TAHOE REGIONAL PLANNING AGENCY

Mail
PO Box 5310
Stateline, NV 89449-5310

Location
128 Market Street
Stateline, NV 89449

Contact
Phone: 775-588-4547
Fax: 775-588-4527
www.trpa.gov

STAFF REPORT

Date: June 16, 2021

To: TRPA Governing Board

From: TRPA Staff

Subject: Greenhouse Gas Inventory Report and Climate Initiative Update

---

Summary:
Staff will provide an informational only update on the TRPA Climate Resiliency Strategic Initiative and recently complete greenhouse gas inventory update for the Tahoe Basin.

Project Description/Background:
TRPA and its partners in the Lake Tahoe Region have long been recognized as leaders in sustainability. A significant new environmental threat, one that many believe will affect sustainability of the entire planet, has emerged: climate change. The Lake Tahoe Basin is already experiencing the direct impacts of climate change. These include rapid change to the ecological composition of our natural environment, more severe and frequent hazard events, retreating snowpack, and socio-economic shifts (such as fluctuation of trends in visitation). Climate change directly impacts the ability of TRPA and regional partners to achieve and maintain thresholds and will cause major disruptions to the region's economic, social, and ecological systems.

Through a collaborative approach and in close collaboration with the states, Basin partners will collectively look at climate vulnerabilities, current regional and local plans, and ongoing climate actions, and will identify gaps and priority actions for the partnership to collaboratively plan and implement.

The states of California and Nevada both have aggressive GHG emission reduction targets of net-zero carbon emissions by 2045 and 2050 respectively. The Tahoe Regional Planning Agency and regional partners have long worked to reduce greenhouse gas emissions. Emission reduction actions are being implemented by a variety of public and private partners through the Lake Tahoe Regional Plan, Regional Transportation Plan, and Lake Tahoe Sustainability Action Plan. State, regional, and local agencies have adopted their own climate plans.

It is important to measure GHG emissions on a regular basis to track progress of local actions and identify areas that need more investment. TRPA recently released the Lake Tahoe Updated Greenhouse Gas Inventory, supported by the California Tahoe Conservancy. The inventory measures emissions from 2015 and 2018, and compares them to past GHG inventory years of 2005 and 2010.

The inventory shows that progress is being made toward GHG emission reduction goals. From 2005 to 2018, the Tahoe Region's emissions have declined significantly by 38.7 percent. Total emissions were reduced from 1,297,446 metric tons of carbon dioxide equivalent to 795,793 metric tons. Metric tons of carbon dioxide equivalent (mtCO2e) is a common measure to compare various greenhouse gases in terms of their equivalent warming potential to carbon dioxide.

Between the years of 2015 and 2018, the energy sector produced more than half the emissions in the basin (59 percent), followed by transportation (37 percent). These two sectors combine to generate more than 95 percent of total basin emissions and therefore have the most potential for reduction. While long-term progress is being made, regional emissions did increase by 4 percent overall between 2015 and 2018. Increased electricity use, better data, growing demand, and changes to landfill operations drove the change. This increase shows that more investment is needed in regional actions to reduce GHG emissions.

Built Environment:
Energy usage is the top source of emissions in the Tahoe Basin, specifically electricity and natural gas used to power and heat buildings. Between 2005 to 2018, natural gas became the top source of GHG emissions in the Tahoe Basin due to electricity getting cleaner and aging legacy development. Most buildings, hotels, and homes around the Tahoe Basin were not built to modern standards and are inefficient in their use of energy.

Much of this development is also built on top of Tahoe's streams and meadows, disrupting natural processes. The inventory update used a digital mapping tool, UrbanFootprint, to model potential greenhouse gas emissions reductions possible within Tahoe's built environment. Lake Tahoe Regional Plan aims to incentivize environmentally beneficial redevelopment. This redevelopment directly reduces the amount of stormwater that impacts Tahoe's clarity.

In addition to the water quality benefits, new development in town centers is more energy efficient and promotes walking and biking, reducing related transportation emissions. Removing the GHG emissions generated from older buildings would be an additional environmental benefit.

Carbon Sequestration:
As GHGs are emitted as a result of human activities and natural processes, carbon dioxide is also sequestered or stored in plants as part of the carbon cycle. Storing carbon in forests and meadows is a natural climate solution, and the Tahoe Region has an abundance of undeveloped landscapes that contribute to this cycle. For the first time, the updated inventory modeled carbon sequestration potential in Tahoe's forests and meadows and compared storage to annual emissions.

The updated inventory found that the natural landscape sequestered or stored between 300,000 and 1 million metric tons of carbon dioxide equivalent (mtCO2e) in 2018. This is compared to about 800,000 mtCO2e for 2018. Many factors impact carbon sequestration on natural landscapes, but as the inventory shows, healthy forests and meadows have the potential to be a critical tool in combating climate change. It is also important to balance other factors such as increased threat of wildfire. Tahoe's forests are overgrown and crowded from historical logging and fire suppression practices. Land management agencies such as the USDA Forest Service recognize the need for forest resiliency and are working with partners to implement fuel reduction projects at an increasing pace. This work will reduce the amount of carbon stored in Tahoe's forests to offset emissions. More research is needed to better understand these dynamic relationships.

Moving Toward Climate Resiliency:
The updated Greenhouse Gas Inventory serves as a benchmark for measuring climate action in the Tahoe Region. The 2014 Lake Tahoe Sustainable Communities Program set a GHG emission reduction goal of 15 percent from 2005 levels by 2020 and 49 percent by 2035. The inventory shows that the region exceeded the 2020 reduction goal in 2018 but more work is needed to reach the 2035 target.

The report will be used by TRPA and partners to develop new climate actions to address rising emissions, continue to promote environmentally beneficial redevelopment, and prioritize environmental restoration projects. To learn more about climate resiliency at Lake Tahoe visit www.trpa.gov/programs/climate-resiliency.

Contact Information:
For questions regarding this agenda item, please contact Devin Middlebrook, Sustainability Program Manager, at (775) 589-5230 or dmiddlebrook@trpa.gov.

Attachments:

A. Greenhouse Gas Inventory Update
B. Greenhouse Gas Inventory Infographic

Attachment A

Greenhouse Gas Inventory Update

AGENDA ITEM NO. VI.B

LAKE TAHOE
Greenhouse Gas Inventory Update

Final Report | April 2021

SIERRA BUSINESS COUNCIL · Spatial Informatics Group · California Tahoe Conservancy · Tahoe Regional Planning Agency

trpa@trpa.gov | www.trpa.gov | (775) 588-4547

AGENDA ITEM NO. VI. B

Credits & Acknowledgements

Sierra Business Council

Primary Authors

Ben Maritato, Planning Technician

John Plaggmier, Project Manager

Justine Quealy, Project Manager

Contributing Authors

Meredith Anderson, Planning Technician

Steve Frisch, President

Sherry Hao, Energy Services Program Director

Jill Sanford, Communications Manager

Zane Stromberg, GHG Intern

Kerri Timmer, Vice President of Climate & Energy

Spatial Informatics Group

Primary Authors

Erin Alvey, Research Scientist

Thomas Buchholz, Senior Scientist

Carl Rudeen, GIS Analyst

David Schmidt, Research Scientist

Contributing Authors

Justine Bui, Research Scientist

Tahoe Regional Planning Agency

Mason Bindl, Senior GIS/Data Analyst

Rebecca Cremeen, Associate Planner

Reid Haefer, Associate Data Analyst/Modeler

Nick Haven, Long Range Planning & Transportation Division Manager

Devin Middlebrook, Sustainability Program Manager

Julie Regan, External Affairs Chief

California Department of Forestry and Fire Protection

Nadia Tase, Climate Change & Forest Inventory Specialist

Built Environment Inventory Technical Advisory Committee
Mason Bindl, Tahoe Regional Planning Agency
Whitney Brennan, California Tahoe Conservancy
Rebecca Cremeen, Tahoe Regional Planning Agency
Nic Enstice, Sierra Nevada Conservancy
Reid Haefer, Tahoe Regional Planning Agency
Devin Middlebrook, Tahoe Regional Planning Agency
Shelly Thomsen, South Tahoe Public Utility District

Forest Carbon Inventory Technical Advisory Committee
Mason Bindl, Tahoe Regional Planning Agency
Whitney Brennan, California Tahoe Conservancy
Scott Carroll, California Tahoe Conservancy
Scott Conway, Vibrant Planet
Rebecca Cremeen, Tahoe Regional Planning Agency
Nic Enstice, Sierra Nevada Conservancy
Brian Garrett, U.S. Forest Service, Lake Tahoe Basin Management Unit
Robert Larsen, Tahoe Basin Science Advisory Group
Jonathan Long, U.S. Forest Service, Pacific Northwest Research Station
Pat Manley, U.S. Forest Service and Tahoe-Central Sierra Initiative
Charles Maxwell, Ph.D, Lake Tahoe West Science Working Group
Amy Merril, American Rivers
Cara Moore, Tahoe Fire and Fuels Team
Rita Mustatia, U.S. Forest Service, Lake Tahoe Basin Management Unit
Cody Reed, Ph.D, Meadow Ecologist
Robert Suarez, Tahoe Truckee Community Foundation
Nadia Tase, California Department of Forestry and Fire Protection
Jason Vasques, California Tahoe Conservancy

Completed with support from the **California Tahoe Conservancy**.

Disclaimer: Neither Tahoe Regional Planning Agency (TRPA) nor the consultant team of Sierra Business Council (SBC) and Spatial Informatics Group (SIG) is liable for results nor any impacts resulting from subsequent or future analysis and interpretation using the data or methodologies described in this report. The data user assumes the entire risk, including quality, performance, and usefulness of any data requested or used from this inventory report.

Table of Contents

Figures & Tables

Figures

Tables

Executive Summary

The Lake Tahoe Greenhouse Gas Inventory Update presents the Lake Tahoe Basin (the basin) greenhouse gas (GHG) inventory, a detailed accounting of GHGs emitted by source, an estimate of energy use and emissions from aging buildings located in stream environment zones, and carbon stored in natural ecosystems from 2014 to 2018. In addition, the inventory projects the Lake Tahoe Region's (the region) GHG emissions from 2018 to 2045 based on a business-as-usual forecast of changes in energy use, transportation, solid waste management, and wastewater treatment. This inventory is an update to an inventory previously completed in 2013. These factors are influenced over time by changes in climate, population demographics, land-use and transportation patterns, the adoption of new technologies, and measures adopted to reduce greenhouse gas emissions.

The purpose of this report is to establish a replicable methodology for measuring GHG emissions and carbon sequestration, establish a baseline measurement or foundation to benchmark progress over time, guide regional climate planning and action, develop and prioritize strategies to reduce GHG emissions and increase carbon sequestration, and communicate progress to the public, stakeholders, and policymakers on a regular basis.

Background

Greenhouse gases are air pollutants as defined by a U.S. Supreme Court and subject to regulation by the U.S. Environmental Protection Agency under the Clean Air Act and the State of California under the Global Warming Solutions Act of 2006 (AB 32). These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and nitrogen trifluoride (NF_3). It is important to note that each of these gases has different potency, or ability to contribute to global warming. For the purposes of this inventory, all gases have been converted to their equivalent in carbon dioxide or CO_2e.

Measuring GHG's emissions over time is important because these gases trap heat from the earth's atmosphere at the earth's surface, causing increases in air and water temperatures and associated increased risks. These risks include more intense dry periods, drought, tree mortality, wildfire, flooding, loss of air and water quality, declining clarity in Lake Tahoe, and public health problems. Climate change will likely result in changes in natural systems and changes to the region's economy, cultural identity and social fabric. Increases in GHG emissions over the last 100 years have been primarily human caused from the burning of fossil fuels. Natural events like wildfire, which is becoming more common in the Sierra Nevada, are also a source of carbon emissions. However, these emissions can be managed to reduce risk and improve quality of life in the region.

This report presents emissions from the region as a whole, and by individual jurisdictions, including the jurisdictions of the City of South Lake Tahoe, El Dorado County, and Placer County in California, and Washoe County, Douglas County, and Carson City in Nevada.

Emissions Methodology

The updated GHG inventory was conducted in accordance with the U.S. Community Protocol (USCP). The USCP was released by ICLEI - Local Governments for Sustainability (ICLEI) in October 2012 and most recently updated in 2019. It represents the national standard in guidance to help U.S. local governments develop effective community-wide GHG emissions inventories. To measure emissions the GHG inventory used ClearPath, an all-in-one online tool designed by ICLEI and used by the California Statewide Energy Efficiency Collaborative to allow local agencies to complete government operations and community-wide greenhouse gas inventories, forecast emissions change and set climate goals, and model actions for climate action plans.

The report measures GHG emissions in four primary areas: energy use, including natural gas and electricity generation used to heat and cool buildings; transportation, including emissions from vehicle operations; solid waste, including materials deposited in landfills that will later decompose; and wastewater treatment. The report measures both emissions occurring within the region and emissions originating outside the region for use inside the region, in order to create a measure of total emissions.

The basic process followed for the inventory is to measure sources of emissions (such as power generation) and activities that create emissions (such as vehicle operations), convert those sources and activities into equivalent GHG emissions, and then measure the change between the date of the first inventoried year in 2005 and the last inventoried year in 2018. The observed change allows measurement of progress toward meeting climate policy goals. The report then uses the change over time to create a forecast of likely changes to occur to aid in decision making.

In addition to the GHG emissions inventory, this project conducted an analysis of infrastructure located on stream environment zones (SEZ), in order to assist in prioritizing the acquisition and redevelopment of aging properties. This analysis used UrbanFootprint, a spatial mapping and scenario planning tool, to determine where buildings overlap on SEZ territory, as well as assess the energy usage and emissions output and reduction potential for the basin.

Carbon Sequestration Methodology

As GHGs are emitted as a result of human activities and natural processes, carbon dioxide, the primary greenhouse gas, is also sequestered or stored in plants and the earth as part of the carbon cycle. Emissions and sequestration are two sides of the same equation. The long-term goal is to balance emissions from human sources with sequestration in natural systems to achieve a neutral or negative carbon balance, meaning sequestration is higher than emissions for any given time period. Carbon sequestration by forests and meadows is a natural climate solution, and the Tahoe region is fortunate to have an abundance of undeveloped landscapes that contribute to this cycle.

To quantify this process of carbon sequestration, the report includes an inventory of carbon stored in forests and meadows, the two largest stored carbon repositories in the basin. This will allow the inventory of emissions and the measure of carbon stored through natural systems as a result of forest and meadow restoration to be used as a tool to understand how restoration can help us meet our climate goals.

Vegetation based carbon (C) stocks and sequestration (or fluxes) play a major role in the global carbon cycle. Forests and meadows are the dominant vegetation types in the Lake Tahoe Basin. Quantifying both carbon stocks and fluxes for vegetation types can inform regional data-driven climate policies and form a more inclusive approach when coupled with emission only focused GHG inventories. Several prior initiatives exist in the region on forest carbon, while data on meadow carbon is sparse. A goal of this project was to validate existing forest carbon inventories and quantify meadow carbon in the basin. Outcomes suggest that current datasets for forest carbon diverge widely in outcomes, approaches, metrics, and temporal availability. For meadow carbon, carbon stock and flux estimates also show considerable uncertainty. Data variation and limitations need to be considered as interagency collaborations plan climate-forward initiatives, including the development of a carbon accounting balance sheet and carbon monitoring indicator.

In total stocking and average total annual carbon sequestration, forests in the Tahoe Basin store more carbon than meadows. However, meadows show considerably higher carbon stocks per hectare (average Soil Organic Carbon: 337 MgC/ha, or 1240 MT CO_2e/ha) than forests (106-216 Mg C/ha, or 390 - 790 MT CO_2e/ha). Additionally, meadows are more stable carbon stocks than forests once management activities are accounted for, as most of the meadow carbon is stored in the soil as opposed to aboveground as with forests. In contrast, forest carbon is less stable in light of increasing risks of stock loss due to wildfire, drought, disease and other disturbances. Targeted management practices for both meadows and forests can yield significant contributions to regional climate goals when paired with GHG emission reduction actions.

State Policy Connection

Finally, this report also serves to meet or inform several state and local policy objectives.

The states of California and of Nevada have provided legislative mandates or guidance on measuring and reducing GHG emissions. In California these include the Global Warming Solutions Act (AB 32), calling for reduction of GHG emissions to 40 percent below 1990 levels by 2030, and Executive Order B-55-18 (Governor Jerry Brown), calling for carbon neutrality by 2045. In Nevada the report is guided by

Senate Bill 254 (2019) requires the State of Nevada to create annual GHG emissions inventory reports and determine whether these policies are enough to achieve a goal of zero or near-zero GHG emissions by 2050, and by Executive Order 2019-22 (Governor Steve Sisolak) calling for reducing greenhouse gas emissions by 2 percent below 2005 levels by 2025 and 45 percent below 2005 levels by 2030.

Many regional and local governance entities in the region have adopted visionary climate goals. The report will also help to meet local objectives established by the Tahoe Regional Planning Agency (TRPA), Placer County, and the City of South Lake Tahoe. The Lake Tahoe Sustainable Communities Program and 2014 Sustainability Action Plan established a GHG emission reduction target of 15 percent by 2020 and 49 percent below the 2005 baseline by 2035. The City of South Lake Tahoe has a goal of 100 percent renewable electricity by 2032, at least a 50 percent reduction in GHG emissions by 2030, and an 80 percent reduction in emissions by 2040. The report is a resource for local jurisdictions in implementing climate actions.

The inventory and report are the result of an extensive stakeholder engagement and public outreach process that was conducted over the last year. This process included stakeholder interviews, advice from a science based technical advisory group, and advice from other local and state inventories and experts.

This report serves as documentation of the methods used to develop updated baseline and forecasted regional GHG emissions and carbon sequestration inventories from the basin. Funding for this project was granted to TRPA by the California Tahoe Conservancy. Emission and sequestration estimates were developed by Sierra Business Council and Spatial Informatics Group.

Key Findings

- Overall, GHG emissions in the basin decreased substantially from 2005 to 2018 but increased slightly from 2015 to 2018.
- On average between the years of 2015 and 2018, the energy sector produced more than half the emissions in the basin (59 percent), followed by transportation (37 percent). In combination, these two sectors generate more than 95 percent of total emissions in the basin and therefore have the most potential for reduction.
- If no further action is taken to continue reducing emissions, overall emissions in the basin are forecast to increase 5.7 percent by 2045.
- Emissions results by year and sector:
    - Build Environment
        - In 2005, emitted 1,297,446 metric tons (MT) CO_2e.
        - In 2010, emissions declined 4 percent to 1,245,672 MT CO_2e.
        - In 2015, emissions declined another 38 percent to 764,605 MT CO_2e.
        - In 2018, emissions increased 2.4 percent to 795,793 MT CO_2e.

- Energy Sector
  - In 2005 and 2010, was the largest GHG emitting portion of the built environment, responsible for over 55 percent of total annual emissions.
  - In 2015 and 2018, accounted for 59 percent of GHG emissions.
  - Electricity
    - Usage between 2015 and 2018 increased while emissions from electricity decreased, showing an increase in the amount of grid-provided electricity that was generated from lower emitting or renewable sources and that the overall increase in energy emissions is driven primarily by natural gas.
  - Natural Gas
    - In 2015, became the energy source with the highest number of emissions.
- Transportation
  - In 2005 and 2010, was the second largest GHG emitting portion of the built environment, responsible for over 30 percent of total annual emissions.
  - In 2015 and 2018, remained the second largest GHG emitting portion of the built environment, responsible for 37 percent of total annual emissions.
- Solid Waste
  - One of the more significant changes in emissions from 2010 to 2018 was a 60 percent drop in solid waste-related GHG emissions due to the incorporation of a methane capture system at Lockwood Landfill, the primary landfill serving the basin. This methane capture system significantly reduced the amount of CH4 released into the atmosphere as a result of the breakdown of solid waste.

- Vegetation based carbon (C) stocks and sequestration (or fluxes) play a major role in the regional carbon cycle. Forests and meadows are the dominant vegetation types in the Lake Tahoe Basin.
- Current datasets for forest carbon diverge widely in outcomes, approaches, metrics, and temporal availability. Forest carbon stocks averaged from 106-216 to Mg C/ha (390 to 790 MT CO_2e/ha) depending on the dataset. Forest carbon is at risk due to threats from wildfire, drought, disease and other disturbances.
- Meadow carbon averaged 337 Mg C/ha (1240 MT CO_2e/ha); both meadow carbon stock and flux estimates also showed considerable uncertainty due to a limited body of knowledge, including knowledge of meadow condition. Meadow carbon is at risk due to threats from land conversion, drought, conifer encroachment, and other disturbances, and limited local research showing how restoration or past land use has impacted soil carbon specifically.

Next Steps

Below is a high level summary of next steps (elaborated on in the conclusion sections of Chapter 1 and Chapter 2 of this report):

- GHG inventory recommendations:
  - Consider more detailed scenario planning to understand greatest opportunities to achieve GHG reductions.
  - Continue conducting periodic re-inventories to measure progress and identify potential areas of emphasis.
  - Coordinate with stakeholders to advance emission reduction strategies by developing a climate resiliency framework.
  - Consider expansion of the aging infrastructure analysis using the UrbanFootprint tool to fine-tune estimated benefits of land use and other decisions.
- Carbon sequestration recommendations:
  - Expand initiatives to stabilize forest carbon through forest health treatment; new initiatives in carbon markets can help co-fund treatments.
  - Assess if increasing (as opposed to stabilizing) carbon stocks is appropriate for the ecological resilience of a landscape; determine if forest restoration activities that result in a net decrease in current carbon stocks across are acceptable if they improve overall forest resilience and function; identify constraints and opportunities for increasing meadow carbon stocks.
  - Improve meadow carbon datasets and metrics; expand meadow restoration initiatives to increase soil carbon storage in meadows, and include standardized sampling methods for soil organic carbon in long-term monitoring.
  - Assess current meadow condition to identify and prioritize conservation and restoration needs.
  - Define climate planning questions and frame them in terms of desired measurable outcomes. Carbon accounting and carbon markets need to consider the opportunities and limitations of various tools and methodologies, including acknowledging the uncertainty inherent in all datasets, and allow for the fluid integration of new science as it becomes available.

Introduction

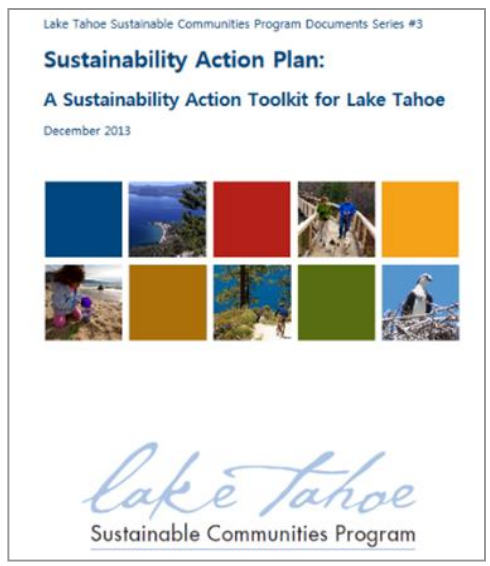
Tahoe Regional Planning Agency (TRPA) recognizes that greenhouse gas (GHG) emissions from human activity are catalyzing profound climate change, the consequences of which pose substantial risks to the future health, wellbeing, and prosperity of the Lake Tahoe Region (the region). There are many opportunities for the region to reduce local GHG emissions and improve carbon sequestration potential of natural landscapes. A GHG emissions inventory provides a detailed estimate of the annual amount of GHG emissions emitted by various sources across a defined geographical area. The quantification of emissions from sectors relevant to the region is the first step toward measuring emission reduction progress, planning future climate action, and developing strategies for reducing GHG emissions over time.

This report serves as documentation of the methods used to develop an updated emission baseline, forecasted regional GHG emissions, and carbon sequestration inventories from the Lake Tahoe Basin (the basin). Funding for this project was granted to TRPA from the California Tahoe Conservancy (the Conservancy), and emissions and sequestration estimates were developed by Sierra Business Council (SBC) and Spatial Informatics Group (SIG).

Background

In 2013, a regional GHG inventory was conducted for the basin, which established a baseline for regional GHG emissions for 2005 and 2010 and forecasted emissions out to 2020 and 2035.[1] The key findings of that inventory showed that over 91 percent of the region's emissions consist of energy use, transportation, and fuel consumption. The 2013 inventory results established reduction targets of 15 percent by 2020 and 49 percent below the 2005 baseline by 2035. This inventory served as the basis for the development of the award-winning Lake Tahoe Sustainable Communities Program and Sustainability Action Plan in 2014.[2] Additionally, this regional inventory supports federal and state climate goals.

Figure 1. Lake Tahoe Sustainable Communities Program Sustainability Action Plan



In the years since the 2013 inventory was completed, considerable progress has been made to reduce GHG

[1] York, T., Pollard, E., Reid, S., Stilley, J. (2013). A Regional Greenhouse Gas Inventory for the Lake Tahoe Basin. California Tahoe Conservancy.

[2] Lake Tahoe Sustainable Communities Program. Sustainability Action Plan: A Sustainability Action Toolkit for Lake Tahoe. (2013). Tahoe Regional Planning Agency and California Strategic Growth Council.

emissions across the region. To better understand the progress made in the years since and to identify future reduction strategies, an updated and expanded inventory has been conducted, as outlined in this report. This inventory will contribute to region-wide climate action. First, it will provide a snapshot of current emissions in the region and any changes that have occurred since the last emissions inventory. Second, it will be used as a tool to address GHG emissions in the basin and prioritize climate mitigation actions. Finally, the inventory will be used as a communication tool for the public, agency partners, funders, and elected representatives to tell the story of climate action and resiliency in the basin.

Climate Change Overview

The greenhouse effect is a process that traps heat in the Earth's lower atmosphere, keeping the planet's surface warm, which makes the planet habitable and perpetuates life. Naturally occurring gases dispersed into the atmosphere determine the Earth's climate by trapping solar radiation and capturing heat that would otherwise escape into space. Scientific observation indicates that average air and ocean temperatures have steadily increased globally over the last 100 years. Evidence of this includes rapid levels of glacial melt, reductions in sea ice, shorter freezing seasons, and decreases in snowpack. Scientific studies suggest that human activities are accelerating the concentration of greenhouse gases, which affects the global climate. The most significant contributor is the burning of fossil fuels for transportation and electricity generation, which introduces large amounts of carbon dioxide and other GHGs into the atmosphere. Collectively, these gases, primarily water vapor, carbon dioxide, methane, and nitrous oxide, intensify the natural greenhouse effect, causing global average surface temperatures to rise.[3]

The Tahoe Region, like most communities in the Sierra Nevada, faces challenges associated with regional climate change. From record temperatures to proliferating wildfires and changing precipitation patterns, climate change poses an immediate and escalating threat to the region's environment, economic strength, and public health. The region is affected by more intense dry and wet periods under warmer conditions which lead to extended and more frequent periods of drought and flooding. The total area in the region burned by wildfires increases in tandem with rising temperatures. Tree mortality in forested areas increases dramatically as they become stressed from higher temperatures and decreased water availability, making them more vulnerable to insects and pathogens. The region is also impacted by a higher proportion of precipitation falling as rain instead of snow, more intense atmospheric river storms, and shortages in runoff and water supply, as well as substantial changes in runoff patterns and timing. This will affect groundwater recharge, and in turn affect the basin, as well as downstream communities. Climate change can impair the ability of ecosystems to provide goods and services, including reliable snowfall and healthy fishing ecosystems. Many of these resources represent cultural, social, and economic benefits that local communities rely on for agriculture, tourism, recreation, and other

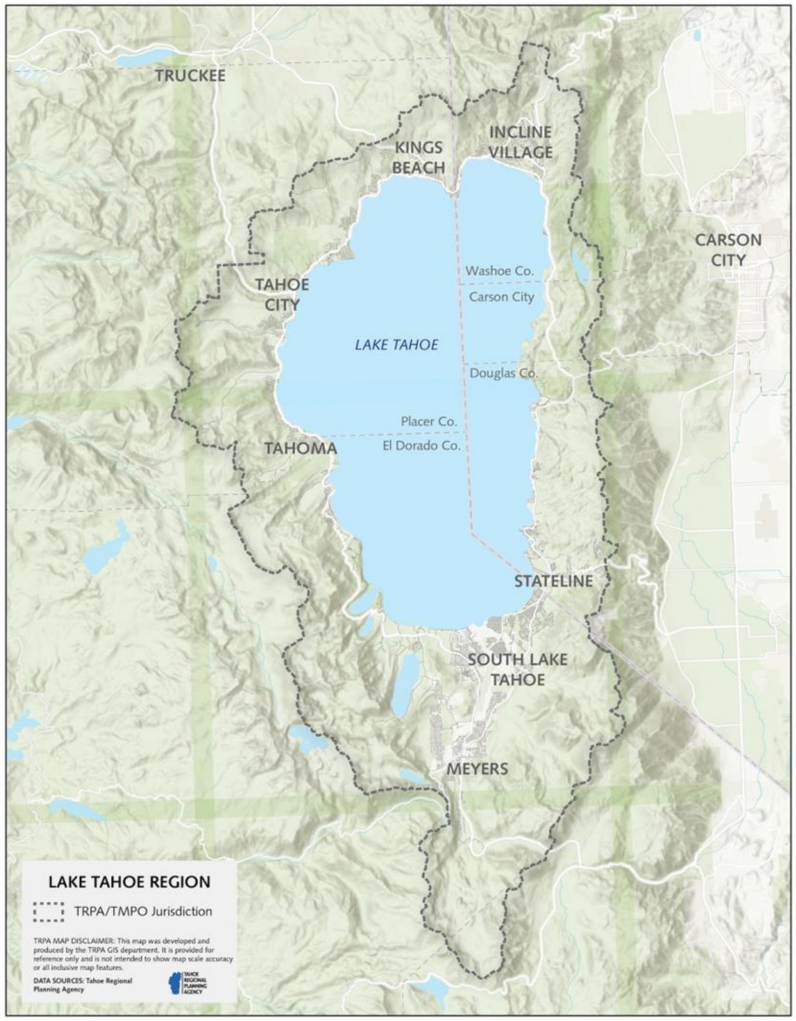
[3] Greenhouse Effect 101. (2021). Natural Resources Defense Council.

industries.[4,5,6] To learn more about how climate change might impact the region, state agencies in California created a new public tool, Cal-Adapt, which provides relevant data, resources, and future projections.[7]

Regional Climate Policy Profile

High in the Sierra Nevada mountains, Lake Tahoe occupies the fault basin on the California-Nevada border between the Sierra Crest and the Carson Range. It is one of the world's largest alpine lakes and is fed by numerous small streams, and drains to the Truckee River in California and to Pyramid Lake in Nevada. The basin, a 501-square-mile watershed, includes jurisdictions in California: the City of South Lake Tahoe, El Dorado County, and Placer County, and Nevada: Washoe County, Douglas County, and Carson City.

