20,976 ODP-weighted tons (UNEP 2007c). From 2005 to 2015, HCFC consumption will grow at an estimated average rate of 9%[2] in A5 countries, though some country growth rates (e.g., China, India) may be significantly higher (ICF estimates). Overall, HCFC growth rates are likely to correlate with the industrial growth rates of A5 countries.

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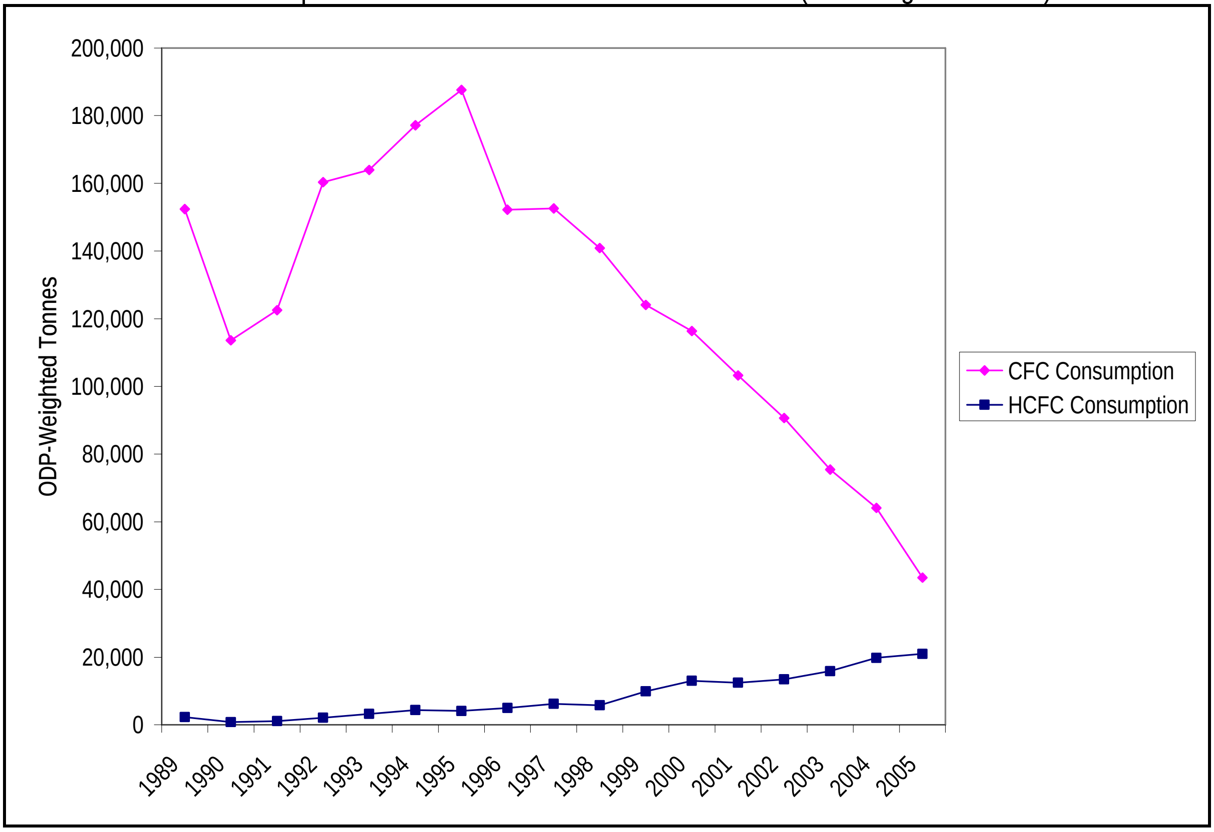
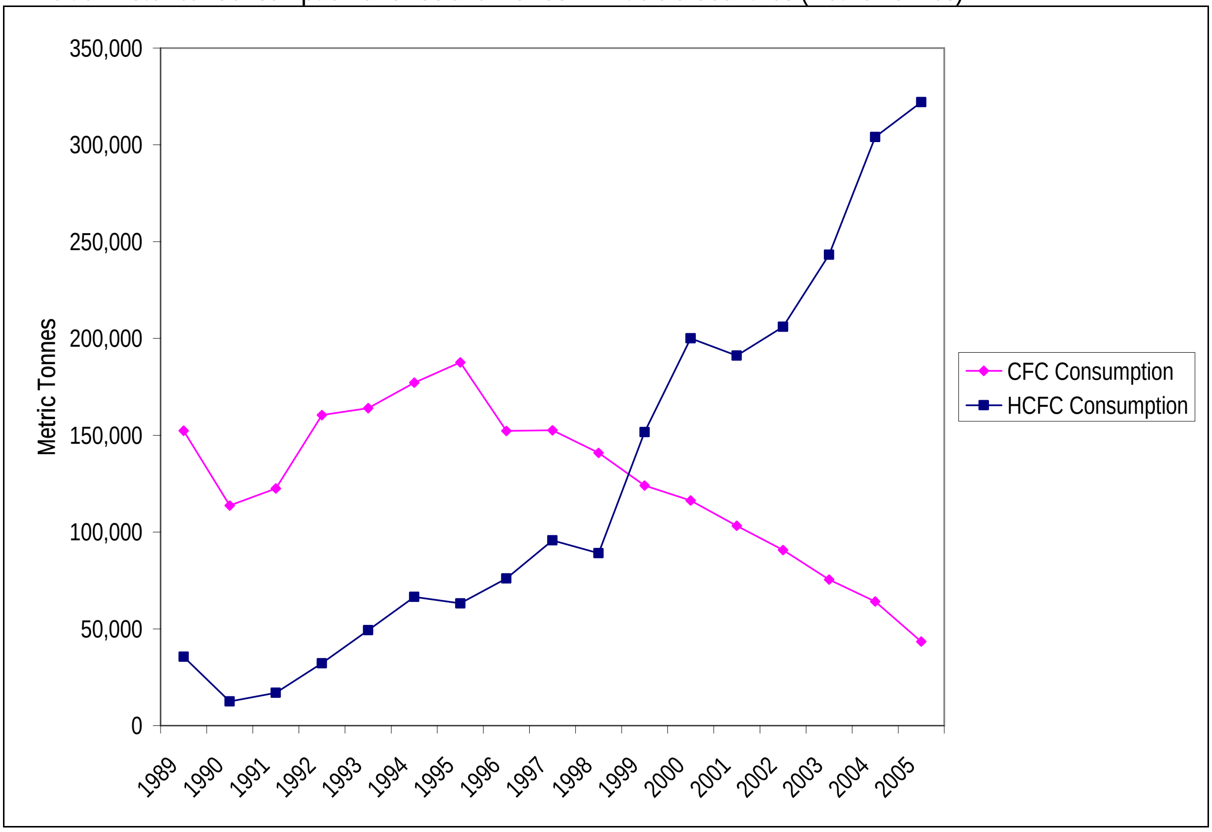
[2] This growth rate was developed by ICF through an effort to harmonize existing projections used by Parties in assessing and negotiating an expedited HCFC phaseout schedule, and is based primarily on actual and projected consumption and production estimates provided by A5 countries through the *Study on the Strategy for the Long Term Management of HCFCs in China and HCFC Surveys in Nine Article 5 Countries*. Other proposed annual growth rates range from 10.9% (World Bank 2006) to 5.9% (IPCC/TEAP 2005) to about 5% (UNEP 2007a). The TEAP XVIII/12 report (UNEP 2007b) based its baseline calculations on the growth rates developed in the SROC (average rate of 5.9%), but recognized that the SROC demand growth is relatively conservative (i.e., low growth compared to other assessments).

Exhibit 4: Historical Consumption of CFCs and HCFCs in Article 5 Countries (ODP-Weighted Tonnes)



Source: UNEP (2007c).

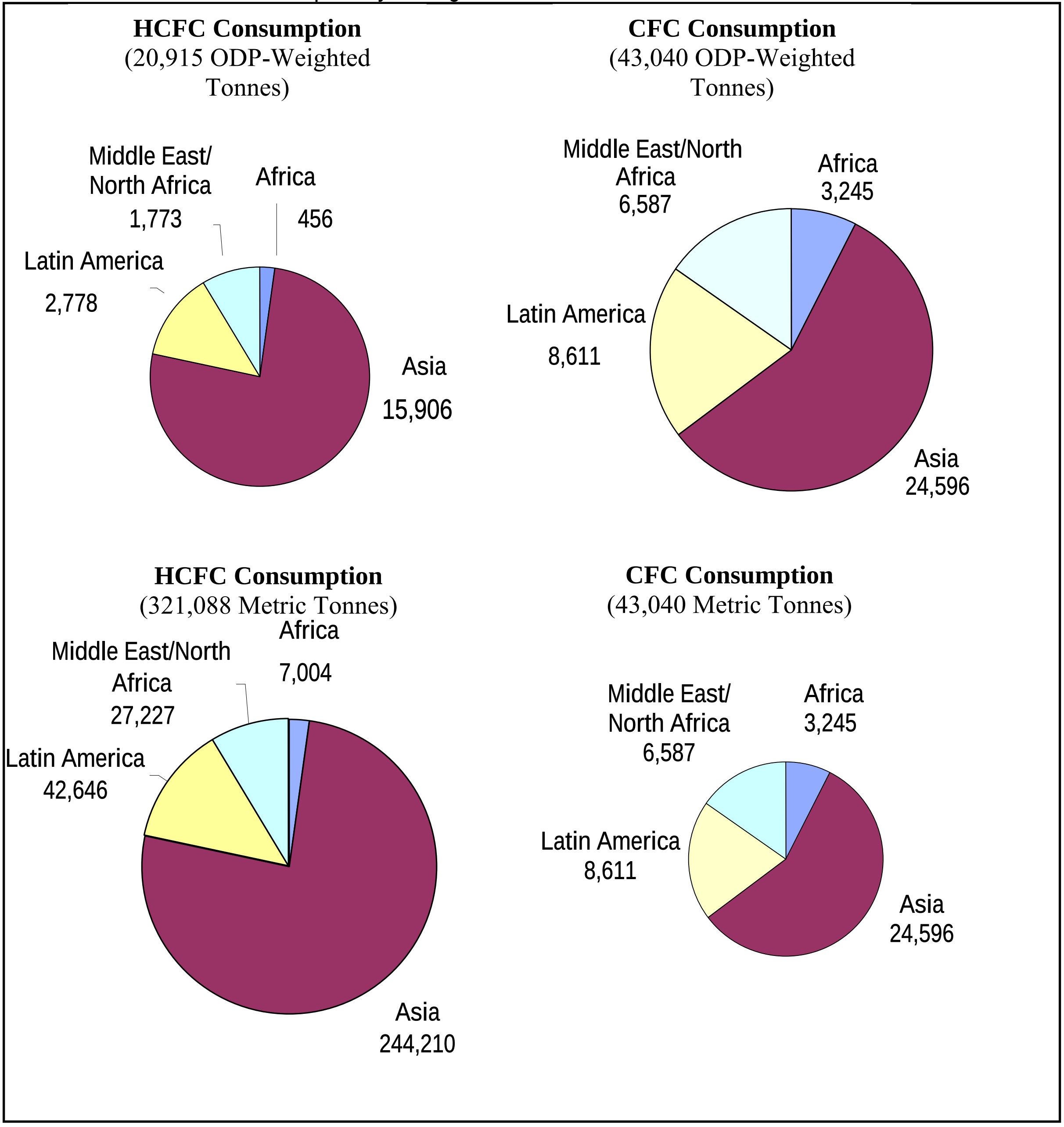
Exhibit 5: Historical Consumption of CFCs and HCFCs in Article 5 Countries (Metric Tonnes)



Source: UNEP (2007c).

While the transition to HCFCs is well underway in A5 countries, a look at current CFC and HCFC consumption figures in individual countries reveals different stages of transition. Some countries continue to rely heavily on CFCs, while others have transitioned away from them, now relying on HCFCs or other ODS alternatives (e.g., HFCs). Still other countries never relied heavily on CFCs, having purchased the majority of ODS-containing equipment later in time, when manufacturers had largely already transitioned to HCFCs. The comparison of CFC and HCFC consumption on a regional basis reveals that Asia, driven by China, is the largest consumer of both CFCs and HCFCs (see Exhibit 6).

Exhibit 6: HCFC and CFC Consumption by A5 Region in 2005



Source: UNEP (2007c).

On a country basis, as shown in Exhibit 7, China has the highest CFC consumption (30%) in A5 countries. Together with the Republic of Korea, Indonesia, Iran, and India, these countries represent over 50% of total A5 CFC consumption. China also dominates HCFC consumption, accounting for 55% of total A5 consumption. China and the five next largest A5 consuming countries—Korea, Mexico, Thailand, Brazil, and India—together represent over 80% of total HCFC consumption (see Exhibit 8). The fast-growing economies of China, Korea, and India, as well as their status as technology centers, help explain why these countries are such large consumers of both CFCs and HCFCs.

Exhibit 7: Top 20 CFC-Consuming A5 Countries in 2005

Rank	Country	ODP-Weighted Metric Tons	Percent of Total CFC 2005 Consumption
1	China	13,124	30%
2	Republic of Korea	2,730	6%
3	Indonesia	2,385	5%
4	Iran (Islamic Republic of)	2,221	5%
5	India	1,958	5%
6	Venezuela (Bolivarian Republic of)	1,842	4%
7	Argentina	1,676	4%
8	Mexico	1,604	4%
9	Thailand	870	3%
10	Philippines	1,014	2%
11	Brazil	967	2%
12	Saudi Arabia	879	2%
13	Syrian Arab Republic	870	2%
14	Algeria	859	2%
15	Egypt	821	2%
16	Yemen	711	2%
17	Malaysia	668	2%
18	Colombia	557	1%
19	Nigeria	466	1%
20	Pakistan	20	1%
TOTAL CFC Consumption by TOP 20		36,240	85%

Source: UNEP (2007c).

Exhibit 8: Top 20 HCFC-Consuming A5 Countries in 2005

Rank	Country	ODP-Weighted Metric Tons	Percent of Total HCFC 2005 Consumption
1	China	11,591	55%
2	Republic of Korea	1,834	9%
3	Mexico	1,179	6%
4	Thailand	901	4%
5	Brazil	847	4%
6	India	725	3%
7	Turkey	575	3%
8	United Arab Emirates	370	2%
9	Indonesia	309	1%
10	Saudi Arabia	213	1%
11	Kuwait	221	1%
12	Philippines	211	1%
13	South Africa	210	1%
14	Argentina	203	1%
15	Iran	193	1%
16	Egypt	174	1%
17	Colombia	152	1%
18	Singapore	149	1%
19	Viet Nam	130	1%
20	Venezuela	97	<1%
TOTAL Consumption of Top 20 A5 Countries		20,283	97%

Source: UNEP (2007c).

Because the use of ODS is being phased out under the Montreal Protocol, alternative refrigerants and technologies are being sought and brought to market. The alternatives, while ozone-friendly, are each associated with certain disadvantages. For example, HFCs have high global warming potentials (GWPs) and therefore contribute to climate change; carbon dioxide (CO_2) and ammonia can pose a human health hazard; and hydrocarbons (HCs) are a flammability risk. Of the HCFC alternatives currently in use, HFCs are the dominant market players. The most common HFCs used in the AC sector, as well as their GWPs, are presented in Exhibit 9.

Exhibit 9: GWPs and Application of Common HFCs in the Air Conditioning Sector[a]

Equipment Type	R-134a (GWP: 1,300)	R-407C (GWP: 1,525)	R-410A (GWP: 1,725)
Chillers	✓		✓
Window Units		✓	✓
Residential Unitary AC		✓	✓
Commercial Unitary AC		✓	✓
Water and Ground Source Heat Pumps	✓	✓	✓
Packaged Terminal Units	✓	✓	✓

[a] GWPs based on IPCC (1996).

R-134a chillers have been widely produced by manufacturers in A5 and non-A5 countries for both domestic and export markets. The use of R-407C and R-410A in AC applications is less mainstream, with producers in non-A5 countries adopting this technology relatively recently, in response to national HCFC phaseout requirements. A number of A5 producers have also begun using these HFC blends in newly produced AC equipment for export, to maintain market share in non-A5 countries.