Figure 2: Lake Tahoe Region & TRPA Jurisdiction Map



In an effort to manage growth and development in the watershed and lead a shared, cooperative mission to conserve and restore the basin and its unique environment, the two states came together to respond to the need. Increased temperatures, decreased snowpack, and shifting ranges of

4 Core Writing Team, Pachauri, R.K., Meyer, L.A.. (2014). Climate Change 2014: Synthesis Report. Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

5 Dettinger, M., Alpert, H., Battles, J., Kusel, J., Safford, H., Fougeres, D., Knight, C., Miller, L., Sawyer, S. (2018). Sierra Nevada Region Report. California's Fourth Climate Change Assessment.

6 Nevada's Climate Strategy. State of Nevada Climate Initiative. (2021).

7 Cal-Adapt. California Energy Commission. (2021).

plants and animals are starting to result in an increased risk of drought, flooding, forest fires, and other impacts affecting natural, built, and human systems. In addition, state-level emissions reduction mandates, such as the California Global Warming Solutions Act (AB 32, 2006)[8] and its successor bill (SB 32, 2016)[9], the California Clean Energy and Pollution Reduction Act (SB 350, 2015)[10], the Sustainable Communities and Climate Protection Act (SB 375, 2008)[11], and the Nevada Executive Order 2019-22[12] and Nevada Senate Bill 254 (2019)[13], are pushing local governments and public agencies to develop ever more effective solutions at the local level.

State & Local Climate Goals

Today, the State of California has mandated the reduction of GHG emissions through a number of legislative and administrative vehicles, including: SB 32, which calls for a reduction in statewide emissions to 40% below 1990 levels by 2030; Executive Order B-55-18 (Governor Jerry Brown), calling for carbon neutrality by 2045; and SB 375, which mandated an 8% reduction in transportation-related GHG emissions by 2020 and an additional 5% reduction by 2035. Locally, the City of South Lake Tahoe is committed to a 50% reduction in emissions by 2030 and 80% by 2040. Additionally, the City recently completed a GHG inventory for the years 2015 and 2018, which complements this project's inventory work.

Similarly, Nevada Governor Steve Sisolak signed Executive Order 2019-22, directing his administration to collaborate with public, private, and tribal partners to help implement and accelerate cutting-edge solutions to advance the State of Nevada's ambitious climate goals. This includes reducing greenhouse gas emissions by 28% below 2005 levels by 2025 and 45% below 2005 levels by 2030. Additionally, Nevada Senate Bill 254 (2019) requires the State of Nevada to create annual GHG emissions inventory reports and determine whether these policies are enough to achieve a goal of zero or near-zero GHG emissions by 2050.

This project's regional inventory will support Nevada's climate goals and align Lake Tahoe Basin climate actions and goals with California climate strategy.

The years selected for future emissions projections align with Nevada goals (2030), California SB 375 targets (2035), and the TRPA Regional Transportation Plan (2045). As with both states, the basin needs to begin producing semi-regular GHG emission inventories.

Inventory Development

Aligning with established methodology and protocols, the inventory development process involved a number of key steps and decision-making points:

- **Stakeholder Outreach and Engagement**: The process for reaching out to and engaging with key stakeholders and

[8] Global Warming Solutions Act of 2006 (AB 32). California Air Resources Board.

[9] Global Warming Solutions Act of 2006: Emissions Limit (SB 32). (2016). California Legislative Information.

[10] Clean Energy and Pollution Reduction Act (SB 350). (2015). California Energy Commission.

[11] Transportation Planning: Travel Demand Models: Sustainable Communities Strategy: Environmental Review (SB 375). (2008). Institute for Local Government.

[12] Order Directing Executive Branch to Advance Nevada's Climate Goals (EO 2019-22). (2019). State of Nevada Executive Department.

[13] Nevada Senate Bill 254. (2019). State of Nevada.

project advisors was twofold. First, the consultant team with support from TRPA staff established Technical Advisory Committees (TACs), one for the Built Environment Inventory, and one for the Forest Carbon Inventory. The teams met with these TACs, respectively, over the course of the inventory development process, in order to seek guidance in the selection of methodologies, identifying available data, and coordinating the project with other relevant planning efforts in the basin. Second, the project team worked together to develop a number of strategies and touchpoints to engage with a wider audience of stakeholders and interested parties. These outreach activities resulted in a webinar[14] to share initial findings and recommendations, as well as the creation of online dashboard materials to share with the community in the future.

- **Identify Emissions Sources and Activities**: In consultation with the TACs, the team assessed the 2015 and 2018 GHG emissions from four different sectors for the built environment: energy (energy use in buildings and the built environment), transportation, solid waste, and water and wastewater. Within each sector, activities that occur in the basin that release emissions outside the basin, as well as sources that generate emissions directly within the basin were accounted for. The team also quantified carbon stocks for the Tahoe Basin's forests and meadows. Forest carbon stocks were also compared to a suite of provided forest carbon datasets used in recent relevant inter-agency initiatives.
- **Inventory Boundaries**: The geographic scope of the inventory is referred to as "the Lake Tahoe Basin" and is defined by TRPA's jurisdictional boundaries, which include parts of both California and Nevada. The basin includes portions of the counties of El Dorado and Placer, as well as the City of South Lake Tahoe on the California side of Lake Tahoe, and includes portions of the counties of Douglas and Washoe, and rural Carson City on the Nevada side of Lake Tahoe. The inventory includes multiple jurisdictions, and the built environment estimates have been geographically broken out for a more detailed assessment.
- **Data Collection and Inventory Years**: The scope included an update to a previously conducted inventory from 2013, which inventoried years 2005 and 2010, and a re-inventory of the years 2015 and 2018 as these were the years with the best available data and analyzing two different years of emissions data will provide a more detailed baseline that is needed to update future emissions projections. The team worked closely with TRPA staff and TAC members to identify and review available data for the baseline inventory and forecast of GHG emissions in the basin. Data sets used for the findings in this report are highlighted throughout, as well as detailed in the appendices. For the carbon inventory, the team quantified forest carbon for the 2014 and 2018 time periods, and compared results to existing provided forest carbon datasets ranging from 2010-2019. Meadow carbon was calculated, and served to represent 2018 conditions.

[14] Lake Tahoe Greenhouse Gas Emissions Webinar. (2021). Sierra Business Council, Spatial Informatics Group, Tahoe Regional Planning Agency, and California Tahoe Conservancy.

- **Inventory Tools**: This inventory utilized the best available tools, methodologies, and data to determine GHG emissions produced and sequestered in the basin.
    - For the Built Environment Inventory, these included, but were not limited to:
        - The Statewide Energy Efficiency Collaborative[15]: a collective of energy efficiency implementers that provides information and best practices for inventorying energy use;
        - ClearPath[16]: a widely used and accepted all-in-one online tool for government operations and community-wide greenhouse gas inventories and forecasting; and
        - UrbanFootprint[17]: a spatial mapping tool that utilizes data on existing buildings, land uses, and other details of the built environment, combined with the ability to test different land use or policy scenarios under consideration for implementation and monitoring.
    - For the Forest and Meadow Carbon Inventory, these included, but were not limited to:
        - Forest Vegetation Simulator (FVS)[18]: a forest modeling tool created by the USDA Forest Service and commonly used by forestry professionals
        - Missoula Fire Lab's TreeMap[19]: a tree-level map created via machine learning that matches forest plot data with biophysical characteristics of the landscape. This map crosswalks to plot data that serves as the treelist input for FVS modeling
        - Gridded Soil Survey Geographic (gSSURGO): a dataset containing soils and soil organic carbon distributed by the USDA Natural Resources Conservation Service

More details about specific tools and methodologies are highlighted in their respective sections throughout this report.

Informing the Inventory

Stakeholder engagement and public outreach are essential to successful inventorying and planning, and stakeholder input was widely sought at key milestones and throughout the process to ensure the scope of the project was appropriate, accurate, and actionable. This set the stage for project success as well as building the regional knowledge base and engagement process required to achieve longer-term emissions reductions, carbon sequestration, and other resource management goals for the basin. The

[15] Statewide Energy Efficiency Collaborative (SEEC). (2020).
[16] ClearPath. (2021). ICLEI - Local Governments for Sustainability USA.
[17] UrbanFootprint. (2021).
[18] What is FVS? (2021). U.S. Forest Service.
[19] TreeMap: A tree-level model of the forests of the United States. (2020). Fire, Fuel, Smoke, Science Program. U.S. Forest Service.

outreach and engagement strategies utilized by the team identified opportunities and methodologies for stakeholders to contribute input on analysis, issues, alternatives, and decisions, while also encouraging active sharing of concerns and ideas for desired outcomes. The overall outreach and engagement strategy was twofold:

- **Technical Advisory Committee**: The consultant team worked closely with TRPA staff to establish two TACs, one for the Built Environment Inventory, and one for the Forest and Meadow Carbon Inventory. These committees were made up of key stakeholders and subject matter experts who supported the inventory process by meeting with the teams, respectively, to share guidance on the selection of inventory methodologies, identify and in some cases supply available data, and ensure the project aligned with other relevant plans in the basin. The ultimate goal of the TAC was to support the project team and create a final product that is useful to stakeholders and planning agencies in the basin and relevant to the work they do. The teams held several meetings to consult with the TAC members to solicit input on project strategies and challenges within different sectors, as well as providing periodic updates to present findings. The TAC members provided invaluable input and insights to the inventory teams, giving this project and the team's efforts a solid foundation for future climate action assessments and strategic planning.
- **Stakeholder and Community Engagement**: The project team worked together to develop a robust and adaptable community engagement process that identified stakeholder needs, answered community questions, and overall ensured that the Lake Tahoe GHG Inventory Update reflected the broader goals and vision of the region. Augmenting TRPA's Sustainable Community Program dashboard[20], Lake Tahoe Information Database[21], and other communications resources and databases is an important part of amplifying the community and engagement process. Building on TRPA's role in the community and continued implementation of the Sustainable Communities Program Sustainability Action Plan, the project team worked together to implement a number of outreach strategies and engagement opportunities to reach a wider audience of interested community members and key stakeholders. Outreach was primarily conducted through digital platforms due to the COVID-19 pandemic. These outreach activities included press releases, social media, e-newsletters, a community webinar to share initial inventory findings and next-step recommendations, and providing answers to specific questions about the inventory process and results. The recording and other documentation were provided to the community to provide further education on GHG emissions in the basin, spark ideas for ways the public can take action, and support wider local climate action. The team developed materials that can be used for TRPA's online dashboard to disseminate information about GHG emissions, carbon sequestration, and other climate impacts in the region.

[20] Lake Tahoe Info Sustainability Dashboard. (2021). Tahoe Regional Planning Agency.
[21] Tahoe Open Data. (2021). Tahoe Regional Planning Agency.

Chapter 1: GHG Emissions Inventory

Inventory Methodology

Understanding a GHG Emissions Inventory

Achieving tangible greenhouse gas (GHG) emissions reductions in order to substantially mitigate the regional impact on climate change requires identifying baseline emissions levels, sources, and activities generating emissions in the community. Warming trends across the region have increased the frequency and severity of damaging wildfire, reduced snowpack, drying meadows, rain-on-snow and flooding events, low lake levels, and decreased biodiversity. These effects are beginning to take hold locally in the basin, threatening not only the environment but also the basin community's way of life.

This report presents emissions from the basin as a whole, including the jurisdictions of the City of South Lake Tahoe, El Dorado County, and Placer County in California, and Washoe County, Douglas County, and Carson City in Nevada. It uses the latest data and modeling to update the 2013 inventory, looking at GHG emissions generated by the built environment (Energy, transportation, water and wastewater, and solid waste management) and assessing the amount of carbon that is stored by the natural environment (forests and meadows) that can help offset those GHG emissions. As local governments and public agencies have continued to join the greater climate action movement, the need for standardized approaches to quantifying GHG emissions has proven essential. The inventory for the built environment GHG inventory utilizes the approach and methods provided by the U.S. Community Greenhouse Gas Emissions Protocol.

Built Environment Inventory

A community-wide inventory of greenhouse gas emissions looks at potential GHG-emitting sources and activities that take place within a given geography -- in this case, the basin -- and determines how much of each activity occurs within that geography. Examples include electricity used in homes and businesses, fuel for stationary combustion, on-road passenger and freight vehicles, and energy for water, wastewater, and solid waste operations. Once the usage figures

Emissions Generation

The combustion of natural gas within the basin, for purposes of space heating or cooking in buildings, results in emissions being generated within the boundary of the basin. However, electricity use within the basin is generated by combusting primarily fossil fuels at power plants located outside the basin, resulting in the release of emissions outside the geographical boundaries of the basin. By looking at both internal and external sources, we provide a more holistic picture of the emissions that the basin is responsible for generating.

Similar to energy generation within and outside the basin, there are emissions created by the transportation of consumable goods brought into the basin and transport of associated waste outside of the basin to the landfills. Both sets of emissions are accounted for in determining the full emissions generated by the basin.

are known, various factors are applied to arrive at a carbon equivalency for each activity. The current carbon equivalencies can then be compared between sectors and over different time periods to gauge the progress and relative effectiveness of various emissions reduction policies and actions.

This updated inventory assesses 2015 and 2018 GHG emissions from the four different built environment sectors identified above: energy (electricity and gas usage), transportation, solid waste, and water and wastewater. Within each sector, we accounted for activities that occur in the basin that release emissions outside the basin, as well as sources that generate emissions directly within the basin.

Community Emissions Protocol

Achieving tangible GHG emissions reductions requires identifying baseline emissions levels, sources, and activities generating emissions in the community. This report presents emissions from the region, accounting for the emissions of carbon dioxide (CO_2), methane (CH_4), and Nitrous Oxide (N_2O), and calculated as the carbon dioxide equivalent (CO_2e). As local governments and public agencies have continued to join the greater climate action movement, the need for standardized approaches to quantifying GHG emissions has proven essential. The inventory for the built environment GHG inventory utilizes the approach and methods provided by the U.S. Community Greenhouse Gas Emissions Protocol.

U.S. Community Protocol

The updated GHG inventory was conducted in accordance with the U.S. Community Protocol (USCP).[22] The USCP was released by ICLEI - Local Governments for Sustainability in October 2012 and most recently updated in 2019. It represents the national standard in guidance to help U.S. local governments develop effective community-wide GHG emissions inventories. It establishes reporting requirements for all community-wide GHG emissions inventories, provides detailed accounting guidance for quantifying GHG emissions associated with a range of emissions sources and community-wide activities, and provides reporting frameworks to help local governments customize their community-wide GHG emissions inventory reports based on their local goals and capacities. In Nevada, the statewide methodology for GHG inventorying is the U.S. Environmental Protection Agency's State Inventory and Projection Tool.[23] The State of California Governor's Office of Planning and Research recommends that California local governments follow the USCP when undertaking their greenhouse gas emissions inventories.

Under the USCP, there are three available reporting frameworks: Local Government Significant Influence (LGSI), Community-Wide Activities (CWA), and Household Consumption (HC). The USCP recommends and this project used the LGSI framework because it emphasizes policy relevance and highlights emissions sources and activities that the local government has the greatest opportunity to address. The

[22] U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. (2019). ICLEI - Local Governments for Sustainability USA.

[23] State Inventory and Projection Tool. (2021). U.S. Environmental Protection Agency.

LGSI framework also includes all five of the Basic Emissions Generating Activities required by the USCP to be protocol compliant: 1) Use of Electricity by the Community, 2) Use of Fuel in Residential and Commercial Stationary Combustion Equipment, 3) On-Road Passenger and Freight Motor Vehicle Travel, 4) Use of Energy in Potable Water and Wastewater Treatment and Distribution, and 5) Generation of Solid Waste by the Community. In addition to these five activities, this inventory also looked at emissions from Off-Road Vehicle Travel and Wastewater Treatment Direct Emissions. For this reason, the community-wide inventory was conducted according to the LGSI framework in order to provide as complete a picture as possible of all of the direct GHG emissions produced within the community.

Quantifying Greenhouse Gas Emissions

Sources and Activities

Communities contribute to GHG emissions in a number of ways, and two central categorizations of emissions are used in the built environment inventory: 1) GHG emissions that are produced by "sources" located within the defined regional boundary, and 2) GHG emissions produced as a consequence of community "activities." All the emissions in this report have been quantified using calculation-based methodologies. Calculation-based methodologies look at GHG-emitting activities and determine how much of each activity occurred in the basin. Then an emissions factor is developed or cited from literature for each specific activity and the two figures are multiplied together to arrive at the total emissions produced by each activity within the basin:

Activity or Source Data x Emissions Factor = Emissions Produced by Activity.

Activity or source data refers to the relevant measurement of energy use or other GHG-generating processes such as fuel consumption by fuel type, metered annual electricity consumption, or annual vehicle miles traveled (VMT). Standard emissions factors are applied to activity or source data to determine the associated emissions. Emissions factors are typically expressed as emissions per unit of activity or source data (e.g. lbs CO_2/kWh of electricity). The Statewide Energy Efficiency Collaborative (SEEC) ClearPath California toolkit was used to complete these quantifications.

Greenhouse Gas Global Warming Potential

The USCP recommends assessing emissions from the seven internationally recognized GHG emissions regulated under the Kyoto Protocol and listed in the table below. Of those seven, this inventory focused on three main greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and Nitrous Oxide (N_2O). Emissions of hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride were not included in this community-wide inventory because the basin does not have substantial manufacturing or other industrial uses that are the primary generators of such emissions**.**

Because different activities measure emissions in different units, this inventory looks at these three different types of emissions and reports out in carbon dioxide equivalent, or CO_2e. This carbon dioxide equivalent combines the three different gaseous emissions types into one single unit based on the Global Warming Potential (GWP) of each gas. The GWP is a measure of how strongly each gas will affect global warming in the atmosphere based on the amount of warming a GHG may cause over a 100-year period, measured against the amount of warming caused by carbon dioxide.

It is common practice to aggregate and report emissions in this single unit. Converting all emissions to equivalent carbon dioxide units allows for the consideration of different GHGs in comparable terms, both between sectors and across different years. For example, methane is 28 times more powerful than carbon dioxide in its warming effect over 100 years; so one metric ton (MT) of methane emissions is equal to 28 MT of carbon dioxide equivalents. It should be noted that previously conducted emission inventories for the basin relied on the best available GWP data which has since become outdated. To allow for accurate comparisons of emissions levels calculated in this inventory and those calculated in previous inventories, previous inventories' emissions levels were recalculated using currently accepted GWPs.

Table 1. Greenhouse Gas Global Warming Potentials

Greenhouse Gas	Chemical Formula	IPCC 5th Assessment Global Warming Potential[24]
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265
Hydrofluorocarbons	Various	4 - 12,400
Perfluorocarbons	Various	6,630 - 11,100
Sulfur Hexafluoride	SH_6	23,500
Nitrogen Trifluoride	NF_3	16,100

Forecast Methodology

Once emissions inventories were completed, a forecast of emissions was developed under a business-as-usual (BAU) scenario. A BAU scenario does not account for any local, state, or federal policy that would impact future greenhouse gas emissions. The BAU forecast, completed using the SEEC ClearPath California toolkit, estimates future Community-Wide GHG Emissions in the years 2030, 2035, and 2045. A BAU forecast requires two inputs — current emissions data and growth rates. Baseline emissions data came from the completed GHG Inventory for 2005 and 2018. Growth rates were calculated based on

[24] Global Warming Potential Values. (2013). Greenhouse Gas Protocol. IPCC.

projected growth of relevant indicator variables. The BAU forecast is beneficial in that it allows for comparison between forecasted and actual observed emissions to determine what emissions reduction progress has been made to date, as well as to assess whether or not future reduction goals could be met solely by the reduction efforts made to date.

Aging Infrastructure Inventory Methodology

The built environment is a primary contributor of GHG emissions from electricity and gas usage. It can be a target for meaningful reductions, especially in the context of sustainable redevelopment projects to meet regional and statewide climate goals. The Lake Tahoe Regional Plan (Regional Plan)[25] aims to create compact mixed-use development by incentivizing removal of aging development in outlying and sensitive habitats. Environmentally beneficial redevelopment improves lake clarity and reduces emissions. To quantify these benefits, this project used UrbanFootprint, a spatial mapping tool that helps determine potential outcomes based on different development or reduction scenarios, to identify priority areas for GHG reduction potential, particularly in terms of projects in Stream Environment Zones (SEZs) and Town Centers.

The UrbanFootprint tool has an extensive data library, with pre-loaded, commercially sourced parcel data along with trusted public and open data sources that applies proprietary algorithms and data normalization processes to conduct its analyses. Data is derived from a number of sources, including participating municipal jurisdictions as well as relevant agencies such as: U.S. Energy Information Administration Residential Energy Consumption Survey, U.S. Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database, U.S. EPA natural gas constant, Commercial Building Energy Consumption Survey data on commercial energy use rates, California Energy Commission Residential Appliance Saturation Study and Commercial End-Use Survey, all of which can be targeted to specific geographic areas.

Data is validated against publicly available census data as well as internal benchmarks to ensure accuracy. It is also routinely updated by UrbanFootprint's team of planners and data scientists through major quarterly releases and weekly targeted updates. Agencies can also input their own data to provide even more customized results.

The team looked at the Tahoe Regional Planning Agency (TRPA) data related to impervious surfaces (e.g., buildings, driveways, roads, trails, etc.) and location and proximity of buildings to sensitive SEZs, and used UrbanFootprint data on location and type of buildings within commercial centers and associated energy use and emissions estimates by building type to model three emissions reduction scenarios. The model generated maps with corresponding data tables that were used to create summary comparative scenario charts related to energy use and emissions and a data workbook that is available for use by TRPA and its partners in future cost/benefit analyses of different development or

[25] The 2012 Update: Restoring Lake Tahoe and Supporting Sustainable Communities. (2012). Tahoe Regional Planning Agency.

redevelopment scenarios in relation to GHG emission reductions. Because the UrbanFootprint tool only uses its own data to produce automated energy analysis reports, the consultant team had to manually develop separate energy analysis reports for the TRPA-sourced SEZ and Commercial Center data sets. For more information on both the UrbanFootprint analysis and this manual analysis process, please see **Appendix C**.

As an additional step, the team attempted to replace the tool's default data with TRPA parcel data and create a crosswalk from the UrbanFootprint building types to the TRPA types. Unfortunately, complications arose with the geographic keys in the crosswalk process that ultimately prevented the use of the more detailed TRPA parcel data in this analysis. Incorporating TRPA-specific parcel data will require further research to successfully align the building types and geographic keys across the two data sets. That additional effort was beyond the scope and timeline of this project.

Of note, there are many strategies and resources to help jurisdictions model reduction scenarios. This project used the Zero Tool[26] developed by Architecture 2030 for building sector professionals, policymakers, identifying three different reduction percentage scenarios that could result from different policy interventions, such as removal or retrofitting of existing buildings in sensitive target areas. For future reference, there are other methods and tools that can contribute additional detail for such evaluations, including:

- EnergyStar Portfolio Manager Energy Use Intensity (EUI) Scores per Building Type
- New Buildings Institute Target EUI
- Set a Target
    - Zero Energy Performance Index Score (Commercial)
    - Home Energy Rating System (Residential)
    - New Construction Targets
- ASHRAE Climate Zones for the Tahoe Region by County
    - El Dorado: 4B
    - Douglas: 5B
    - Placer: 3B
    - Washoe: 5B

Inventory Results

Based on the methodologies outlined above, inventory results provide information on the sources of GHG emissions, the relative magnitude of those emissions by source, and emissions trends in the basin over time.

[26] About the Zero Tool. (2021). Architecture 2030.

GHG Emissions Summary

Key Findings

Overall, GHG emissions in the basin decreased substantially from 2005 to 2018 but increased slightly from 2015 to 2018.

Measured reductions in transportation emissions show the basin's ability to meet GHG reduction targets and the success of agency investments in trails and transit to get people out of their cars. Statewide fuel standards and electric vehicles have also contributed.

The energy sector produces more than half the emissions in the basin (59 percent), followed by transportation (37 percent). In combination, these two sectors generate more than 95 percent of total emissions in the basin and therefore have the most potential for reduction.

Climate and energy actions outlined in the Sustainable Communities Program and Sustainability Action Plan and Regional Transportation Plan -- such as increasing energy efficiency and investing in trails and transit to reduce VMT -- are helping to reduce emissions in these two sectors, as is the ongoing effort to transition away from natural gas to electricity in space heating and cooking.

If no further action is taken to continue reducing emissions, overall emissions in the basin are forecast to increase 5.7 percent by 2045.

By continuing to conduct GHG emissions inventories, TRPA and partners can track emissions over time, allowing us to monitor and evaluate reduction efforts and inform future project planning.

As data gets more robust and methodologies improve, accuracy of inventory results will continue to improve, giving us an even clearer picture of the emissions landscape in the basin.

Overview of Past Inventories: 2005 and 2010

Prior to this project, a 2013 project completed a region wide GHG inventory for the years 2005 and 2010. In 2005, the built environment in the basin emitted 1,297,446 MT CO_2e. In 2010, the built environment emissions declined 4 percent to 1,245,672 MT CO_2e. For both 2005 and 2010, the energy sector was the largest GHG emitter, responsible for over 57 percent and 66 percent of total annual emissions, respectively. It was followed by the Transportation sector, responsible for over 30 percent of total annual emissions (see **Table 2** below).

Table 2. 2005 & 2010 Emissions Summary

Sector	2005		2010	
	MT CO_2e	Percent of Total Emissions	MT CO_2e	Percent of Total Emissions
Energy*	743,426	57.3%	826,521	66.4%
Electricity		66%		69%
Natural Gas		32%		29%
Other Fuel		2%		2%
Solid Waste	147,336	11.4%	35,616	2.9%
Wastewater	69	0.0%	74	0.0%
Total	**1,297,446**	**100.0%**	**1,245,672**	**100%**

The **energy sector includes emissions from electricity, natural gas, and other fuel consumption. This is reflected below the energy row. The percentages for electricity, natural gas, and other fuel are included in the energy totals.*

Landfill Emissions Capture

One of the more significant changes in emissions from 2005 to 2010 was the incorporation of a methane capture system at Lockwood Landfill, the primary landfill serving the basin. This methane capture system significantly reduced the amount of CH_4 released into the atmosphere as a result of the breakdown of solid waste. Captured CH_4 is used to generate electricity that is sold back into the electrical grid.

At the time it was conducted, the 2013 inventory used the best available methodologies and data to determine GHG emissions produced by the basin. As those methodologies have since been updated, minor corrections were made to align with currently accepted best practices.

- Removal of emissions from livestock
  - Emissions from livestock were removed from 2005 and 2010 inventoried emissions. These emissions were calculated for the entirety of the counties that make up the basin and then scaled proportionally for the basin. In reality, the basin did not have significant livestock operations in 2005 or any year after that.
- Updated emissions from wood combustion
  - The previous inventory included CO_2, CH_4, and N_2O emissions from wood combustion in its total emissions levels. Current best practices only account for CH_4 and N_2O emissions from wood combustion, with CO_2 emissions being measured, but not actually counted in total emissions because they are considered biogenic (emissions that would have occurred were the wood left to decompose naturally in the landscape.)

- Recalculation of CO_2e
  - The 2013 project calculated CO_2e metrics based on the global warming potentials included in the International Panel on Climate Change's (IPCC) 4th Assessment. Since the release of this project, the IPCC has released a 5th Assessment that includes slight alterations to its global warming potential data, which were used to calculate CO_2e metrics for the current project. To better compare results between the 2013 and current project, CO_2e metrics for the 2013 project were recalculated using the global warming potentials included in the IPCC 5th assessment.

Overview of Current Inventories: 2015 and 2018

In 2015, the built environment in the basin emitted 764,605 MT CO_2e and in 2018 it emitted 795,793 MT CO_2e.[27] Like the 2005 and 2010 inventories, the energy sector remained the largest source of emissions, followed by transportation, with transportation making up a slightly larger percentage of total emissions than in 2005 and 2010 (see table below)

Table 3. 2015 & 2018 Emissions Summary

Sector	2015		2018	
	MT CO_2e	Percent of Total Emissions	MT CO_2e	Percent of Total Emissions
Energy*	449,592	58.8%	469,379	59.0%
Electricity		47%		43.5%
Natural Gas		52.5%		56%
Other Fuel		0.5%		0.5%
Transportation	289,154	37.8%	288,207	36.2%
Solid Waste	24,966	3.3%	37,244	4.7%
Wastewater	892	0.1%	963	0.1%
Total	**764,605**	**100.0%**	**795,793**	**100.0%**

The **energy sector includes emissions from electricity, natural gas, and other fuel consumption. This is reflected below the energy row. The percentages for electricity, natural gas, and other fuel are included in the energy totals.*

[27] Community-Master-Data-Workbook. (2021). Sierra Business Council.

2005 to 2018

> **Contributing Factors to Emissions Reduction Findings**
>
> Electricity: reduction in electricity consumption compounded by improvement in electricity emissions factor led to:
>
> 12% reduction in electricity consumption
>
> 63% reduction in emissions from electricity consumption
>
> Total sector emissions reduction of 29%
>
> Transportation: reduction in on-road VMT compounded by improvement in vehicle fleet efficiency led to:
>
> 12% reduction in On-Road VMT
>
> 22% reduction in emissions from On-Road Transportation
>
> Total sector emissions reduction of 5%
>
> General: more accurate methodologies and data led to more accurate estimates:
>
> When the 2005 and 2010 inventories were conducted, limited availability of some activity data required conservative estimates to be developed. By 2015 and 2018, data collection and storage methods improved, resulting in fewer data gaps and fewer estimates to be made.

Figure 3 is a stacked area graph where each colored section represents emissions from one of the specific sectors, with the four inventory years on the x-axis (including both the original 2013 inventory years of 2005 and 2010 and the updated inventory years of 2015 and 2018) and MT of CO_2 equivalents or actual GHG emissions levels for each sector on the y-axis. The amount of area that each sector takes up on the chart represents the amount of emissions from that specific sector across the time span of 2005 to 2018. Energy (blue) had the largest amount of emissions, followed by transportation (red), solid waste (yellow), and wastewater (green). **Table 3** presents the same information in chart form, specific to the updated inventory years of 2015 and 2018, in numeric form, where the energy sector accounted for roughly 59 percent of total basin emissions, transportation in the range of 36-38 percent, solid waste 3-5 percent, and wastewater well under 1 percent.

Looking at these two figures, several notable trends and data points arise. The first is that from 2010 all sectors saw substantial declines in emissions, except for the wastewater sector. The reason for this shift is twofold. First, the energy, transportation, and solid waste sectors each saw general levels of reduction in GHG emitting activities/sources (i.e., electricity consumption declined, VMT declined, solid waste amounts declined, in large part due to the implementation of the Regional Plan and Regional Transportation Plan (RTP)[28], among others). These declines in GHG emitting activities were compounded by improving emissions factors for each of these sectors. Electricity was generated by larger amounts of renewable energy, on-road vehicle fleet fuel efficiency improved.

The second most notable observation is the large percentage increase in emissions from the wastewater sector from 2010 to 2015. This sizable increase can be explained by the use of new methodologies that allow for additional emissions from the wastewater sector to be accounted for. Further detail will be

---

[28] Linking Tahoe: Regional Transportation Plan and Sustainable Communities Strategy. (2017). Tahoe Regional Planning Agency.

provided in the wastewater sector, however even with this sizable percentage increase in wastewater sector emissions, it should be noted that in 2015 and 2018 wastewater made up only 0.1 percent of total emissions, so the large relative increase for the sector did not skew total emissions levels.

Figure 3. Basin-Wide Emissions by Sector

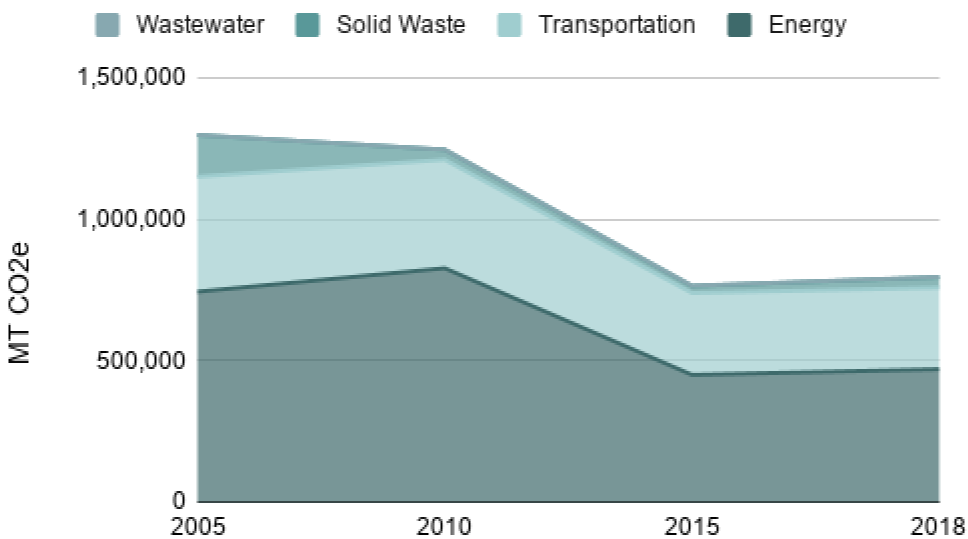


Table 4. Percent Change in Emissions

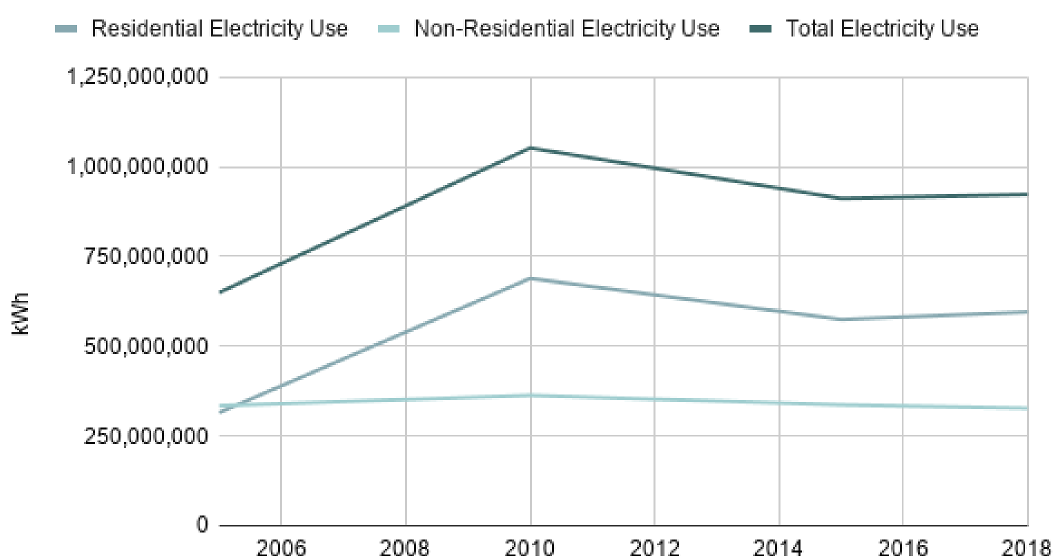
Sector	Nominal Percent Change			Net Percent Change
	2005 - 2010	2010 - 2015	2015 -2018	2005 - 2018
Energy	11.2%	-45.6%	4.4%	-36.9%
Transportation	-5.7%	-24.6%	-0.3%	-29.1%
Solid Waste	-75.8%	-29.9%	49.2%	-74.7%
Wastewater	7.2%	1105.7%	8.0%	1296.2%
Total	**-4.0%**	**-38.6%**	**4.1%**	**-38.7%**

Energy

> **Local and Regional Reductions**
>
> The states of California and Nevada both have aggressive targets to reach 100% renewable electricity generation and net-zero carbon emissions. Locally, the City of South Lake Tahoe has a goal to reach 100% renewable electricity by 2032. Significant regional actions to reduce energy consumption and increase renewable energy generation are underway. This includes expansion of solar on the South Shore and sustainable redevelopment in North Shore. The Lake Tahoe Regional Plan encourages sustainable redevelopment which is more energy efficient than the region's legacy buildings.

The energy sector consists of building electricity, natural gas, and other fuel use, as noted below **Table 2** and **Table 3**. Aggregated electricity use data was provided by Liberty Utilities and NV Energy[29] and is shown in **Figure 4** below. Note the electricity use and emissions metrics include transmission and distribution (T&D) losses in 2015 and 2018. T&D losses are slight losses in electrical energy as a result of transmission across power lines. T&D losses were measured at approximately 5 percent of end use consumption in both 2015 and 2018. The large reduction in emissions from 2010 to 2015 can be attributed to two factors. First looking at the electricity usage graph, it can be seen that electricity consumption declined slightly from 2010 to 2015. While electricity usage between 2015 and 2018 increased, emissions from electricity decreased, showing an increase in the amount of grid-provided electricity that was generated from lower emitting or renewable sources. Ultimately, this indicates that the increase in overall energy emissions is driven by natural gas.

Figure 4. Electricity Use



[29] Electricity data provided by Liberty Utilities and NV Energy. Located in the Community-Master-Data-Workbook.

Aggregated natural gas use was provided by Southwest Gas[30] and is shown in **Figure 5** below. Natural gas consumption has increased from 2005 to 2018 by 11.2 percent. Non-residential consumption has steadily increased since 2005, whereas residential consumption has fluctuated. Note that in 2015, natural gas became the energy source with the highest number of emissions.

Figure 5. Natural Gas Use

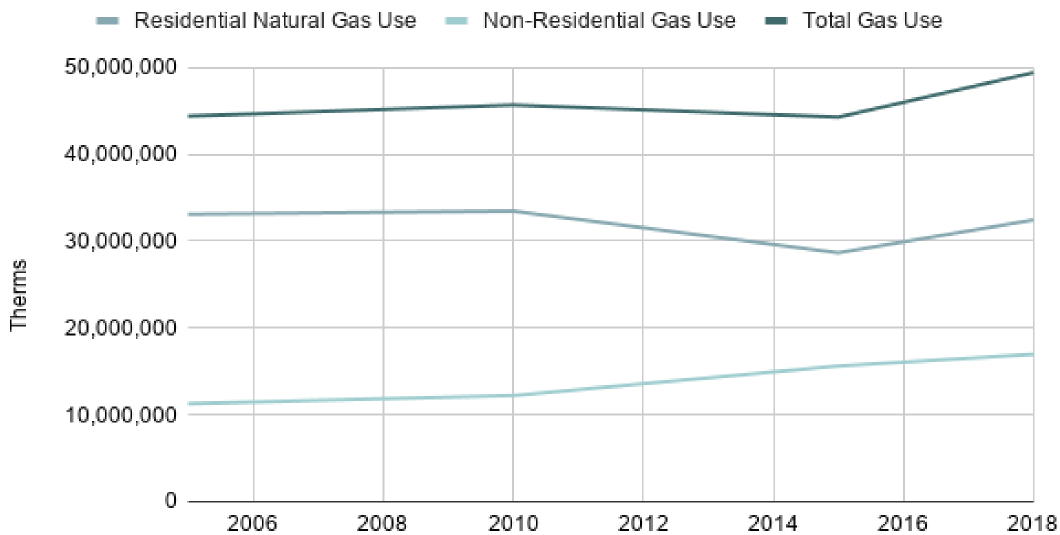
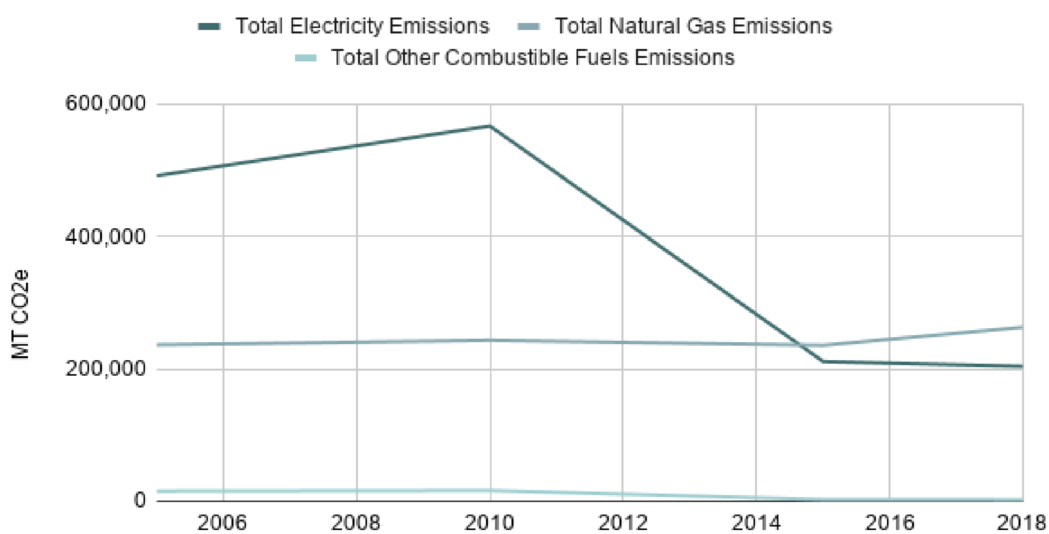


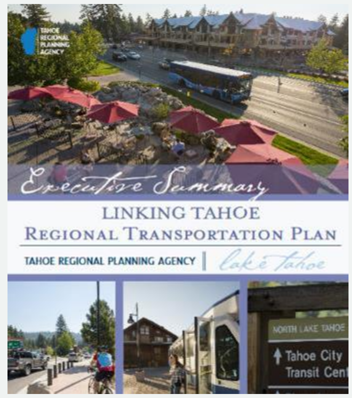
Figure 6. Emissions by Energy Type



[30] Natural Gas data provided by Southwest Gas. Located in the Community-Master-Data-Workbook.

As shown in **Figure 6**, emissions from electricity increased from 2005 to 2010, decreased substantially between 2010 and 2015, and kept decreasing between 2015 and 2018. Residential natural gas emissions fluctuated from 2005 to 2018, while non-residential emissions steadily increased. From 2005 to 2018, other sources of fuel (propane, fuel oil, and wood) remained relatively similar, but did decrease between 2015 and 2018. Refer to **Appendix A** for data on 2015 and 2018 emissions factors.

Transportation Emissions

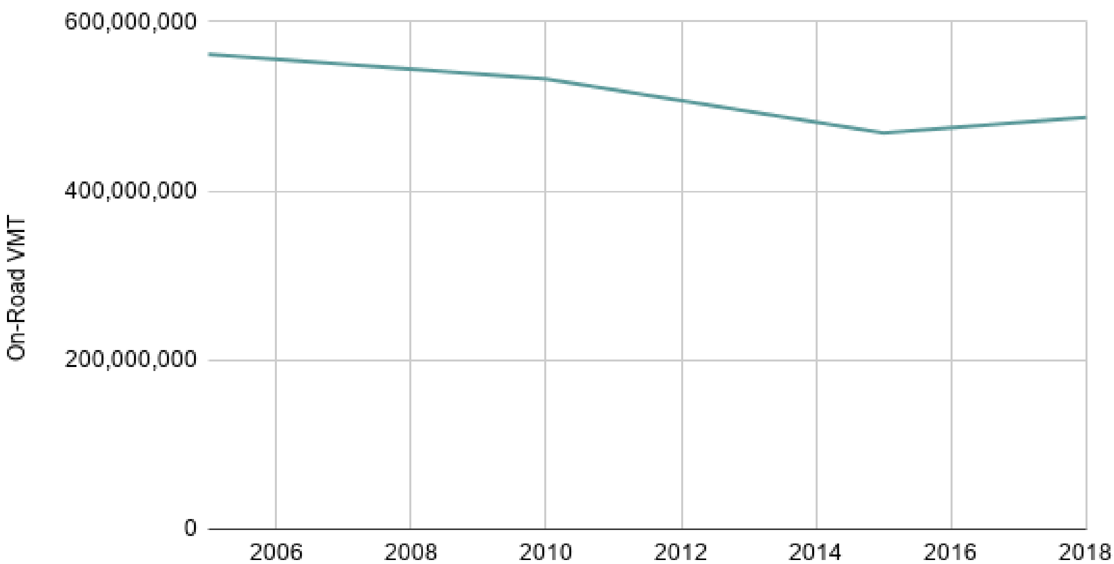


Transportation is a major source of GHG emissions in the Tahoe Region. The 2020 Lake Tahoe Regional Transportation Plan (RTP) identifies a variety of strategies to reduce those emissions including electric vehicles, connections to land-use, and expansion of transit, trails, and technology.

The RTP also serves as the Sustainable Communities Strategy for California SB 375. The RTP estimates that the California portion of the region will achieve -13.7 percent. Similar reductions are expected in Nevada.

Transportation

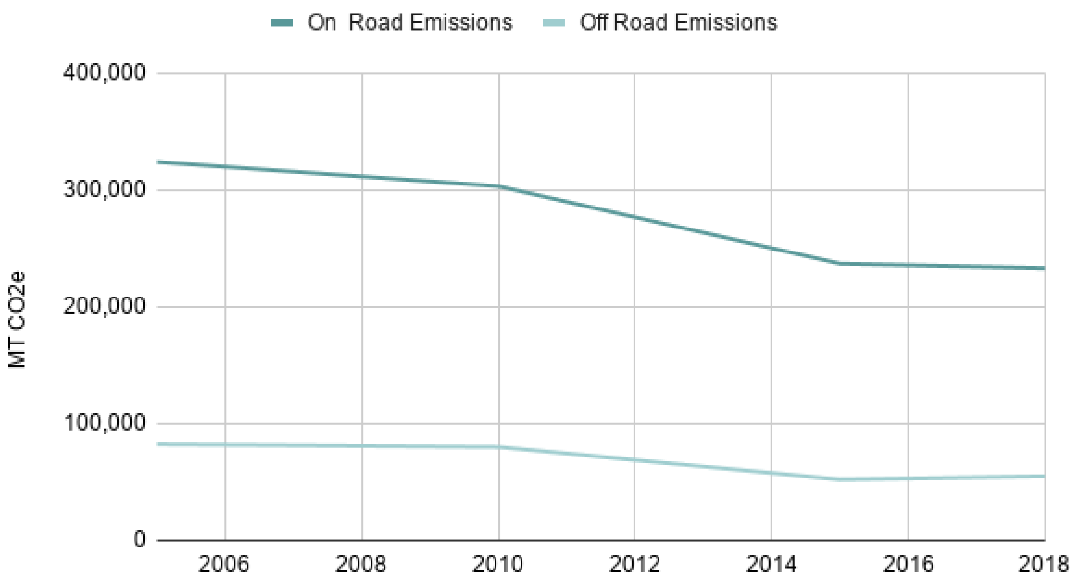
Figure 7. On-Road VMT



Climate change and its impacts pose significant and growing risks to the safety, reliability, effectiveness, and sustainability of the basin and its transportation network. Many impacts are already occurring, and Lake Tahoe communities need to adapt to become more resilient to these changes.

On-Road VMT declined 13 percent from 2005 to 2018, although it did experience a relative increase from 2015 to 2018.[31]

Figure 8. On-Road and Off-Road Emissions



The net reduction in emissions from on-road transportation outpaced the reduction in VMT, suggesting that improved vehicle fuel efficiency played a role in reducing emissions in addition to regional transportation projects. This is supported by the fact that on-road VMT actually increased from 2015 to 2018 yet emissions from on-road transportation still decreased slightly. The increasing adoption of electric vehicles (EV) may have also contributed to reductions in emissions from on-road transportation. However, because EV adoption is still in early phases, we expect it will have a greater impact in future years and future inventories.

Table 5. Transportation Emissions

	2005	2010	2015	2018	2005-2018 Percent Change
On-Road VMT	561,767,120	532,644,135	468,740,569	487,236,693	-13.27%
On-Road Emissions (MT CO_2e)	324,097	303,295	237,028	233,201	-28.05%
Off-Road Emissions (MT CO_2e)	82,518	80,166	52,126	55,006	-33.34%

[31] On-Road data provided by TRPA. Off-Road data provided by EMFAC (California Air Resources Board). Aviation and boating data provided by City of South Lake Tahoe GHG Inventories. Fuel consumption data provided by respective counties. Located in Community-Master-Data-Workbook.

Solid Waste

Total waste sent to landfills from 2005 to 2018 declined 51 percent from 2005 to 2018, with the reduction primarily occurring between 2010 and 2015.[32] From 2015 to 2018, the amount of solid waste sent to landfills increased. Solid waste generated in the basin is primarily sent to the Lockwood Landfill, with a small portion that is generated in Unincorporated Douglas, El Dorado and City of South Lake Tahoe sent to the Carson City landfill. In the graph below, you can see that while total waste sent to landfills increased from 2015 to 2018, the amount of waste sent to Lockwood Landfill decreased as a larger amount of waste was sent to the Carson City landfill. There was no waste sent to Carson City Landfill in 2005 or 2010.

Figure 9. Total Waste Landfilled

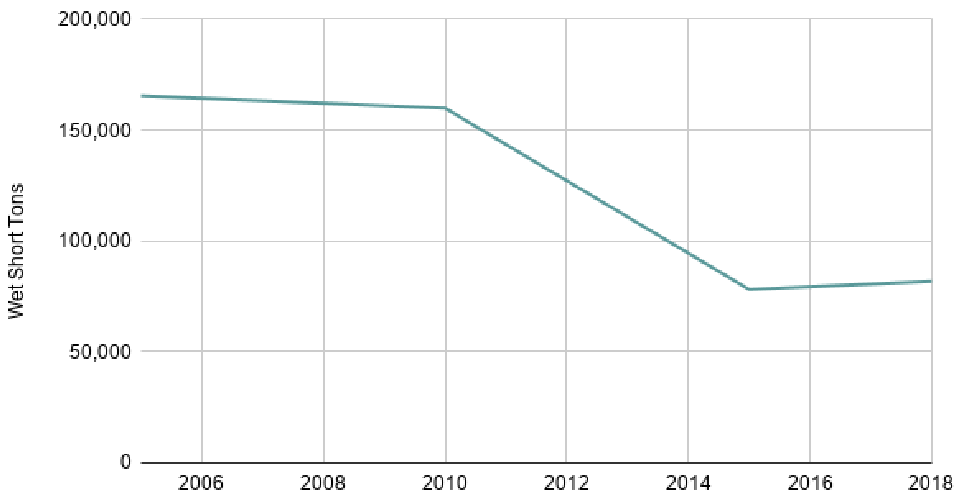


Table 6. Total Waste Landfilled

	Wet Short Tons			
	2005	2010	2015	2018
Lockwood Landfill	165,460	159,915	75,536	62,296
Carson City Landfill	0	0	2,620	19,552
Total Waste Landfilled	**165,460**	**159,915**	**78,156**	**81,848**

While the largest reduction in solid waste generation occurred from 2010 to 2015, the largest reduction in emissions generated by solid waste actually occurred from 2005 to 2010. During that time, Lockwood

[32] Solid waste data provided by South Tahoe Refuse and Tahoe Truckee Sierra Disposal. Located in Community-Master-Data-Workbook.

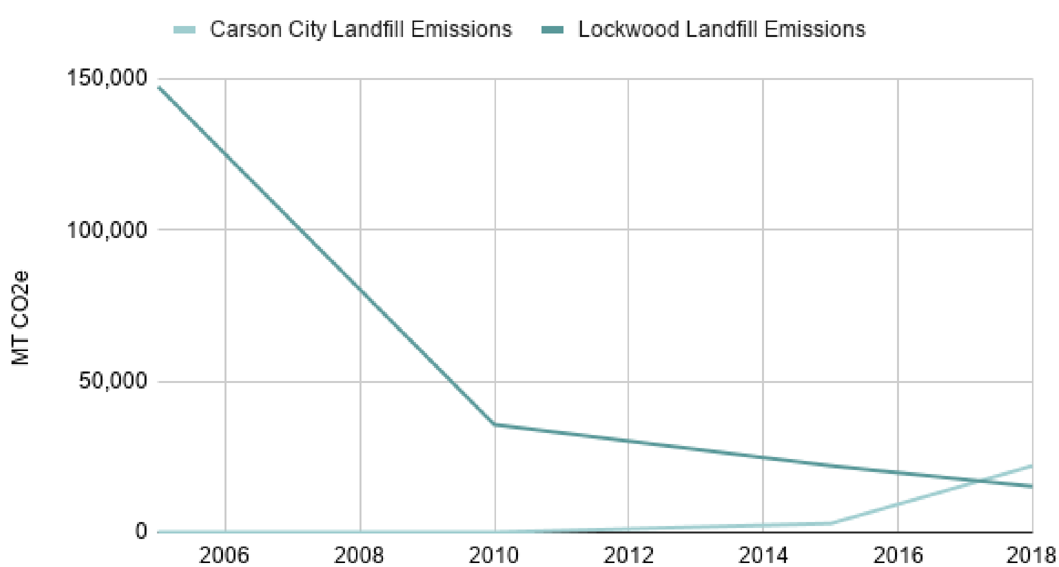
Landfill installed a methane capture system on site, reducing the amount of methane released into the atmosphere by waste as it breaks down in the landfill. The system captured nearly 75 percent of landfill gas emissions, which was with the 3 percent reduction in solid waste sent to the landfill resulting in a nearly 76 percent reduction in emissions. By comparison, from 2010 to 2015 the amount of solid waste sent to landfills declined by just over 51 percent and emissions declined by 30 percent. This can be attributed to a combination of changes in waste stream composition and improvements in methodology that more accurately capture emissions from solid waste decomposition.

Waste Reductions Programs

Regional organizations implement waste reduction programs, such as Incline Village General Improvement District's Waste Not program and South Tahoe Refuse's waste reduction and recycling programs. California has goal of 75% waste diversion from landfills which will influence emissions over time as that goal is reached.

From 2015 to 2018, solid waste sent to landfills increased only 5 percent but emissions increased by nearly 50 percent. Increased diversion of waste to the Carson City Landfill caused this disproportionate increase in emissions. Unlike Lockwood Landfill, the Carson City landfill does not have a methane capture system. This means that waste sent to the Carson City Landfill releases far more GHG emissions into the atmosphere than waste sent to Lockwood. This is represented by the diverging slopes of the turquoise and light blue lines in the graph below, with the distance between them representative of the GHG emissions resulting from waste sent to Carson City Landfill.

Figure 10. Total Waste Emissions

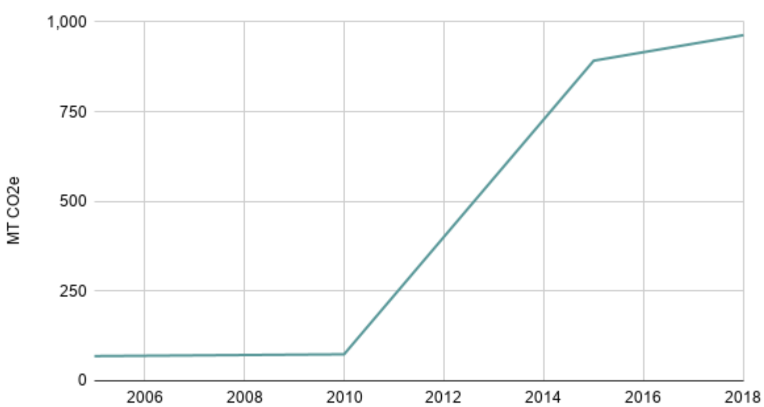


Wastewater

> **Local Water Treatment Efforts**
>
> The South Tahoe Public Utility District (the District) is actively working to reduce GHG emissions while providing the South Lake Tahoe community with delicious Tahoe Tap and reliable wastewater services. The District recycles 100% of its treated wastewater and biosolids and recently began producing renewable energy through the hydro-electric turbine on their recycled water system. The District's System Efficiency and Sustainability Committee continues to evaluate and implement efficiency measures, such as time of use pumping, replacing aging and inefficient infrastructure and assets, electrifying the fleet, and pursuing a solar energy project at the wastewater treatment plant.

On the surface wastewater sector emissions increased by 1100 percent from 2010 to 2015.[33] However, this large increase can be attributed to incorporation of a new methodology for calculating emissions generated by the wastewater sector. Previous methodologies only accounted for emissions released by wastewater as it was being treated at wastewater treatment plants. More recent methodologies have been developed that also account for emissions from wastewater effluent that is discharged after it has been treated. In addition, there are now methodologies that account for the release of GHGs from the use of fossil fuel-derived methanol in the wastewater treatment process. Accounting for these additional emissions was the primary factor for the massive increase in emissions produced by the wastewater sector from 2010 to 2015. Without accounting for these additional emissions, the sector would have still seen an increase in emissions, but on a much smaller scale of only 9 percent. Emissions from water treatment and wastewater generation are also produced through electricity and natural gas consumption. Electricity and natural gas emissions, however, were accounted for in the respective basin-wide calculations and were considered "information only" items in this section to avoid double counting.

Figure 11. Wastewater Emissions

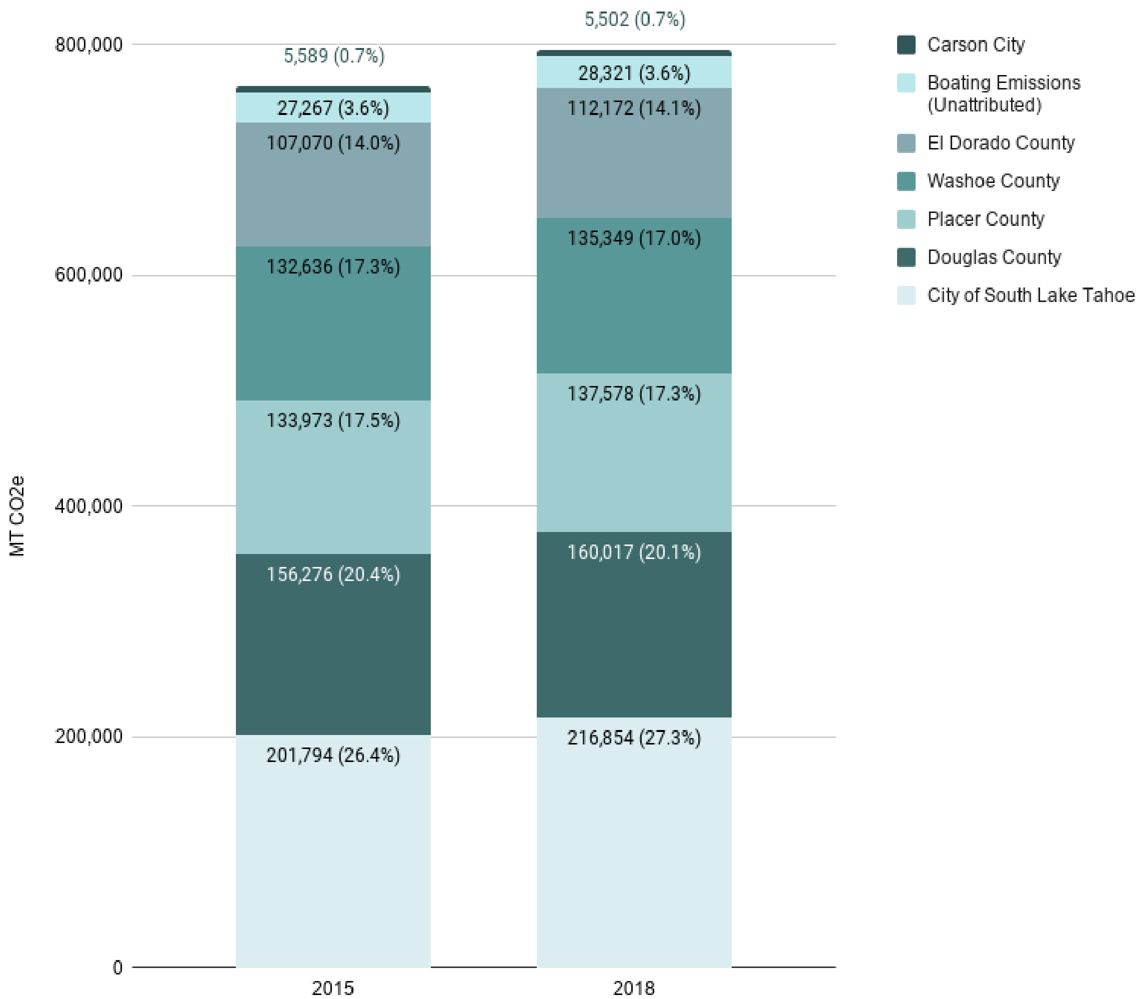


[33] Water and wastewater data provided by South Tahoe Public Utility District, Tahoe-Truckee Sanitation Agency, Tahoe City Public Utility District, North Tahoe Public Utility District, Round Hill General Improvement District, Kingsbury General Improvement District, Douglas County Water Utilities, and Glenbrook Water Cooperative. Located in Community-Master-Data-Workbook.

Emissions by Jurisdiction

To better inform planning and project implementation, it is important to understand emission by source for each jurisdiction within the Tahoe Region. Understanding emissions by jurisdiction highlights differences in emission source and intensity at a local scale. This can inform local decision makers, planners, and project implementers. The figure below shows emission from 2015 and 2018 by jurisdiction.

Figure 12. Greenhouse Gas Emissions by Basin Jurisdiction



Note: Boating emissions were calculated using information on boat usage and fuel types taken from the City of South Lake Tahoe GHG Inventories[34] and TRPA's Shoreline Plan[35]; however, boating activities could not be

[34] Anderson, M., Ruderman, S. (2019). City of South Lake Tahoe Community-Wide & Government Operations Inventories for 2015. City of South Lake Tahoe and Sierra Nevada Alliance.

[35] Shoreline Implementation Program. (2018). Tahoe Regional Planning Agency.

attributed to specific jurisdictions since once a boat launches, it can travel anywhere on the lake. As a result, boating emissions are shown in total rather than being incorporated into individual jurisdictional emission profiles.

Although actual percentages may have changed slightly, the relative ranking of GHG emissions by jurisdiction from lowest to highest remained constant across 2015 and 2018: Carson City, NV; followed by El Dorado County, CA; Washoe County, NV; Placer County, CA; Douglas County, NV; and City of South Lake Tahoe. Carson City emissions represent the small amount of on-road transportation that occurs in the Carson City portion of the Basin.