Ultimately, however, regional refrigerant/technology choices are influenced by many factors, including local laws, regulations, standards, and economics. Ideally, in selecting ODS alternatives, climate-friendly options (i.e., CO_2, ammonia, and HCs) should be considered, though these options are currently rather limited in the air conditioning sector. Research suggests that not-yet-commercialized alternatives, including HC refrigerant blends, are being developed as next-generation alternatives to HCFCs.

The remainder of this report provides a more detailed look at current and future uses of CFCs, HCFCs, HFCs, and alternative refrigerants in air conditioning equipment in A5 countries.

3. Methodology Overview

This section summarizes the broad methodology used to develop this study.

As a first step, literature and internet research was conducted to identify reports and key industry players that could provide data on current and future stocks of chillers and air conditioning (AC) equipment in Article 5 countries, as well as estimated costs associated with this transition. Specifically, data were collected from a variety of sources, including:

- Industry publications, such as the 2007 Latin America Chiller Market report from the Building Services Research and Information Association (BSRIA), and Appliance Magazine.
- Published reports from the United Nations Environment Programme (UNEP),[3] the World Bank,[4] the United Nations Development Programme (UNDP),[5] GTZ,[6] the Intergovernmental Panel on Climate Change (IPCC),[7] and others.
- Selected project documents from the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol (MLF), including the African Fund for the Replacement of Chillers (AFROC) project report on the conversion of CFC chillers in five African countries.
- Selected technical presentations, such as those presented at the Stakeholder Meeting for the Implementation of UNEP Global Technical Assistance Programme in the Chiller Sub-Sector in New Delhi in October 2006, Open-ended Working Group of the Parties to the Montreal Protocol in Nairobi in June 2007 and the Stockholm Group meeting in Montreal in July 2007.

In addition, questionnaires were developed for key industry and government representatives (provided in Appendix I), and follow-up interviews were conducted. The following companies, trade associations, and government agencies were contacted:

- Bharat (India)
- Blue Star (India)
- Carrier (India, US)
- Danfoss (Denmark)
- Fujitsu (Japan)
- GTZ
- Haier (China)
- LG (Korea)
- Lennox (US)
- McQuay/Daikin (India, US)
- Mitsubishi (Japan)
- National Ozone Units from Brazil, China, India, Mexico, South Africa, South Korea, and Thailand
- ONIDA (India)
- Refrigeration and Air Conditioning Manufacturer's Association of India
- Samsung (Korea)
- Trane (US)

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[3] UNEP (2004, 2007b, 2007d, 2007e).
[4] World Bank (2002, 2005).
[5] UNDP (2007).
[6] UNEP (2007a), GTZ (2006).
[7] IPCC/TEAP (2005).

- York (US)

Due to time constraints, not all contacts listed above were capable of providing input to this study. Significant information was collected from York, Carrier India and Carrier US, Trane, ONIDA, and the National Ozone Unit in South Africa. To avoid disclosure of any confidential business information, all industry information received through surveys, emails, and telephone queries conducted for the purposes of this study has been aggregated in this report. To the extent possible, estimates developed based on industry sources were substantiated against other available data (e.g., UNDP 2007, UNEP 2007a, BSRIA 2007).

Both qualitative and quantitative data were obtained from the above sources regarding current and future stocks of AC equipment, by equipment type. Specifically, estimates were developed for the following end uses:

- **Centrifugal chillers**: Centrifugal chillers are large, centralized air-conditioning systems commonly used in large buildings, such as offices, hotels, and factories. Chillers can range in cooling capacity from 350 kW to 30,000 kW, with an average refrigerant charge of about 0.33 kg/kW (UNEP 2004, ICF 2007). They also have very long lifetimes, up to 30 years or more (IPCC 2000, ICF 2007).

- **Positive Displacement chillers:** Positive displacement chillers are smaller than centrifugals, but are similarly used for cooling in buildings, offices, and large residential structures. They have average lifetimes of up to 25 years (ICF 2007).
  - ***Scroll***: Scroll chillers have a cooling capacity range of 7-1,600 kW with an average refrigerant charge of 0.28 kg/kW (UNEP 2004, ICF 2007).
  - ***Screw***: Screw chillers have a cooling capacity range of 140-2,275 kW with an average refrigerant charge of 0.28 kg/kW (UNEP 2004, ICF 2007).
  - ***Reciprocating***: Reciprocating chillers range in cooling capacity from 7 kW to 1,600 kW, with an average refrigerant charge of 0.35 kg/kW (UNEP 2004, ICF 2007).

- **Other Air Conditioners**: For the purpose of this study, other air conditioners include small self-contained AC units, non-ducted split residential and commercial units, and ducted split commercial and residential units (see text box below for additional description of the equipment types included). This analysis disaggregates this end use into “small” and “large” systems as follows:
  - ***Small AC:*** charge size of 0.75 - 3.5 kg.
  - ***Large AC:*** charge size of 7.5 -15 kg.

Self Contained Units

- *Window AC units*: fit into open windows or through walls; refrigerative coolers packaged into a single box that produces cool air on one side and rejects hot air on the other.
- *Packaged terminal AC/heat pumps*: used in small- and medium- sized low-rise buildings (e.g., offices, motels, barracks, and warehouses); units are typically installed in the wall, and are self-contained.

Ducted Split Systems

- *Unitary AC*: central AC systems used in houses and commercial applications; a compressor/heat exchanger unit outside the conditioned space supplies refrigerant to a heat exchanger, and the cooled/heated air is then supplied by a duct system.
- *Water and ground-source heat pumps*: use the earth and/or ground water as the sources of heat in the winter, and as the "sink" for heat removed from the building in the summer; common in office buildings, hotels, health care facilities, banks, schools, condominiums and apartments.

Non-Ducted Split Systems

- *Ductless AC*: used in residences; comprised of an outdoor condenser and an air handler.

For the purpose of this analysis, assumptions were developed regarding average charge size and lifetime for each of the equipment types listed above, as summarized in Exhibit 10.

Exhibit 10. Assumptions on Average Charge Size and Lifetime

Equipment Type	Assumed Average Charge Size (kg)	Assumed Average Lifetime (years)
Centrifugal Chillers	450	30
Screw Chillers	330	25
Scroll Chillers	150	25
Reciprocating Chillers	150	25
Large AC	10	15
Small AC	2	15

Source: ICF estimates based on UNEP (2004), Manikela (2007), IPCC (2000), World Bank (2002), ICF (2007), Stockholm Group (2007).

All information was used to develop an Excel-based model to "inventory" current and future stocks of equipment for four distinct A5 regions: (1) Asia, (2) Latin America and the Caribbean, (3) Middle East/North Africa, and (4) Africa. The following general methodological steps were followed to develop such an inventory:

- ***Step 1: Estimate Stock by Region.*** Number of units currently in use by region, including average charge size, were estimated based on UNEP reports, BSRIA (2007), Manikela (2007), and ICF (2007).

- ***Step 2: Disaggregate Stock by Refrigerant Type.*** Equipment was disaggregated by refrigerant based on data from UNEP reports, Manikela (2007), Stratus (2006), and industry information (ICF 2007).

- ***Step 3: Project Future Stocks.*** Market growth was projected in the short term (2007-2009) and long term (2010-2040) by equipment type and region based on industry insights on published market information (ICF 2007, Han 2007).

- ***Step 4: Project ODS Transition.*** The transition away from ODS was projected by retiring old equipment at a linear rate (based on equipment lifetime) and modifying the penetration of alternative refrigerants into new equipment based on anticipated market and regulatory trends. Specifically, in projecting the future penetration of refrigerants into new equipment, this analysis considered (a) the primary market players (i.e., A5 versus non-A5 equipment manufacturers), (b) the availability and cost effectiveness of ODS and substitute refrigerants, and (c) national and international regulations governing the use of ODS refrigerants. ICF estimates were developed based on input from industry, Manikela (2007), and UNEP reports.

A more detailed explanation of the assumptions, methodology, and sources used to develop current and future inventories of equipment and refrigerant by region is provided in chapters 4 and 5.

4. Chiller Sector

Chillers are centralized air conditioning systems used in medium and large buildings—including offices, hotels, shopping centers, and other large buildings—as well as in specialty applications on ships, submarines, nuclear power plants, and other industrial applications. Large chillers are generally installed in large cities and resort areas, primarily in temperate, hot-arid or hot humid climates (UNEP 2004, US EPA 2006). Chillers represent large investments and have a very long life of up to 30 years or more, particularly when maintained through proper service and occasional overhaul (ICF 2007, IPCC 2000, ARAP 2006, UNEP 2004).

Two broad types of chillers are manufactured—vapor compression chillers and absorption chillers. Vapor compression chillers are identified by the type of compressor they employ: centrifugal compressors or positive displacement compressors. The positive displacement category includes reciprocating, screw, and scroll compressors. Vapor compression chillers have historically relied on ODS refrigerants. Conversely, absorption chillers commonly use water or ammonia as the refrigerant (with lithium bromide or water as the absorbent, respectively). Because absorption chillers do not use ODS, the remainder of this chapter is focused only on centrifugal and positive displacement chillers.

Chillers may range in capacity from a few kilowatts (kW) to 30,000 kW, as shown in Exhibit 11. Centrifugal chillers are the most common type of chillers with a capacity greater than 700 kW. The use of CFCs in chillers has been limited to the large centrifugal machines in the range of 1,000 to 10,000 kW (IPCC/TEAP 2005, UNEP 2004)

Exhibit 11: Cooling Capacity Range Offered by Single Unit Chillers

Chiller Type	Capacity Range (kW)[a]	Average Refrigerant Charge (kg/kW)[b]
Centrifugal	350 - 30,000	0.33
Scroll and Reciprocating	7.0 - 1,600	0.28
Screw	140 - 6,000	0.35

Note: Many applications use multiple chillers to cool a particular space. For example, a large commercial office building may have 2 or more chillers.
[a] Source: UNEP (2004).
[b] Actual refrigerant charge varies slightly by refrigerant type; only average values are shown here.

Reciprocating compressors have been used in smaller chillers for many decades. Beginning in the mid-1980s, screw compressors became available as alternatives to reciprocating compressors in the capacity range from 140 - 700 kW, and as alternatives to centrifugal compressors up to about 2,275 kW. Scroll compressors were introduced around the same time, and have been used as alternatives to reciprocating compressors in the range from 7 to about 100 kW (UNEP 2007d). Because positive displacement chillers use higher-pressure refrigerants than centrifugal chillers, these smaller chillers never used CFC refrigerants, but have instead relied on HCFCs and, more recently, HFCs. (IPCC/TEAP 2005, UNEP 2004)

The remainder of this section examines the current market characteristics of centrifugal and positive displacement chillers, as well as available alternatives, and the projected transition away from ODS in this end use.

4.1 Market Characterization

4.1.1 Centrifugal Chillers

Centrifugal chillers have historically been manufactured primarily in the United States, with later production in Europe and more recent production in Asia (UNEP 2004). The major centrifugal chiller manufacturers are: Carrier (US), Daikin/McQuay (Japan), Trane (US), and York (US). Centrifugal chillers are also produced in Korea, China, and India; these A5 manufacturers supply an estimated

15%-20% of the A5 chiller market, while the remainder is satisfied by imports from non-A5 countries (ICF 2007). A more comprehensive listing of manufacturers is provided in Appendix 2.

Prior to 1993, centrifugal chillers were offered with CFC-11, CFC-113, CFC-12, CFC-114, R-500, and HCFC-22 refrigerants. CFC-12 was the dominant refrigerant used in high-pressure chillers, while CFC-11 was the dominant refrigerant for low-pressure chillers (IPCC/TEAP 2005). Combined, in 2004, these two refrigerants represented almost 100% of the installed CFC centrifugal chiller base (UNEP 2004). R-500, a blend containing CFC-12, was historically used in a limited number of centrifugal chillers, although very few are believed to be installed in A5 countries. Centrifugal chillers used in naval submarines and surface vessels historically employed neat CFC-114 as the refrigerant (IPCC/TEAP 2005).

With the signing of the Montreal Protocol, the four US-based manufacturers and their European affiliates discontinued the production of chillers using CFCs starting in 1993, which significantly limited production of new CFC chillers by the end of 1992, since these companies accounted for a large market share of production (US EPA 2005, UNEP 2004, UNEP 2007d).

Since the early 1990s, HCFCs and HFCs have been used primarily in new centrifugal chillers, though centrifugal chillers using HCFC-22 rarely were produced after the late 1990s, primarily because they were less efficient than HCFC-123 chillers at the time (Calm 2004, UNEP 2004). Since the 1990s, HCFC-123 and HFC-134a have become the dominant market players (US EPA 2005, UNEP 2007d). Centrifugal chillers produced for A5 markets by Carrier, Daikin/McQuay, and York contain HFC-134a, while those produced by Trane for A5 markets contain HCFC-123. A5 producers in Korea, China, and India produce chillers using both R-134a and R-123 (ICF 2007).

Based on available information, the current estimated stocks of centrifugal chillers by A5 region are presented in Exhibit 12.

Exhibit 12: Installed Base of Centrifugal Chillers by Region (2007)

Existing Stock	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
Number of units in use	30,000	9,000	10,000	4,000

[a] ICF estimates based on BSRIA (2006), UNEP (2007d), ICF (2007).

The above estimates were developed based on the following data points:

- **Asia:** India has an estimated 6,000 centrifugal chillers currently installed (ICF 2007). China, which represents nearly 50% of the centrifugal chiller stocks in Asia (ICF 2007), reported had about 11,000 centrifugal chillers installed in 2004 (UNEP 2007d). Using an annual growth rate of 10.4% in China—China's GDP growth from 2005 to 2007—the current stock in China is estimated to be about 13,000. Based on this information, this analysis estimates centrifugal chiller stocks for the region to be 30,000.
- **Latin America/Caribbean:** According to industry experts, centrifugal chiller stocks in this region, excluding Mexico, are approximately 7,500 (ICF 2007). BSRIA (2007) reported that Mexico installed 79 new chillers in 2005. Assuming an average historical growth rate of approximately 3% per year over a 30-year period, the stock of chillers in Mexico is estimated at approximately 1,500 (BSRIA 2007, ICF estimates). Thus, 2007 estimated chiller stocks for the region are estimated at 9,000 (7,500 + 1,500).
- **Middle East/North Africa:** According to industry estimates, there are between 9,000 and 11,000 centrifugal chillers installed in the Middle East/North Africa today (ICF 2007). For the purposes of this analysis, the median value of 10,000 was assumed.
- **Africa:** According to industry estimates, there are between 3,000 and 5,000 centrifugal chillers installed in Africa today (ICF 2007). For the purposes of this analysis, the median value of 4,000 was assumed.

As shown in Exhibit 12, Asia has the largest installed base of centrifugal chillers. The Asian market is driven by China, with Korea and Taiwan also representing significant markets for centrifugal chillers in Asia (UNEP 2007d, ICF 2007). The centrifugal markets in China, Korea, and Taiwan are also significant on a global scale; according to market reports, China represented approximately 18% of global centrifugal chiller sales in 2004 (~1,500 chillers), while South Korea comprised approximately 4% (~400 chillers), and Taiwan represented 3.5% (~300 chillers) (BSRIA 2007, UNEP 2007d).

In Africa, South Africa is the most prominent user of centrifugal chillers, while the Middle East/North Africa region has its most significant chiller use in Saudi Arabia, Turkey, and the United Arab Emirates (ICF 2007). In Latin America, Mexico and Brazil are the largest users of centrifugal chillers, with about 80 new centrifugal chillers having entered the markets of both countries in 2005 (UNEP 2007d, BSRIA 2007).

Centrifugal chillers in Article 5 countries contain CFC-11, CFC-12, HCFC-123, HCFC-22, and HFC-134a as refrigerants. A small number of R-500 units may also be in operation. To disaggregate the regional stocks of centrifugal chillers by refrigerant type, ICF relied on individual country data to the extent possible.

Specifically, for Asia, 2004 data on the refrigerant composition of chiller stocks in China were used as proxies for the entire region (UNEP 2007d). To account for equipment retirement between years 2004 to 2007, CFC stocks were reduced by 1/18 (5.6%)[8] while the share of non-CFC refrigerants were grown by 10.4%—China's GDP growth rate from 2004 to 2007. Exhibit 13 presents the 2004 and 2007 refrigerant inventories in centrifugal chillers in China, used as proxies for all of Asia. It should be noted that, based on data on India's refrigerant inventory, the share of HFC-134a relative to HCFC-123 may be higher in China than in other A5 countries (ICF 2007).

Exhibit 13: Refrigerant Inventory in Centrifugal Chillers in China, Used as Proxies for All of Asia[a]

Refrigerant Type	Percent of Installed Base in 2004	Estimated Percent of Installed Base in 2007
CFCs	37%	27%
HCFC-123	29%	33%
HCFC-22	5%	6%
HFC-134a	29%	34%

Source: UNEP (2007d), ICF (2007).

For all other regions, data on refrigerant inventories was limited; only data on the number of CFC chillers were available for selected countries for 2004, as shown in Exhibit 14. In order to translate the 2004 CFC centrifugal stock estimates for these few countries into reasonable CFC stock estimates for their entire geographic regions, CFC stock estimates for these countries were first estimated for the year 2007 (by retiring CFC units at 5.6% or 1/18). Next, 1990 GDP values were used as proxies for scaling up total regional CFC chiller markets.[9] The results derived using this methodology (as presented in Exhibit 14) are supported by various other sources. For example, it has been estimated that between 600 and 1,000 large tonnage CFC chillers are in use in Africa (UNEP 2007a).

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[8] Because production of CFC centrifugal chillers was phased out in 1995 and the assumed lifetime of a centrifugal chiller is 30 years, the number of CFC chillers is assumed to decline linearly to reach zero in 2025.

[9] GDPs from 1990 were used because the majority of CFC chillers were installed in Article 5 countries in the late 1980s and early 1990s (Kuijpers 2006); thus, 1990 is an approximation for the peak demand for CFC chillers in Article 5 countries.

Exhibit 14: CFC Chiller Stocks and Share of Regional GDP for Select A5 Countries

Region	Countries with Known CFC Chiller Stocks (2004)	Number of CFC Chillers in Selected Countries (2004)[a]	Estimated Number of CFC Chillers in Selected Countries (2007)	Percent of Region GDP Represented by Selected Countries, 1990	Total Estimated Number of CFC Chillers in Region (2007)[b]
Africa	Cameroon, Namibia, Sudan, Cote D'Ivoire, Nigeria	144	135	16.7%	810
Latin America/ Caribbean	Argentina, Brazil, Chile, Colombia, Ecuador, Jamaica, Mexico	3,990	3,390	86.7%	3,910
Middle East/ North Africa	Egypt	223	190	8.3%	2,290

[a] Sources: UNEP (2004)

[b] Regional estimates were calculated by growing CFC chiller stocks to account for the remaining GDP of region.

For example, for Latin America and the Caribbean, individual country data is available from UNEP (2004) on the 2004 CFC chiller stock in seven countries—Argentina, Brazil, Chile, Colombia, Ecuador, Jamaica, and Mexico—which was equal to approximately 3,990 chillers. After accounting for equipment retirement since 2004, it is estimated that these seven countries have about 3,390 CFC chillers in 2007 (ICF estimate). Because the aggregate share of these countries' 1990 GDP represents approximately 87% of the total GDP for the Latin America/Caribbean region, it was assumed that these seven countries hold approximately 87% of the region's centrifugal chillers. Accordingly, for 2007, it is estimated that the Latin America/Caribbean region as a whole has 3,910 CFC chillers.

Once the total number of CFC chillers by region was estimated, the percent of total regional chiller stocks (shown in Exhibit 12) that contain CFCs was calculated, and the remaining refrigerant inventory was apportioned based on China's estimated refrigerant breakout of non-CFC chillers, namely:

- HCFC-123: 46% of non-CFC centrifugal chiller stocks
- HFC-134a: 46% of non-CFC centrifugal chiller stocks
- HCFC-22: 8% of non-CFC centrifugal chiller stocks

While refrigerant inventories will of course vary by country, the above percentages are supported by data provided by the World Bank (2002), which indicate that the installed base of R-123 and R-134a in centrifugal chillers in Latin America are roughly equal. Thus, at a macro-level, this breakout is believed to be reasonable. At a country level, however, the actual installed base of R-123 versus R-134a may vary widely. For example, in South Africa, the vast majority of centrifugal chillers use R-134a, with R-123 chillers being very uncommon; conversely, in India, R-123 chillers account for an estimated 35-40% of the installed base, whereas R-134a only accounts for an estimated 20-25% (Manikela 2007, ICF 2007). Refrigerant preference at the national level depends in part on the dominant market players in the region (i.e., company presence/size of sales force).

The resulting refrigerant inventory, by percent of refrigerant, is shown by region in Exhibit 15. Because the manufacture of CFC chillers generally stopped in 1995, countries with a lower overall percent of installed CFCs were later entrants to the centrifugal chiller market.

Exhibit 15: Assumptions of Refrigerant Inventory in Centrifugal Chillers (2007)

Refrigerant Type	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
CFCs[a]	27%	43%	23%	20%
HCFC-123	33%	26%	36%	37%
HCFC-22	6%	4%	6%	6%
HFC-134a	34%	26%	36%	37%

[a] CFC-11, CFC-12, R-500.

Exhibit 16 presents the corresponding estimates by stock (number of units by refrigerant and region).

Exhibit 16: Estimated Number of Centrifugal Chillers by Refrigerant Type (2007)

Refrigerant Type	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa	TOTAL
CFCs	8,240	3,910	2,290	810	15,250
HCFC-123	9,950	2,350	3,560	1,470	17,330
HCFC-22	1,710	390	590	250	2,940
HFC-134a	10,100	2,350	3,560	1,470	17,480

These estimates of CFC refrigerant inventory are supported by other published sources. According to GTZ (2006), there are an estimated 600 and 1,000 large tonnage CFC chillers installed in Africa. According to UNEP (2004), there were between 15,000 and 20,000 CFC chillers in A5 countries in 2004; therefore, it is reasonable that roughly 16,000 CFC chillers still remain in A5 countries in 2007. Similarly, according to the Alliance for Responsible Atmospheric Policy (2006), there are an estimated 50,000 remaining CFC chillers worldwide, and it is reasonable to assume that roughly 30% of these units are installed in Article 5 countries. No data are readily available to corroborate the stock estimates for HCFC and HFC centrifugal chillers.

4.1.2 Positive Displacement Chillers

Manufacturers of positive displacement chillers are located in Europe, the US, Japan, and Korea (World Bank 2005). The estimated number of positive displacement units currently installed in Article 5 countries is presented in Exhibit 17.

Exhibit 17: Installed Base of Positive Displacement Chillers by Region (2007)

Chiller Type/Attribute	Asia	Latin America and Caribbean	Middle East/ North Africa	Africa
Scroll & Screw	550,000	61,000	70,000	5,000
Reciprocating	40,000	12,000	10,000	500

These estimates of stocks were developed based on available market data and input from industry representatives, as outlined below:

- **Asia:** Based on industry information, there are an estimated 550,000 screw and scroll chillers in Asia—about 30% of which are installed in China—and approximately 40,000 reciprocating chillers—about two-thirds of which are installed in China. (ICF 2007)
- **Latin America/Caribbean:** BSRIA (2007) reported that the demand for new reciprocating, screw and scroll chillers was approximately 2,000 in 2005 in Brazil, Argentina, and Mexico. Assuming an average historical growth rate of 3% per year over a 30-year period, there were an estimated 39,000 scroll and screw chillers in these three countries in 2005. To account for market growth between 2005 and 2007, this stock was grown by 5.6% per year—the average GDP growth rate for these three countries from 2006-2007. Next, this 2007 stock estimate was grown further to account for the rest of the countries in the region, based on the most recent GDP values available (2006). Specifically, because Argentina, Brazil, and Mexico represented approximately 72% of regional GDP in 2006, it was assumed that these three countries account for approximately 72% of the scroll and screw chillers in the region.. Thus, it is estimated that there are approximately 61,000 scroll and screw chillers and 12,000 reciprocating chillers in this region. (ICF 2007)
- **Middle East/North Africa:** According to industry representatives contacted for this report, there are an estimated 70,000 scroll/screw chillers and approximately 10,000 reciprocating chillers installed in the Middle East/North Africa today (ICF 2007). No other data estimates were readily available for this region.

- **Africa:** According to industry estimates developed for this report, there are an estimated 5,000 scroll/screw chillers and 500 reciprocating chillers installed in Africa (ICF 2007). No other data estimates were readily available for this region.

As shown in Exhibit 17, Asia has the largest installed base of positive displacement chillers, comprising over 80% of the total stock in A5 countries. UNEP (2007d) reported that the majority of positive displacement chillers are used in Europe and Asia, with Malaysia, Thailand, Singapore, Indonesia, and the Philippines accounting for several hundred units. In Latin America, demand for new chillers using positive displacement compressors accounts for 3,200 to 3,300 units with around 6% increase in stock every year. (UNEP 2007d)

Screw chillers generally employed HCFC-22 as the refrigerant when they were first produced in the mid-1980s. The trend has been to replace HCFC-22 product offerings with HFC-134a products when manufacturers introduce new product lines. Screw chillers using a higher pressure HFC blend refrigerant, R-410A, also have been introduced recently, largely in Europe. A small number of screw chillers with ammonia as the refrigerant are produced by some manufacturers, used primarily in northern European countries. Before implementation of the Montreal Protocol, some of the smaller reciprocating chillers (<100 kW) were offered with CFC-12 as the refrigerant, but most of the smaller chillers and nearly all the larger chillers employed HCFC-22. (UNEP 2007d) There is little data available on the number of small (non-centrifugal) CFC chillers (<350 kW), particularly in A5 countries; however, generally, the majority of small chillers for comfort cooling use HCFC-22 (UNEP 2004). Positive displacement chillers are sold with HFCs and HFC blends (i.e., R-407C and R-410A) in non-A5 countries; it is assumed that R-407C and HFC-134a have begun to penetrate a small share of the A5 market, but that R-410A has not (ICF 2007, Manikela 2007). Exhibit 18 presents the estimated current stock of positive displacement chillers in Article 5 countries by refrigerant type. Based on this assumed refrigerant inventory, Exhibit 19 presents the number of positive displacement chillers in use by refrigerant type in each A5 region, based on the total stock identified in Exhibit 17.

Exhibit 18: Assumptions of Refrigerant Inventory in Positive Displacement Chillers (2007)

Chiller Type	Percent of Current Inventory
Scroll and Screw [a]	
HCFC-22	95%
HFC-134a	5%
Reciprocating	
HCFC-22	95%
HFC-134a	1%
R-407C	4%

[a] Current percent of installed R-410A and R-407C in scroll and screw chillers is negligible.
Source: ICF (2007).

Exhibit 19: Breakout of Current Positive Displacement Chiller Stock by Refrigerant Type

Chiller Type	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
Scroll and Screw				
HCFC-22	522,500	57,950	66,500	4,750
HFC-134a	27,500	3,050	3,500	250
Reciprocating				
HCFC-22	38,000	11,400	9,500	475
HFC-407C	1,600	480	400	20
HFC-134a	400	120	100	5

Source: ICF (2007).

4.2 Alternatives and Barriers/Drivers to Implementation

The following table summarizes non-HCFC alternatives currently available in new chillers.

Exhibit 20: Availability of Non-HCFC Alternatives in New Chiller Equipment

Chiller Type	R-134a	R-245fa	R-407C	R-410A	HCs	Ammonia
Centrifugal	✓	✓[a]			✓[a]	
Screw	✓					
Scroll				✓		
Reciprocating	✓		✓		✓[a]	✓[a]

[a] Alternative has not measurably penetrated the global market.
Source: ICF (2007).

The remainder of this section describes these and other potentially feasible alternatives.

4.2.1 Centrifugal Chillers

For the relatively small centrifugal chiller segment, the primary refrigerant that has replaced the market segment formerly reliant on CFC-11 is HCFC-123, while the primary alternative that has replaced the original CFC-12, R-500, and CFC-114 chiller markets is HFC-134a (US EPA 2005). Until the use of HCFC or HFC refrigerants (e.g., R-123, R-134a) is no longer allowable, the costly redesign of new equipment and the cost of testing to ensure refrigerant reliability render it unlikely that manufacturers will pursue other alternatives to replace these refrigerants (UNEP 2007d). The current and potential future alternatives to ODS refrigerants that are/may be used in centrifugal applications are described in more detail below.

- **HFC-134a:** Currently, the primary alternative to HCFC-123 is HFC-134a (R-134a). This refrigerant has been used in centrifugal chillers since the early 1990s.

- **HFC-245fa:** Another alternative to replace the use of R-123 in new centrifugal chillers is R-245fa. Theoretical efficiency tests performed on R-245fa indicate that equipment using this refrigerant consumes a similar amount of energy as R-123 systems, but could have a higher cost due to the manufacturing processes entailed (Calm 2004). R-245fa is higher pressure than HCFC-123 and CFC-11 but lower than R-134a, and could be used as a potential alternative for R-134a in high-pressure chillers. However, to use it in new equipment, compressors and heat exchangers must be redesigned (IPCC/TEAP 2005). One small manufacturer in Japan (Ebara) has adopted this refrigerant already in chillers above 2,800 kW (UNEP 2007d, York 2007). This manufacturer has reported that R-245fa has favorable heat transfer characteristics exceeding those of HCFC-123 (York 2007). However, due to the limited and uncertain availability of HFC-245fa, it is unlikely that this refrigerant will become widely used in centrifugal chillers in the foreseeable future (ICF 2007).

- **Hydrocarbons:** Currently, hydrocarbon (HC) refrigerants, such as propane (R-290) and propylene (R-1270), are used in centrifugal chillers in petrochemical plants. However, due to the large charge sizes associated with centrifugal chillers, the flammability risk prevents HC centrifugal chillers from being used in any other applications.

Exhibit 21 summarizes the relative energy consumption and life cycle climate performance (LCCP)[10] of HCFC-22, R-123, R-134a, and R-245fa in centrifugal chillers. (Note that efficiencies of R-245fa are theoretical.) No information is available for HC chillers used in petrochemical plants.

[10] LCCP measures direct refrigerant emissions and indirect greenhouse gas emissions associated with energy consumption, accounting for cradle to grave emissions.

Exhibit 21: Relative Energy Consumption and LCCP of Alternative Refrigerants in Centrifugal Chillers

Alternative Refrigerant	Baseline	Energy Consumption[a] (Source)	LCCP (Source)
R-134a	HCFC-22	Similar (ADL 2002, Calm and Domanski 2004)	-10% (ADL 2002)
	R-123	+9% to +20% (Calm 2004)	Slight increase (Soffientini et al. undated)
R-245fa[b]	HCFC-22	-7% to -11% (ADL 2002)	-9% (ADL 2002)
	R-123	Similar (Calm 2004)	Slight increase (Soffientini et al. undated)

[a] Positive energy consumption indicates that the alternative refrigerant consumes more energy than the baseline refrigerant.
[b] Calculations performed were based on theoretical efficiencies.

Retrofits of existing stock of ODS centrifugal chillers are possible, though uncommon; such conversions are costly and typically result in efficiency losses or performance losses (i.e., lower cooling capacity). Moreover, by now, the conversion of most of the chillers that still have reasonable remaining operating life and relatively good energy efficiency have already been retrofit to use non-CFC refrigerants. Technically feasible retrofit options (which are not necessarily economically viable) are described below:

- CFC-11 centrifugal chillers may be retrofit to use HCFC-123. When performing such conversions, some non-metallic materials and hermetic motors must be replaced with compatible materials, and the compressor may need to be replaced with one that has a higher capacity. If the retrofit is done properly, there will only be a small reduction in capacity and a negligible reduction in energy efficiency. However, because retrofitting CFC-11 chillers to use HCFC-123 is technically difficult and is not always cost effective, replacing the chiller with a new unit may be a better investment (UNEP 2007d)

- CFC-12 and R-500 (which consists of CFC-12 and HFC-152a) centrifugal chillers may be retrofit to use HFC-134a. Such conversions may require compressor replacement (due to the need for higher impeller tip speeds) and/or the retubing of heat exchangers to minimize loss of capacity and efficiency. When converting from CFC-12 to R-134a, mineral oils must be replaced with polyolester oils and residual mineral oil concentrations must be minimized to prevent a reduction in heat exchanger performance. (UNEP 2007d),

- CFC-114 centrifugal chillers used in naval submarines and surface vessels can be retrofit to use HFC-236fa as a transitional refrigerant.[11] While a number of such conversions have been performed globally, such equipment is not common in Article 5 countries. (UNEP 2007d)

- HFC-134a and R-407C (a blend containing HFC-134a/HFC-125/HFC-32) are possible retrofit options for HCFC-22. However, switching to R-134a reduces cooling capacity by one third, unless the compressor is replaced with one that has 50 % greater displacement. Further, converting an HCFC-22 unit to R-407C or R-134a requires the removal and replacement of the mineral oil lubricant with a compatible synthetic lubricant. In addition, switching to R-407C results in loss of capacity and energy efficiency. (UNEP 2007d)

- R-427A (a new blend containing HFC-134a/HFC-125/HFC-32/HFC-143a) can be retrofit for R-22 equipment, requiring only the replacement of the system's original oil with a PolyOilEster (POE) lubricant. The performance of equipment retrofit to use R-427A is reportedly similar to that of R-22. However, because this refrigerant blend has a GWP of 1,830, it may not be a viable long-term solution. (Arkema 2006, BOC Gases 2007)

[11] No manufacturer has produced new chillers using HFC-236fa; new naval chillers primarily use HFC-134a (UNEP 2007d).