Figure 13. 2018 El Dorado County Emissions by Sector

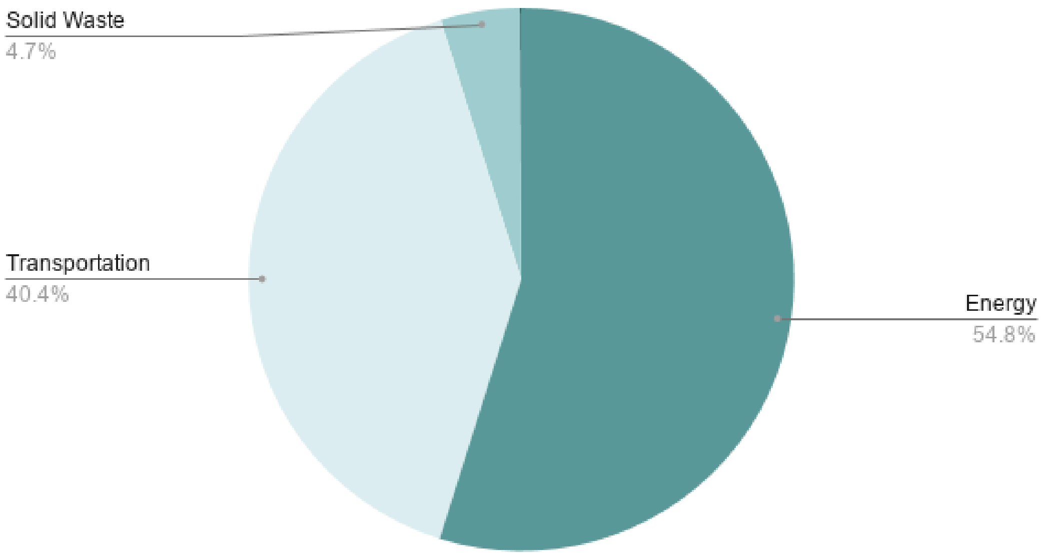


Figure 14. 2018 Washoe County Emissions by Sector

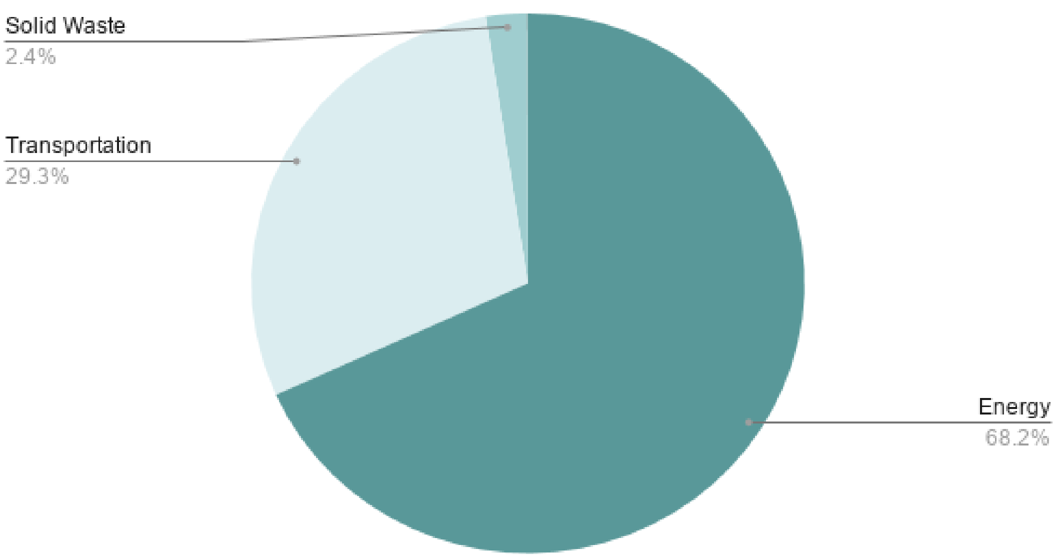


Figure 15. 2018 Placer County Emissions by Sector

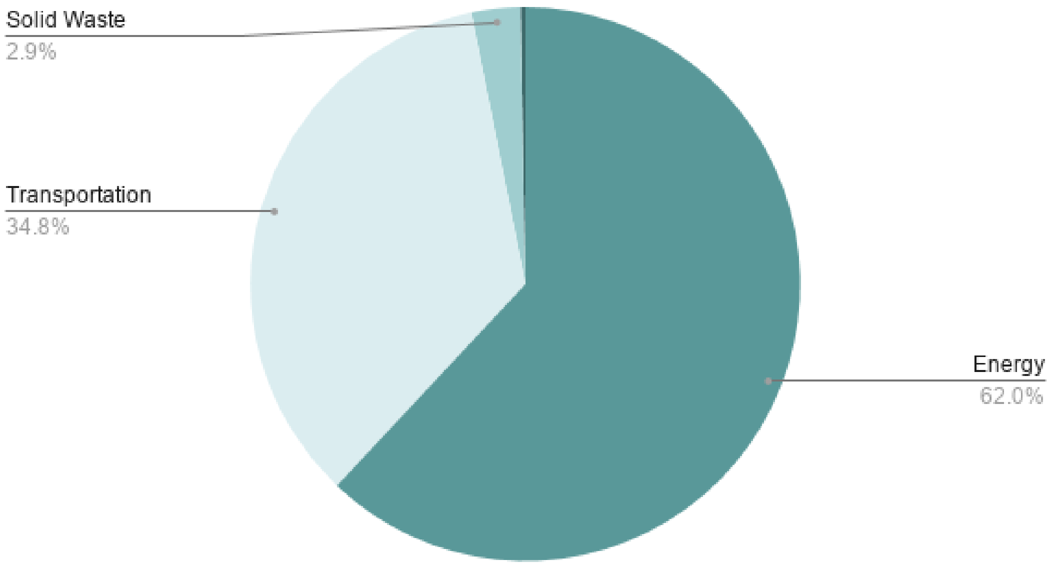


Figure 16. 2018 Douglas County Emissions by Sector

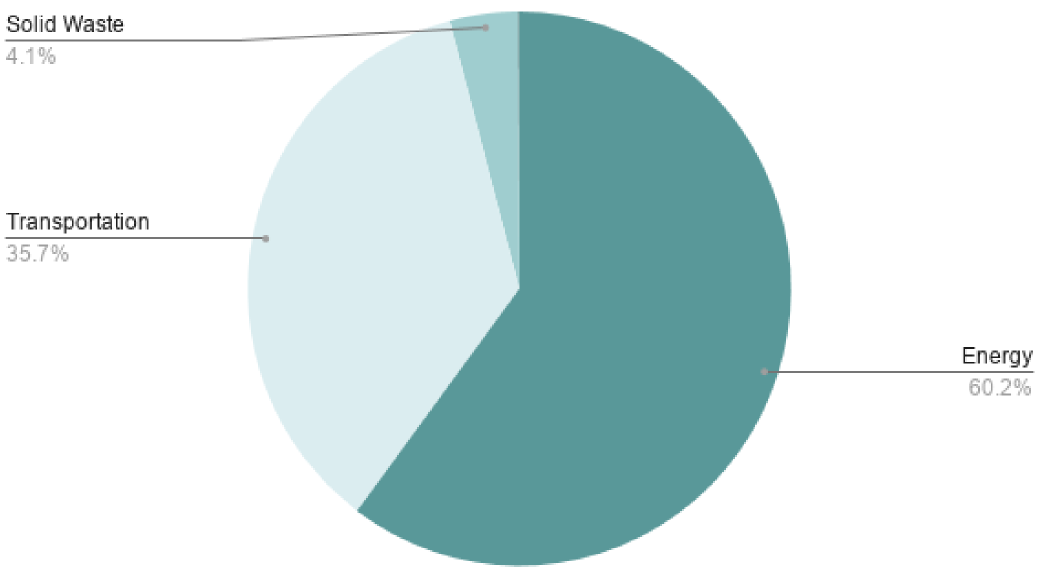


Figure 17. 2018 City of South Lake Tahoe Emissions by Sector

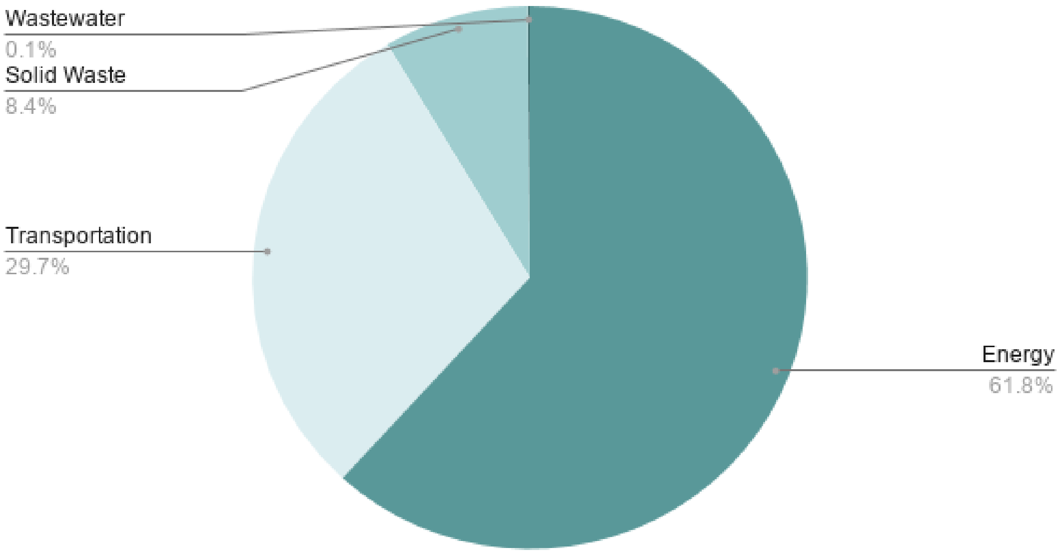


Table 7. 2018 Total Emissions by Jurisdiction

Sector	City of South Lake Tahoe	Douglas County	Placer County	Washoe County	El Dorado County	Carson City	Boating (Unattributed)
Energy	132,105	94,506	84,065	90,526	60,567	--	--
Transportation	64,378	57,093	47,894	39,711	45,309	5,502	--
Solid Waste	18,312	6,497	3,942	3,246	5,247	--	--
Wastewater	286	107	405	58	107	--	--
T&D Losses	1,772	1,813	1,273	1,808	942	--	--
Total	**216,854**	**160,017**	**137,578**	**135,349**	**112,172**	**5,502**	**28,321**

Note: All values in MT CO_2e.

Emissions Forecast

After inventorying current emissions, the next step is to look at the level of emissions one could expect to see in the future for the same sectors, also known as a business-as-usual (BAU) Forecast. The BAU scenario takes the emissions from a snapshot in time and projects them out over time on a per capita basis, assuming no other changes or variables that might otherwise affect emissions. In general, emissions forecasting does not account for any local, state, or federal policy that would impact future greenhouse gas emissions, nor does it account for potential changes in technology or individual consumption behavior. The BAU forecast estimates how annual emissions would change from 2018 to 2030, to 2035, and to 2045. These years align with existing regional, local, and statewide emission reduction goals. A BAU and adjusted forecast require two inputs, baseline emissions data and growth rates, both of which are presented in **Appendix B**. Growth rates were calculated using projections of housing units, commercial square footage, and several other indicator variables.

Rate of Change Projection

For example, to forecast residential energy, the team looked at projected change for the number of households throughout the basin out to 2045, then applied that rate of change to the emissions coming from the residential energy sector, using a number of indicator variables for different sectors and subsectors to arrive at our BAU forecast.

Calculating the emissions forecast is achieved by isolating an indicator variable for the various sectors and sub-sectors that were evaluated in the inventory and then assess how that indicator variable is projected to grow into the future and apply that rate of change to the emissions from that sector or sub-sector. The main energy sectors consist of residential and non-residential energy sub-sectors.

Table 8. Emissions Forecast Variables & Data Sources

Sector	Sub-sector	Indicator Variable	Data Source
Energy	Residential Energy	Residential Units	TRPA Regional Transportation Plan
	Non-Residential Energy	Commercial Floorspace	TRPA Regional Transportation Plan
Transportation	On-Road Transportation	Vehicle Miles Traveled	TRPA Regional Transportation Plan
	Air-Travel	Airport Operations Activity	FAA Airport Operations Forecast
	Boat Travel	Boating Operating Hours	TRPA Shoreline Plan
	Other Off-Road Emissions	Combination of Residential Units and Commercial FloorSpace	TRPA Regional Transportation Plan
Solid Waste	Solid Waste	Combination of Residential Units and Commercial FloorSpace	TRPA Regional Transportation Plan
Wastewater	Wastewater	Population	TRPA Regional Transportation Plan

Under the BAU scenario, from 2018 to 2030, to 2035, and to 2045, emissions were forecast to increase by 2.3 percent, 3.3 percent, and 5.7 percent, as shown in **Table 8**. This equates to 841,121 MT CO_2e in 2045, as shown in **Figure 18**.

Figure 18. Basin-Wide Greenhouse Gas Emissions Forecast

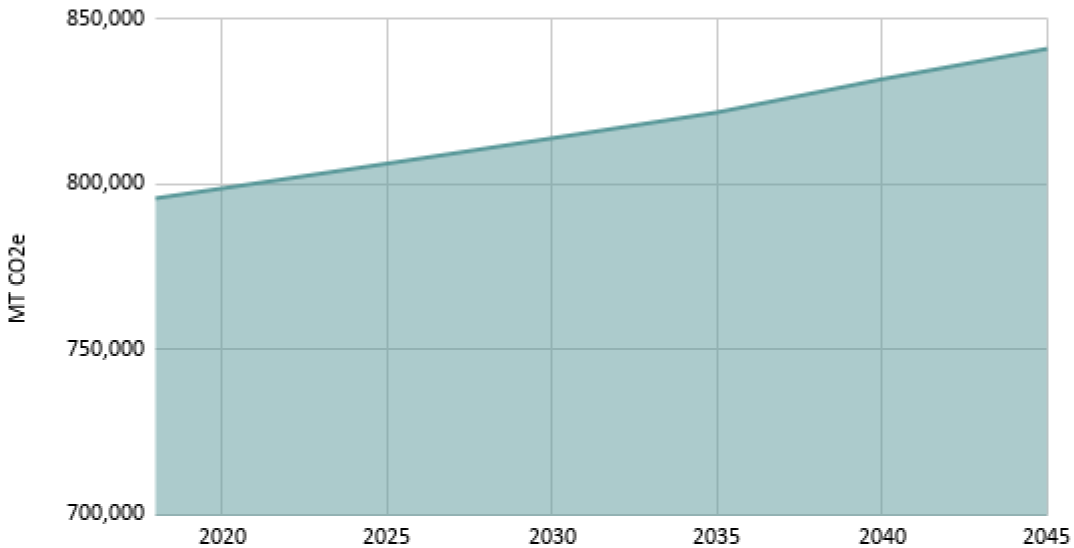


Table 9. Forecasted Emissions by Sector

	Forecasted Emissions by Sector (MT CO_2e)					
Year	Energy	Transportation	Solid Waste	Wastewater	Total	Percent Change in Total Emissions Since 2018
2018	469,380	288,207	37,244	963	795,794	--
2030	483,541	290,977	38,457	1,014	813,990	2.3%
2035	489,592	292,221	38,976	1,037	821,826	3.3%
2045	501,966	298,034	40,039	1,083	841,121	5.7%
Net Percent Change	**6.9%**	**3.4%**	**7.5%**	**12.4%**	**5.7%**	**--**

Inventory of Aging Infrastructure

To provide a basis for estimating the energy and emissions benefits of potentially transferring development out of sensitive areas like stream environment zones (SEZs), an initial inventory of aging infrastructure was developed using the geospatial software, UrbanFootprint. As described in the methodology section above, the UrbanFootprint software provides a comprehensive view of building type and size, to which energy usage/intensities can be applied. As an example, **Figure 19** shows a map zoomed in on the South Lake Tahoe area, where different colors indicate different building and land use types. Application of national average energy use intensities -- from the U.S. Energy Information Administration's Residential Energy Consumption Survey[36] and Commercial Buildings Energy Consumption Survey[37] datasets -- to each building type resulted in an estimate of current energy use throughout the basin. With this baseline, TRPA or other agencies can estimate potential energy savings and resulting emissions reductions if certain building types were removed from or their energy usage reduced within the SEZ.

Figure 19. UrbanFootprint Aging Infrastructure in South Lake Tahoe

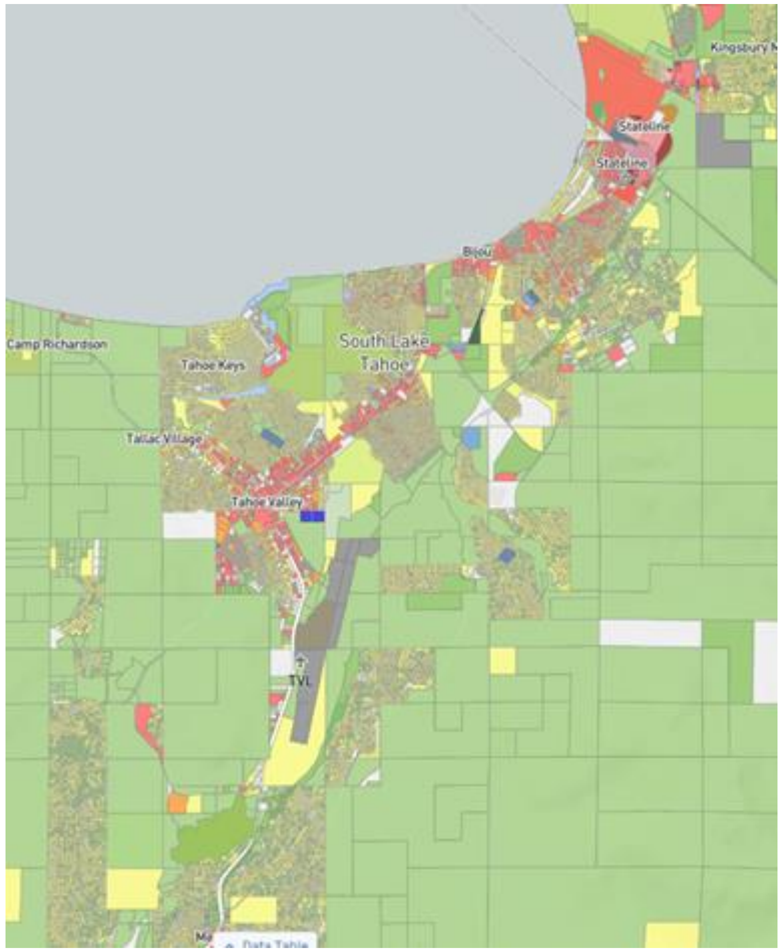


Table 10 and **Table 11** below show the annual baseline electricity and natural gas usage amounts by residential and commercial building types and how that usage and associated emissions would drop based on different overall reduction scenarios.

[36] Residential Energy Consumption Survey. (2020). U.S. Energy Information Administration.

[37] Commercial Buildings Energy Consumption Survey. (2020). U.S. Energy Information Administration.

This analysis looked at three different percent reduction scenarios; but the tool can be used in the future to evaluate potential benefits of specific changes in building profiles in different areas, such as if current SEZ development shifts to urban areas or potentially into newer construction with a lower energy use profile, or if developments are eliminated altogether and the SEZ area is restored. Additionally, UrbanFootprint's technical resources could support further investigation of development scenarios, including financial models, TRPA development rights models, and collaboration with state housing program developer models.

Applying the Research

For example, there could be a motel located within a SEZ. By looking at the number of square feet occupied by the hotel buildings, the climate zone where the hotel building is located, and the energy use or intensity associated with a hotel building type in that climate zone, one can estimate the amount of electricity kilowatt hours, natural gas therms, and carbon equivalent emissions that could be saved if that building were removed from the SEZ or otherwise retrofitted to reduce energy consumption.

Initial findings from this evaluation indicate that approximately one-fifth, or 20 percent, of the basin's total building energy use is occurring in SEZs.

Table 10. Tahoe Basin Building Energy Use in Stream Environment Zones

Energy Type	Percent of Energy Use Occurring in SEZ
Electricity Use	22%
Natural Gas Use	19%
Total Energy Use	**20%**

From this baseline estimate, three different reduction goals as articulated by Architecture2030's Zero Tool were applied to see what anticipated energy savings could be expected if the basin's existing building stock were to be reduced to achieve those stated goals.

2030 Challenge Reduction Targets for Existing Buildings:

- 20 percent today
- 35 percent in 2025
- 50 percent in 2030

Table 11. Annual Electricity Use and Reduction Potential by Building Type

	Annual Electricity Use, kilowatt-hours / year (millions)			
	Base Scenario	20% Energy Reduction	35% Energy Reduction	50% Energy Reduction
Residential Electricity Use	185.92	148.74	120.85	92.96
Commercial Electricity Use	386.08	308.87	250.95	193.04
Total	**572.01**	**457.60**	**371.80**	**286.00**

Table 12. Annual Natural Gas Use and Reduction Potential by Building Type

	Annual Gas Use, therms / year (millions)			
	Base Scenario	20% Energy Reduction	35% Energy Reduction	50% Energy Reduction
Residential Natural Gas Use	13.83	11.07	8.99	6.92
Commercial Natural Gas Use	11.28	9.02	7.33	5.64
Total	**25.11**	**20.09**	**16.32**	**12.56**

From there, the baseline estimate was filtered to determine the amount of energy being used by the buildings located in SEZs. This exercise found that approximately 20 percent of energy use in the basin is occurring in SEZs, of which the overwhelming majority is used in commercial buildings. **Tables 12** and **13**, below, detail the percent basin-wide annual energy use for electricity and natural gas in SEZ territories.

Table 13. Annual Electricity Use by Buildings in Stream Environment Zones

	Annual Electricity Use, kilowatt-hours / year (millions)	
	Base Scenario	Percent Basin-Wide Energy Use
Residential Electricity Use	12.50	7%
Commercial Electricity Use	113.08	29%
Total	**125.58**	**22%**

Table 14. Annual Natural Gas Use by Buildings in Stream Environment Zones

	Annual Gas Use, therms / year (millions)	
	Base Scenario	Percent Basin-Wide Energy Use
Residential Natural Gas Use	0.92	7%
Commercial Natural Gas Use	3.80	34%
Total	**4.73**	**19%**

The UrbanFootprint tool provides the ability to overlay different data sets to reveal the ways in which they interact. By merging SEZ parcel data with commercial center energy use data and GHG emissions data, a map can be built that displays intersecting points of interest between these data sets. Below are snapshot images (**Figures 20** to **23**), broken into south shore, north shore and the west shore, that highlight areas of SEZ parcels with high building energy use and GHG emissions. Portions of the east shore did not demonstrate notable data due to a scarcity of development, therefore no map is included of that region.

Analysis Process

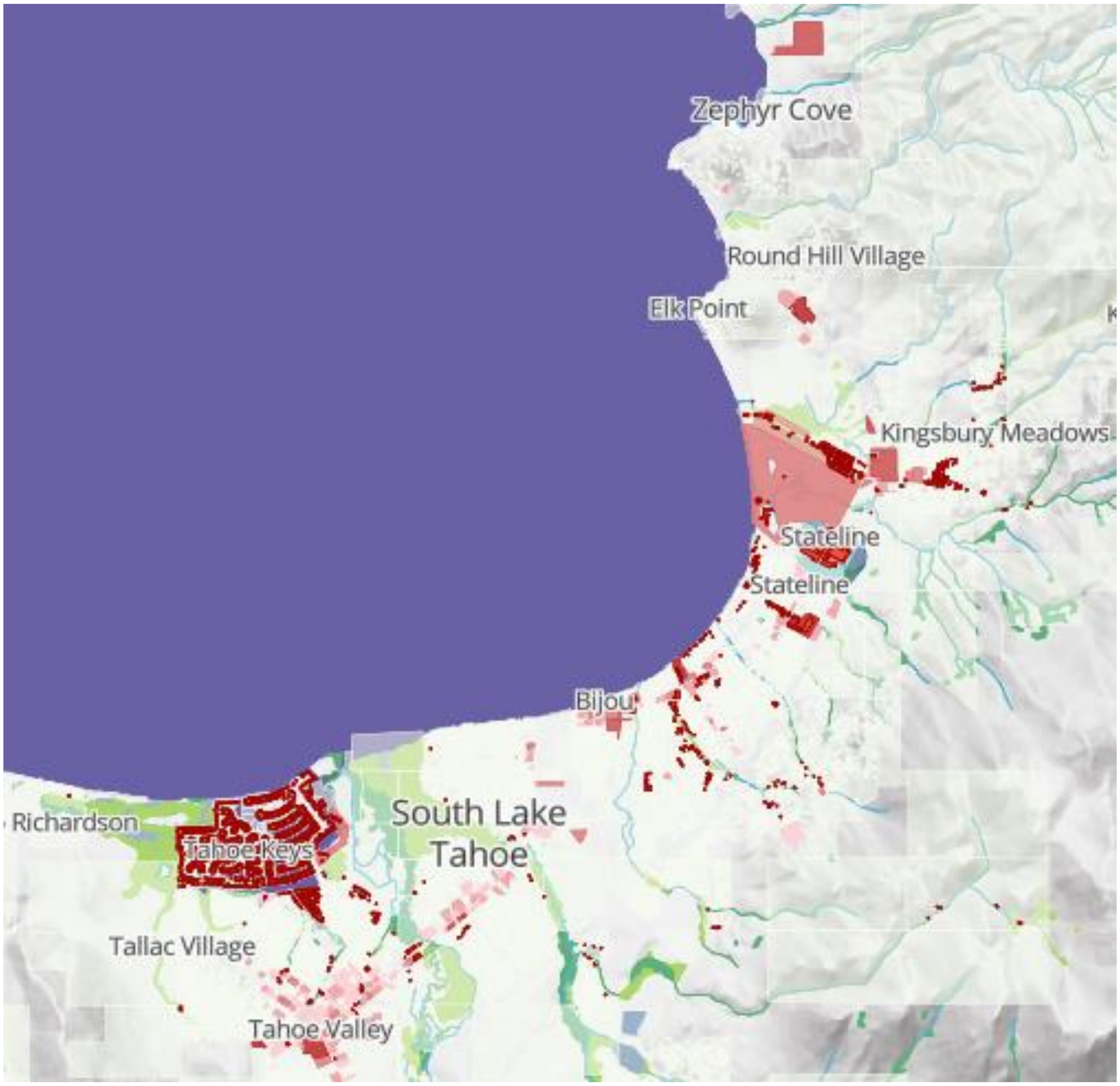
UrbanFootprint allows planners to evaluate the geographic distribution of key factors such as how much energy is being used by different building types in a particular area, the emissions associated with that energy use, or how many housing units or commercial buildings are located with a certain distance of a specific criterion, such as SEZ, Town Center, or transit stop. In addition, planners can explore the effects of different land use, population, or other scenarios -- such as looking at potential outcomes of existing planning efforts that aim to transfer development out of SEZs -- and compare potential outcomes across those scenarios or planning alternatives by applying the emissions calculation:

$$GHG_{electricity\text{-}use} = Electricity_{(kwh)} \times ElectricityEmissionRate_{(lbs/kwh)}$$

With additional analysis modules, the UrbanFootprint tool can also look at other resource consumption types beyond energy, such as water use, to create an even more robust picture of potential benefits associated with different planning or policy scenarios.

The UrbanFootprint GHG emissions module uses data pulled from generalized estimates of transportation and building energy and water use. Using this module, the analysis showed that the Stateline area has the highest energy use and emissions outputs located in SEZs, demonstrating the potential for future actions to further improve energy use and transportation mitigation measures (see **Figure 21** below).