- Other potentially feasible retrofit candidates proposed for CFC-12 are R-416A and R-423a but they have yet to be fully investigated. Testing on R-416A (GWP ~975) has been done in motor vehicle air conditioning but the resulting reduction in cycle performance indicates that its performance in chillers will be less than CFC-12. R-423a (GWP ~2,400) is now being sold by one manufacturer and tests show that its coefficient of performance is almost equal to that of CFC-12, but it leads to reduced evaporator capacity. (UNEP 2004) Due to the high GWP of R-423a, it may not be a viable long-term solution.

Anecdotal information indicates that CFC replacements are occurring at a much slower pace in A5 countries than they are in non-A5 countries. This is in part because chillers in A5 countries are operated for as long as possible, and generally only replaced after a catastrophic failure, when servicing becomes uneconomical. (UNEP 2004)

While the conversion of old equipment may not be economically feasible, it should be emphasized that replacing old chillers with new ones, regardless of refrigerant type, will bring energy savings and climate benefits. Manufacturers offer HCFC and HFC chillers with significantly improved energy efficiency compared to most CFC chillers in service. The average new chiller is estimated to use approximately 20 % less electricity than the average chiller manufactured 20 years ago, with the most energy efficient chiller manufactured today requiring up to 65 % less electricity. These energy savings can lead to the recovery of the investment cost of replacing an old CFC chiller in three to five years or less (assuming the region requires cooling for more than three months a year). If the building's overall energy efficiency is improved along with the replacement of the chiller, the typical return on investment is 20% to 35%. This efficiency improvement results in indirect greenhouse gas emission reductions. (UNEP 2007d)

An additional climate benefit of replacing old CFC chillers is the reduction in refrigerant emissions. Newer HCFC and HFC chillers are typically more leak tight. Further, reduced refrigerant losses can also reduce operating costs (because the building owner will not have to purchase as much refrigerant and systems will cool more effectively with the proper amount of refrigerant charge, hence reducing energy requirements).

4.2.2 Positive Displacement Chillers

Historically, most positive displacement chillers have been manufactured with HCFC-22. As the HCFC phaseout advances in non-A5 countries, a number of HFC and other alternatives have been introduced. The development and adoption of these alternatives represent a significant opportunity for technological improvement, in the form of more leak-tight, efficient equipment. Each of the current and potential future alternatives that are or may be used in positive displacement chillers are described in more detail below.

- **HFC-134a:** R-134a is currently the primary replacement for HCFC-22 in all types of positive displacement chillers. However, R-134a requires larger compressor displacement than HCFC-22, which may initially result in higher prices for R-134a screw chillers. Market penetration is now such that the costs of HFC-134a screw chillers are similar to HCFC-22 screw chiller costs (UNEP 2007d).

- **R-410A:** This HFC blend (containing HFC-32 and HFC-125), with a GWP of 1,890, can be used in positive displacement chillers up to 350 kW capacity. It is currently used in newly manufactured scroll chillers. Because R-410A has a much higher pressure than HCFC-22, system components must be redesigned to meet pressure safety codes. The required redesign is costly and requires significant financial investments. However, using R-410A enables a reduction in refrigerant charge (up to 40% less than an HCFC-22 system) for a particular cooling capacity and leads to improved heat exchanger performance, enabling a reduction in heat exchanger sizes (UNEP 2007d). The cost of R-410A is expected to be somewhat higher than that of HCFC-22 refrigerant, at least in the near-term, as discussed in more detail in Appendix 1, which will render equipment containing R-410A more costly. In addition, the high GWP of this refrigerant may undermine its long-term viability.

- **R-407C:** This HFC blend, with GWP of 1,610, is offered in reciprocating chillers from a number of manufacturers, largely used as an intermediate option in the transition to R-410A or R-134a. In general, only minor changes in design are required to switch equipment from HCFC-22 to R-407C. For example, to maintain performance, R-407C requires the use of larger heat exchangers (due to changes in heat transfer capability), which are more expensive. (UNEP 2006, 2007d)

- **HFC-32:** R-32 is a potential alternative to HCFC-22 that has not yet been commercialized. However, it has operating pressures higher than HCFC-22 and is flammable so would require significant additional research and development to become a market player. (UNEP 2007d)

- **Hydrocarbons (HCs):** Although hydrocarbons have not measurably penetrated the global market, several new reciprocating chillers have been manufactured using R-290 (propane) and R-1270 (propylene) in Europe. Safety guidelines limit the charge size of HC positive displacement chillers, depending on application, and require protective measures to be taken, including proper placement and/or gas tight enclosure of the chiller, use of a low-charge system design, fail-safe ventilation systems, and gas detector alarm systems. Alternatively, HC chillers may be located outdoors to minimize health risks (IPCC/TEAP 2005). The safety concerns that limit the marketability of chillers using hydrocarbons results in a higher cost for HC chillers. (IPCC/TEAP 2005, UNEP 2007d)

- **Ammonia:** A very small number of water-cooled reciprocating chillers were manufactured with ammonia as refrigerant but ammonia has not yet significantly penetrated the market (UNEP 2007d). Ammonia can also be used in open drive screw chillers (200-1,500 kW, 50-400 tons), provided that safety issues are addressed (ADL 2002).

There is little information on the energy efficiency of alternative refrigerants relative to CFCs and HCFC-22; however, some calculations indicate that alternatives may be slightly more efficient than refrigerants used historically. Exhibit 22 summarizes the relative energy consumption and LCCP of actual and potential alternative refrigerants in positive displacement chillers, based on published data.

Exhibit 22: Relative Energy Consumption and LCCP of Alternative Refrigerants in Positive Displacement Chillers

Alternative Refrigerant	Baseline	Energy Consumption[a] (Source)	LCCP (Source)
Screw Chillers			
R-134a	CFC-12		Less (UNEP 2007d)
	HCFC-22	-	+ 6% (ADL 2002)
R-410A	HCFC-22	-	Similar (IPCC/TEAP 2005)
Ammonia	HCFC-22	Same (Sand et al. 1997)	Slight increase (IPCC/TEAP 2005)
	R-134a	Same (Sand et al. 1997)	-
Scroll Chillers			
R-407C	R-290	-	Similar (IPCC/TEAP 2005)
Reciprocating Chillers			
R-290	HCFC-22	-5% (IPCC/TEAP 2005)	-
	R-407C	-	Similar (IPCC/TEAP 2005)

\- = No information available

[a] Positive energy consumption indicates that the alternative refrigerant consumes more energy than the baseline refrigerant.

While retrofits of positive displacement chillers may be technically possible, they are typically not economically feasible. In general, it costs less to purchase a new R-410A scroll chiller than to convert an existing HCFC-22 unit to use R-410A (ICF 2007). Similarly, it costs less to purchase a new R-134a screw chiller than to convert an existing HCFC-22 unit to use R-134a (ICF 2007). Technically feasible retrofit options are described below:

- The most common replacement for CFC-12 is HCF-134a, due to their similarities in operating pressure levels and cooling capacities. (UNEP 2007d)

- HCFC-22 is most often replaced with R-407C, R-417A, or HFC-134a, all of which are compatible. HCFC-22 may also be replaced by R-404A or R-507A, which are more suitable as replacements for R-502, but no superior substitute has emerged. (UNEP 2007d)

4.3 Projected Transitions

4.3.1 Centrifugal Chillers

The majority of ODS will be phased out of chillers not through retrofit activity, but through eventual replacement, once old units reach retirement. To project how the equipment stock and refrigerant inventory in centrifugal chillers will change over time, this analysis models the retirement of old equipment and the phase-in of new units through 2040; no significant number of retrofits are assumed to occur in the future, assuming the current regulatory regime is maintained. Because CFC production was phased out in 1995 and the assumed lifetime of a centrifugal chiller is 30 years, the number of CFC chillers in all regions declines linearly to reach zero in 2025 at a retirement rate of 1/30 or 3.3% per year).

Meanwhile, as older CFC chillers are phased out, new chillers are added according to their market share of sales in that year. Exhibit 23 summarizes the projected overall market growth of centrifugal chillers by region, based on input from industry sources. As indicated, China and the Middle East/North Africa are expected to maintain high growth rates in the short run, but growth in all regions is expected to slow between 2010 and 2040, as economic growth stabilizes and the market becomes saturated (ICF 2007).

Exhibit 23: Projected Market Growth for Centrifugal Chillers by Region

Timeframe	Asia		Latin America/ Caribbean	Middle East/ North Africa	Africa
	China	All Others			
2007-2009	10.0%	6.5%	6.5%	10.5%	4.5%
2010-2040	5.0%	3.3%	5.0%	5.3%	4.0%

Source: ICF (2007).

Current and future equipment sales by refrigerant type were projected through 2040. Assumptions used in developing these projections are as follows:

- Current (2007) market penetration of refrigerants into new equipment sales are assumed to be: 75% R-134a, 24% R-123, and 1% R-22. These market penetration rates are projected to remain constant until 2010.

- In 2010, use of R-22 in new centrifugal chillers is assumed to stop in 2010, with R-123 taking its place. From 2010 to 2040, the choice of refrigerant used in new equipment sold in A5 countries is projected to stay constant, with R-134a accounting for 75% of the market and R-123 accounting for the remaining 25%. While it is unlikely that actual market trends will remain constant for 30 years, this analysis does not attempt to project whether demand for R-123 chillers in A5 markets will increase or decrease in future.

Applying these assumptions regarding equipment retirement, market growth, and anticipated penetration of refrigerants into new equipment, Exhibit 24 and Exhibit 25 graphically present the projected refrigerant bank in centrifugal chiller equipment across all A5 regions. More detailed results on the estimated stocks by refrigerant and region are presented in Appendix 3.

Exhibit 24: Projected Transition of Refrigerant Bank in Centrifugal Chillers in A5 Countries, 2007-2040

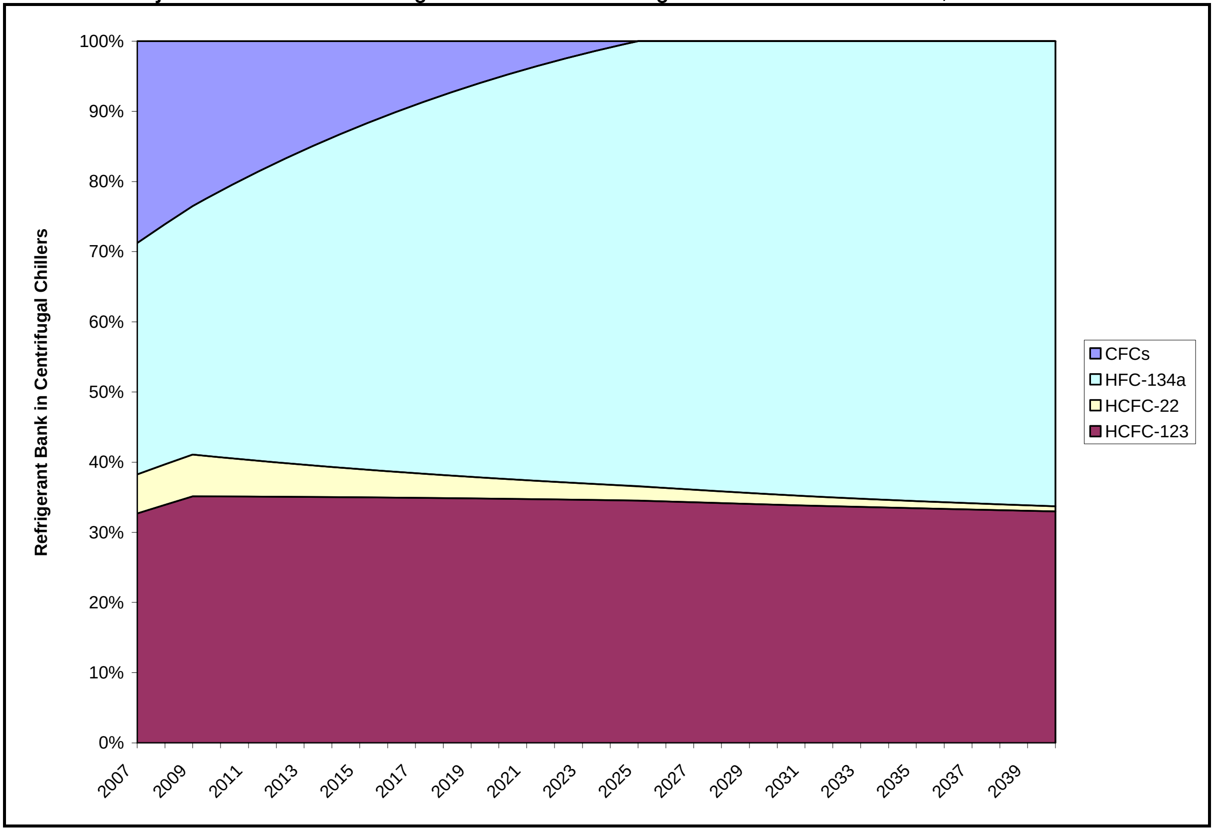
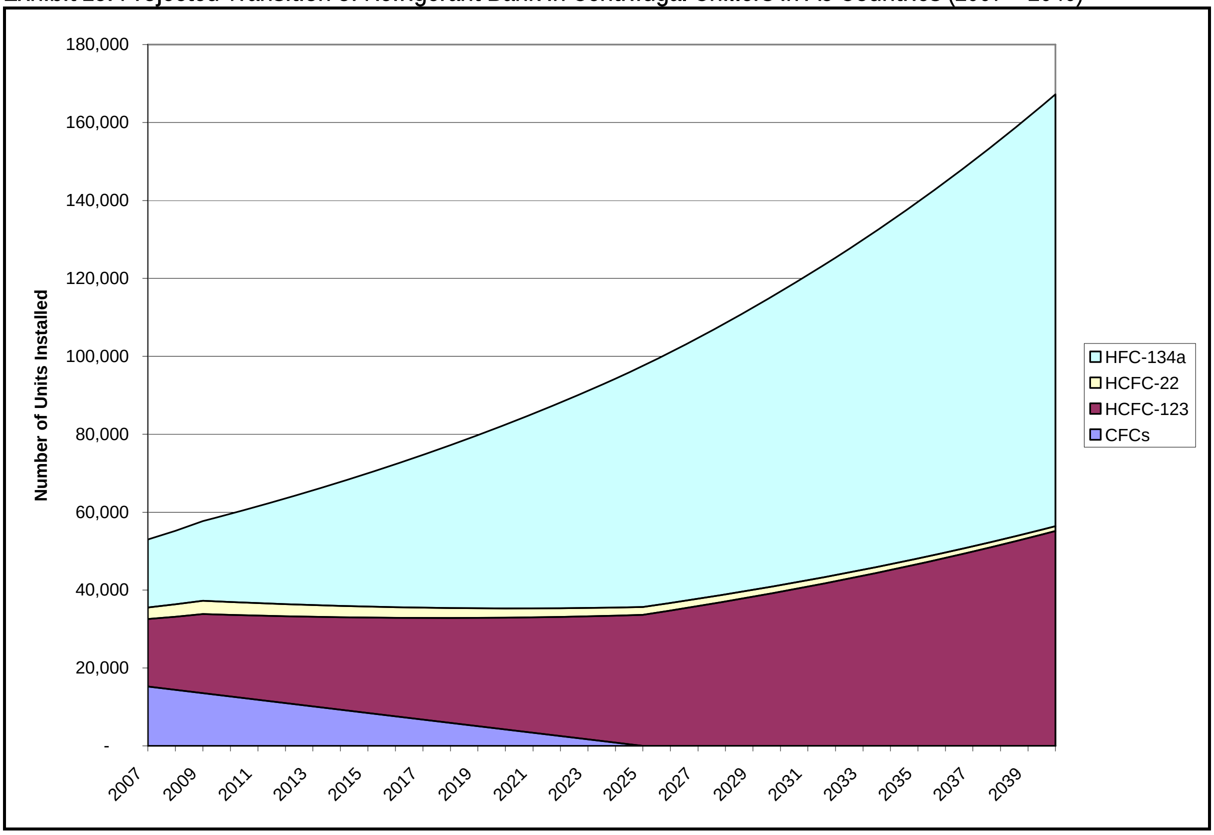


Exhibit 25: Projected Transition of Refrigerant Bank in Centrifugal Chillers in A5 Countries (2007 – 2040)



4.3.2 Positive Displacement Chillers

The market share of screw and scroll chillers is expected to increase due to compactness of the units, maintainability, and ease of operation (World Bank 2005). Indeed, most of the volume increase in the positive displacement chiller market is moving to scroll and screw compressors, while markets for reciprocating chillers are decreasing (UNEP 2007, ICF 2007).