Figure 20. Map of South Shore Energy Use and Emissions in Stream Environment Zones



Legend

Buildings located on SEZ

GHG Emissions Metric Tons / Year	Energy Use BTUs / Year
0 - 4,695	0 - 408,996,628
4,695 - 9,390	408,996,628 - 1,459,465,612
9,390 - 14,085	1,459,465,612 - 3,116,953,794
14,085 - 18,780	3,116,953,794 - 6,119,837,259
18,780 - 23,476	6,119,837,259 - 10,369,010,127

Figure 21. Map of Enlarged Image of Stateline South Shore Energy Use and Emissions in Stream Environment Zones

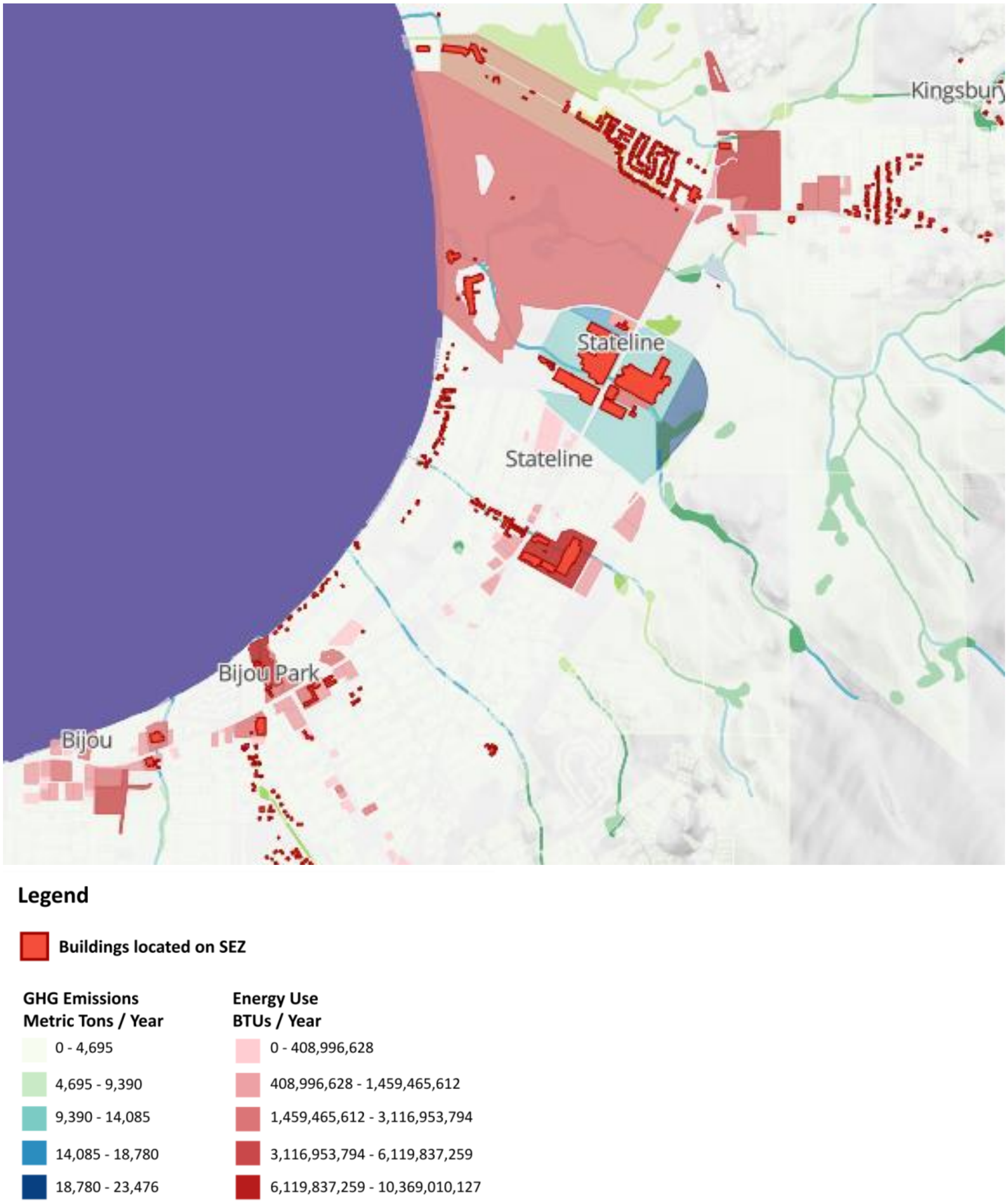


Figure 22. Map of North Shore Energy Use and Emissions in Stream Environment Zones

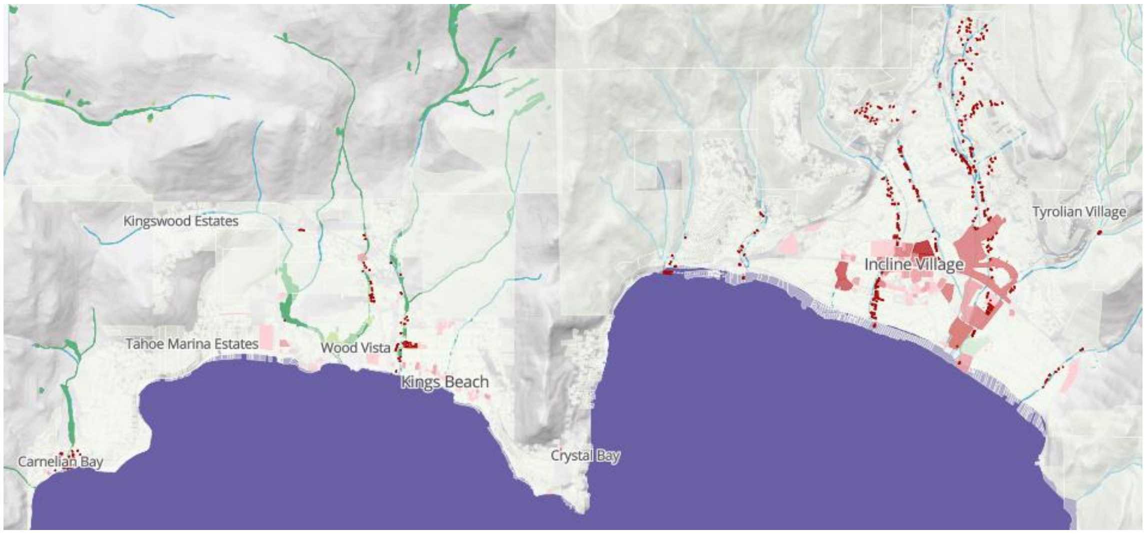
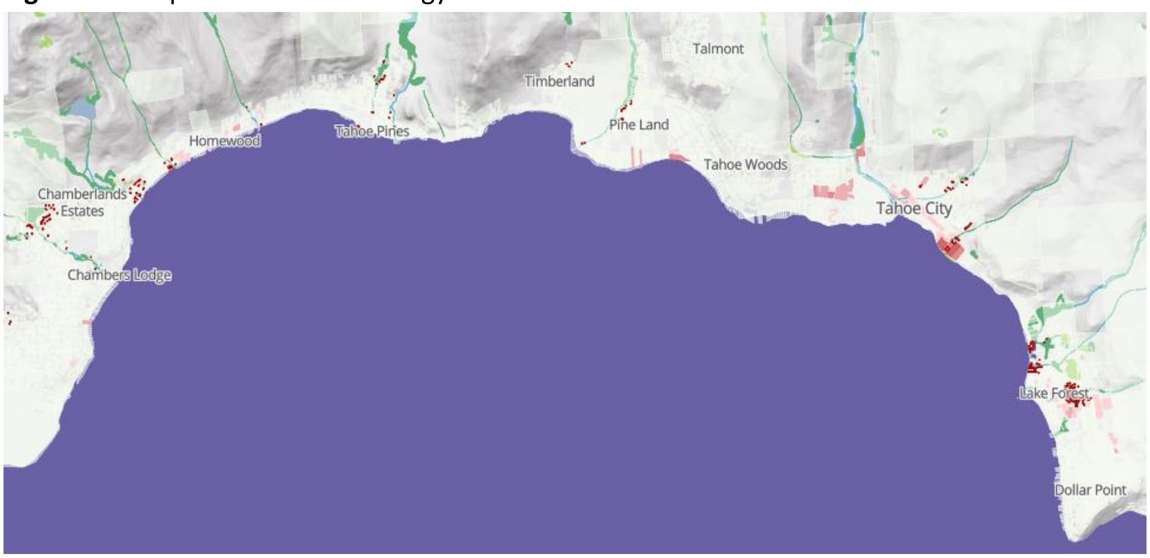
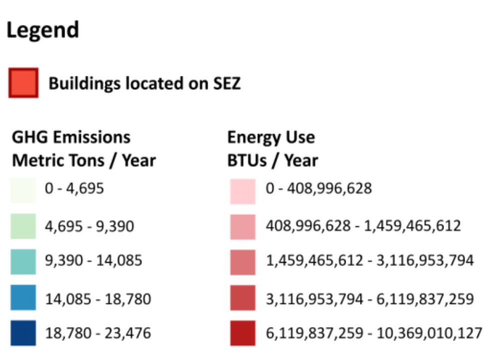


Figure 23. Map of West Shore Energy Use and Emissions in Stream Environment Zones



(*Note: orientation for the West Shore has been rotated by 90 degrees.)*



One note on the use of UrbanFootprint, it is not as conducive to collaboration and sharing as other tools, such as CalEEMod.[38] But it is a useful tool that can be tailored to some degree, and subscriptions are available free of charge for California government planning departments through a civic partnership between UrbanFootprint, the State of California, and venture firm Social Capital.[39]

Built Environment Conclusions & Recommendations

These Chapter 1 findings identify the major sources of GHG emissions within the basin and provide a starting point for setting reduction targets and identifying potential mitigation strategies that can be implemented to meet those reduction targets in the future. As TRPA moves forward with considering emissions reduction strategies and works to develop sustainable climate action, TRPA should work with stakeholders and the community to identify and quantify the emissions reduction benefits of climate and sustainability strategies that could be implemented in the future, including energy efficiency, renewable energy, vehicle fuel efficiency, alternative transportation, vehicle trip reduction, land use planning, waste reduction, and other strategies. We offer the following recommendations for improving these inventories and future strategic planning:

- Develop adjusted scenario forecasts
    - The BAU Forecast does not account for impacts of any existing policies or future technology changes. There are numerous planning efforts and regulations already underway in the basin. Potential next steps would include developing one or more adjusted scenario forecasts that do account for those potential impacts. Examples of policies that may be taken into account in an adjusted scenario include state level regulations in CA and NV that require utilities to source increasing amounts of electricity from renewable sources. When implemented, TRPA's latest RTP is forecasted to reduce emissions from on-road transportation by 13.7 percent for the California portion of the Tahoe Basin.
    - Examples of existing policies that could be used for adjusted scenario forecasting:
        - State Level - Regulations requiring utilities to source increased amounts of renewable electricity exist:
            - CA: 60 percent renewable electricity by 2030, 100 percent carbon free electricity by 2045;
            - NV: 50 percent renewable electricity by 2030, goal of 100 percent by 2050;
            - As electricity continues to be generated from more and more renewable sources, additional opportunity for emissions reductions will become

[38] California Emissions Estimator Model (CalEEMod). (2017). California Air Pollution Control Officers Association.

[39] Let's Build a Sustainable Future for California. (2021). UrbanFootprint.

available by electrifying natural gas combusting activities, like space heating and water heating.

    - Local Level:
        - By 2045 TRPA's RTP is forecasted to reduce on-road transportation emissions by 13.7 percent for California portion of the Tahoe Basin;
        - City of South Lake Tahoe's 100 percent renewable goal.

- Conduct regular GHG Inventory updates
    - Ongoing GHG emissions inventories will continue to track emissions to monitor reductions efforts and inform future planning efforts.
    - Future inventories will continue to improve in accuracy due to data and inventory methodology updates.
- Collaborate with stakeholders to create a climate resiliency framework
    - Coordinate with TRPA and Lake Tahoe Basin partners and their planning efforts (Sustainability Action Plan, RTP, etc.) to use this built environment inventory as a new baseline to further inform emission reduction efforts. Examples could include the Tahoe Truckee plugin vehicle readiness plan, the California Tahoe Conservancy's Vulnerability Assessment and upcoming Climate Adaptation and Action Portfolio, and other efforts. Such coordination could allow partner agencies to work together to create a climate resiliency framework for the Tahoe Region that brings federal, State and local goals and policies, regional programs, priority projects, and current activities together to further advance climate-related efforts.
- Consider building upon the aging infrastructure analysis
    - Conduct further research into the geographic key issue that prevented the successful use of TRPA-specific parcel data in place of the UrbanFootprint tool's default data to get even more refined results. Use of TRPA's detailed parcel data in UrbanFootprint will help identify high priority aging buildings in SEZ territory. Energy use data can then be gathered and analyzed to determine GHG emissions profiles for these high priority buildings.
    - Continue to refine the tool's accuracy by sourcing more granular data and more recent data, as it becomes available.
    - Consider the use of additional UrbanFootprint analysis modules that can provide scenario-based data around other resource sectors, such as water use.
    - Seek technical support from UrbanFootprint or other expert users to determine ways in which UrbanFootprint can more specifically provide a cost/benefit analyses of different development or redevelopment scenarios, such as transferring development out of SEZs into urban areas, testing emissions results from new construction, or eliminating certain buildings/developments altogether. Using UrbanFootprint technical support, additional development scenarios can be investigated, including financial models, TRPA

development rights models, and collaboration with State housing program developer models.
    - Encourage other government jurisdictions in the basin to take advantage of the UrbanFootprint civic program that offers a free subscription to planning departments at various state, regional, and local planning departments, and offer data from this project to conduct further analysis on the potential emissions reduction benefits of different land use and building type/location scenarios.
- Consider using CalEEMod for a singular but more precise evaluation of specific scenarios
    - CalEEMod is a statewide land use emissions model that provides a uniform platform to quantify, identify ways to potentially reduce, and calculate associated benefits of reducing GHG emissions and criteria pollutants associated with both construction and operations from a variety of land use project types. CalEEMod is also free and available to anyone, allowing for easy replication of analyses.
- Conduct a life cycle assessment of landfill materials
    - In response to comments received during the public webinar, consider conducting a consumption-based life cycle assessment of landfill materials, as opposed to looking at end-of-life impacts of the products being landfilled. There are consumption-based methodologies; but they tend to be more effective at the company or location level versus a regional or multi-jurisdictional evaluation.

Chapter 2: Carbon Sequestration

Introduction

A Primer on Carbon Sequestration

Carbon sequestration is a part of a natural process called the carbon cycle. The carbon cycle is composed of two interwoven parts: emissions and sequestration. Throughout most of Earth's history, emissions such as carbon dioxide gas were released into the atmosphere by animals, decaying plants, and natural disturbances such as wildfire or volcanic activity. Sequestration is the opposite of emissions and occurs when plants conduct photosynthesis. Vegetation like trees and meadows breathe in carbon dioxide emissions and take greenhouse gas out of the atmosphere, converting the carbon dioxide (in combination with sunlight, water, and soil nutrients) into more plant matter. The bigger the trees, or the greater number of trees on a landscape, or the more protected and pristine a meadow—the more carbon dioxide emissions are taken out of the air and sequestered on these natural landscapes. Carbon sequestration by forests and meadows is a natural climate solution, and the Lake Tahoe region is fortunate to have an abundance of undeveloped landscapes to offer this ecosystem service.

However, human-caused emissions have tipped the carbon cycle out of balance. Additionally, more than a century of land management largely defined by wildfire suppression, logging, grazing, and development has caused the Sierra Nevada's landscapes to undergo structural and compositional shifts that frequently resulted in decreased forest and meadow resilience. The continued emissions of greenhouse gases into the atmosphere will accelerate climate change, leading to heightened disturbances and disasters such as catastrophic fires or mass flooding. Sequestering carbon into natural landscapes with restored resilience is an important strategy to address the impacts of climate change.

Purpose of Including Carbon Sequestration in GHG Inventory

Pair Traditional GHG Inventory with Carbon Sequestration Accounting

The purpose of this task was to pair a traditional GHG emission inventory with carbon sequestration calculations and to better understand the climate benefits of Tahoe's forests and meadows. A carbon accounting balance sheet can show how many human-caused GHGs are being emitted versus how much carbon sequestration is occurring is essential for guiding climate change policy.[40] Outcomes can help inform management actions for both the built environment and natural resources, and drive efficient investment in restoration or climate-smart redevelopment.

There is previous scientific work in the Tahoe Basin that quantifies forest carbon stocks and sequestration. No previous effort has been made to date across the Tahoe basin to quantify carbon

[40] Gonzalez, P., et al. (2015). Aboveground live carbon stock changes of California wildland ecosystems, 2001–2010. Forest Ecology and Management.

stocks and sequestration rates in meadows. The focus of the carbon sequestration task was to validate existing forest carbon datasets and create a meadow carbon quantification approach and dataset.

Quantifying Tahoe's forest and meadow carbon for the 2014-2018 time period utilized methods, tools, and data that were accessible, repeatable, and transparent. These three key criteria will allow the agencies to conduct subsequent carbon inventory updates using the same methods to achieve an accurate comparison of carbon stocks to track sequestration over time. These methods are non-proprietary, use public data, and are free federal tools with excellent documentation, which provides transparency in the assumptions and criteria being input into the models and allows for flexibility to adjust as new research becomes available.

These carbon values provide a snapshot into contemporary carbon cycle dynamics, and kick off further development of a carbon accounting balance sheet and carbon monitoring indicator threshold. Developing an understanding of approximately how many GHG emissions may be offset by carbon sequestration from Tahoe's forests and meadows will be useful in policy goal setting and driving efficient investment and prioritization in data-driven climate actions.

Forest Carbon Quantification and Validation

Existing Initiatives

Over the decades, numerous forest health and resilience studies have been conducted in the Tahoe Basin, largely driven by interagency collaboration. Science, partnerships, and regulations develop over time, and older initiatives serve as the springboard for newer initiatives. One recent multi-stakeholder collaboration is the Lake Tahoe West Restoration Partnership (LTW), which commenced the novel approach of landscape-scale restoration. LTWs goal is to engage private landowners, federal, and local agencies in restoring the resilience of roughly 24,000 hectares of Lake Tahoe's west shore watersheds, forests, and communities, all of which are threatened by climate change.

To kick off the LTW initiative, stakeholders drafted the Lake Tahoe West Resilience Assessment[41] to evaluate the current conditions and resilience of the west shore landscape. LTW employed a LiDAR-derived approach to map existing forest and geophysical structure to aid in identifying potential restoration challenges and opportunities. This geospatial product, known as "EcObject" was used for individual tree detection/approximation to delineate trees and forest stands. Tree data can be converted to biomass and carbon stocks. The individual trees or "objects" that are extracted are then aggregated by stand and tree-level ecological relationships and are turned into usable polygons called "EcObjects'' for analysis. These "EcObjects" are populated with a collection of forest metrics compiled from a suite of multidimensional datasets.

[41] Gross, S. et al. (2017). Lake Tahoe West Landscape Resilience Assessment, Version 1. Unpublished report. National Forest Foundation, South Lake Tahoe, CA.

Developing Initiatives

The Tahoe-Central Sierra Initiative (TCSI), California's Natural and Working Lands (NWL) committee, and the Lake Tahoe Climate Adaptation Action Portfolio (CAAP) are additional efforts working towards figuring out ways to increase the pace and scale of improved resiliency in the Sierra Nevada that also account for socio-economic factors in addition to environmental factors. These collaborative efforts include forecasting how land-management tradeoffs and climate change might affect carbon sequestration among other factors such as wildfire resilience and watershed health.

The Tahoe-Central Sierra Initiative (TCSI) is a program developed by the Sierra Nevada Conservancy and others that aims to increase the pace and scale of forest management and restoration. It spans a 2.4 million acre landscape and involves state, federal, nonprofit, and private partners. TCSI utilizes California Climate Investments (CCI) grant funds to implement high priority forest health projects that sequester carbon and reduce the risk of wildfires. These projects are currently thinning 20,000 acres, removing 164,000 tons of biomass, and implementing 8,000 acres of prescribed fire across the landscape.

The State of California is leading the charge in carbon sequestration through executive orders, grant funding, and carbon offset programs. The California Air Resources Board's Natural and Working Lands committee is a state-led working group and initiative focused on stewarding California toward achieving state climate goals, primarily by lowering GHG emissions, leveraging nature-based solutions to carbon sequestration, and transitioning equitably to a greener future.[42] California Natural Resources Agency developed CALAND, a look-up based tool that links management activities on California's landscape with estimated impacts to the carbon budget.[43] Both the NWL and CALAND contribute to the state's development of climate strategy planning.

A new climate change mitigation initiative is the California Biodiversity Collaborative. Signed in October 2020 by California Governor Gavin Newsom, Executive Order N-82-20 sets California on a path to conserve 30 percent of its land and coastal water by 2030. In addition to this "30 by 30" goal, this executive order also directs agencies to work towards storing carbon in the state's natural and working lands and removing it from the atmosphere to limit the impacts of climate change and protect communities from climate change-driven events such as wildfire, floods, droughts, and extreme heat. At the federal level, the new Biden administration pledged complementary "30 by 30" goals for the nation by signing Executive Order E.O.14008 on Jan 27, 2021.

---

[42] CARB (California Air and Resources Board). (2018). An Inventory of Ecosystem Carbon in California's Natural & Working Lands. California Air Resources Board.

[43] Di Vittorio, A., and M. Simmonds. (2019). California Natural and Working Lands Carbon and Greenhouse Gas Model (CALAND), Version 3, Technical Documentation.

In addition to these initiatives and executive orders and funding opportunities, California hosts various funding opportunities for implementing climate mitigation projects. In the forest and forestry realm, the California Air Resources Board's Cap-and-Trade Program leverages a market-based approach to climate change mitigation. This program creates economic incentives for companies to offset their emissions or develop cost effective and efficient technologies to decrease their emissions. A voluntary version of this market is available nationally under the American Carbon Registry. Forest conservation activities in particular have been instrumental in reducing GHG emissions. Additionally, California Climate Investments (CCI) grants distributed by CAL FIRE and other agencies fund projects that help restore forest health to reduce GHGs and promote long-term storage of carbon in forests among other landscape and fire prevention goals.

In the context of expanding fuel treatments and forest health restoration efforts, a new effort is under way to provide GHG emission related funds to support those treatments. Climate Forward is a newly established platform under the Climate Action Reserve (a major carbon offset registry in the cap-and-trade market) to provide a home for climate-relevant activities that will show immediate and scalable GHG benefits in the near future. Climate Forward has begun working on a new methodology for avoided wildfire emissions that builds on a decade of science led by Spatial Informatics Group LLC and other organizations. The Climate Forward avoided wildfire emissions protocol may better reflect true carbon savings from the implementation of forest health treatments than the CA CCI protocol is able to show because it accounts for the full carbon cycle and wildfire risk.

Meadow Carbon Quantification

At the time of writing this document, no research exists that focuses solely on meadow carbon sequestration and carbon flux within the Tahoe Basin. Nonetheless, there are existing meadow restoration efforts that focus on improving riparian function (mainly in the form of reducing river sedimentation to Lake Tahoe), wildlife habitat, and monitoring trends in plant communities. Integrating long-term site-specific carbon assessments and biogeochemical research into these meadow restoration efforts could enhance the value of these efforts by improving measurable restoration success, and building a body of knowledge. This could be leveraged to create a carbon monitoring indicator, carbon accounting balance sheet, and data-driven government policies aimed at mitigating climate change.

Seventy-five percent of the marshes and 50 percent of the meadows in the Tahoe Basin have been altered because of development and other land use alterations. Conserving and restoring the wetland and riparian areas is an important priority for agencies in the Lake Tahoe Region. These systems provide several critical ecosystems services, including enhancing lake clarity and sequestering carbon. The Taylor and Tallac Restoration project in southern Lake Tahoe includes sensitive habitats such as barrier beaches, wetlands, meadows, and stream channels that have been adversely affected by previous land management practices including grazing, infrastructure construction, and introduction of aquatic invasive species. The purpose of this project is to restore ecological processes and functions while maintaining or even enhancing the existing recreational facilities and infrastructure.

The Upper Truckee Marsh once covered over 1,100 acres but urban development in the late 1950s and 1960s reduced the wetland by more than half. During this time, extensive wetland areas were filled, and the lowermost portion of the river was straightened. Now, widespread upland development has made this the most disturbed watershed in the basin, increasing pressure on the marsh's natural filtration and carbon sequestration capacity. Remaining wetlands in the basin represent a significant resource value by providing critical wildlife habitat. Years of investments through Lake Tahoe Environmental Improvement Program (EIP) have helped to restore or enhance several wetlands by removing sand that was once used to fill the marsh and replacing it with native soils, species, rushes, sedges, grasses, and shrubs. These efforts are expected to improve the wetland carbon sequestration capacity.

The Tahoe Aquatic Resources Inventory (TARI) was an initiative to represent all aquatic systems and riparian areas in the Tahoe Basin utilizing science investments provided by the Southern Nevada Public Lands Management Act (SNPLMA) – namely, the acquisition of LiDAR data and high-resolution WorldView-2imagery. TARI is the Tahoe version of the California Aquatic Resource Inventory (CARI) and is entirely consistent with CARI standards. The source data consisted of the 2010 LiDAR and 2010 WorldView-2 imagery, both of which were available basin-wide. Aquatic features were mapped according to the original CARI/TARI standards[44] but with automation.

Another effort in the area is the Watershed Restoration Program which focuses on the Stream Environment Zone (SEZ). The SEZ is a term unique to the Lake Tahoe Region and includes streams, meadows, marshes, riparian areas, beaches, and other areas that have the presence or influence of surface or groundwater. SEZs are extremely valuable because they help maintain water quality through nutrient cycling and sediment retention, accomplish flood attenuation, execute infiltration and groundwater recharge, and house many wildlife habitats among many other functions and values. With large-scale SEZ disturbance occurring in the past, such as logging, grazing, damming, and fire suppression, the environmental consequences on this landscape can still be seen today. According to the USDA Forest Service, about 75 percent of wetlands in the urban areas of the Lake Tahoe Basin were lost to development. The Tahoe Regional Planning Agency and their partners have now implemented a program to protect, monitor, prioritize, and restore SEZs.

With many programs in the Tahoe Region working towards ecosystem restoration, there is still a significant need to sample, measure, and monitor the soil carbon within these restoration efforts. Employing a "wetness" indicator of restoration success has limited usefulness in capturing the

[44] SFEI (San Francisco Estuary Institute). (2013). Tahoe Aquatic Resources Inventory: Mapping standards and methodology for channels, wetlands, and riparian areas in the Tahoe basin. Wetland Riparian Area Monitoring Program (WRAMP).

complexities of meadow condition and carbon sequestration. Applying lab and field components to these restoration programs would allow for building datasets on meadow carbon stocks at a single point in time and help further research on soil carbon flux needed for planning and modeling efforts. Soil data from the USDA National Resource Conservation Service's Soil Survey Geographic Database (SSURGO or gSSURGO) is a standard soil dataset commonly used by industry professionals. While the breadth of its coverage is helpful, this dataset only has static information on soil organic matter and soil organic carbon that is not updated frequently, and does not provide insight into dynamic carbon flux. More frequent, localized, and long-term soil carbon monitoring, in addition to the work already being done, will help us better understand how carbon sequestration varies through time (seasonally and annually) and how restoration activities actually impact carbon sequestration abilities of the landscape. Research shows that pristine meadow landscapes are powerful carbon sinks, whereas their degraded counterparts could actually be net carbon sources.[45] The goal would therefore be to maximize the carbon sequestration ecosystem services of Tahoe's meadows by protecting existing pristine meadows, targeting degraded meadow landscapes for restoration, and establishing long-term meadow soil monitoring to aid understanding of carbon flux and restoration success. Once a rough assessment of meadow condition status is in place, prioritizing restoration becomes more straightforward. There is no need to develop novel methodologies to achieve this work in the Tahoe Basin; meadow carbon sampling protocols are already in existence and target requisite data collection, processing, and analysis. Implementing existing methods has the added benefit of standardizing research across the Sierra Nevada and beyond, thus growing a robust body of information to further aid applied ecology and planning efforts.

Forest Carbon

Methodology

This portion of the report is a validation of five datasets, three previously produced and two derived from a new modeling effort specifically conducted for this component of the GHG inventory update. While all previously existing datasets were created with a rigorous collaborative scientific process, each uses a different toolkit for deriving carbon estimates of the same landscape, at different points in time, with different purposes and limitations. The two new datasets created for this current initiative employ a fourth toolkit that is versatile, transparent, repeatable, free or relatively inexpensive, and allows for comparison to and between the previously produced datasets. The function of this validation assessment is not intended to criticize the solid work of past collaboratives, but rather to assist agencies and professionals in their pursuit of developing a carbon accounting balance sheet or carbon monitoring indicator for regional and local planning.

[45] Reed, C.C., Merrill, A.G., Drew, W.M. et al. (2020). Montane Meadows: A Soil Carbon Sink or Source?. Ecosystems.

The three previously produced datasets cover the Tahoe Basin, and are related to the Lake Tahoe West Restoration Partnership and the Tahoe-Central Sierra Initiative. The first of these is EcObject ("2010 EcObject"), a LiDAR-based spatial dataset produced by the USDA Forest Service and representing conditions as of 2010. The second dataset is LANDIS-II, an ecological process model ("Landis," "LANDIS-II") from which forecasted conditions for 2018 were developed. The third dataset was created by Silviaterra and used a proprietary LiDAR-based interpolated carbon estimation process to estimate carbon stocks for 2019.

In addition to summarizing the results of these three products, we conducted our own carbon modeling using the Fire and Fuels Extension of the Forest Vegetation Simulator (FVS-FFE), forest activity layers of completed on-the-ground forest treatments, and the Missoula Fire Lab tree list to estimate 2014 and 2018 forest carbon. Results were reported and compared for the entire Lake Tahoe Basin (LTB) and then the relevant datasets were clipped to analyze the Lake Tahoe West (LTW) area separately.

This validation allows users to better understand the average carbon stocks, spatial distribution, and temporal change of forest carbon within the Lake Tahoe Basin.

EcObject

This forest carbon validation employs the 2010 "Ecobject_LakeTahoeBasin" feature class (2010 EcObject). As of March 2021, the 2018 EcObject was still in creation; only forest stand polygons for the western shore of Lake Tahoe were available (v. 11/7/20). No biomass or carbon data has yet been attributed for that area, nor were stand polygons for the entire Basin available (pers. comm. M. Bindl, S. Conway). Thus, this forest carbon validation utilizes the best available existing dataset (meaning, the 2010 EcObject).

EcObject was produced by the USDA Region 5 Remote Sensing Lab and Vibrant Planet. LiDAR for the study region was flown and post-processed. Segmentation using Individual Tree Detection, a 1-m canopy height model, and adjusting omission vs. commission errors, resulted in 'tree approximate objects' which delineate locations of trees and multi-canopy stands on the landscape. The producers then attributed the final GIS polygon with various ecological and geographic data. The Aboveground live biomass attribute was estimated by generating an allometric equation that fit a linear model to all trees in the California FIA dataset, then plugging the LiDAR-measured tree or stand height into that equation.[46]

We assessed the 2010 EcObject attributes and excluded non-forest stands for the validation comparison. The dataset contains estimated aboveground live carbon (AGL) attributed for each polygon.

[46] USFS RSL (USDA Forest Service Region 5 Remote Sensing Lab). (2017). EcObject Vegetation Map v2.1 Product Guide, April 2017.

We then summed the area and carbon metric to derive AGL carbon summaries for both the entire Basin and the Lake Tahoe West extent.

LANDIS-II

LANDIS-II is a free, open-source tool produced by the USDA Forest Service to simulate forest ecosystem processes across large landscapes and long time periods (50-100+ years). LANDIS-II uses a spatially-dependent modeling process that allows interaction among and between forest species-age cohorts and ecosystem processes (management, disturbance). The tool is appropriate for investigating big-picture concepts and overall landscape trajectory[47,48]; disturbances are stochastics within the LANDIS-II model due to spatially and temporally interdependent multiple model runs (pers. comm., C. Maxwell). In contrast, FVS models trees and forest stands independent of distance, but allows users to custom-tailor the type, timing, and location of specific treatments during growth-and-yield modeling on an annual timescale (traditionally 5-10 year time steps over a few decades - 100 years).

LANDIS-II and the Net Ecosystem Carbon and Nitrogen success extension was employed in the LTW/TSCI initiative to forecast the effects of various climate pathways, management strategies, and disturbance regimes on landscape forest and carbon dynamics. LTW Science Committee provided LANDIS-II data outputs (tif format) for this validation analysis. The modeling start year for LTW/TSCI was 2010, therefore we selected year 8 to correspond with 2018 conditions. We ultimately selected the tif file "Scenario 2TOTC_Scenario2_1_CNRM5_8.5_8.tif" because it most closely represented the management and climate scenario most similar to contemporary, 'business-as-usual' conditions[49] Integrated Vulnerability Assessment of Climate Change in the Lake Tahoe Basin, 2020):

- Management Scenario 2 (WUI-focused strategy similar to recent management[50])
- Global Climate Model CNRM5, and
- Radiative concentration pathway (RCP) 8.5

Nonetheless, disturbance is stochastic and 8 years is a short modeling period in LANDIS-II. Therefore, a variety of provided LANDIS-II outputs would have been appropriate, and differences between datasets for the year 2018 should not be extreme. We converted the data in the selected tif to a raster, and converted units from g/m2 to Mg/ha. We also clipped the LANDIS-II study area to the same extent we

[47] Mladenoff, D. (2004). LANDIS and forest landscape models. Ecol. Model.180:7–19.

[48] Taylor, A.; Van Damme, L. (2009). A review of forest succession models and their suitability for forest management planning. Forest Science 55(1).

[49] Lake Tahoe West Restoration Partnership. (2020a). Integrated Vulnerability Assessment of Climate Change in the Lake Tahoe Basin.

[50] Lake Tahoe West Restoration Partnership. (2020b). Lake Tahoe West Science Summary of Findings Report.

used for the FVS modeling to provide a separate, more direct comparison to FVS (reported as "adjusted" values).

Silviaterra

Silviaterra is a private data information and mapping company that produced a raster dataset that was purchased for a LTW/TSCI project. Like EcObject, Silviaterra utilizes a LiDAR-based approach to identifying trees or forest stands. Through a proprietary black-box method, Silviaterra estimates forest biomass for a single point in time across the surveyed landscape.