On a global scale, HFC-134a now accounts for approximately 15-20% of all positive displacement chiller sales, and will become the dominant refrigerant by 2020 as HCFC-22 is phased out. Specifically, it is projected that HFC-134a will comprise 80% of the new screw chiller market, 20% of the new scroll chiller market, and 100% of the new reciprocating chiller market, globally. After R-134a, R-410A will be the leading replacement for HCFC-22, especially in scroll chillers. However, without the need to phaseout HCFCs in the near future, A5 producers are likely to continue to rely on R-22 longer than producers in non-A5 countries; therefore, the transition away from ODS in A5 counties will be slower than in non-A5 countries. One exception to this will be A5 manufacturers that produce for export to non-A5 markets; such manufacturers will be required to transition away from ODS in order to maintain their market share.

To project how the equipment stock and refrigerant inventory in positive displacement chillers will change over time, this analysis modeled the retirement of old equipment and the phase-in of new units through 2040. Based on an assumed lifetime of 25 years, positive displacement chillers are retired at a rate of 4% (1/25) per year. It is assumed that no significant number of retrofits will occur in future under a business-as-usual scenario. Meanwhile, as the old chillers phase out, new chillers are added according to their market share of sales in that year. Exhibit 26 summarizes the projected market growth of positive displacement chillers by region, based on industry input. (ICF 2007).

Exhibit 26: Projected Market Growth of Positive Displacement Chillers by Region

Timeframe	Asia		Latin America/ Caribbean	Middle East/ North Africa	Africa
	China	All Others			
Screw & Scroll					
2007-2009	10.0%	6.5%	6.0%	5.5%	4.0%
2010-2040	5.0%	3.3%	5.0%	2.8%	4.0%
Reciprocating					
2007-2009	2.0%	1.3%	1.2%	1.1%	0.8%
2010-2040	0%	0%	0%	0%	0%

As presented, it is projected that the market growth for reciprocating chillers will be 0% in the long-term (beyond 2010), as market trends and industry representatives suggest that this equipment type is becoming obsolete. While this may not be the case in all A5 countries, it is assumed that overall sales of these units in the long-term will be negligible across A5 regions. Meanwhile, growth for screw and scroll chillers will be high. In fact, due to lack of market saturation and high growth potential in China, Africa, and Latin America/Caribbean, growth for screw and scroll chillers is projected to remain relatively high through 2040. For Asia and the Middle East, which have a higher rate of saturation, long term growth rates are projected to decline by 50% between 2010 and 2040, relative to short term growth rates. (ICF 2007).

Based on information provided by industry representatives, current and future market penetration rates by refrigerant type into new positive displacement chiller sales were projected through 2040. Assumptions used in developing these projections are as follows:

- Current (2007) market penetration of refrigerants into new equipment sales are assumed to be as follows:
  - Screw: 70% R-22, 30% R-134a
  - Scroll: 80% R-22, 10% R-134a, 10% R-410A
  - Reciprocating: 85% R-22, 10% R-407C, 5% R-134a

- Estimated 2007 market penetration rates of refrigerant into new equipment are projected to remain constant until 2010.
- In 2010, it is assumed that no new manufacture of reciprocating chillers occurs. For scroll and screw chillers, it is assumed that a shift away from HCFCs takes hold in response to the HCFC phaseout in non-A5 countries. While not all positive displacement chillers entering A5 markets are produced in non-A5 countries, the phaseout will influence the choice of refrigerants being offered in chiller equipment worldwide. Specifically, it is assumed that from 2010 to 2020, the market will gradually shift to the following make-up:
  - — Screw: 20% R-22, 80% R-134a
  - — Scroll: 30% R-22, 20% R-134a, 50% R-410A
- The choice of refrigerant used in new equipment sold in A5 countries is projected to stay constant from 2020 to 2040.

Applying these assumptions regarding equipment retirement, market growth, and anticipated penetration of refrigerants into new equipment, Exhibit 27 illustrates the total A5 projected refrigerant bank in positive displacement chillers through 2040. Exhibit 28 and Exhibit 29 present the total A5 projected refrigerant stock of scroll/screw and reciprocating chillers, respectively. More detailed results on the estimated stocks by equipment type and region are presented in Appendix 3.

Exhibit 27: Positive Displacement Chiller Stock in Article 5 Countries by Refrigerant, 2007-2040

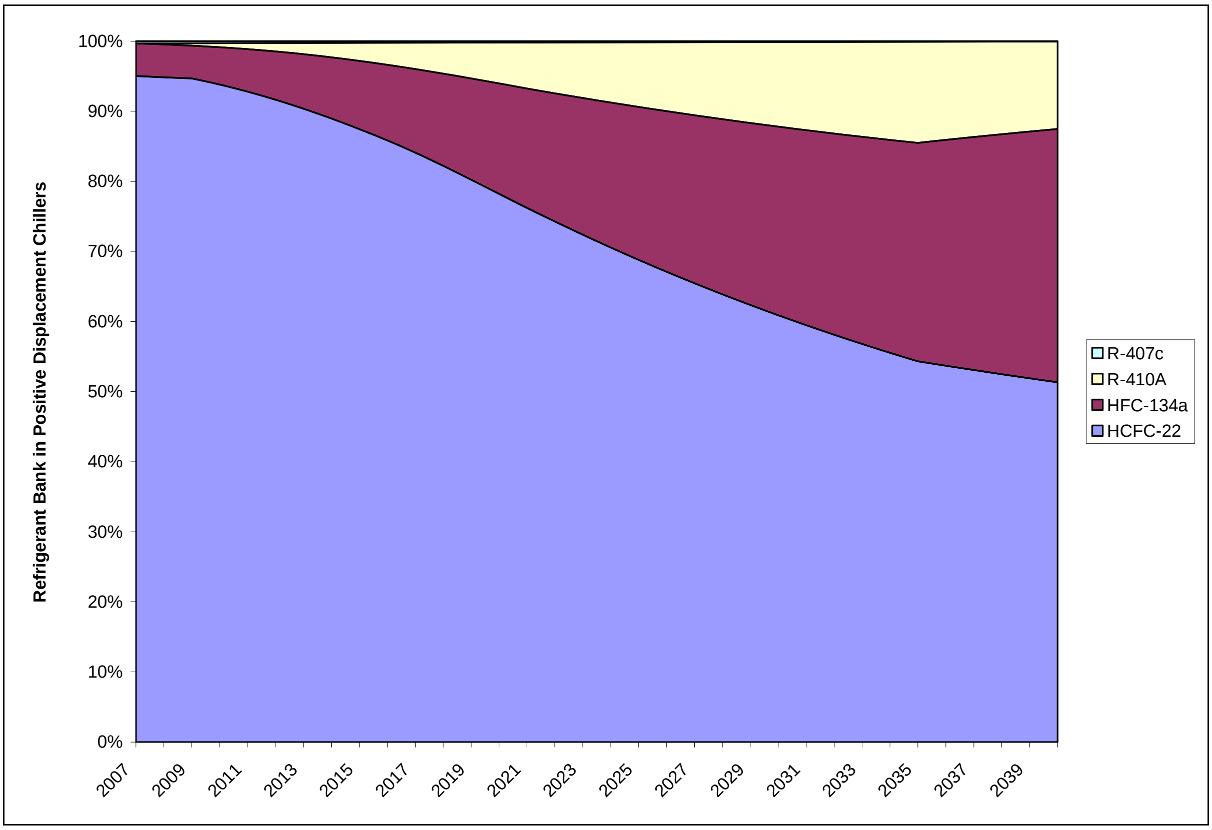


Exhibit 28: Projected Transition of Refrigerant Stock in Screw & Scroll Chillers in A5 Countries (2007 – 2040)

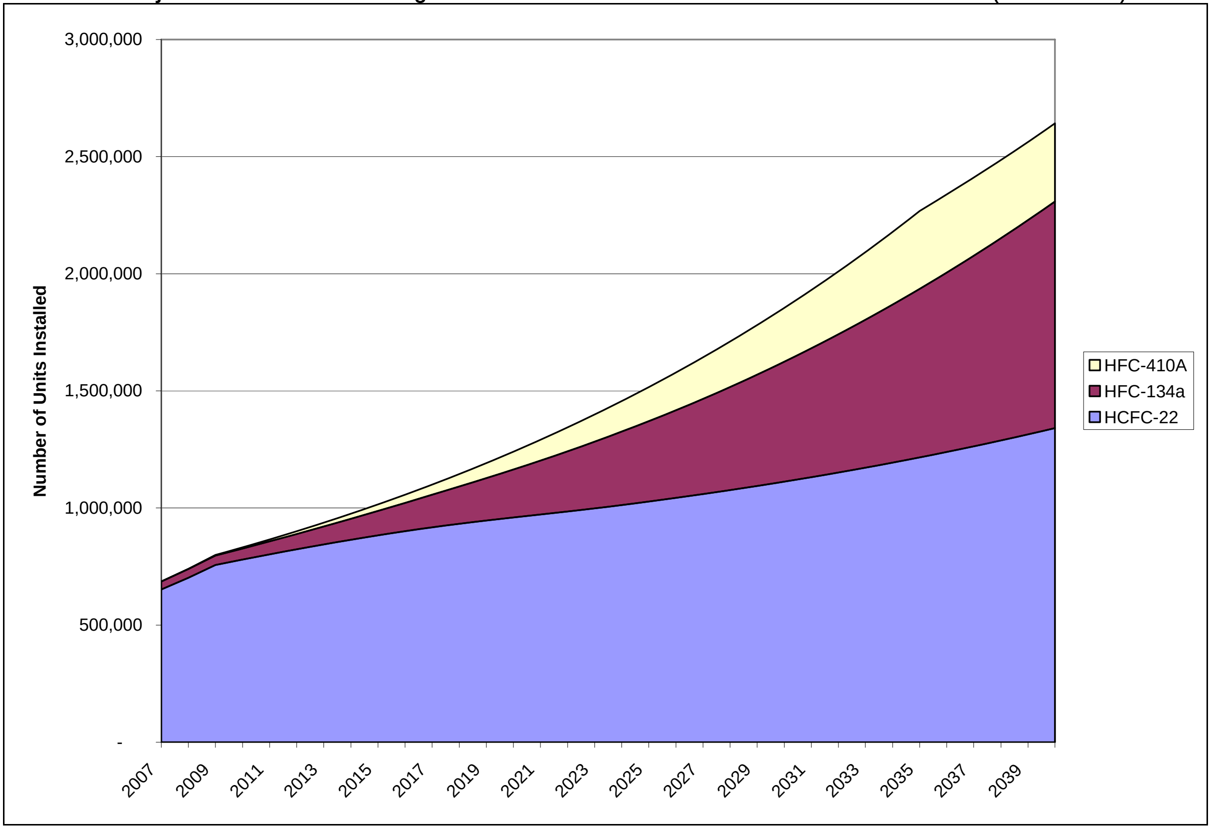
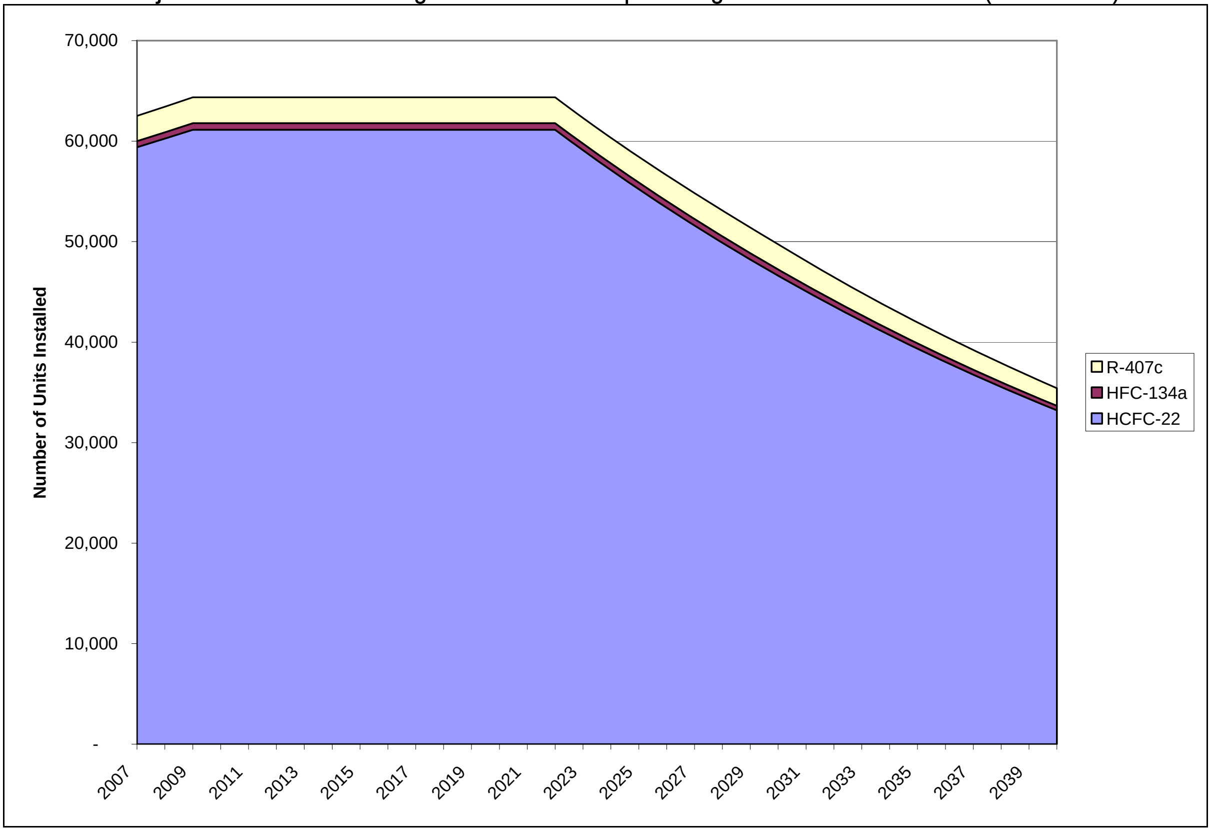


Exhibit 29: Projected Transition of Refrigerant Stock in Reciprocating Chillers in A5 Countries (2007 – 2040)



Note: the decline in banked refrigerant starting in 2023 represents the phaseout of equipment, as no new reciprocating chillers are assumed to be sold after 2009. The net stock of R-22 units begins to decline in 2023, while those of R-134a and R-407C begin to decline in 2030 (assuming an equipment lifetime of 30 years and that R-22 units began production in 1993 and R-134a/R-410A units began production in 2000).

5. Small and Large Air Conditioning Sector

Small and large air conditioners comprise the vast majority of the global air conditioning market (UNEP 2007d). These systems cool enclosed spaces ranging from single rooms to large exhibition halls. Most are electrically-driven vapor-compression systems where air is drawn over a coil containing evaporating refrigerant. They generally fall into the following four categories:

- **Small self contained air conditioners:** These include small window-mounted, portable, and through-the-wall air conditioners. Due to their small size and relatively low cost, these are quite popular in Article 5 countries and are used in small shops and offices, as well as private residences. They range in capacity from 1.0 kW to 10.5 kW and have an average charge size of 0.75 kg or 0.25 kg per kW of cooling capacity (UNEP 2007d, IPCC/TEAP 2005)**.**

- **Non-ducted or duct-free split air conditioners:** Non-ducted split air conditioners include a compressor/heat exchanger unit installed outside the space to be cooled or heated. The outdoor unit is connected via refrigerant piping to one (‘single-split’) or more (‘multi-split’) indoor units (fan coils) located inside the air conditioned space. These have become increasingly popular in Article 5 countries as entry-level ACs, especially in Asia for residential and light commercial applications (e.g., in schools, large apartments and free-standing residences). Capacities range from 2−28 kW for a single split, and from 4.5−135 kW for a multi-split system; charge sizes average about 1.28 kg or approximately 0.25 to 0.30 kg per kW of cooling capacity. (UNEP 2007d, IPCC/TEAP 2005).

  A sub-category of non-ducted multi-split systems gaining ground in Article 5 countries are Variable Refrigerant Flow (VRF) systems. These systems provide air conditioning to multiple spaces using a single outdoor unit and multiple indoor units. VRF systems can regulate refrigerant flow in response to system demand and their capacities range from 10 kW to over 130 kW (UNEP 2007d).

- **Ducted split residential air conditioners:** Ducted split residential air conditioners have a duct system that supplies cooled or heated air to each room of a residence or individual zones within commercial or institutional buildings. Ducted systems are predominantly used in non-Article 5 countries; their capacities range from 2−20 kW, with corresponding charge sizes ranging from 0.26 to 0.35 kg per kW of capacity. (UNEP 2007d, IPCC/TEAP 2005).

- **Ducted split commercial air conditioners:** Ducted commercial air conditioners range in capacity from about 5 kW to as large as 420 kW. The majority of ducted, commercial split and single package air conditioners are mounted on the roof of buildings (e.g.., offices, retail stores and restaurants), or on the ground adjacent to the building. These can range in capacity from 5 to 420 kW (UNEP 2007d, IPCC/TEAP 2005).

Given that these types of residential and commercial AC equipment can range significantly in charge size, this analysis models a “small” and a “large” end use. Small AC is assumed to have an average charge size of 2 kg; large AC is assumed to have an average charge size of 11 kg (UNEP 2007d, IPCC/TEAP 2005). Equipment in this sector is assumed to have an average life span of 15 years (US EPA 2006).

The remainder of this section explores the market characteristics and refrigerants in use in this sector, as well as the projected transition away from ODS.

5.1 Market Characterization

According to industry sources there are hundreds of manufacturers of small and large AC equipment around the world (ICF 2007). China is the largest Article 5 manufacturer of AC equipment, with its total production having reached 67.6 million units in 2005 (UNEP 2007a). In 2006, China’s production of central AC equipment alone increased 20% over 2005, worth a total value of US$1.3

billion (Han 2005). In 2005, the top 10 brands in China accounted for about 75% of the domestic market (with Haier, Midea, and Gree alone representing nearly 40%), while the 29 smallest brands each accounted for less than 0.01%. Foreign and joint venture brands in China accounted for roughly 27% of the market (China Daily 2005).

A significant share of China's production is for the export market. From August 2004 to July 2005, China exported nearly 24.68 million AC units (China Daily 2005). China supplies nearly 85% of the window, wall, and mini split AC imports to the United States. Other A5 producers are also important exporters; including South Korea, Thailand, Brazil, and Mexico. While non-A5 countries are small players in this global market, Canada, Germany, Italy, the United States, Israel, and others produce AC equipment for domestic and export markets. (Stratus 2006).

According to UNEP (2007), there were an estimated 478 million small window-mounted and wall air conditioning systems installed globally in 2004, of which 92.3% (or 441,194,000) used ODS refrigerants (UNEP 2007d). The same report estimates that a total of 21 million large AC systems were installed worldwide in 2004. According to UNEP (2005), 75% of AC units are installed in non-Article 5 countries. Thus, this analysis estimates that 25% of global AC units are installed in A5 countries (i.e., 108,842,000 small AC units, and 5,180,000 large AC units in 2004). To estimate current (2007) stocks of AC units, 2004 estimates were grown based on annual growth rates of 9% and 7% for small and large AC equipment, respectively,[12] and A5 stocks were then disaggregated by region based on average GDPs from 1992-2006. Exhibit 30 presents the number of small and large AC units currently installed by A5 region.

Exhibit 30: Installed Base and Average Charge Size of Small and Large AC by Region (2007)[a]

AC Type/ Attribute	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
Small AC				
Number of units in use	86,446,200	30,177,700	12,938,900	12,168,400
Large AC				
Number of units in use	3,892,700	1,358,900	582,600	547,900

[a] ICF estimates based on UNEP (2007, 2005), ICF (2007).

The majority of Article 5 countries are still using HCFC-22 to produce AC products for their domestic markets (UNEP 2007d). According to various reports and industry sources, virtually the entire installed base of AC equipment in Article 5 countries contains HCFC-22 refrigerant (ICF 2007, UNEP 2007d, Stockholm Group 2007, Stratus 2006). However, some Article 5 countries do have access to HFC equipment, and such equipment has begun to penetrate A5 markets. For example, there were an estimated 100,000 R-407C AC units and 300,000 R-410A AC units in China in 2003 (UNEP 2007a). It is believed that much of the HFC-containing AC equipment penetrating the Chinese market is for "trophy projects," where "green" products are sought, such as for new facilities being constructed for the Olympics (ICF 2007). Likewise, an estimated 5% of new AC equipment entering the market in South Africa contains R-410A, which is imported from Europe (Manikela 2007).

To estimate the current (2007) AC equipment stock that contains HFC refrigerants, China's 2003 stock estimates of R-407C and R-410A were grown at an annual rate of 5% per year.[13] These stock estimates were translated into share of current refrigerant inventory contained in AC equipment, assuming that China holds 50% of the AC units installed today in A5 countries in Asia (UNEP 2007a, ICF 2007). Based on this methodology, it is estimated that R-410A comprises 0.75% of the current stock of small and large AC units, while R-407C comprises 0.25% (see Exhibit 31). These percentages were assumed to apply to all Article 5 regions. Based on these estimates, Exhibit 32 presents the number of small and large AC units by refrigerant type currently installed by A5 region.

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[12] This growth rate is the weighted average projected market growth rates for A5 regions from 2007-2010, as shown in Exhibit 34.

[13] This growth rate is half of the projected market growth rate for AC equipment in Asia from 2007-2010, as shown in Exhibit 34; it is reflective of the fact that demand for HFCs (e.g., for "trophy projects") is growing, but not in step with the overall market.

Exhibit 31: Current Refrigerant Inventory in AC Units by Region[a]

AC Type	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
Small AC				
R-22	99%	99%	99%	99%
R-410A	0.75%	0.75%	0.75%	0.75%
R-407C	0.25%	0.25%	0.25%	0.25%
Large AC				
R-22	99%	99%	99%	99%
R-410A	0.75%	0.75%	0.75%	0.75%
R-407C	0.25%	0.25%	0.25%	0.25%

[a] ICF estimates based on UNEP (2007a), ICF (2007).

Exhibit 32: Installed Base of Small and Large AC Equipment by Refrigerant and Region (2007)[a]

AC Type	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
Small AC				
R-22	85,581,700	29,875,900	12,809,500	12,046,700
R-410A	648,300	226,300	97,000	91,300
R-407C	216,100	75,400	32,300	30,400
Large AC				
R-22	3,853,800	1,345,300	576,800	542,420
R-410A	29,200	10,200	4,400	4,110
R-407C	9,700	3,400	1,500	1,370

[a] ICF estimates based on UNEP (2007d), Manikela (2007), ICF (2007).

5.2 Alternatives and Barriers/Drivers to Implementation

As mentioned earlier, almost all of the small and large AC equipment manufactured in Article 5 countries uses HCFC-22. Currently, the only feasible alternatives for such equipment are HFCs, primarily R-410A and R-407C (IPCC/TEAP 2005, Calm and Domanski 2004). However, R-410A operates more efficiently than R-407C and globally, already accounts for approximately 10 percent of residential and small commercial AC sales, up from just 5 percent in 2004 (ICF 2007).

In the future, other alternatives may also become market players. R-417A is feasible for use in both new and existing unitary AC units, but has a high GWP (DuPont 2006). CO_2 and HCs (e.g., propane) may also one day be feasible, but extensive research and development is still needed to design systems to address potential safety hazards (CIAA/ECSLA/EuroCommerce 2005, IPCC/TEAP 2005). However, these are unlikely to significantly displace R-410A unless regulations are introduced that require a shift away from R-410A.

Each of the current and potential future alternatives that are/may be used in AC applications are described in more detail below.

- **R-410A:** R-410A, with a GWP of 1,890, is a binary blend (HFC-32/HFC-125) that can replace HCFC-22 in new equipment production. R-410A air conditioners (up to 175 kW) are commercially available in the U.S., Asia, and Europe. A significant portion of the duct-free products manufactured in Japan and Europe now use R-410A as the preferred refrigerant. After 2010, air conditioners sold in the U.S. market will predominately utilize R-410A as the HCFC-22 replacement. This blend results in system pressures approximately 50 percent higher than with HCFC-22. However this has been addressed by implementing design changes such as heavier wall compressor shells, pressure vessels (accumulators, receivers, filter driers), heat exchangers and refrigerant tubing (UNEP 2007d).

- **R-407C:** R-407C, with a GWP of 1,610, is a blend composed of HFC-32, HFC-125, and HFC-134a. There are currently R-407C air conditioning products widely available in Europe, Japan and other parts of Asia. R-407C has also seen some limited usage in the United States and Canada, primarily in commercial applications. R-407C requires only modest modifications to existing HCFC-22 systems and is sometimes used for retrofits of air conditioning equipment. Performance tests with R-407C indicate that in properly designed air conditioners, this refrigerant will have capacities and efficiencies within ±5% of equivalent HCFC-22 systems. However, many of these products are now beginning to transition from R-407C to R-410A to obtain improved serviceability and higher efficiencies. (UNEP 2007d).

- **HFC-134a:** R-134a is the only single component HFC that has seen any commercial application. However, R-134a is not a drop-in replacement for HCFC-22 since the compressor displacement must be increased approximately 40 percent to compensate for the lower refrigeration capacity of R-134a. Significant equipment redesign is necessary to achieve efficiency and capacity equivalent to HCFC-22 systems. These design changes include larger heat exchangers, larger diameter interconnecting refrigerant tubing, and re-sized compressor motors. R-134a has not seen broad use because manufacturers have been able to develop lower cost air conditioning systems using HFC blends such as R-407C and R-410A.

- **R-417A:** R-417A, with a GWP of ~1,955, is composed of HFC-134a, HFC-125, and HC-600 (butane). This zeotropic blend has primarily been promoted as a drop-in and retrofit refrigerant for HCFC-22 in air conditioning and refrigeration applications.

- **Hydrocarbons:** While it has been reported that hydrocarbon blends such as HC-290, HC-1270 and HC-290/HC-170 have been used drop-in replacements for HCFC-22 in a few locations, the future use of hydrocarbon refrigerants in the air-conditioning sector will largely depend on the added costs of safety mitigation technologies. Compared to HFCs, hydrocarbon refrigerants offer reduced charge levels (approximately 0.10 - 0.15kg/kW of cooling capacity), miscibility with mineral oils (synthetic lubricants are not required), reduced compressor discharge temperatures, and improved heat transfer due to favourable thermo-physical properties. However, using hydrocarbon refrigerants in air conditioning systems also presents challenges, including safety concerns and difficulties with handling, installation practices, and field service skills and practices. (UNEP 2007d).

- **Carbon dioxide (R-744):** While R-744-based air conditioners have not been introduced into the market yet and it is not expected to play a significant role in the replacement of HCFC-22 in air conditioning applications in the immediate future, the UNEP RTOC report (2007d) indicates that a number of compressor manufacturers have active R&D programs for R-744 compressors. R-744 offers a number of desirable properties as a refrigerant: readily available, low GWP and low cost. R-744 systems are also likely to be very compact; though not necessarily lower cost than HCFC-22 systems. These desirable characteristics are offset by the fact that R-744 air conditioning systems can have low operating efficiencies and very high operating pressures. It is also anticipated that the cost of CO_2 air conditioning will be significantly more than conventional systems (up to 30% more than HCFC-22 systems), due to modifications that are required to improve safety (ADL 2002, IPCC/TEAP 2005, Sand et al. 1997)

In addition to these alternative refrigerants, a number of other non-ODS technologies—such as absorption, desiccant cooling systems, stirling systems, and thermoelectric systems—were previously presented as options that could have a positive impact on the phase-out of ODS in air-conditioning equipment. However, industry input and literature survey indicates that these technologies have not progressed much closer to commercial viability for air conditioning applications. While these alternative systems are theoretically feasible, it is highly unlikely that they will penetrate Article 5 markets in the next decade. (UNEP 2007d)

Exhibit 33 presents a summary of the energy consumption and LCCP of actual and potential alternative refrigerants in unitary and window AC units relative to HCFC-22, based on published data.

Exhibit 33: Relative Energy Consumption and LCCP of Alternative Refrigerants in Unitary and Window AC Relative to HCFC-22

Alternative Refrigerant	Energy Consumption[a] (Source)	LCCP (Source)
Unitary AC		
R-134a	+5% to +10% (Sand et al 1997)	-1% (ADL 2002)
R-407C	Similar (Sand et al 1997, ADL 2002)	Similar (ADL 2002)
R-410A	-4% to -7% (Sand et al 1997)	Similar (Minor 2004)
CO_2	Similar (ADL 2002)	Slight reductions (IPCC/TEAP 2005)
R-290	+12% to +23% (Goetzler and Dieckmann 2001, Sand et al. 1997)	-3% to -8% (ADL 2002)
Window AC		
R-134a	Greater (Hundy and Pham 2001)	-
R-407C	0% to +5% (Minor 2004)	Similar (Minor 2004)
R-410A	0% to -7% (Calm and Domanski 2004, Minor 2004)	-
R-290	Similar (Hickman 2004)	-

- = No information available

[a] Positive energy consumption indicates that the alternative refrigerant consumes more energy than the baseline refrigerant.

5.3 Projected Transitions

Commercialized products using HFC refrigerants are available in most non-Article 5 countries. In addition, climate-friendly products that utilize HC refrigerants are available to a limited extent in some product categories, such as portable air conditioners. The widespread availability of these technologies in non-Article 5 countries should provide optimism that the technologies will be cost effective and readily available in Article 5 countries in the next decade. In addition, some ODS alternatives have begun to penetrate Article 5 markets, including China and South Africa.

However, given the low price of HCFC-22 equipment, it is anticipated that most small and large AC equipment sold in Article 5 countries will continue to utilize HCFC-22 for the foreseeable future, within the limits imposed by the cap on consumption that enters into force in 2016. An accelerated phaseout of HCFCs in Article 5 countries could change this.

Exhibit 34 presents the projected overall market growth rates in the short- and long-terms for small and large AC equipment by Article 5 region. Short-term growth rates were based on:

- *Latin America/Caribbean*: weighted average of the projected growth rates from 2007-2010 for Argentina, Brazil, Colombia, Mexico, and Venezuela (UNDP 2007).
- *Middle East/North Africa*: weighted average of the growth rates in Lebanon and Iran (UNDP 2007).
- *Asia*: growth rates in China, India, and Indonesia (Han 2007, UNDP 2007, ICF 2007).
- *Africa*: growth rates based on industry information (ICF 2007) and the projected growth rate for South Africa (Manikela 2007).

Long term (2010-2040) growth rates in small air conditioning systems were assumed to be half as much as the short term, due to fluctuations in economic growth and increasing market saturation.

Exhibit 34: Projected Market Growth by Region

Timeframe	Asia	Latin America/ Caribbean	Middle East/ North Africa	Africa
Small AC				
2007-2009	10%[a]	9%	9%	6%
2010-2040	5%	4%	4%	3%
Large AC				
2007-2009	10%[a]	3%	3%	3%
2010-2040	3%	3%	3%	2%

Source: UNDP (2007), Manikela (2007), Han (2007), ICF (2007).
[a] While a 10% growth rate for the region is projected, actual growth may be significantly higher in certain countries, such as China and India. For example, because the urbanization level in China may reach 45% in 2010, considerable demand may be created for upgraded residences in that country (Han 2007). Similarly in India, domestic industry sources project that the compound annual growth rate in the short-term may be as high as 23% for small AC and 17% for large AC (ICF 2007).