In this report, project partners provided Silviaterra data as a tif file (CNRM85_Scenario1_1_1.tif) representing total stand biomass for 2019. We converted this tif to an ESRI GRID raster and clipped to the LTW area (35,935 ha). The biomass was summed and then converted to carbon using a conversion factor of 0.5.[51] This total was then divided by the total area to obtain an average carbon (C) density. In addition, we clipped the Silviaterra study area in the same manner described above as for the adjusted LANDIS-II comparison.

Forest Vegetation Simulator

The Forest Vegetation Simulator (FVS) is a forest modeling tool created by the USDA Forest Service and commonly used by forestry professionals. It is an individual-tree, distance-independent, growth and yield model[52] which allows for the forecasting (growing), backcasting (degrowing), and contemporary (date of field inventory) quantification of forestry metrics, including biomass and carbon. The tool contains regional defaults but allows for manual calibration via 'keyfiles' to suit local characteristics and tailor treatments to project-specific needs. FVS allows for the incorporation of geographically-specific forest treatments or simulated disturbance. FVS is a free tool with transparent documentation plus a live support team of scientists and technical specialists who release program updates to reflect the best available science and offer instructor-led and web-based trainings.

At minimum, FVS needs a treelist, and plot or stand locations to quantify carbon stocks and model tree growth. For this analysis, the treelist came from the 2014 USDA Rocky Mountain Research Station's Missoula Fire Lab 'TreeMaps'[53], and stand locations came from the 2010 EcObject. The Tahoe Fire and Fuels Team collated and shared GIS of all disturbance and forest treatments that occurred in the Tahoe

[51] Penman, J. et al. (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. 590.

[52] Dixon, G. Dixon, Gary E. comp. (2002, Revised Jan. 2020). Essential FVS: a user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: USDA Forest Service, Forest Management Service Center. 226p.

[53] Riley, K. L., Grenfell, Isaac C., Finney, M. A. & Wiener, J. M. (2018). Fire Lab tree list: A tree-level model of the western US circa 2009 v1.

Basin from 2014-2018. The Lake Tahoe Basin Management Unit (LTBMU) of the USDA Forest Service provided FVS keyfiles and reviewed our modifications.

Table 15. Raw Forest Vegetation Simulator Data Sources

Raw FVS Data	Source
Treelist	Missoula Fire Lab
Stand location	EcObject 2010
Disturbance and forest treatments (2014-2018)	Tahoe Fire and Fuels Team
Regional calibration (FVS keyfiles)	LTBMU
FVS Software and Regional Variant	USDA Forest Service

We used the regional variant of FVS with an initial constraint to 71,290 forested hectares as defined by the EcObject dataset. About 6.5 percent of that area lacked the tree value ID necessary to link a USDA Forest Services' Forest Inventory and Analysis (FIA) plot, resulting in 66,648 forested hectares that we simulated with FVS.

We used the 2010 EcObject polygons for the Lake Tahoe Basin, selected only the forested polygons, and simplified the polygons to reduce the total number from almost 700,000 to fewer than 90,000 polygons, which we used to represent individual forest stands to simulate.

The tree inventory used to populate the stands came from the 2014 Missoula Fire Lab 'TreeMaps'.[53] This dataset has been approved by the California Air Resources Board for carbon modeling in support of applications for funding from the state's Greenhouse Gas Reduction Fund. The TLID is a 30-m raster map that covers the entire coterminous United States and can be used to explore tree-level data ca. 2014. Pixel values are the keys to a database that contains interpolated FIA plot data. These plots were assigned using a random-forests algorithm built around disturbance, topographic, and biophysical variables derived from FIA and LANDFIRE data.

A single value from the TLID raster -- the most common within each polygon -- was assigned to each of the stand polygons by using the Zonal Statistics tool in ArcGIS. About 6.5 percent of the forested stand polygons did not receive a TLID value, excluding them from the FVS simulation. The TLID values are partially based on LANDFIRE, which masks out all urban or developed areas, whereas our EcObject-based stand polygons do not automatically exclude urban and developed areas. This would result in a slight reduction of our carbon estimates. On the other hand, FVS occasionally slightly overestimates the carbon contained by the stand polygons because the most common TLID is assigned, regardless of the number of null raster values within that particular polygon. The TLID data is already converted to per-acre values from the underlying per-plot FIA data. We did, however, convert the crown ratio measurements from compacted crown ratios (FIA) to the uncompacted crown ratios expected by FVS as input.

We needed to simulate disturbances (primarily fuel treatments) that occurred between 2014 and 2018 to update the TLID from 2014 conditions. We obtained a spatial database of disturbance history for the Lake Tahoe Basin from the Tahoe Fire and Fuels Team, and extracted disturbances that occurred in the years of interest. The disturbances, including the 2016 Emerald Fire, were combined into seven broad disturbance types such as “biomass removal,” “hand thin,” etc. Keyfiles for each of these were built by modifying keyfiles obtained from a USDA Forest Service LTBMU Forest Silviculturist. We did not have a vegetation burn severity map for the Emerald Fire so we assumed it was all high-severity based on the BAER report[54], and simulated it as such in FVS.

The stand polygons and the TLID data were used to create an FVS input database which also included disturbance keywords assigned to specific stands. Keyfiles were built on Windows using the Suppose FVS tool. The FVS runs, however, were completed with open-FVS running on a Linux server due to its superior computation speed and stability given the number of stands to be simulated. Nonetheless, computation time was excessive, so we aggregated the undisturbed stands represented by the same FIA plot into a much smaller (fewer than 7,000) set of representative stands. No disturbed stands were consolidated. After consolidation a complete FVS simulation would complete in fewer than two hours and the SQL output database queries were adjusted to account for this consolidation.

Employing the Fire and Fuels Extension (FFE) of FVS, FVS-FFE calculates and tracks carbon in the following pools: total aboveground live which includes merchantable and unmerchantable live stems, branches, and foliage; standing dead; understory (shrub and herbaceous layers); forest floor (litter and duff); forest down dead wood; belowground live roots, and belowground dead roots. These pools are estimated using two sets of equations: “FFE,” which were developed by the FVS team, and “Jenkins,” which are based on Jenkins et al. (2003).[55] Although most of these pools use one set of equations or the other, the choice of either set is presented for calculating aboveground live total carbon and merchantable aboveground live carbon. We ran FVS separately, once with each set of equations. In contrast, LANDIS-II doesn't use allometric equations -- it uses its own process based growth model that relies on "local" (in cell) weather, soil factors, and competition to determine rate of growth; the growth model is calibrated based on remotely sensed NPP values (MODIS17A3) (pers. comm., C. Maxwell).

We specified an annual time step for FVS which allowed us to report carbon (C) in 2014 (the inventory year) as well as in 2018 which we chose as a convenient year for comparison to the other datasets. The

---

[54] Elliot, W., et al. (2018). Estimates of surface and mass erosion following the 2016 Emerald wildfire: Final report to the Lake Tahoe West Shore Restoration Project.

[55] Jenkins, J., Chojnacky, D., Heath, L., Birdsey, R. (2003). National-scale biomass estimators for United States tree species. Forest Science, Vol. 49, No. 1, February 2003.

carbon tables of the output databases from these runs were queried to summarize annual carbon stocks (either AGL- aboveground live) or total stand carbon (TSC) for comparison to the other datasets, as well as formatted to join to the stand polygons for mapping and further analysis in GIS. Finally, because we had carbon stocks at two distinct points in time, we were able to calculate average annual forest carbon sequestration rates as the difference between the two stocks divided by the number of years between them. We also calculated average per-hectare forest carbon sequestration rates.

Results

EcObject

The LTW area covered by our EcObject dataset is 36,130 ha and 71,280 ha for the LTB. The sum of the Live_AGC attribute is 2,105,572 Mg. This yields an average aboveground live carbon density across the area of 58.3 Mg C/ha.

LANDIS-II

The LANDIS-II data covers 36,148 ha of the LTW study area (84,737 ha for LTB). As with the Silviaterra data, we assumed that 35 percent of the total stand carbon is soil organic carbon. That leaves 2,281,989 Mg of total stand C which produces an average density of 63.1 Mg C/ha across the LTW area. When clipped to the same extent as the FVS modeling, the LANDIS-II area becomes 29,559 ha, which then contains 2,008,410 Mg C in total stand C (excluding soil organic carbon; SOC). This produces an adjusted average density of 68.0 Mg C/ha.

Silviaterra

According to this dataset, there is 10,017,440 Mg of total stand biomass in the LTW area. This was then converted to carbon using a conversion factor of 0.5 to get 5,008,720 Mg of C. If we assume that 35 percent of this carbon is soil organic carbon, we get 3,255,668 Mg of total stand C (excluding SOC), and a mean C density of 91 Mg/ha. After clipping the Silviaterra data to the same extent as the FVS modeling, Silviaterra's area becomes 29,463 ha, which then contains 2,869,866 Mg C in total stand C (excluding SOC). The adjusted average density is 97 Mg C/ha.

FVS

The FVS results are higher than the other three studies, but the FVS-FFE results are similar to the Board of Forestry and Fire Protection's FIA-based 2019 inventory for LTBMU.[56] Specifically, comparable FVS results are about 43 percent higher than EcObject, 51 percent higher than LANDIS-II, and 30 percent higher than Silviaterra, whether we looked at LTW or LTB. The FVS results are skewed upward somewhat in comparison to the other studies because FVS simulated carbon on forested land only, while C is

[56] Christensen, G., Gray, A., Kuegler, O., Tase, N., Rosenberg, M. (2021). AB 1504 California Forest Ecosystem and Harvested Wood Product Carbon Inventory: 2019 Reporting Period Data update. U.S. Forest Service agreement no. 18-CO-11052021-214, California Department of Forestry and Fire Protection and California Board of Forestry and Fire Protection. 447p.

summarized for the other three studies across all vegetation types. The “adjusted” aboveground life C (AGL) and total stand C (TSC) values in **Tables 16 and 17** somewhat account for this by dividing the FVS C totals by 36,130 ha (the EcObject area) instead of the 29,748 forested ha used in the other FVS totals. Similarly, the “adjusted” values in **Table 17** use 71,280 ha (the EcObject area) instead of the 66,648 ha used in the other FVS totals.

Using the FFE equations for the 2014 FVS outputs resulted in 5,486,855 Mg total stand C and an average total stand density of 184 Mg C/ha. The 2018 results were similar: 5,946,698 Mg total stand C and an average total stand density of 200 Mg C/ha.

The 2014 total aboveground live C using the FFE equations was 3,029,988 Mg with an average aboveground stand C value of 102 Mg C/ha, while the 2018 results were 3,342,599 Mg and 112 Mg C/ha respectively.

The same outputs using the Jenkins equations were about 19 percent higher than the results produced with the FFE equations. Total stand C in 2014 was 6,780,598 Mg (228 Mg/ha on average) and 7,287,639 Mg (245 Mg C/ha on average) in 2018. Aboveground live carbon in 2014 was 4,323,731 Mg (144 Mg C/ha on average), rising to 4,683,540 Mg (157 Mg C/ha on average) in 2018.

Dataset Comparison

Datasets varied considerably across a range of C stock and flux metrics for LTW (**Table 16**). For instance, EcObject suggests a mean AGL of 58.3 Mg C/ha for 2010 while FVS outputs for the closest comparable year (2014) suggest close to two to three times those values, with mean AGL of 101.9 Mg C/ha (FVS FFE) and 145.3 Mg C/ha (FVS Jenkins). A similar discrepancy can be observed for the Adjusted mean TSC-SOC density between LANDIS-II (2018) and Silviaterra (2019) of 68.0 and 97.4 Mg C/ha, respectively. **Table 16** further shows the limits of some datasets such as EcObject that does not provide more recent 2018 data. The same observations hold true for the entire Lake Tahoe Basin (**Table 17**).

AGL and TSC annual flux rates were very similar for the entire Lake Tahoe Basin and its subset (LTW) as well as across the both FVS modeling approaches (**Table 18**). For instance, AGL fluxes ranged from 2.6 to 3.0 Mg C/ha/y while TSC annual fluxes ranged from 3.8 to 4.3 Mg C/ha/y. Lake Tahoe West accounts for almost half of the total annual carbon sequestration in the Tahoe Basin for both AGL and TSC carbon pools.

Table 16. Lake Tahoe West Carbon Stocks and Densities

Dataset	Year	Area represented (ha)	AGL C (million Mg C)	TSC (million Mg C)	TSC – SOC (million Mg C)	Mean AGL C density Mg C/ha	Adjusted mean AGL C density Mg C/ha	Mean TSC density Mg C/ha	Adjusted Mean TSC density Mg C/ha	Mean TSC – SOC density Mg C/ha	Adjusted Mean TSC – SOC density Mg C/ha
EcObject	2010	36,130	2.11	-	-	**58 .3**	-	-	-	-	-
EcObject	2018	N/A									
LANDIS-II	2018	36,148	-	3.51	2.28	-	-	97.1	104.6	63.1	***68.0***
Silviaterra	2019	-	-	5.01	3.26	-	-	139.4	149.9	90.6	***97.4***
FVS (FFE)	2014	29,748	3.03	5.49	-	101.9	**83.9**	184.4	151.9	-	-
FVS (FFE)	2018	29,748	3.34	5.95	-	112.4	92.5	***199.9***	164.6	-	-
FVS (Jenkins)	2014	29,748	4.32	6.78	-	145.3	119.7	227.9	187.7	-	-
FVS (Jenkins)	2018	29,748	4.68	7.29	-	157.4	129.6	***245.0***	201.7	-	-

Soil organic carbon (SOC) was estimated to be 35 percent of Total Stand C ("TSC" = Total Stand C, "AGL" = aboveground live"). TSC from FVS excludes SOC. Adjusted values are included to account for differences between datasets in total area quantified for forest carbon; while FVS used only "forested" areas according to EcObject and the Missoula Fire Lab data, other datasets may include forest carbon for areas that were considered non-forest by the former, which could account for lower AGL and TSC carbon averages in the unadjusted datasets. Adjusted FVS values use 36,130 ha as land base for more direct comparison to the 2010 EcObject extent (**bold underlined** emphasis in table for convenient comparison between EcObject and FVS). Adjusted Silviaterra values use 29,463 ha as land base, while adjusted LANDIS-II values use 29,559 ha, when both datasets are clipped to geographic extent employed in FVS modeling (***bold italic*** emphasis in table for convenient comparison between FVS, LANDIS-II and Silivaterra).

Table 17. Lake Tahoe Basin Carbon Stocks and Densities

Dataset	Year	Area represented (ha)	AGL C (million Mg C)	TSC (million Mg C)	TSC – SOC (million Mg C)	Mean AGL C density Mg C/ha	Adjusted mean AGL C density Mg C/ha	Mean TSC density Mg C/ha	Adjusted Mean TSC density Mg C/ha	Mean TSC – SOC density Mg C/ha	Adjusted Mean TSC – SOC density Mg C/ha
EcObject	2010	71,280	4.78	-	-	**67 .0**	-	-	-	-	-
EcObject	2018	N/A									
LANDIS-II	2018	84,737	-	8.24	5.36	-	-	97.3	105.9	63.2	***68.8***
Silviaterra	2019	88,081	-	11.34	7.37	-	-	128.7	140.6	83.7	***91.4***
FVS (FFE)	2014	66,648	6.49	11.61	-	97.5	**91.1**	174.2	162.9	-	-
FVS (FFE)	2018	66,648	7,19	12.63	-	107.8	100.8	189.5	***177.2***	-	-
FVS (Jenkins)	2014	66,648	9.17	14.29	-	137.6	128.7	214.4	200.4	-	-
FVS (Jenkins)	2018	66,648	9.97	15.41	-	149.6	139.9	231.2	216.2	-	-
BOF/CDF**	2019	43,301	4.75	12.09	7.39	109.7	-	279.0	-	***170.7***	-

***Carbon data in the California Board of Forestry and Fire Protection/California Department of Forestry and Fire Protection (BOF/CFD) row were provided by Nadia Tase, CALFIRE. See Christensen et. al., 2021 for more information.*

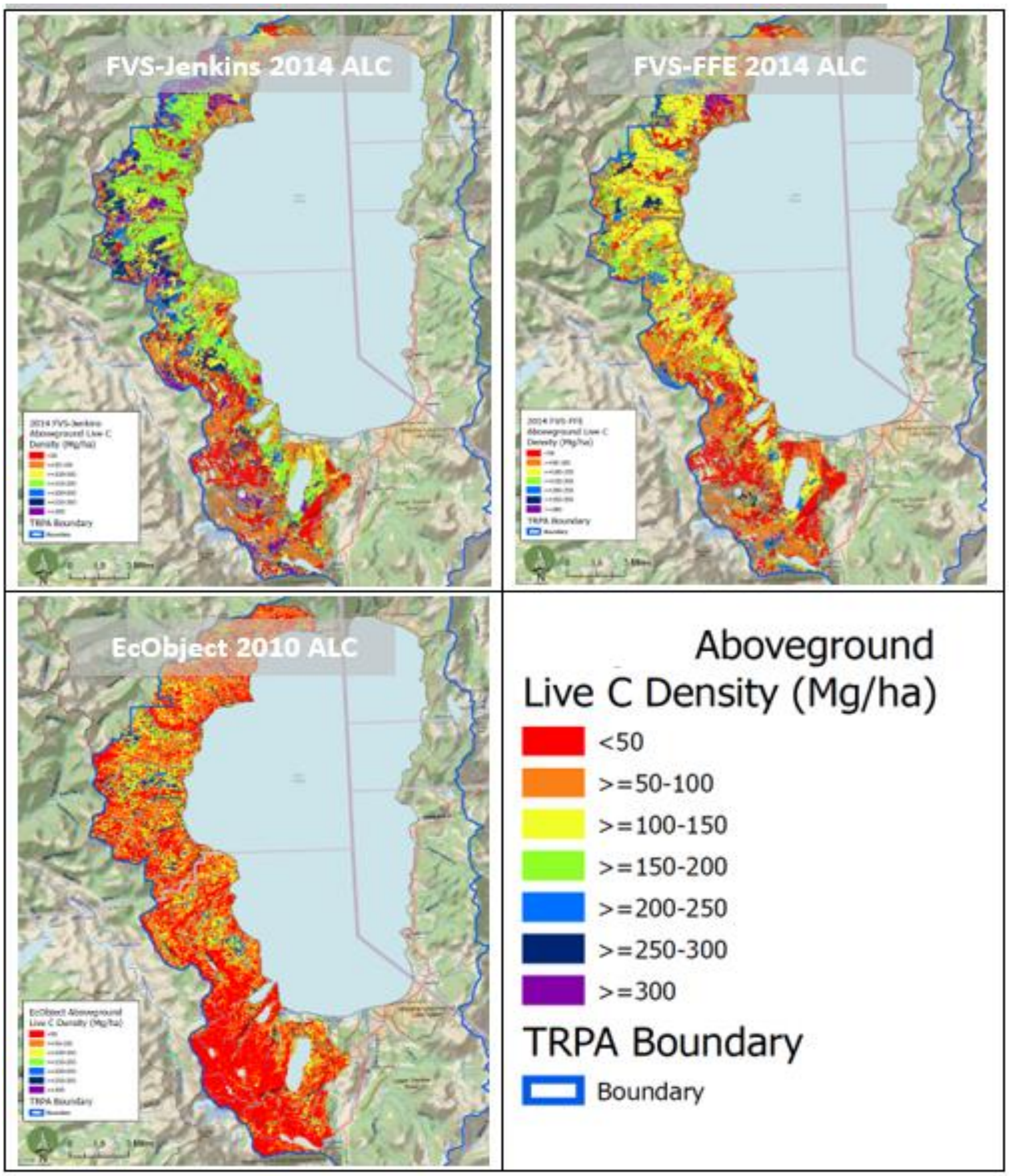
Soil organic carbon (SOC) was estimated to be 35 percent of Total Stand C ("TSC" = Total Stand C, "AGL" = aboveground live"). TSC from FVS excludes SOC. Adjusted FVS values use 71,280 ha as land base. Adjusted Silviaterra values use 71,070 ha as land base. Adjusted LANDIS-II values use 66,546 ha as land base. **Bold underlined** emphasis is added in the table for convenient comparison between EcObject and FVS. ***Bold italic*** emphasis is for convenient comparison between FVS, LANDIS-II and Silviaterra. Underlined emphasis is for convenient comparison between FVS and BOF/CDF**.

Table 18. Lake Tahoe West and Lake Tahoe Basin Forest Carbon Sequestration from 2014 to 2018

Dataset	AGL C annual sequestration rate (1,000 Mg C/yr)	TSC annual sequestration rate (1,000 Mg C/yr)	AGL C annual flux (Mg C/ha/yr)	TSC annual flux (Mg C/ ha/yr)	TSC annual sequestration rate (MT CO_2e/yr)
FVS (FFE) – West Shore	78	115	2.6	3.9	422,000
FVS (Jenkins) – West Shore	90	127	3.0	4.3	465,000
FVS (FFE) – Lake Tahoe Basin	173	255	2.6	3.8	934,000
FVS (Jenkins) – Lake Tahoe Basin	199	281	3.0	4.2	1,030,000

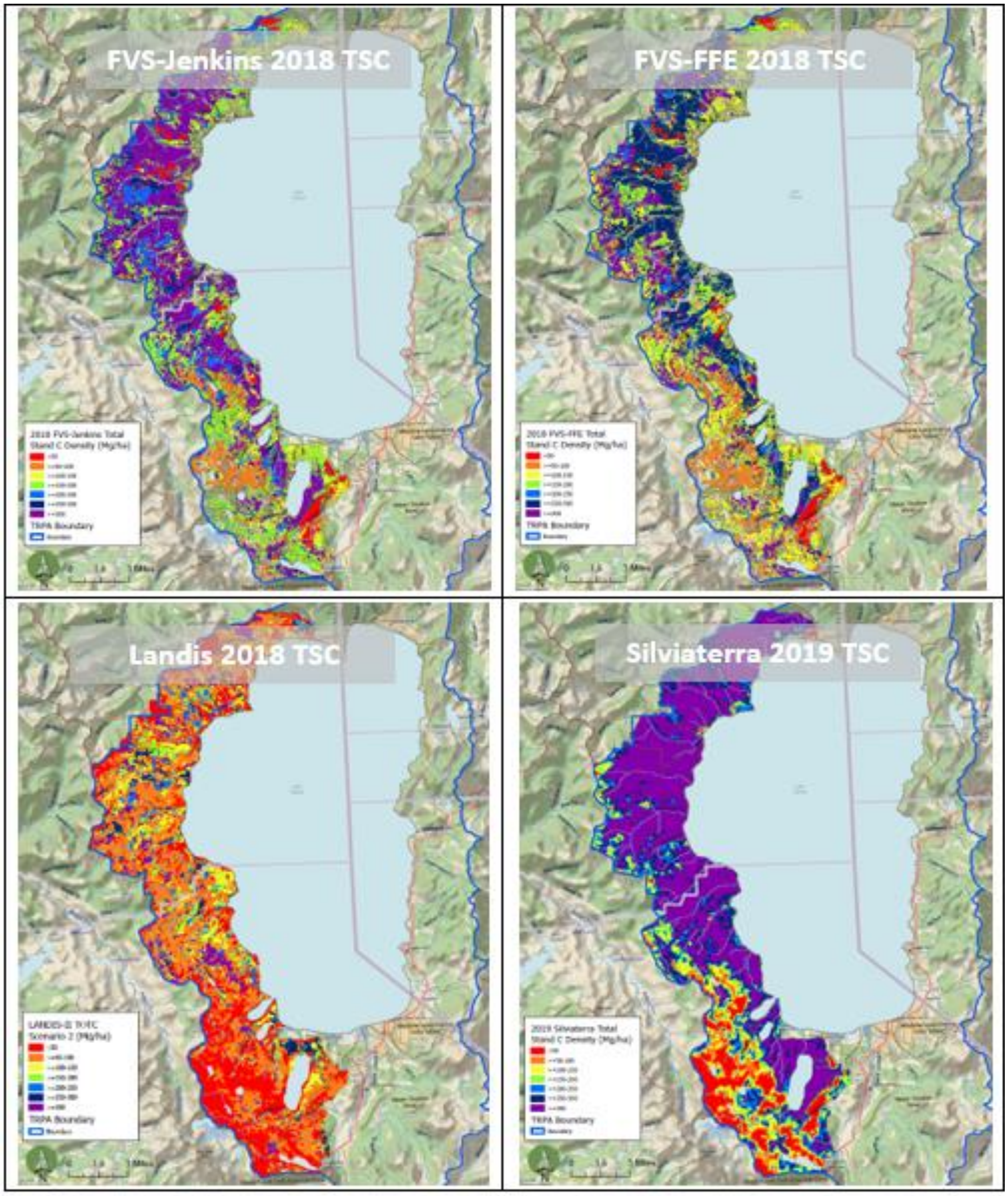
The following information is generated by annualizing the net change in FVS carbon values resulting over the 4-year time period. Values shown in the table are mean annual rates. Annual flux is derived from dividing the total annual carbon sequestration by forested hectares (66,648 ha for the Basin, 29,748 ha for the west shore) to generate an average per-hectare annual sequestration rate. TSC from FVS excludes SOC. TSC annual sequestration rate is also represented in metric tons (MT) carbon dioxide equivalent (MT CO_2e) to match units reported for anthropogenic emissions in the GHG inventory.

Figure 24. Visual Comparison of Forest Carbon (Aboveground Live Carbon) for the Lake Tahoe West Area Between Datasets



Forest carbon (aboveground live carbon pool) storage for FVS-Jenkins (2014), FVS-FFE (2014), and EcObject (2010) outputs. Carbon was calculated for the entire basin but zoomed to the west shore in this map for display purposes. All images symbology are scaled to the same values. See **Appendices** for higher resolution maps.

Figure 25. Visual Comparison of Forest Carbon (Total Stand Carbon) for the Lake Tahoe West Area Between Datasets



Forest carbon storage (total stand carbon) for FVS-Jenkins (2018), FVS-FFE (2018), LANDIS-II (2018), and Silviaterra (2019) outputs. LANDIS-II and Silviaterra represent adjusted values, with TSC reduced by 35 percent to account for embedded SOC soil pool. Carbon was calculated for the entire basin but zoomed to the west shore in this map for display purposes. All images symbology are scaled to the same values. See **Figure 24** for a high-resolution legend, see **Appendices** for higher resolution maps.

Meadow Carbon

Methodology

Meadow carbon stocks were also quantified for the entire basin using publicly available gridded soil survey data from the USDA National Resources Conservation Service (NRCS). In total there are 2,060 hectares (5,091 acres) of meadows in the Tahoe Basin, which results in 694,133 units of carbon stocks. Meadows have the potential to play a very important role in carbon sequestration; their ability to sequester carbon is influenced by meadow condition (pristine or degraded)[45] and climate change.[49]

Delineated meadow boundaries were sourced from the Sierra Nevada Meadows Clearinghouse[57] by UC Davis's Center for Watershed Sciences and the Information Center for the Environment and affiliated organizations. This Sierra-wide UC Davis Meadows GIS dataset was clipped to the Tahoe Regional Planning Agency boundary to query all meadows in the Tahoe Basin. This GIS subset resulted in 2081 ha of meadow boundaries. We then cleaned the data by removing ~21 ha of non-soil cover types (soils labeled as "water", "urban", and "gravel pits"). This resulted in 2060 ha of Tahoe Basin meadows for our meadow carbon analysis.

We calculated meadow carbon in the Tahoe Basin using the NRCSs Gridded Soil Survey Geographic (gSSURGO).[58] Databases for California and Nevada were downloaded from the NCRS website ("2019 gSSURGO by State") and clipped to the meadow boundaries. gSSURGOs 10-meter resolution raster contains values that relate to a map unit key that joins to a look-up table in the downloaded gSSURGO dataset. This Value1 (Value Added Look Up) Table contains the weighted average grams of soil organic carbon (SOC) per square meter (g C/m2). We queried meadow carbon (Soil Organic Carbon) for the 0 to 100 cm soil depth, and converted the resulting value from g C/m2 to Mg/ha.

gSSURGO is widely used by natural resource planning and management professions (pers. comm., Meg Miranda, California Air and Resources Board), but is not regularly updated nor does it provide attributes associated with soil carbon flux. Note that the gSSURGO GIS version year is 2019/2020 but the soil data itself may have been collected at an older date. While this is considered some of the best data currently available with the greatest geographic coverage, we encourage rigorous long-term local SOC sampling efforts to improve soil data, inform our understanding of meadow carbon stocks and sequestration, forecast the effects of climate change, and aid data-driven planning and restoration efforts. Improving soil data thus improves the development of a carbon accounting balance sheet for the Tahoe Basin.

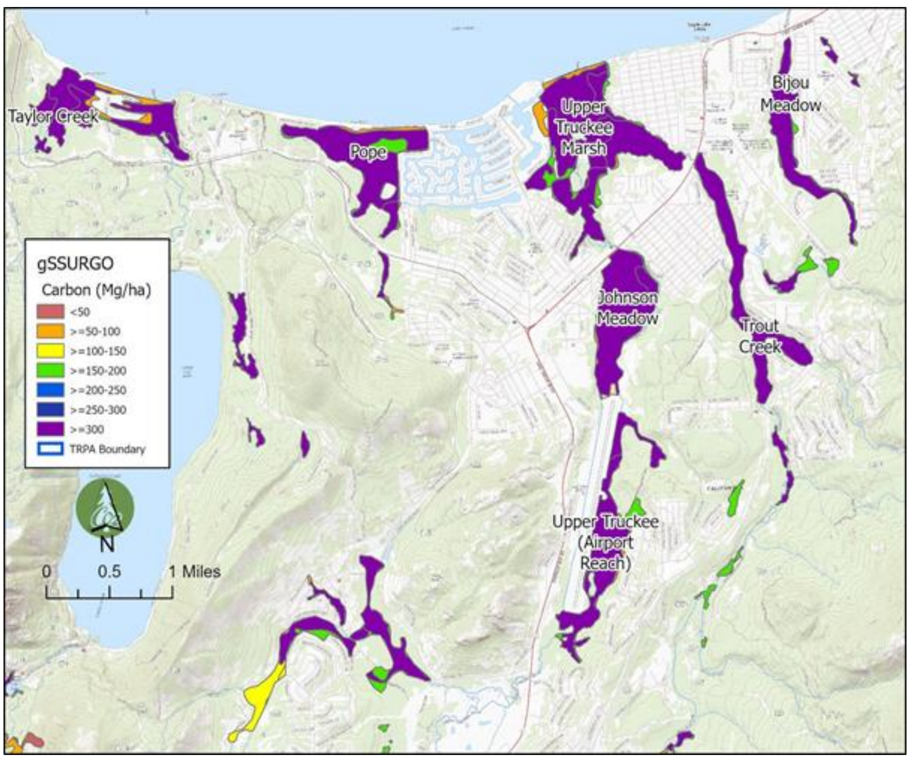
[57] UC Davis, Center for Watershed Sciences & USDA Forest Service, Pacific Southwest Region. (2017). Sierra Nevada Multi-Source Meadow Polygons Compilation (v 2.0), Vallejo, CA, Regional Office: USDA Forest Service. 2017.