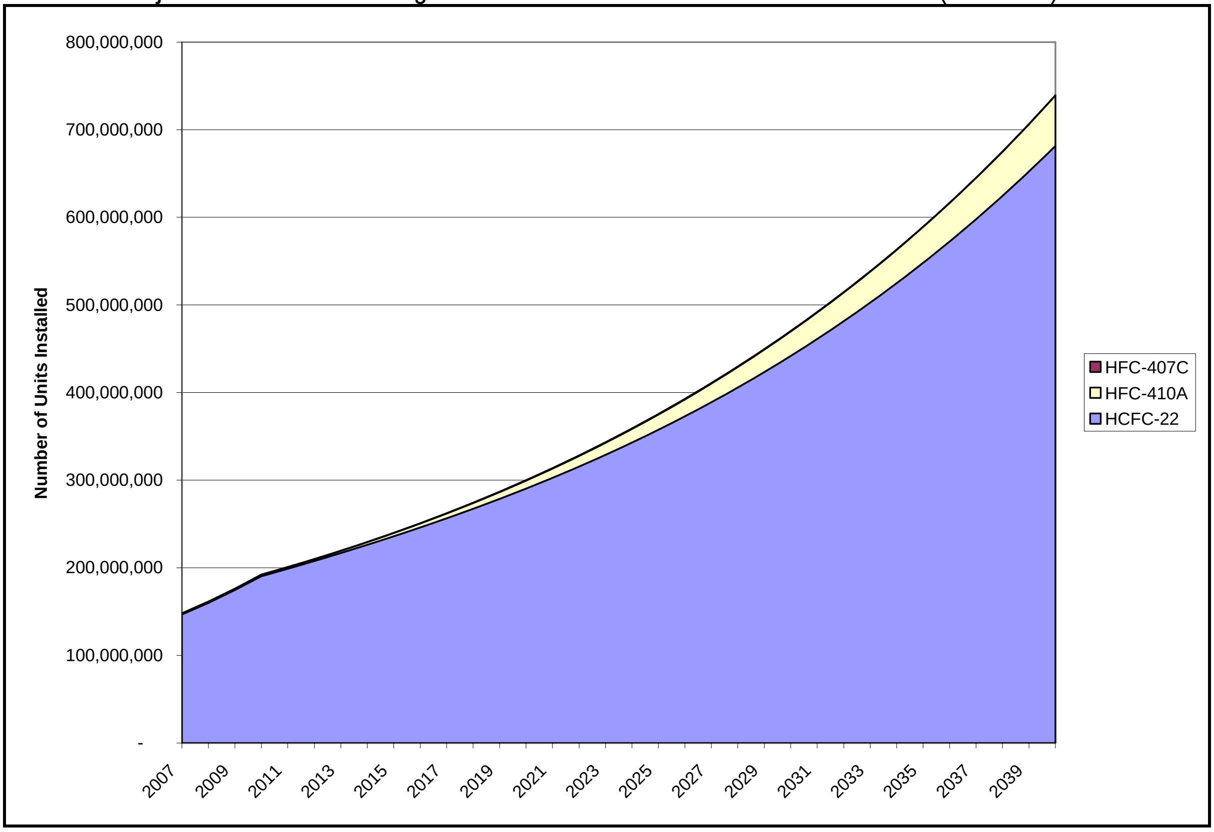
Because no significant number of retrofits is assumed to occur in the future, the transition to alternative refrigerants in AC equipment will occur as equipment manufacturers offer different refrigerants in new equipment in response to political and economic constraints. Based on industry consultations, current and future equipment sales by refrigerant type were projected through 2040. Assumptions used in developing these projections are as follows:

- Current market penetration of refrigerants remains constant until 2010 (i.e., 99% R-22, 0.75% R-410A, and 0.25% R-407C) in all Article 5 regions.
- In 2010, a slight, gradual shift towards increasing sales of HFC-containing equipment is projected to occur, as a result of the U.S. HCFC phaseout (which is expected to ban the import of pre-charged AC equipment), which will in turn compel A5 manufacturers to further transition their AC production away from R-22 to satisfy demand in export markets. Specifically, it is projected that the market share of R-22 in newly manufactured equipment will decline from 99% in 2010 to 90% in 2020.[14] Meanwhile, it is projected that the market share of R-410A will gradually increase from less than 1% in 2010 to 10% in 2020. R-407C is assumed to drop out of the market in 2010, as it is less efficient than R-410A.
- From 2020 to 2040, the market penetration of refrigerants into new equipment is projected to remain constant (at 90% R-22 and 10% R-410A).

Applying these assumptions on equipment retirement, market growth, and anticipated penetration of refrigerants into new equipment, Exhibit 35 presents the refrigerant transition for all A5 countries in small and large AC equipment in terms of the installed bank. More detailed results on the estimated stocks by equipment type and region are presented in Appendix 3.

[14] This analysis does not attempt to project how individual A5 countries will meet the HCFC consumption/production cap in 2016; given that use of HCFC-22 in small AC equipment was among the last HCFCs/equipment types to be phased out in many non-A5 countries (in order to meet phaseout targets), this analysis assume that use of HCFC-22 in AC equipment will be unconstrained in A5 countries until 2040.

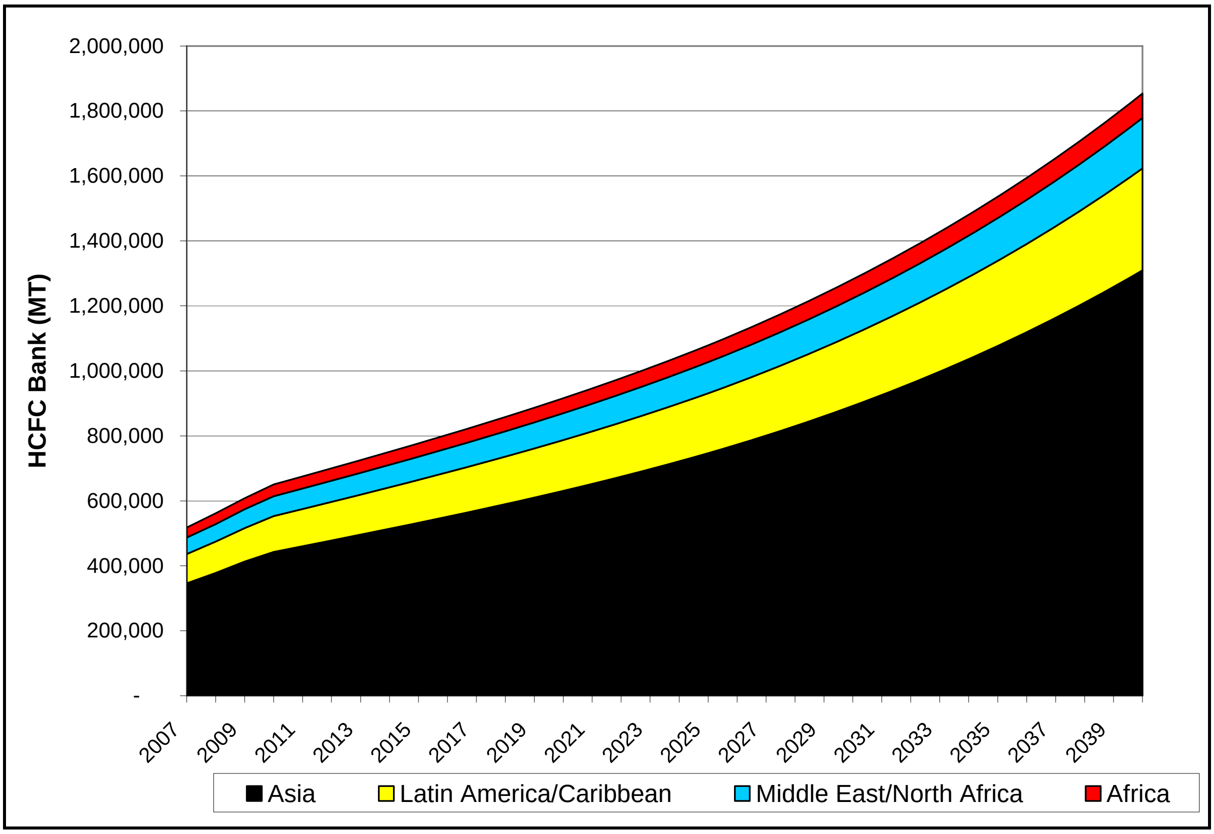
Exhibit 35: Projected Transition of Refrigerant Stock in Installed AC Units in A5 Countries (2007-2040)



6. Summary of Results and Considerations for HCFC Phaseout

Based on information from recently published reports and key industry representatives, this report developed estimates of the current and future stocks of chillers and AC equipment in Article 5 regions under a business-as-usual scenario. The findings of the analysis indicate that the current installed base of CFCs in Article 5 countries, primarily contained in centrifugal chillers, will decline and reach full phase out by 2025. Meanwhile, HCFCs banks will continue to rise. As shown in Exhibit 36, the installed base of HCFCs in Article 5 countries will grow from nearly 518,250 MT in 2007 to more than 776,800 MT in 2015, nearly all of which will be HCFC-22. By 2040, this installed base of HCFCs in AC equipment will reach 1,853,700 MT; Asia, led by China, is projected to account for more than 70% of this amount.

Exhibit 36: Projected HCFC Bank in Chillers/ AC Equipment in Article 5 Countries (2007-2040)



- **Centrifugal Chillers:** The total bank of HCFCs currently installed in centrifugal chillers in Article 5 countries is estimated to be 9,100 MT, 85% of which is composed of R-123 and the rest by R-22. The total bank of CFCs is estimated to be 6,900 MT. Around 60% of the bank is installed in Asia, 20% is in the Middle East/North Africa, 15% is in Asia; and the rest is installed in Africa. Market trends indicate that this sector will continue to grow rapidly in the near future, driven by growth in China and the Middle East.

  The majority of the current bank is expected to be phased out through replacement—not retrofit—activity, as old equipment is retired. R-134a is and will remain the dominant refrigerant used in new centrifugal chillers, although R-123 captures 25% of the market. Given the costs involved in commercializing alternatives, it is unlikely that manufacturers will pursue the development of any other alternatives to replace these refrigerants—unless there is a regulatory imperative to do so, which there currently is not.

- **Positive Displacement Chillers:** The total bank of HCFCs currently installed in positive displacement chillers in Article 5 countries is estimated to be 164,000 MT, all of which is composed of R-22. Of this, screw and scroll chillers account for 156,400 MT and reciprocating chillers account for 8,900 MT. 80% of the total bank is installed in Asia, 11% in Middle East/North Africa, and 9% in Latin America/Caribbean; the rest of Africa accounts for less than 1% of the current bank. Market trends indicate that the future market for screw and scroll chillers will remain strong, while markets for reciprocating chillers will decrease.

R-134a, which currently accounts for approximately 15-20% of all positive displacement chiller sales, will be the dominant refrigerant installed in new units by 2020—capturing 80% of the screw chiller market and 20% of the scroll chiller market. The remainder of the screw chiller market is projected to use R-22, while the remainder of the scroll chiller market is projected to use R-410A (50%) and R-22 (30%). Due to cost and efficiency constraints, retrofits are not expected to play a significant role in the transition away from HCFCs in this end use.

- **Small and Large Air Conditioning:** The total bank of HCFCs currently installed in small and large AC equipment is estimated to be 343,800 MT, nearly all of which is composed of R-22. Around 60% of this bank is installed in Asia, 20% in Latin America/Caribbean, with the remainder split between the Middle East/North Africa and Africa. This end use is expected to experience significant growth in the next few years across all Article 5 regions, especially the small AC segment.

  R-22 is expected to continue dominating this sector in future. A slight shift towards R-410A is anticipated from 2010 onwards, when the U.S. bans imports of equipment pre-charged with R-22. Availability of R-410A and R-407C based AC equipment in Article 5 regions that manufacture equipment for export may promote the penetration of these alternatives. However, without an accelerated phaseout, the transition away from HCFCs in this sector will be slow.

6.1 Market Drivers

Only regulatory drivers are likely to force the transition away from HCFCs in A5 countries to occur faster than projected in Exhibit 36. Simply stated, manufacturers will avoid incurring the capital costs and down-time associated with plant conversion as long as possible, even though the annual costs associated with the transition (i.e., refrigerant and component prices) will not vary significantly once economies of scales are reached. Current market drivers will not promote a shift away from ODS, as explained further below.

Currently, the price of R-22 in China is $1.32/kg, while that of R-410A is $13.18/kg, and that of R-407C is $10.30/kg (UNEP 2007a). With no technical reasons to compel the switch to alternative refrigerants (e.g., significant efficiency improvements), these prices send clear signals to A5 equipment manufacturers to continue to rely on R-22. This is especially true given the intensely competitive nature of the AC market, with AC manufacturers facing market pressure associated with rising production and marketing costs, the implementation of new energy efficiency standards, and shrinking profits (China Daily 2005). Thus, while A5 countries export AC equipment containing R-407C and R-410A to non-A5 markets (e.g., Europe, Japan, U.S., Australia), market signals dictate that it continue using R-22 in new equipment sold in A5 markets.

Further, because of the financial incentives provided by the Kyoto Protocol's Clean Development Mechanism (CDM) for the production of HCFC-22 (and capture of HFC-23), a large, steady supply of R-22 for use in new equipment, as well for the servicing of existing equipment, is guaranteed until 2012.

Indeed, the accessibility and affordability of refrigerants is critical for the servicing sector in A5 countries. Similarly, the servicing sector requires access to the AC equipment components; thus, to the extent that HFC refrigerants will require different materials and parts, the after-market will require that they be made available, at affordable prices. In short, the availability and affordability of HFC refrigerants and their associated components will be critical not only to compel manufacturers to adopt ozone-friendly alternatives in the new equipment they produce, but also to compel consumers to choose that alternative equipment—and to ensure a well-functioning after-service market. This will be particularly critical after 2040 (under the current phaseout schedule for HCFCs), as HCFCs will become scarce and servicing needs for HCFC equipment will have to be met through recovered and reclaimed sources. To the extent that natural refrigerants can earn a larger market share over time, this will reduce dependence on HFCs as the market leader for transition, and will reduce demand for reclaimed HCFCs in non-essential sectors. A strong regulatory push away from HFCs with high global warming potentials (GWPs) in the future would trigger the intensified development and use of natural refrigerants (beyond that projected in this analysis).

Refrigerant price trends will also change because of availability. As the global phaseout of HCFC-22 in non-Article 5 countries reduces global supply of virgin R-22, quantities in Article 5 countries may also decline slightly, which would in turn cause prices to rise. In addition, the financial incentives to produce HCFC-22 under the CDM may no longer be in play beyond 2012. Meanwhile, R-410A, which is under patent until 2009, will drop in price once the patent expires, and once it begins to be produced at economies of scale in non-A5 countries (i.e., when R-22 is banned).

Further, as the HCFC phaseout progresses in non-A5 countries, global demand for HCFCs and other ozone-friendly alternatives will rise (e.g., in response to the expected US ban on the import of pre-charged products containing R-22 in 2010). These changes may cause a shift in refrigerant pricing structures over time and, potentially, provide a market signal to Article 5 countries to invest in manufacturing facilities that produce equipment and products without HCFCs. Such investments for alternative product lines may cause Article 5 countries, such as China, to produce the same products for domestic consumption as well, if economies of scale can be achieved.

Should economies of scale be reached, the overall costs to produce R-410A units will be similar to those of producing R-22 units, even though different components will be needed. In particular, R-410A units will require superior design to account for the higher pressure refrigerant, including tighter joints and better seals, but they will also require smaller (lower cost) compressors, so these costs will offset to some degree. Actual component costs will vary based on the location of suppliers, volumes purchased, and other factors (ICF 2007)

Under the current schedule, the shift to non-ODS alternatives in A5 countries will occur slowly. It will take years, if not decades, before equipment based on HFCs and other refrigerants become more readily available at truly competitive prices, and for equipment manufacturers to acquire the necessary capital investment in the form of factory tooling, sub-product design, and networks of suppliers of components, as described in more detail below.

6.2 Costs and Barriers Associated with HCFC Phaseout

Whenever the transition away from HCFCs in the AC sector occurs in A5 countries, there will be costs associated with the replacement of AC installations (i.e., large tonnage chillers), as well as the conversion of manufacturing facilities that produce HCFC-containing AC equipment.