[58] NCRS (USDA Natural Resources Conservation Service). (2020). Soil Survey Staff. Gridded Soil Survey Geographic (gSSURGO) Database for Nevada. March, 24, 2021 (FY2020 official release).

Results

UC Davis mapped 368 meadows within the TRPA boundary, totaling 2,060 hectares (5,091 acres). Total SOC for the meadows is 694,133 Mg (**Table 19**). On average, meadows contain a SOC of 174 Mg/ha, yielding a total average of 744 Mg. The soil with the highest SOC concentration is of the Bidart complex soil type, with a concentration of 483 Mg/ha. The Bidart complex comprises 277 ha or 13 percent of the meadow soils in the TRPA area. Other important soils include Tahoe mucky silt loam (482 Mg/ha), Tahoe complex (397 to 441 Mg/ha), and Watah peat (336 Mg/ha). These soils comprise the majority of the soils in the important meadows in the South Tahoe area (**Figure 26**). The average C stock equaled 337 Mg C/ha. C stocks varied considerably within and across all meadows (**Table 19**). For all meadows, the variation ranged from 3 Mg C/ha to 483 Mg C/ha (SD=135). **Table 20** presents a range estimate of annual carbon flux in the Basin's meadows. Whether meadows were net C sinks or sources was driven primarily by the magnitude of below ground C inputs but also appears to be related to meadow condition. More work is being done to evaluate this relationship.

Figure 26. Important Meadows in the South Tahoe Area and their Concentration of Soil Organic Carbon Mg/ha from the Gridded Soil Survey Geographic Database



While SOC was calculated for the entire basin, we zoomed in on the south shore of Lake Tahoe for visual display purposes.

Table 19. Summary of Soil Organic Carbon in Meadows in the Tahoe Basin, Weighted by Area

Meadow Name	Area (ha)	Total SOC (Mg C)	Average SOC (Mg C/ha)	Min. SOC (Mg C/ha)	Max. SOC (Mg C/ha)	St. Dev.
Bijou Meadow	50	23,141	461	174	482	178
Johnson Meadow	86	40,299	468	81	482	166
Pope	90	30,442	337	54	441	125
Taylor Creek	78	27,103	346	54	441	156
Trout Creek	66	28,645	435	70	441	126
Upper Truckee Marsh	166	63,100	421	70	482	144
Upper Truckee (Airport Reach)	80	33,573	380	54	441	161
All Other Meadows	1,444	447,830	310	3	483	135
Total	**2,060**	**694,133**	**337**	**3**	**483**	**136**

While soil C was calculated for the entire basin (see 'Total' row), this table also presents carbon values for meadows on the South shore of Lake Tahoe, selected for illustration purposes due to relevant past/current restoration initiatives in this area (see **Figure 26**).

Table 20. Range Estimate of Annual Carbon Sequestration in the Lake Tahoe Basin's Meadows

	Area (ha)	Annual net soil C flux (Mg C/ha/y)	Total annual C sequestration (Mg C/y)	Total annual C sequestration (MT CO_2e/yr)
Sink (pristine condition)	2,060	5.8	11,948	43,800
Source (degraded condition)	2,060	(3.9)	(8,034)	(29,500)

Mean values used for meadows that were annual net C sinks (n=3) and net C sources (n=10) from Reed et al. 2020. Whether meadows were net C sinks or sources was driven primarily by the magnitude of belowground C inputs but also appears to be related to meadow condition. Total annual C sequestration was calculated by multiplying the annual net soil C flux by the Tahoe Basin's meadow hectares (2086 ha). Total annual C sequestration for meadows is also represented in MT CO_2e to match units reported for anthropogenic emissions in the GHG inventory.

Carbon Sequestration Conclusions & Recommendations

Takeaways

The main takeaways from improving carbon sequestration work in the basin can be broken down in four points:

1. **Reducing emissions is crucial** because we can't sequester our way out of climate change. California ecosystems harbor natural solutions to climate change via carbon storage and sequestration. The potential contributions ecosystems can have in offsetting human-caused GHG emissions highlights that landscape conservation and restoration are essential to combating climate change. Even resilient forests and meadows can't fully offset those emissions, however.
2. **Resilience greatly influences ecosystems' ability to offset emissions**. It is important not only to quantify existing carbon stocks and sequestration (flux), but to also assess the ecological appropriateness (climate resiliency) of those existing carbon stocks and what conservation and restoration actions are needed to move ecosystems towards a functional, climate-resilient state. Currently, degraded meadows may be net carbon sources, instead of carbon sinks like their pristine counterparts. Currently, Tahoe and the Sierra Nevada forests are overstocked and have undergone compositional changes that have resulted in high carbon stocks for the short term, but decreased forest resilience for the long-term. An avoided wildfire emissions protocol endorsed by a carbon registry such as Climate Forward (under CAR) can provide funds to implement treatments that would help decrease the occurrence of uncharacteristically large and severe wildfires and potentially increase forest resiliency. Even if the implementation of these treatments, such as prescribed burning, managed wildland fire, or mechanical fuel reduction decreases carbon stock through those activities, the forest is more resilient, carbon stocks are more stable, and overall the ecosystem is less susceptible to catastrophic disturbance.
3. **Meadows have the potential to be an important carbon sink**. Meadows have often been overlooked by planners and developers in their ability to provide important ecosystem services; many meadows in California have been lost (converted) or degraded. While it is clear that meadows have the potential to sequester a high amount of carbon per hectare, more research is needed to understand belowground meadow ecosystems and their soil organic carbon flux in order to understand how management or restoration actions can improve sequestration, and to fully appreciate all meadows have to offer in the fight against climate change. There is a need for long-term standardized meadow soil carbon sampling and monitoring integrated with restoration planning and monitoring. A better understanding of meadow carbon flux can help ensure restoration success, while also informing land management actions and data-driven policies needed for combating climate change.

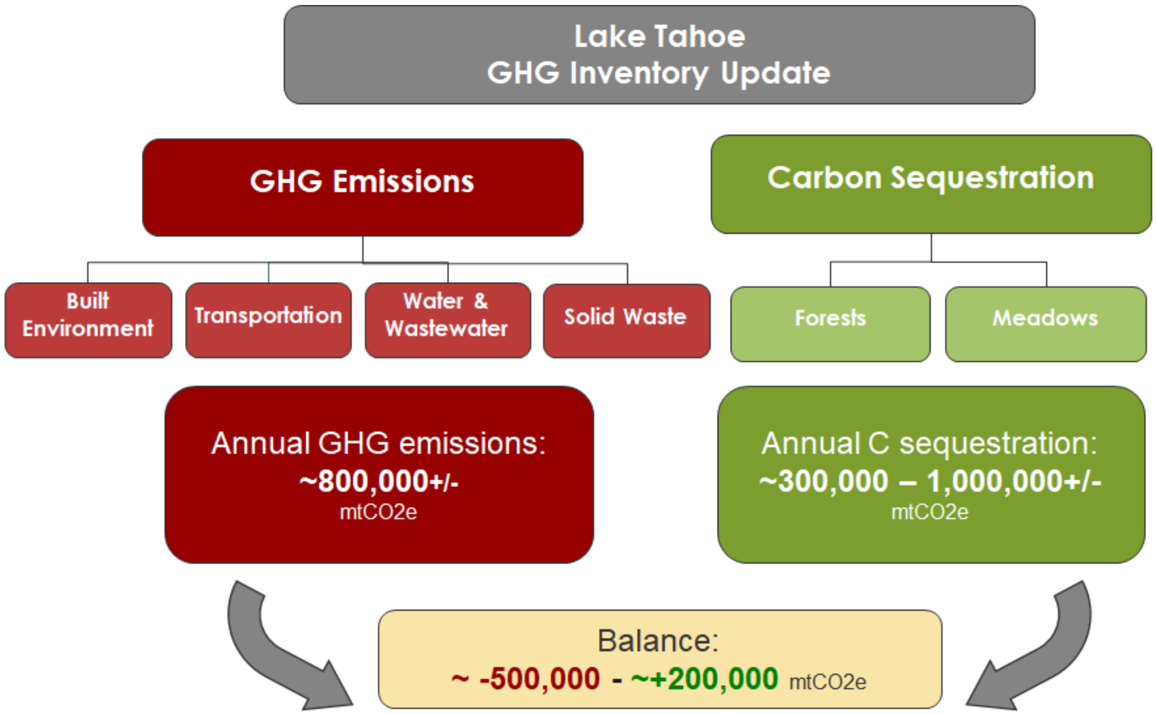
4. **Data-driven policies need to be based on transparent, repeatable methods and results**. It is essential to ask targeted, measurable research questions about emissions and sequestration, then leverage the most appropriate data and tools for those questions. Transparent, repeatable methods allow for the integration of new science and data as they emerge. Additionally, it is important to validate results, and make conservative allowances for data uncertainty when developing a regional carbon accounting balance sheet, carbon monitoring indicator, and other climate thresholds. It is always important to share data with scientists and other agencies, especially given the need for landscape-level planning and multi-stakeholder collaboration. Improving our understanding of carbon science, identifying where gaps are, and identifying what additional research or developments are needed, will help us close those knowledge gaps and maximize the effectiveness of regional and local climate planning and policies.

Application

As Tahoe agencies, California, Nevada, and the world start to enact climate change action, interest has increased in natural climate solutions that may help offset GHG emissions. Various tools and data currently exist to estimate ecosystem carbon stocks and carbon sequestration, but this is largely an emerging science. Therefore it is important to validate existing results, and use transparent repeatable methodologies that allow for inventory updates as new data becomes available, thereby improving our understanding, planning, and climate goals.

One way to explore the relationship between GHG emissions, carbon sequestration—and how that could translate into data-driven climate policy—could be through the development of a carbon accounting balance sheet. At present, there is not an adopted standard or protocol for carbon balance sheets, but such a tool could help track the annual exchange of emissions and sequestration (retrospective look). **Figure 27**, below, provides a snapshot of an example carbon accounting balance sheet. Here, we show the relationship between the Tahoe Basin's annual emissions and carbon sequestration estimated for the year 2018. In order to mitigate climate change, there needs to be more sequestration than emissions that year (and every year moving forward). Paired with an estimate of forecasted emissions or sequestration, agencies are in a prime position to be able to track progress, weigh future management tradeoffs, and develop informed, data-driven climate policy. As the science progresses, reduced data uncertainty can improve estimates for both GHG emissions and carbon sequestration, thereby improving recommended climate actions.

Figure 27. Example Carbon Accounting Balance Snapshot for the Year 2018



A snapshot of inventoried GHG emissions vs. carbon sequestration that occurred in the Tahoe Basin during 2018. Methods that produced these numerical estimations are described in the relevant sections of this report.

Uncertainty is inherent to all datasets, including the ones employed in the built environment and carbon inventories. The wide range in 2018 carbon sequestration values for the Tahoe basin is a result of the variation in forest carbon outputs compared in this analysis, as well as unknown meadow condition status. This indicates that additional strategic reduction actions are needed to secure net-zero carbon emissions to temper climate change, or net-negative emissions to mitigate or reverse climate change.

Even with the wide range in 2018 carbon sequestration values presented in the snapshot above, there is strong evidence that contemporary carbon stocks in the Sierra Nevada and other western US forests are artificially high compared to historical conditions, and that total forest carbon needs to be reduced to steward these forests toward a long-term climate-resilient state. Consensus among published research shows that the current structure and composition of Sierra Nevada's forests have drastically deviated from historical characteristics, largely due to a century of fire suppression.[59,60,61,62] More trees presently than historically in Sierra Nevada's conifer forests[63] may have resulted in significantly higher carbon stocks or sequestration today than what resilient landscapes evolved with. In fact, some studies found upwards of double the live tree carbon stocks at present compared to historically over the short-term period (Sierra Nevada Mountains[64]; Arizona[65]). As a consequence, many forests across the western United States are at significant risk of becoming long-term net carbon emitters as untamed climate change increases catastrophic wildfire and decreases forest resilience.[66]

With many forest resilience and fuels reduction initiatives already in place or being developed, such as the previously mentioned California Natural and Working Lands Inventory, the Tahoe-Central Sierra Initiative, and Lake Tahoe West, there is now a need to compare the relevant results of these programs and work towards accelerating the implementation of their communal goals. Adaptively managing projects, sharing data, and integrating new science (such as local or regional allometric biomass equations, new climate normals, or extreme-but-becoming-more-common wildfire behavior), and acknowledging the climate benefits of avoided wildfire emissions can help reduce carbon accounting uncertainty. Tabular and spatial data about ecosystem carbon stocks and carbon fluxes that contain less variation than the outputs compared in this analysis (which were produced using rigorous scientific methods, expert local insight, and multi-stakeholder collaboration) could provide natural resource management agencies with the information needed to evaluate the best management pathways and their locations, such as fuel treatments or erosion control.

Another recommendation is to consider conducting a full avoided wildfire emissions inventory. Such an inventory was not part of this project; this project was focused on identifying current carbon sequestration to offset built environment emissions for the inventory year of 2018. An avoided wildfire emissions inventory could reveal the long-term net carbon savings of the forest health treatments needed to steward the forest towards a resilient state, despite the short-term net carbon losses those activities might incur. Such a protocol is currently in development by Spatial Informatics Group, Climate

[59] Parsons, D., deBennedetti, S. (1979). Impact of fire suppression on a mixed-conifer forest. For. Ecol. Manag. 2, 21-33.

[60] Agee, J. (1993). Fire ecology of Pacific Northwest Forests. Island Press, Washington, DC.

[61] Sugihara, N., et al., (Eds). (2006). Fire in California's ecosystems. University of California Press, Berkeley, CA.

[62] Dunbar-Irwin, M., Safford, H.D., 2016. Climactic and structural comparison of yellow pine and mixed-conifer forests in northern Baja California (Mexico) and the eastern Sierra Nevada (California, USA). For. Ecol. Manag. 363, 252-266.

[63] Safford, H., Stevens, J. (2017). Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen. Tech. Rep. PSW-GTR-256. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

[64] Collins, B., Everett, R., Stephens, S. (2011). Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. Ecosphere 2(4):51.

[65] Hurteau, M., Stoddard, M., Fule, P. (2011). The carbon costs of mitigating high-severity wildfire in southwestern ponderosa pine. Global Change Biology. 17:1516-1521.

[66] Wear, D. N. & Coulston, J. W. (2015). From sink to source: Regional variation in U.S. forest carbon futures. Sci. Rep. 5, srep16518.

Forward, and the Climate Action Reserve, and is expected to be published in the near future. There are also models and assumptions that can be made about the emissions associated with firefighting efforts, as well as from the wildfire smoke itself, which could be incorporated into a future research project.

Increased data collection would also help inform meadow landscape restoration techniques, and therefore maximize carbon sequestration of these ecosystems. Three considerations to guide meadow restoration are: 1) conducting a rapid assessment of meadows condition to determine which are carbon sinks versus sources, 2) establishing soil carbon metrics to measure meadow restoration success, and 3) pairing current initiatives with long-term monitoring to generate more accurate and complete data. Soil data from the USDA National Resource Conservation Service's Soil Survey Geographic Database (SSURGO or gSSURGO) is a standard soil dataset commonly used by industry professionals. While the breadth of its coverage is helpful, this dataset only has static information on soil organic matter and soil organic carbon that is not updated frequently, does not provide insight into dynamic carbon flux, and is better suited for upland environments than riparian ones. Though there are programs in the Tahoe Region working towards meadow restoration, there is still a significant need to sample, measure, and monitor the soil carbon within these restoration efforts.

Research shows that pristine meadow landscapes can be powerful carbon sinks, whereas their degraded counterparts could actually be net carbon sources.[45] The goal would therefore be to maximize the carbon sequestration ecosystem services of Tahoe's meadows by protecting existing pristine meadows, targeting degraded meadow landscapes for restoration, and establishing long-term meadow soil monitoring to aid understanding of carbon flux and restoration success. Tahoe Aquatic Resources Inventory or other recent SEZ assessments could be crosswalked with Dave Weixelman's (Tahoe National Forest) work on Sierra Nevada meadows and rangelands to produce a preliminary rapid assessment of estimated categorical meadow condition for meadows in the Tahoe basin. This estimated categorical meadow condition can be confirmed through in-field measurements. There is no need to develop novel methodologies for soil carbon sampling in the Tahoe Basin; meadow carbon sampling protocols are already in existence and target requisite data collection, processing, and analysis. Local meadow experts can help land managers to determine appropriate protocols and survey parameters that are necessary for the development of soil carbon flux models. Thus, implementing existing protocols has the added benefit of standardizing research across the Sierra Nevada and beyond, thereby growing a robust body of information to further aid applied ecology and planning efforts.

Meadows are biologically active ecosystems with a high rate of carbon flux. While soil carbon is generally considered stable ("steady state") on the medium to long-term, new research is showing that soil carbon can change appreciably year to year.[45] Additionally, meadows don't necessarily act like wetlands, grasslands, or even fens, so we are now only at the tip of the iceberg when it comes to understanding meadow ecosystem dynamics which presents an exciting opportunity for novel climate research (pers. comm. C. Reed, A. Merrill). Employing "wetness" as a sole indicator of restoration success has limited usefulness in capturing the complexities of meadow recovery and carbon sequestration. Integrating standardized lab and field soil sampling into meadow restoration initiatives that involve frequent, localized, and long-term soil carbon monitoring, in addition to the work already being done, will help land managers better understand how carbon sequestration varies through time (seasonally and annually) and how restoration activities actually impact carbon sequestration abilities of the landscape.

Lastly, another strategic tool for maximizing the carbon sequestration contributions of natural areas to climate change mitigation would be to expand the carbon offset markets (‘cap-and-trade’) and allow all landowners of natural areas the ability to generate revenue from their properties’ contributions to carbon sequestration, especially if landowners commit to implementing landscape scale restoration actions on their own properties or with their neighbors. The California Air Resources Board’s compliance carbon offset market mandates companies that releasing GHG emissions over a certain threshold must pay enrolled landowners for their natural areas’ carbon sequestration ecosystem services, but the current programmatic structure makes it difficult for smaller landowners to participate. Additionally, only private and California State lands can enroll in the compliance market. Expanding access to cap-and-trade markets, such as through the enrollment of aggregated small parcels; developing a nation-wide carbon market to allow participation of federal lands (like the 75 percent of the Tahoe Basin’s forests managed by the USDA Forest Service); or integrating the consideration of avoided wildfire emissions, could increase conservation financing, reduce GHG emissions, and create economic incentives for climate action.

Conclusion

This report provides an updated accounting of the Tahoe Basin's greenhouse gas emissions by major source and jurisdiction, looks at the potential for reducing emissions by changing or removing buildings located in sensitive areas like stream environment zones, provides an assessment of carbon stored in natural ecosystems that can help to offset emissions from the built environment, and highlights current actions that have already been making a difference in reducing basin emissions. By establishing data sources and methodologies that can be used again in the future, this report sets the stage for ongoing monitoring of the basin's progress in achieving national, statewide, regional, and local GHG emission reduction and other goals. It also offers ideas for further analysis that could inform future planning, policy development, and climate-related actions in the basin, including potential mitigation project prioritization and future updates to the Lake Tahoe Sustainable Communities Program and Sustainability Action Plan. And finally, it provides practical information – including key findings, graphs, charts, and maps – that can be used by TRPA and other agencies to communicate needs and progress to the public, stakeholders, and policymakers on a regular basis.

The consultant team of Sierra Business Council and Spatial Informatics Group LLC wishes to thank the project staff at TRPA and the many professionals from throughout the basin and beyond who lent their expertise and knowledge to this project.

References and Further Reading

1. York, T., Pollard, E., Reid, S., Stilley, J. (2013). A Regional Greenhouse Gas Inventory for the Lake Tahoe Basin. California Tahoe Conservancy. Available at https://www.trpa.org/wp-content/uploads/Appendix-A-GHG-Inventory-2013.pdf
2. Lake Tahoe Sustainable Communities Program. Sustainability Action Plan: A Sustainability Action Toolkit for Lake Tahoe. (2013). Tahoe Regional Planning Agency and California Strategic Growth Council. Available at https://www.trpa.org/wp-content/uploads/Final-Sustainability-Action-Plan_FINAL.pdf
3. Greenhouse Effect 101. (2021). Natural Resources Defense Council. Available at https://www.nrdc.org/stories/greenhouse-effect-101#:~:text=The%20main%20gases%20responsible%20for,over%20time%2C%20by%20different%20processes.
4. Core Writing Team, Pachauri, R.K., Meyer, L.A. (2014). Climate Change 2014: Synthesis Report. Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Available at https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf
5. Dettinger, M., Alpert, H., Battles, J., Kusel, J., Safford, H., Fougeres, D., Knight, C., Miller, L., Sawyer, S. (2018). Sierra Nevada Region Report. California's Fourth Climate Change Assessment. Available at https://www.energy.ca.gov/sites/default/files/2019-11/Reg_Report-SUM-CCCA4-2018-004_SierraNevada_ADA.pdf
6. Nevada's Climate Strategy. State of Nevada Climate Initiative. (2021). Available at https://climateaction.nv.gov/our-strategy/
7. Cal-Adapt. California Energy Commission. (2021). Available at https://cal-adapt.org/
8. Global Warming Solutions Act of 2006 (AB 32). California Air Resources Board. Available at https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006
9. Global Warming Solutions Act of 2006: Emissions Limit (SB 32). (2016). California Legislative Information. Available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32
10. Clean Energy and Pollution Reduction Act (SB 350). (2015). California Energy Commission. Available at https://www.energy.ca.gov/rules-and-regulations/energy-suppliers-reporting/clean-energy-and-pollution-reduction-act-sb-350
11. Transportation Planning: Travel Demand Models: Sustainable Communities Strategy: Environmental Review (SB 375). (2008). Institute for Local Government. Available at https://www.ca-ilg.org/post/basics-sb-375
12. Order Directing Executive Branch to Advance Nevada's Climate Goals (EO 2019-22). (2019). State of Nevada Executive Department. Available at https://gov.nv.gov/News/Executive_Orders/2019/Executive_Order_2019-22_Directing_Executive_Branch_to_Advance_Nevada_s_Climate_Goals/

13. Nevada Senate Bill 254. (2019). State of Nevada. Available at https://www.leg.state.nv.us/Session/80th2019/Bills/SB/SB254.pdf
14. Lake Tahoe Greenhouse Gas Emissions Webinar. (2021). Sierra Business Council, Spatial Informatics Group, Tahoe Regional Planning Agency, and California Tahoe Conservancy. Available at https://vimeo.com/520108760
15. Statewide Energy Efficiency Collaborative (SEEC). (2020). Available at https://californiaseec.org/
16. ClearPath. (2021). ICLEI - Local Governments for Sustainability USA. Available at https://icleiusa.org/clearpath/
17. UrbanFootprint. (2021). Available at https://urbanfootprint.com/
18. What is FVS? (2021). U.S. Forest Service. Available at https://www.fs.fed.us/fvs/whatis/index.shtml
19. TreeMap: A tree-level model of the forests of the United States. (2020). Fire, Fuel, Smoke, Science Program. U.S. Forest Service. Available at https://www.firelab.org/project/treemap-tree-level-model-forests-united-states
20. Lake Tahoe Info Sustainability Dashboard. (2021). Tahoe Regional Planning Agency. Available at https://sustainability.laketahoeinfo.org/
21. Tahoe Open Data. (2021). Tahoe Regional Planning Agency. Available at https://www.tahoeopendata.org/
22. U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. (2019). ICLEI - Local Governments for Sustainability USA. Available at https://icleiusa.org/us-community-protocol/
23. State Inventory and Projection Tool. (2021). U.S. Environmental Protection Agency. Available at https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool
24. Global Warming Potential Values. (2013). Greenhouse Gas Protocol. IPCC. Available at https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf
25. The 2012 Update: Restoring Lake Tahoe and Supporting Sustainable Communities. (2012). Tahoe Regional Planning Agency. Available at https://www.trpa.org/regional-plan/
26. About the Zero Tool. (2021). Architecture 2030. Available at https://www.zerotool.org/about/
27. Community-Master-Data-Workbook. (2021). Sierra Business Council.
28. Linking Tahoe: Regional Transportation Plan and Sustainable Communities Strategy. (2017). Tahoe Regional Planning Agency. Available at https://www.trpa.org/regional-plan/regional-transportation-plan/
29. Electricity data provided by Liberty Utilities and NV Energy. Located in the Community-Master-Data-Workbook.
30. Natural Gas data provided by Southwest Gas. Located in the Community-Master-Data-Workbook.
31. On-Road data provided by TRPA. Off-Road data provided by EMFAC (California Air Resources Board). Aviation and boating data provided by City of South Lake Tahoe GHG Inventories. Fuel

consumption data provided by respective counties. Located in Community-Master-Data-Workbook.
32. Solid waste data provided by South Tahoe Refuse and Tahoe Truckee Sierra Disposal. Located in Community-Master-Data-Workbook.
33. Water and wastewater data provided by South Tahoe Public Utility District, Tahoe-Truckee Sanitation Agency, Tahoe City Public Utility District, North Tahoe Public Utility District, Round Hill General Improvement District, Kingsbury General Improvement District, Douglas County Water Utilities, and Glenbrook Water Cooperative. Located in Community-Master-Data-Workbook.
34. Anderson, M., Ruderman, S. (2019). City of South Lake Tahoe Community-Wide & Government Operations Inventories for 2015. City of South Lake Tahoe and Sierra Nevada Alliance. Available at http://cityofslt.us/DocumentCenter/View/14444/City-of-South-Lake-Tahoe-Inventory-Report
35. Shoreline Implementation Program. (2018). Tahoe Regional Planning Agency. Available at https://www.trpa.org/programs/shorezone/
36. Residential Energy Consumption Survey. (2020). U.S. Energy Information Administration. Available at https://www.eia.gov/consumption/residential/
37. Commercial Buildings Energy Consumption Survey. (2020). U.S. Energy Information Administration. Available at https://www.eia.gov/consumption/commercial/
38. California Emissions Estimator Model. (2017). California Air Pollution Control Officers Association. Available at http://www.caleemod.com/
39. Let's Build a Sustainable Future for California. (2021). UrbanFootprint. Available at https://info.urbanfootprint.com/california-civic-program
40. Gonzalez, P., et al. (2015). Aboveground live carbon stock changes of California wildland ecosystems, 2001–2010. Forest Ecology and Management. Available at https://doi.org/10.1016/j.foreco.2015.03.040.
41. Gross, S. et al. (2017). Lake Tahoe West Landscape Resilience Assessment, Version 1. Unpublished report. National Forest Foundation, South Lake Tahoe, CA.
42. CARB (California Air and Resources Board). (2018). An Inventory of Ecosystem Carbon in California's Natural & Working Lands. California Air Resources Board. Available at https://www.researchgate.net/publication/330144562_An_Inventory_of_Ecosystem_Carbon_in_California's_Natural_Working_Lands
43. Di Vittorio, A., and M. Simmonds. (2019). California Natural and Working Lands Carbon and Greenhouse Gas Model (CALAND), Version 3, Technical Documentation. Available at https://resources.ca.gov/CNRALegacyFiles/wp-content/uploads/2019/06/caland_technical_documentation_v3_june2019.pdf
44. SFEI (San Francisco Estuary Institute). (2013). Tahoe Aquatic Resources Inventory: Mapping standards and methodology for channels, wetlands, and riparian areas in the Tahoe basin.Wetland Riparian Area Monitoring Program (WRAMP).

45. Reed, C.C., Merrill, A.G., Drew, W.M. et al. (2020). Montane Meadows: A Soil Carbon Sink or Source?. Ecosystems. Available at https://doi.org/10.1007/s10021-020-00572-x
46. USFS RSL (USDA Forest Service Region 5 Remote Sensing Lab). (2017). EcObject Vegetation Map v2.1 Product Guide, April 2017. Available at https://trpa-agency.github.io/ThresholdEvaluation/EcObject_Vegetation_Map_v2_1_Product_Guide.pdf
47. Mladenoff, D. (2004). LANDIS and forest landscape models. Ecol. Model.180:7–19.
48. Taylor, A.; Van Damme, L. (2009). A review of forest succession models and their suitability for forest management planning. Forest Science 55(1).
49. Lake Tahoe West Restoration Partnership. (2020a). Integrated Vulnerability Assessment of Climate Change in the Lake Tahoe Basin. Available at https://tahoe.ca.gov/programs/climate-change/
50. Lake Tahoe West Restoration Partnership. (2020b). Lake Tahoe West Science Summary of Findings Report. Available at https://www.fs.fed.us/psw/topics/restoration/laketahoewest/documents/LTW-Science-Summary-Final-Report-03Nov20.pdf
51. Penman, J. et al. (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. 590.
52. Dixon, G. Dixon, Gary E. comp. (2002, Revised Jan. 2020). Essential FVS: a user's guide to the Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: USDA Forest Service, Forest Management Service Center. 226p. Available at https://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf
53. Riley, K. L., Grenfell, Isaac C., Finney, M. A. & Wiener, J. M. (2018). Fire Lab tree list: A tree-level model of the western US circa 2009 v1. Available at https://www-fs-usda-gov/rds/archive/catalog/RDS-2018-0003.
54. Elliot, W., et al. (2018). Estimates of surface and mass erosion following the 2016 Emerald wildfire: Final report to the Lake Tahoe West Shore Restoration Project. Available at https://www.fs.fed.us/psw/partnerships/tahoescience/documents/p101_FinalReport.pdf
55. Jenkins, J., Chojnacky, D., Heath, L., Birdsey, R. (2003). National-scale biomass estimators for United States tree species. Forest Science, Vol. 49, No. 1, February 2003. Available at https://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2003jenkins01.pdf
56. Christensen, G., Gray, A., Kuegler, O., Tase, N., Rosenberg, M. (2021). AB 1504 California Forest Ecosystem and Harvested Wood Product Carbon Inventory: 2019 Reporting Period Data update. U.S. Forest Service agreement no. 18-CO-11052021-214, California Department of Forestry and Fire Protection and California Board of Forestry and Fire Protection. 447p. Available at https://bof.fire.ca.gov/media/beddx5bp/6-final_forest_ecosys_hwp_c_2019_feb2021_all_ada.pdf

57. UC Davis, Center for Watershed Sciences & USDA Forest Service, Pacific Southwest Region. (2017). Sierra Nevada Multi-Source Meadow Polygons Compilation (v 2.0), Vallejo, CA, Regional Office: USDA Forest Service. 2017. Available at http://meadows.ucdavis.edu/
58. NCRS (USDA Natural Resources Conservation Service). (2020). Soil Survey Staff. Gridded Soil Survey Geographic (gSSURGO) Database for Nevada. March, 24, 2021 (FY2020 official release). Available at https://gdg.sc.egov.usda.gov/
59. Parsons, D., deBennedetti, S. (1979). Impact of fire suppression on a mixed-conifer forest. For. Ecol. Manag. 2, 21-33.
60. Agee, J. (1993). Fire ecology of Pacific Northwest Forests. Island Press, Washington, DC.
61. Sugihara, N., et al., (Eds). (2006). Fire in California's ecosystems. University of California Press, Berkeley, CA.
62. Dunbar-Irwin, M., Safford, H.D., 2016. Climactic and structural comparison of yellow pine and mixed-conifer forests in northern Baja California (Mexico) and the eastern Sierra Nevada (California, USA). For. Ecol. Manag. 363, 252-266.
63. Safford, H., Stevens, J. (2017). Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen. Tech. Rep. PSW-GTR-256. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. Available at https://www.fs.fed.us/psw/publications/documents/psw_gtr256/psw_gtr256.pdf
64. Collins, B., Everett, R., Stephens, S. (2011). Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests. Ecosphere 2(4):51. Available at https://www.fs.fed.us/psw/publications/ff/psw_2011_collins001.pdf
65. Hurteau, M., Stoddard, M., Fule, P. (2011). The carbon costs of mitigating high-severity wildfire in southwestern ponderosa pine. Global Change Biology. 17:1516-1521.
66. Wear, D. N. & Coulston, J. W. (2015). From sink to source: Regional variation in U.S. forest carbon futures. Sci. Rep. 5, srep16518.