6.2.1 Chiller Equipment Replacement

Given the large stocks of large tonnage HCFC chillers that are projected to be installed in A5 countries (see Exhibit 37), in addition to the long lifetime and high investment cost of such equipment, HCFC chillers are likely to remain in use for many more decades *beyond* 2040.

Exhibit 37. Projected Number of HCFC Centrifugal Chillers Installed in A5 Countries (2007-2040)

Year	2007	2010	2015	2020	2030	2040
HCFC-123	17,330	20,920	24,490	28,690	39,580	55,190
HCFC-22	2,940	3,320	2,810	2,370	1,690	1,200
Total	20,270	24,240	27,300	31,060	41,270	56,390

In Article 5 countries, the average cost of a centrifugal chiller is roughly $140,000 (GTZ 2006, BSRIA 2007, ICF 2007). Based on this estimate, the information on number of units provided in Exhibit 37, and an assumed average equipment lifetime of 30 years, the cost of early retirement in 2020—assuming 100% of units are immediately retired in 2020—is approximately $1.6 billion at a 7% discount rate (or $2.1 billion at a 5% discount rate); in 2030, the estimated cost of early retirement is estimated at $1.1 billion at a 7% discount rate (or $1.7 billion at a 5% discount rate).

6.2.2 Conversion of AC Manufacturing Facilities

The total costs for converting chiller/AC manufacturing facilities to use non-HCFC refrigerants will largely depend on the total number and production capacity of manufacturing plants in Article 5 countries. At the facility-level, the cost can vary widely based on specific equipment type and the volume of refrigerant used.

For example, to rebuild a 500,000-unit product line of R-22-based window AC units to produce R-410A units, UNEP (2007a) estimates that it will cost roughly US$100,000. Industry research indicates, however, that this is a low-end conversion cost that could likely only be realized if the HCFC-based plant already produces a limited amount of HFC-based equipment; such that investment would only be required to switch the charging station to HFCs. In some places, this type of dual production may already be underway; for example, China is currently producing HCFC-based equipment for certain markets, and may have parallel production lines in the same manufacturing facilities that produce HFC-based equipment for other markets. However, if HFC technology is not already integrated into the production facility, an HCFC-based plant would require upwards of US$6 million to cover the cost of technology transfer, other research and development, retooling, and other conversion costs. Similar costs may be expected to convert manufacturing plants that produce other types of equipment with equivalent output. For example, for a plant that produces 3,000 chillers per year with average capacity of 3,500 kW, it would cost around US$6 million to convert from HCFCs to HFCs. (ICF 2007)

In addition to the capital cost of conversion, incremental operating costs will also be incurred in the form of higher incremental refrigerant costs and component costs. For window AC units, for example, the cost of R-410A is greater than that of R-22, and higher component costs (up to $5/unit) are associated with the use of thicker walled copper tubing, newly developed compressors, and other components needed to withstand the high pressures of R-410A (Actrol 2007, ICF 2007).

6.3 Policy Implications

The findings of this analysis indicate that in the absence of stronger regulatory drivers in Article 5 countries, the use of HCFC in chillers, and especially in other AC equipment, will continue to rapidly increase in the coming years. Due to the pervasive use of R-22, a large inventory will likely remain in service long after production is scheduled for phaseout in 2040. This build-up will lead to a surge in ODS emissions from equipment leakage, servicing, and disposal. Accelerating the phaseout of HCFCs in Article 5 countries could reduce this deepened reliance on R-22 and avoid emissions of ODS that could delay the recovery of the ozone layer. Programs that provide an economic incentive to replace older equipment, coupled with technical assistance programs that highlight the energy efficiency gains from replacing older ODS equipment, can help redirect this path.

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Appendix 1 –Questionnaire for Key Government and Industry Contacts

Questionnaires were tailored to industry contacts, associations, and government representatives based on their areas of expertise (in terms of equipment types and regional coverage). The questionnaire presented below is a sample questionnaire sent to the National Ozone Unit in South Africa.

[Sample] Questionnaire on the Chiller/AC Markets in South Africa

Part I: Chillers

1. What percent of all chillers in use in Africa (excluding North Africa) are found in South Africa?
2. What is the estimated total number of centrifugal and positive displacement chillers currently in use in South Africa?

Current Chiller Stock by Type

Chiller Type	South Africa
Centrifugal	
Positive Displacement Chillers	
Screw & Scroll	
Reciprocating	

3. What is the current market growth rate for chillers in South Africa? What do you project will be the growth rate from 2010-2015?
4. How do you expect the chiller market to grow in the rest of Africa (excluding North Africa)?
5. From where does South Africa import most of its centrifugal chillers? What about positive displacement chillers?
6. What is the average capacity (kW) of centrifugal chillers used in South Africa? What about the average capacity (kW) of positive displacement chillers?
7. Does the cost of chiller equipment sold in South Africa vary significantly by refrigerant type?

Part II: Residential and Commercial Air Conditioning

NOTE: Residential and commercial AC is assumed to include small self contained AC systems; non-ducted split residential and commercial AC systems; ducted, split residential AC systems; and ducted commercial split and packaged AC systems. For the purposes of this analysis, AC equipment is grouped into two general categories: (1) small AC, with an average charge size of 2 kg; and (2) large AC, with an average charge size of 10 kg.

8. From where does South Africa import most of its small and large AC equipment?
9. What percent of all residential/commercial AC equipment in use in Africa (excluding North Africa) is found in South Africa?
10. Can you estimate current stocks of small and large AC equipment in use in South Africa?

Existing AC Equipment Stock by Type (2007)

AC Equipment Type	Number of Units in South Africa
Small (average 2 kg charge size)	
Large (average 10 kg charge size)	

11. What is the current market growth rate for small and large AC equipment in South Africa? What do you project these market growth rates to be from 2010-2015?
12. What are the primary refrigerants in use in current stocks of AC equipment today, and how do you expect that mix of gases to change between now and 2020? For example, do you expect the phaseout of HCFC-22 in developed countries to influence the types of refrigerant used in newly manufactured equipment sold in South Africa?
13. What is the average cost of small and large AC equipment sold in South Africa?

Appendix 2 – List of Major Chiller and AC Manufacturers

Exhibit: Major Chiller and AC Manufacturers

Company	Headquarter Country
Advance Cool Technology Co., Ltd.	Thailand
Aermec	Italy
Bharat Refrigerations Pvt. Ltd	India
Blue Box	Italy
Blue Star	India
C&D International	China
Carrier	US
Chigo	China
Ciat	France
Climaveneta	Italy
Clivet	Italy
Daikin/McQuay	Japan/US
Danfoss	Denmark
Dunham-Bush Inc	Malaysia
Emicon	Italy
Ferroli	Italy
Fujitsu-General	Japan
Gree Air Conditioners	China
Guangdong Kelon Electrical Holdings Co Ltd	China
Haier	China
HCF-Lennox	France
HITSA	Spain
Hstars Group	China
LG Electronics Ltd.	South Korea
Midea	China
Mitsubishi	Japan
Rhoss	Italy
Samsung	Korea
Teba	Turkey
Trane	US
Weeseng HVAC Technology Pte Ltd	Singapore
York (JCI)	US
Zamil	Saudi Arabia
Zhongshan Asiatic Electric Co. Ltd	China

Appendix 3 – Detailed Results Tables

Exhibit 38 through Exhibit 42 present detailed results of projected stock through 2040 by equipment type, refrigerant type, and A5 region.

Exhibit 38: Projected Stock of Centrifugal Chillers by Refrigerant and Article 5 Region (Units)

Year	2007	2010	2015	2020	2030	2040
Asia						
CFCs	8,240	6,870	4,580	2,290	-	-
HCFC-123	9,950	12,000	13,850	15,990	21,410	28,900
HCFC-22	1,710	1,940	1,630	1,380	980	700
HFC-134a	10,100	12,990	19,090	25,830	40,030	57,100
Total	30,000	33,800	39,150	45,490	62,420	86,700
Latin America and Caribbean						
CFCs	3,910	3,260	2,170	1,090	-	-
HCFC-123	2,350	2,780	3,420	4,180	6,200	9,180
HCFC-22	390	430	360	300	220	150
HFC-134a	2,350	3,100	5,410	7,980	13,390	20,140
Total	9,000	9,570	11,360	13,550	19,810	29,470
Middle East/North Africa						
CFCs	2,290	1,910	1,270	640	-	-
HCFC-123	3,560	4,500	5,340	6,370	9,160	13,390
HCFC-22	590	700	590	500	350	250
HFC-134a	3,560	4,800	7,260	10,120	16,990	26,570
Total	10,000	11,910	14,460	17,630	26,500	40,210
Africa						
CFCs	810	680	450	230	-	-
HCFC-123	1,470	1,650	1,880	2,140	2,810	3,730
HCFC-22	250	260	220	190	130	100
HFC-134a	1,470	1,740	2,460	3,250	4,960	7,050
Total	4,000	4,330	5,010	5,810	7,900	10,880
All Regions						
CFCs	15,250	12,710	8,470	4,240	-	-
HCFC-123	17,330	20,920	24,490	28,690	39,580	55,190
HCFC-22	2,940	3,320	2,810	2,370	1,690	1,200
HFC-134a	17,480	22,630	34,220	47,180	75,360	110,860
Total	53,000	59,580	69,990	82,480	116,630	167,250

Exhibit 39: Projected Stock of Scroll & Screw Chillers by Refrigerant and Article 5 Region (Units)

Year	2007	2010	2015	2020	2030	2040
Asia						
HCFC-22	522,500	631,100	716,200	778,500	904,200	1,090,300
HFC-134a	27,500	38,300	85,300	167,900	419,200	791,500
R-410A	0	4,200	22,900	62,600	188,300	272,900
TOTAL	550,000	673,600	824,400	1,009,000	1,511,700	2,154,700
Latin America/Caribbean						
HCFC-22	57,950	67,500	78,800	87,400	105,900	135,600
HFC-134a	3,050	4,200	10,400	21,900	58,900	118,400
R-410A	0	500	3,000	8,500	27,000	40,300
TOTAL	61,000	72,200	92,200	117,800	191,800	294,300
Middle East/North Africa						
HCFC-22	66,500	75,500	82,100	86,600	94,800	105,500
HFC-134a	3,500	4,400	8,000	14,000	30,400	51,700
R-410A	0	300	1,800	4,700	12,900	17,900
TOTAL	70,000	80,200	91,900	105,300	138,100	175,100
Africa						
HCFC-22	4,750	5,300	6,000	6,500	7,500	9,000
HFC-134a	250	320	700	1,400	3,400	6,300
R-410A	0	40	200	500	1,500	2,200
TOTAL	5,000	5,660	6,900	8,400	12,400	17,500
All Regions						
HCFC-22	651,700	779,400	883,100	959,000	1,112,400	1,340,400
HFC-134a	34,300	47,200	104,400	205,200	511,900	967,900
R-410A	0	5,000	27,900	76,300	229,700	333,300
TOTAL	686,000	831,600	1,015,400	1,240,500	1,854,000	2,641,600

Exhibit 40: Projected Stock of Reciprocating Chillers by Refrigerant and Article 5 Region (Units)

Year	2007	2010	2015	2020	2030	2040
Asia						
HCFC-22	38,000	39,300	39,300	39,300	28,300	18,800
HFC-134a	400	400	400	400	400	300
R-407C	1,600	1,700	1,700	1,700	1,600	1,100
TOTAL	40,000	41,300	41,300	41,300	30,300	20,200
Latin America and Caribbean						
HCFC-22	11,400	11,680	11,700	11,700	8,400	5,600
HFC-134a	120	120	100	100	100	100
R-407C	480	500	500	500	500	300
TOTAL	12,000	12,300	12,300	12,300	9,000	6,000
Middle East/North Africa						
HCFC-22	9,500	9,710	9,700	9,700	7,000	4,700
HFC-134a	100	100	100	100	100	100
R-407C	400	400	400	400	400	300
TOTAL	10,000	10,200	10,200	10,200	7,500	5,000
Africa						
HCFC-22	475	480	480	480	350	230
HFC-134a	5	10	10	10	0	0
R-407C	20	0	0	0	0	0
TOTAL	500	500	500	500	400	200
All Regions						
HCFC-22	59,375	61,100	61,100	61,100	44,100	29,300
HFC-134a	625	600	600	600	600	400
R-407C	2,500	2,600	2,600	2,600	2,500	1,600
TOTAL	62,500	64,300	64,300	64,300	47,200	31,400

Exhibit 41: Projected Stock of Small AC Units by Refrigerant and Article 5 Region

Year	2007	2010	2015	2020	2030	2040
Asia						
HCFC-22	85,581,700	113,909,200	144,194,900	181,003,800	285,901,600	456,759,100
R-410A	216,100	273,400	323,200	340,800	340,800	241,400
R-407C	648,300	872,400	2,324,500	6,068,000	19,032,900	40,150,100
Total	86,446,100	115,055,000	146,842,600	187,412,600	305,275,300	497,150,600
Latin America/Caribbean						
HCFC-22	29,875,900	38,070,500	46,455,700	56,268,100	82,626,900	122,427,100
R-410A	75,400	92,000	105,900	110,600	110,600	78,300
R-407C	226,300	291,100	691,800	1,688,100	4,945,900	9,865,000
Total	30,177,600	38,453,600	47,253,400	58,066,800	87,683,400	132,370,400
Middle East/North Africa						
HCFC-22	12,809,500	16,435,100	20,170,500	24,567,800	36,489,700	54,706,000
R-410A	32,300	39,600	45,800	47,900	47,900	33,900
R-407C	97,000	125,700	304,300	750,800	2,224,300	4,475,800
Total	12,938,800	16,600,400	20,520,600	25,366,500	38,761,900	59,215,700
Africa						
HCFC-22	12,046,700	14,145,700	16,124,200	18,281,988	23,480,200	30,297,900
R-410A	30,400	34,700	38,000	39,010	39,000	27,600
R-407C	91,300	107,900	201,900	420,264	1,062,700	1,905,400
Total	12,168,400	14,288,300	16,364,100	18,741,262	24,581,900	32,230,900
All Regions						
HCFC-22	140,313,800	182,560,600	226,945,200	280,121,600	428,498,400	664,190,200
R-410A	354,200	439,700	512,800	538,300	538,300	381,200
R-407C	1,062,900	1,397,000	3,522,500	8,927,100	27,265,800	56,396,300
TOTAL	141,730,900	184,397,300	230,980,500	289,587,000	456,302,500	720,967,700

Exhibit 42: Projected Stock of Large AC Units by Refrigerant and Article 5 Region

Year	2007	2010	2015	2020	2030	2040
Asia						
HCFC-22	3,853,800	5,129,400	5,915,600	6,783,600	8,914,100	11,777,000
R-410A	9,700	12,100	13,400	13,800	13,800	9,800
R-407C	29,200	37,700	75,100	163,000	426,300	780,200
Total	3,892,700	5,179,200	6,004,100	6,960,400	9,354,200	12,567,000
Latin America/Caribbean						
HCFC-22	1,345,300	1,461,700	1,670,500	1,898,900	2,451,300	3,179,600
R-410A	3,400	3,700	4,000	4,100	4,100	2,900
R-407C	10,200	11,500	21,400	44,500	112,800	202,800
Total	1,358,900	1,476,900	1,695,900	1,947,500	2,568,200	3,385,300
Middle East/North Africa						
HCFC-22	576,800	628,200	720,800	822,400	1,069,700	1,398,400
R-410A	1,500	1,600	1,800	1,800	1,800	1,300
R-407C	4,400	5,000	9,400	19,600	50,200	90,800
Total	582,700	634,800	732,000	843,800	1,121,700	1,490,500
Africa						
HCFC-22	542,420	592,700	652,100	714,600	856,800	1,030,200
R-410A	1,370	1,500	1,600	1,600	1,600	1,100
R-407C	4,110	4,600	7,400	13,700	31,300	52,700
Total	547,900	598,800	661,100	729,900	889,700	1,084,000
All Regions						
HCFC-22	6,318,320	7,812,000	8,959,000	10,219,500	13,291,900	17,385,200
R-410A	15,970	18,900	20,800	21,300	21,300	15,100
R-407C	47,910	58,800	113,300	240,800	620,600	1,126,500
TOTAL	6,382,200	7,889,700	9,093,100	10,481,600	13,933,800	18,526,800