Appendices

Chapter 1: GHG Inventory Appendices

Appendix A. Emissions Factors

Electricity

Grid Electricity Factor Set

Factor Set	Year	Emissions Factor			
		CO_2 lbs/MWh	CH_4 lbs/GWh	N_2O lbs/GWh	CO_2e MT/GWh
General Electricity Use	2005	1,657.876	29.98	80.91	1,680,156.59
General Electricity Use	2010	1,803.381	28.22	62.39	1,820,704.51
Liberty	2015	707.68	34.85	4.25	709,782.05
NV Energy	2015	877.69	79.95	11.7	883,029.1
TDPUD	2015	374.95427	79.95	11.7	380,293.37
CAMX 2015	2015	573.9	34.85	4.25	576,002.05
NWPP 2015	2015	783.45	79.95	11.7	788,789.1
2014 Grid Loss Factor	2015	4.79%	Clearpath Entry >	5.03%	--
Liberty	2018	688.81229	34	4	690,824.292
NV Energy	2018	778.01	64	9	782,187
TDPUD	2018	333.77986	64	9	337,956.8649
CAMX 2018	2018	496.5	34	4	498,512
NWPP 2018	2018	639	64	9	643,177
2018 Grid Loss Factor	2018	4.8%	Clearpath Entry >	5.04%	--

Waste Characterization

CalRecycle Waste Characterization Factor Set

Factor Set	CalRecycle Statewide 2014 Study
Year	**2015 & 2018**
Percentage Mixed MSW	0
Percentage Newspaper	1.2
Percentage Office Paper	4.6
Percentage Corrugated Cardboard	3.3
Percentage Magazines / Third Class Mail	8.1
Percentage Food Scraps	18.7
Percentage Grass	1.1
Percentage Leaves	2.7

Percentage Branches	4.8
Percentage Dimensional Lumber	11.9
Total	**56.4**

Transportation

**Note: All transportation emissions factors (on-road and off-road) are incorporated into the Transportation activity data, located in the Community-Master-Data-Workbook.*

Appendix B. Forecast Data & Growth Rate Sources

Forecast

Greenhouse Gas Emissions Forecast Data

Year	Energy MT CO_2e	Transportation MT CO_2e	Solid Waste MT CO_2e	Wastewater MT CO_2e	Total Emissions
2018	469,380	288,207	37,244	963	795,794
2019	470,541	288,427	37,343	967	797,278
2020	471,705	288,648	37,443	971	798,768
2021	472,873	288,872	37,543	976	800,264
2022	474,045	289,097	37,644	980	801,765
2023	475,219	289,325	37,744	984	803,273
2024	476,398	289,555	37,845	988	804,786
2025	477,580	289,786	37,946	993	806,305
2026	478,765	290,020	38,048	997	807,830
2027	479,954	290,256	38,150	1,001	809,361
2028	481,146	290,494	38,252	1,006	810,898
2029	482,342	290,735	38,355	1,010	812,441
2030	483,541	290,977	38,457	1,014	813,990
2031	484,744	291,222	38,561	1,019	815,545
2032	485,951	291,468	38,664	1,023	817,106
2033	487,161	291,717	38,768	1,028	818,674
2034	488,375	291,968	38,872	1,032	820,247
2035	489,592	292,221	38,976	1,037	821,826
2036	490,813	292,892	39,081	1,041	823,828
2037	492,037	293,566	39,186	1,046	825,835
2038	493,266	294,242	39,292	1,050	827,850
2039	494,497	294,921	39,397	1,055	829,871
2040	495,733	295,603	39,503	1,059	831,899
2041	496,972	296,086	39,610	1,064	833,732
2042	498,215	296,571	39,717	1,069	835,571

2043	499,462	297,057	39,824	1,073	837,415
2044	500,712	297,544	39,931	1,078	839,265
2045	501,966	298,034	40,039	1,083	841,121

Growth Rates

Growth Rate Indicators & Sources

Sector	Indicator	Source
Residential Energy	Total Residential Units	RTP: Appendix G, p. 231
Commercial Energy	Commercial Floor Area	RTP: Appendix G, p. 231
On-Road Transportation	Total VMT	Tahoe Metropolitan Planning Organization
Off-Road Transportation	Residential Units and Commercial Floor Area	RTP: Appendix G, p. 231
Air Travel	Total Aircraft Operations	Federal Aviation Administration Forecasts
Boat Travel	Change in Boating Activity	Shoreline Plan
Solid Waste	Residential Population and Commercial Floor Area	RTP: Appendix G, p. 231
Wastewater	Residential Population	RTP: Appendix G, p. 231

Appendix C. UrbanFootprint & Aging Infrastructure Methodology

UrbanFootprint Methodology Notes

Data Sources to Build Map and Perform Analysis

- Project Area/Boundary
    - Boundary layer sourced from TRPA
        - Shapefile
    - This layer gets established during creation of map/project canvas
- Impervious Surface Map Layer
    - Data sourced from TRPA
        - Shapefile
    - Includes built environment data such as:
        - Building
        - Driveway
        - Road
        - Trail
        - Other
- Stream Environment Zone (SEZ) Map Layer

  - Data sourced from TRPA
    - Shapefile
  - Prioritizing buildings in this region as per RFP
  - Energy Use Analysis for this layer calculated by:
    - Building Energy Use layer > Filter > Join > Select SEZ Assessment Unit layer > saved as new layer
      - Join: SEZ Building Energy Use (Base Scenario) layer
- Commercial Centers Map Layer
  - Data from UrbanFootprint
  - To create this layer from Base Canvas:
    - Base Canvas > Filter tab > Filter > Commercial Centers > Save as
      - Filtered: Base Canvas Commercial Centers layer
  - Prioritizing buildings in this region as per RFP
  - Got Energy Use Analysis for this layer by:
    - Building Energy Use layer > Filter > Join > Filtered: Base Canvas Commercial Centers > saved as new layer
      - Join: Commercial Centers Energy Use layer
- Building Energy Use Estimates
  - Data from UrbanFootprint
  - See Building Energy Use analysis layer
    - Analysis is done at level of base canvas
    - Link to UrbanFootprint methodology
- GHG & Pollutant Emissions Estimates
  - Data from UrbanFootprint
  - See Greenhouse Gas and Pollutant Emissions analysis layer
    - Analysis is done at level of base canvas
    - Link to UrbanFootprint methodology
- Reduction percentage per building type to model intervention scenarios
  - Architecture 2030 developed the Zero Tool for building sector professionals, 2030 Challenge and 2030 Commitment adopters, 2030 District Network Members, and policymakers.
  - The Zero Tool is used to compare a building's design or an existing building's energy use intensity (EUI) with similar building types, understand how a building achieved its EUI (via energy efficiency, on-site renewable energy, and/or green power purchases), and set EUI targets.
    - 2030 Challenge reduction targets for existing buildings are (link):

            - 20 percent today
            - 35 percent in 2025
            - 50 percent in 2030
    - See these additional resources for alternate strategies to model reduction scenarios:
        - EnergyStar Portfolio Manager EUI scores per building type (link)
        - NBI target EUI (link)
        - Set a target (link)
            - ZEPI score (link) commercial
            - HERS (link) residential
            - New construction targets (link)
        - Climate Zones for Tahoe Region:
            - ASHRAE by County
                - Placer: 3B
                - El Dorado: 4B
                - Washoe: 5B
                - Douglas: 5B

Reduction Scenarios

- Scenarios in UrbanFootprint
    - 20 percent Energy Reduction
    - 35 percent Energy Reduction
    - 50 percent Energy Reduction
- Manage > Energy Use > Adjustment Factors

Base Canvas Modification Potential Build Outs

- Build Base Canvas to use TRPA parcel data rather than the default of UrbanFootprint parcel data
    - Currently analysis used default UrbanFootprint data in the Base Canvas
    - Then integrated TRPA data into the Base Canvas so when energy analysis was performed it would use the more precise TRPA data
- Created crosswalk from TRPA building types to UrbanFootprint building types
    - Complication in comparing building types based on differing levels of specificity
    - UrbanFootprint in build on Base Canvas is done at level of Land Use Type 4 for the Building Type or Place Type
        - Analysis level building types are at a more general level than the build Land Use Type 4

- Geometry key from Base Canvas exported data and Parcel layer exported data do not match; therefore unable to merge TRPA parcel data for this analysis

Output

- Mapped spatial output layer with corresponding data table
- Individual and comparative scenario results
    - Summary charts
        - See in UrbanFootprint:
            - Reports > Energy Use
            - Reports > Emissions
    - Spreadsheet summary in Excel format
        - See Aging Infrastructure Energy Use Workbook in Master Data Workbook
            - Tahoe Regional Planning Agency > 10. Working Documents and Drafts > Aging Infrastructure
- Focused on generalized building types that create most energy reduction in SEZ and commercial centers

UrbanFootprint: Documentation and Methodology

- Energy Use Analysis
    - Default set of baseline rates for electricity and natural gas use
        - Derived from U.S. Energy Information Administration (EIA) survey data on energy consumption
        - Rates vary by building type and climate zone
        - Appropriate for generalized estimates
        - Can replace default energy rate inputs if local data available or for future year scenarios
    - Analysis at scale of parcels or census blocks
    - Spatial output layer and corresponding data table
        - Mapping
        - Data exploration
        - Exportable
    - Summary charts and spreadsheet summary in Excel
- Methodology
    - Building and place types
    - Energy use rates

        - Residential energy by type
        - Commercial floor area by type
        - Home/building size is main factor
- Energy Use Calculations
    - Electricity and natural gas use rates (kWh and therms)
        - Residential: per year per dwelling unit
        - Commercial: per square foot of floor area
    - Rates differ by dwelling unit type, commercial building category, and climate zone
- Input Parameters
    - Default electricity GHG emissions rates in UrbanFootprint are based on data from the EPA Emissions & Generation Resource Integrated Database 2016 (eGRID)
    - The GHG emissions rate for natural gas is a constant as indicated by the EPA
    - EIA Residential Energy Consumption Survey (RECS)
        - Residential energy use rates from this 2009 dataset
    - Commercial Building Energy Consumption Survey (CBECS)
        - Commercial energy use rates from this 2012 dataset
    - California Energy Commission (CEC) Residential Appliance Saturation Study (RASS) and Commercial End-Use Survey (CEUS)
    - Can replace defaults with localized baseline inputs via Analysis Module Parameters Manager
- Default Residential Energy Use Rates
    - How dataset was transformed for use in energy use model
    - California
        - West
        - Climate Zone 16
- Output Metrics
    - Mapped spatial output layer
    - Corresponding data table
    - Individual and comparative scenario results via summary charts and spreadsheet
- Endnotes
    - Analysis does not include energy use associated with other fuel types, including fuel oil, propane, and wood
- Base Canvas (see more)
    - Data pipeline

        - The UrbanFootprint Base Canvas combines commercially-sourced parcel data along with trusted public and open data sources using proprietary algorithms and data normalization processes.
    - Civic partnerships
        - UrbanFootprint acquires and integrates the latest land use data and parcel geometries from participating cities in the UrbanFootprint Civic program.
    - Validation & accuracy
        - To ensure the highest quality and accuracy, UrbanFootprint validates our canvas against publicly available census data as well as internal benchmarks.
    - Regular updates
        - UrbanFootprint's team of planners and data scientists routinely update canvas data via major quarterly releases and weekly targeted updates.
- Building Energy GHG Emissions Calculations (see more)
    - The Energy Use module estimates electricity and natural gas use for residential and commercial buildings.
    - Building energy GHG emissions from electricity and natural gas use are calculated on the basis of emissions rate assumptions that can be set separately for the base and individual future-year scenarios.
    - The equation for calculating GHG emissions generated by residential and commercial buildings' electricity use is as follows:

$$GHG_{electricity-use} = Electricity\ (kwh) * ElectricityEmissionRate\ (lbs\ /\ kwh)$$

Chapter 2: Carbon Sequestration Appendices

Appendix D. Meadow Carbon

Notes about Meadow Carbon Restoration

Developing an understanding about which meadows are carbon sinks versus sources could allow for prioritization of landscape resiliency efforts. Employing standardized soil carbon sampling and assessment metrics will allow for transparent and repeatable results across the different meadow landscapes, leading to a better understanding of soil carbon flux. Pairing current initiatives, such as the SEZ Assessment in the region, with long-term monitoring of the area's carbon stocks, will generate richer data to use when informing restoration and climate action policies.

It is critical that multistakeholder collaboratives work with scientists to increase overall understanding of meadow biogeochemistry, which aids the development of meadow carbon flux models. While increased sampling efforts with standardized protocols and long-term monitoring are necessary, proper planning and guidance from meadow experts can help direct efforts to maximize parameter usefulness for models. Additionally, additional research questions (e.g. the impact of soil mineralogy and nutrients on meadow carbon dynamics) may greatly improve model predictions. Many of these studies will need to be conducted using laboratory methods and specialized equipment.

Meadows are biologically active ecosystems with a high rate of carbon flux. While soil carbon is considered stable ("steady state") on the medium to long-term, new research is showing that soil carbon can change appreciably year to year (Reed et al., 2020). Meadows don't necessarily act like wetlands, grasslands, or even fens. For meadows, the NWL CALAND tool references Drexler et al 2015, which is actually a study on fens. Fens are similar to meadows and often lumped in with meadows, but they are not representative of all meadows (pers. comm., C. Reed, A. Merrill). This also means that CALAND is based only on one study at this point.

Interannual meadow carbon flux is influenced by climate and disturbance like conifer encroachment or channel incision. Most of the biomass/carbon in meadows is stored belowground (aboveground biomass is regrown annually). Dense root mats stabilize soil and are a fairly stable pool of C on the medium-long term. It is not obvious which meadows have net C loses vs net C gains without measuring & studying them. Nonetheless, identifying & preserving pristine meadows increases the likelihood of protecting areas that are net carbon sinks. Good indicators of meadows that could be carbon sinks are:

- Vegetation community has high percent of obligate & facultative wetland species (e.g. sedges & rushes)
- No/low channel incision
- No or few indicators of streambank instability
- Shallow depth to groundwater for extended periods of the year

Appendix E. Map of 2014 Forest Carbon (aboveground live carbon pool) in Lake Tahoe West, according to FVS, using Jenkins Allometric Equations

Appendix F. Map of 2014 Forest Carbon (aboveground live carbon pool) in Lake Tahoe West, according to FVS, using FVS-FFE Allometric Equations

Appendix G. Map of 2010 Forest Carbon (aboveground live carbon pool) in Lake Tahoe West, according to the 2010 EcObject created by the USDA Forest Service R5 Remote Sensing Lab

Appendix H. Map of 2018 Forest Carbon (total stand carbon) in Lake Tahoe West, according to FVS, using Jenkins Equations

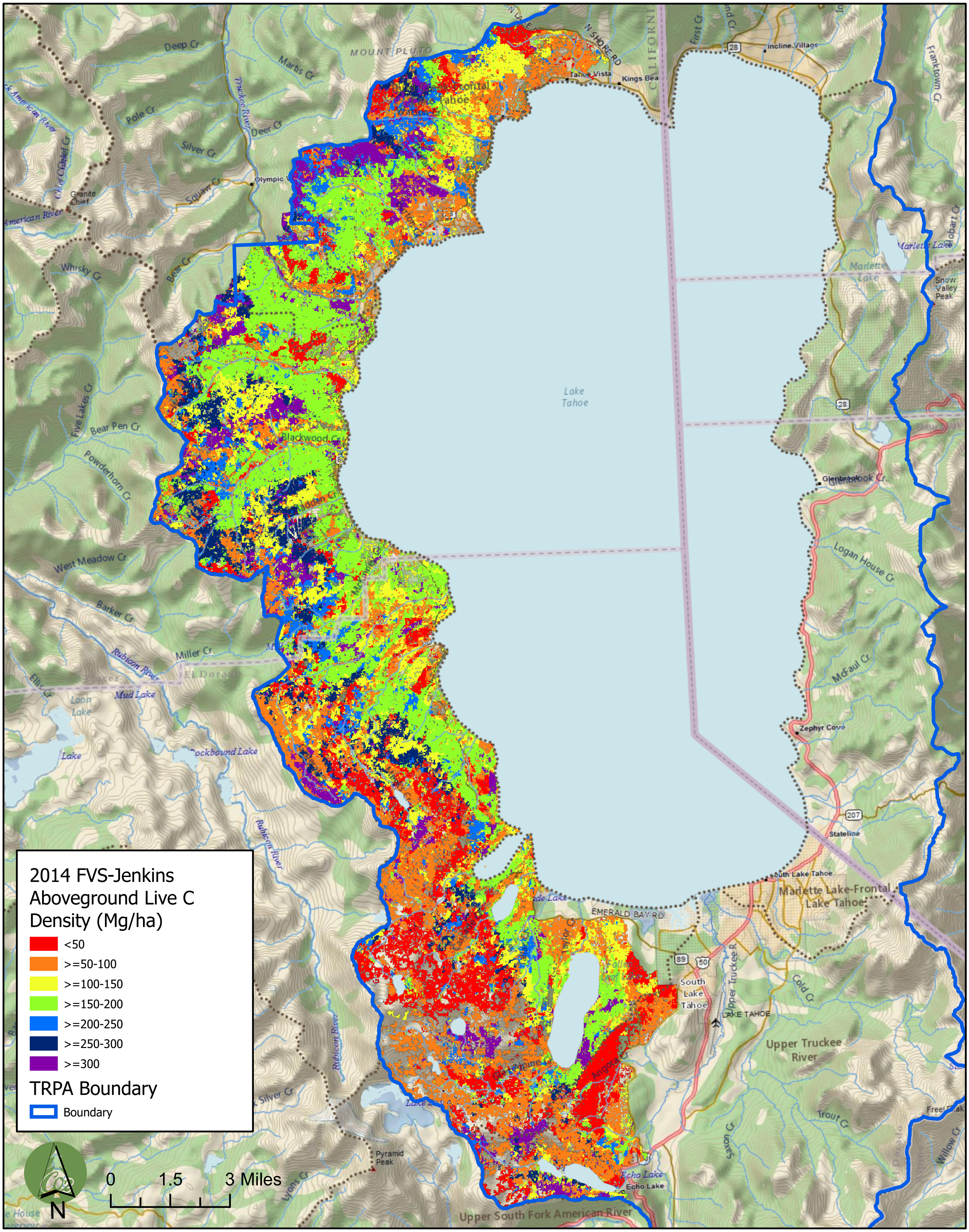
Appendix I. Map of 2018 Forest Carbon (total stand carbon) in Lake Tahoe West, according to FVS, using FVS-FFE Allometric Equations

Appendix J. Map of 2019 Forest Carbon (total stand carbon) in Lake Tahoe West, according to Silviaterra, Purchased for use in the Tahoe Central Sierra Initiative

Appendix K. Map of 2018 Forest Carbon (total stand carbon) in Lake Tahoe West, according to LANDIS-II Modeling by the Lake Tahoe West Restoration Partnership

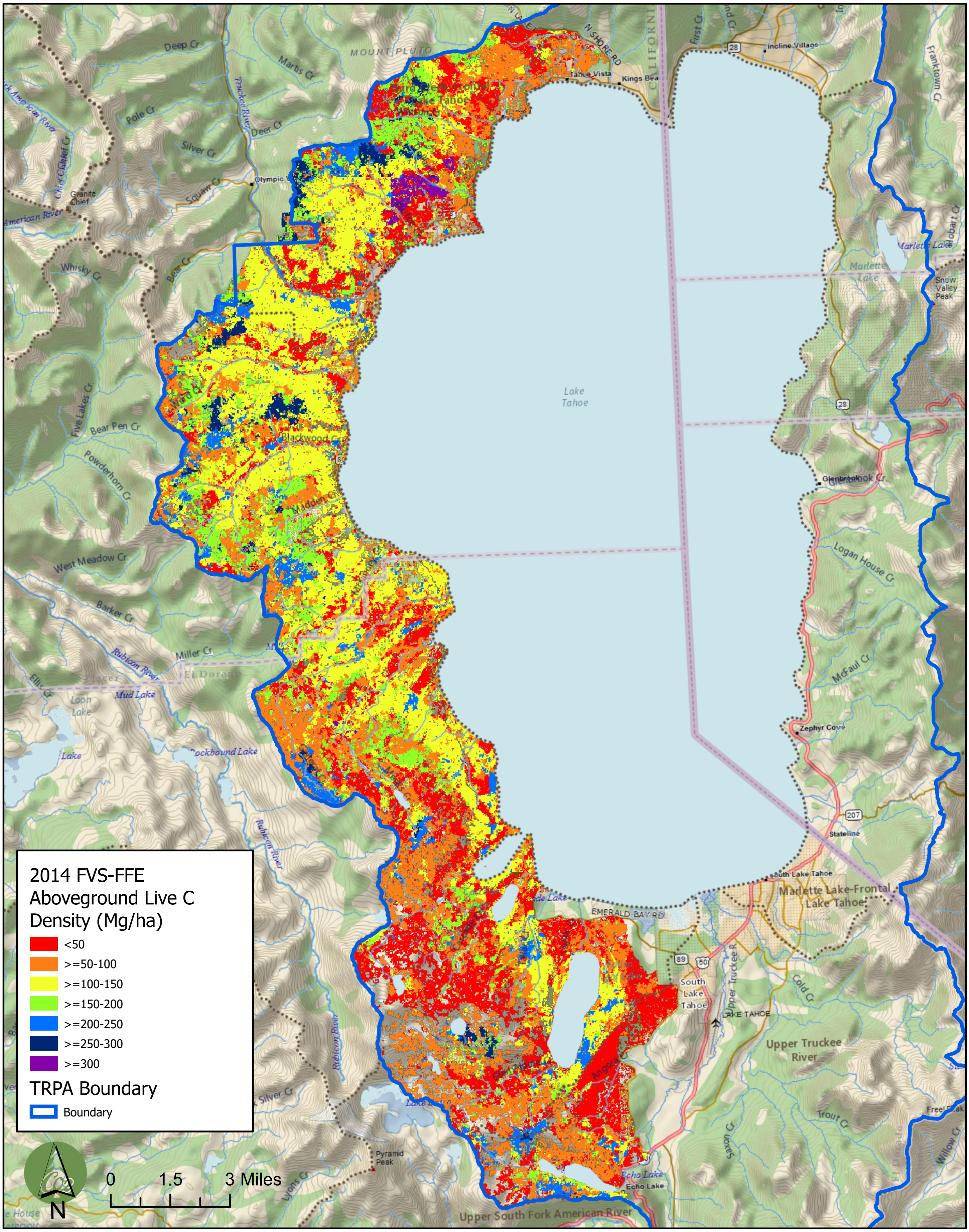
Appendix L. Map of Soil Organic Carbon for Meadows on Tahoe's South Shore

All carbon sequestration appendices attached below.



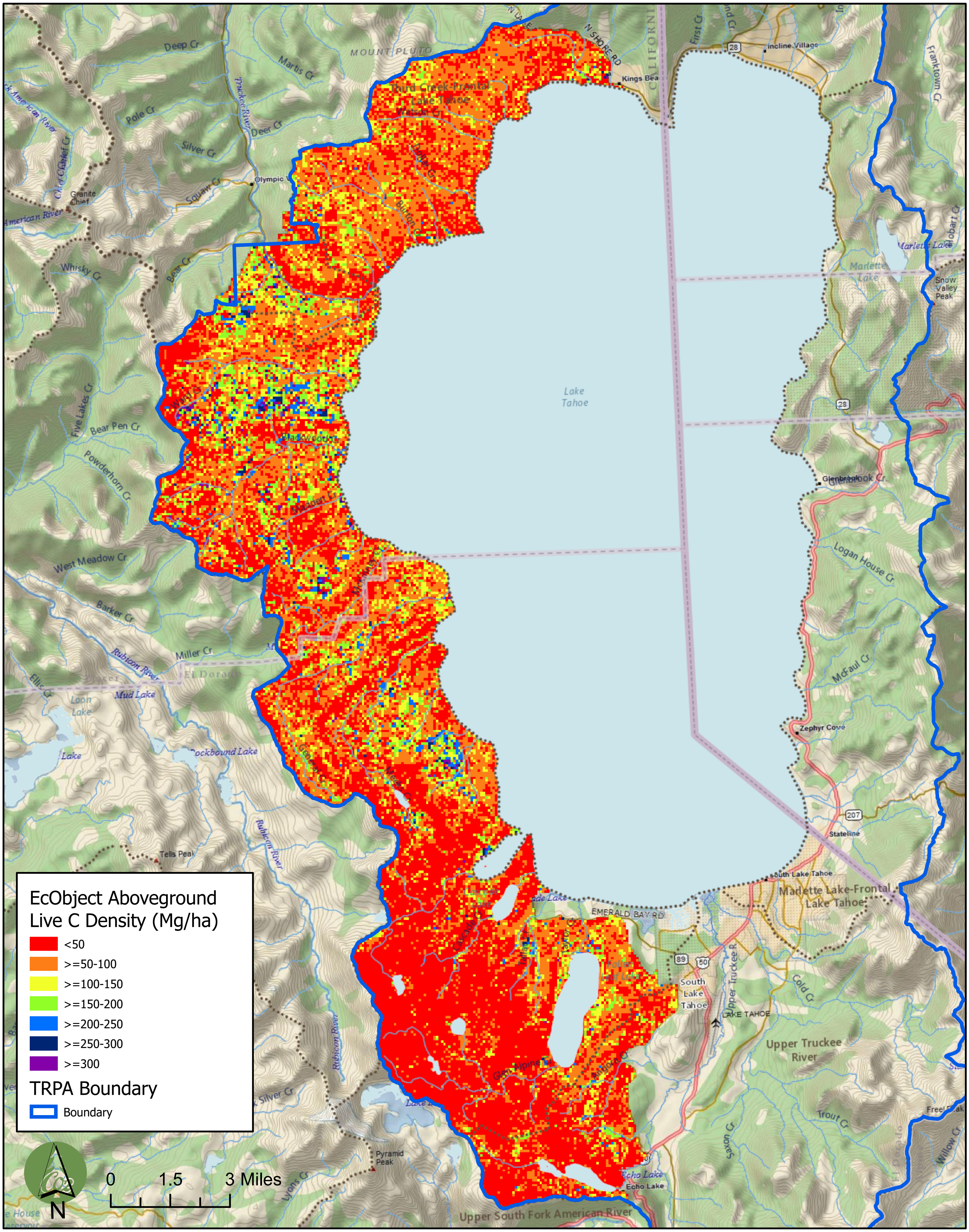
Spatial Informatics Group

AGENDA ITEM NO. VI. B



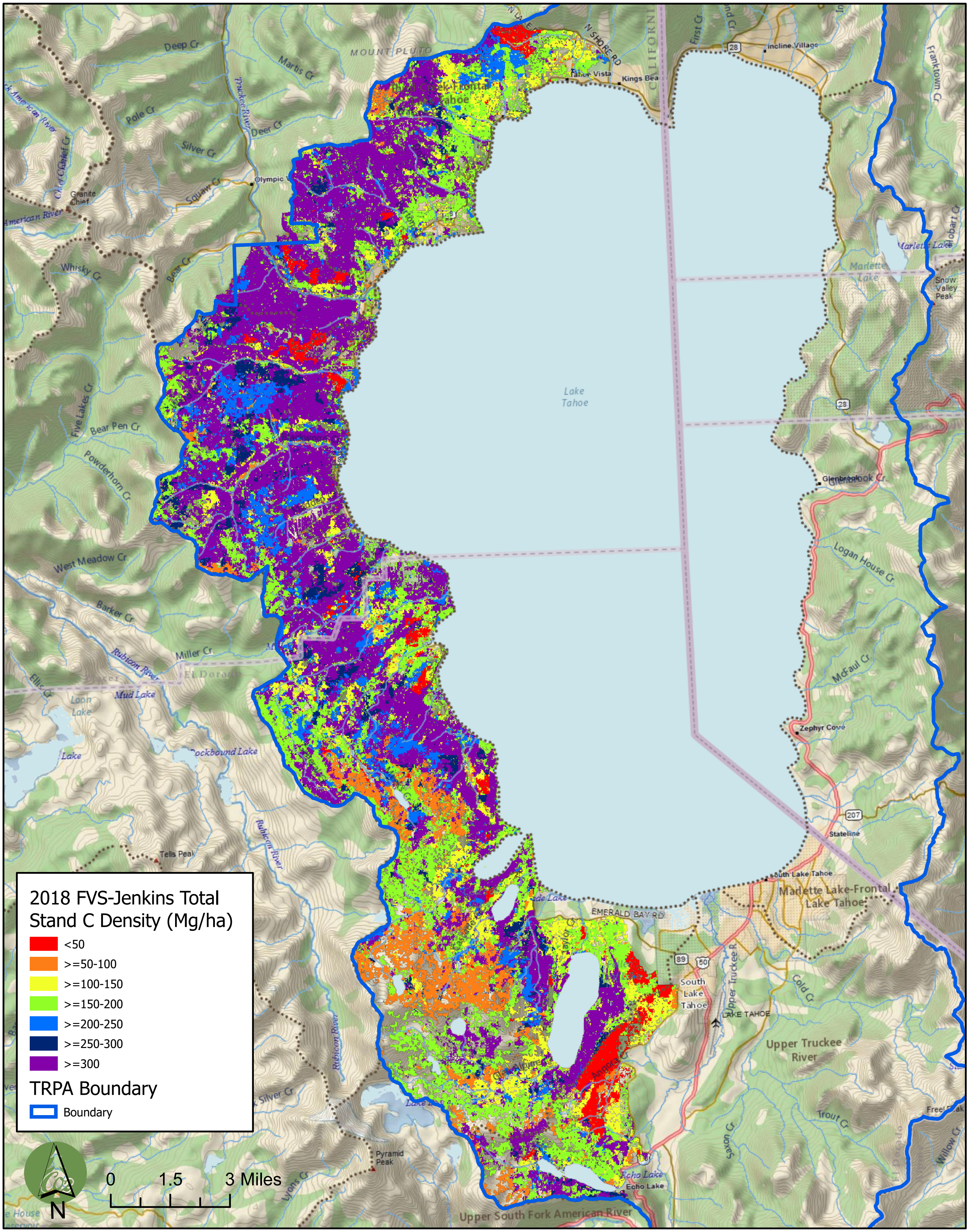
Spatial Informatics Group

AGENDA ITEM NO. VI. B

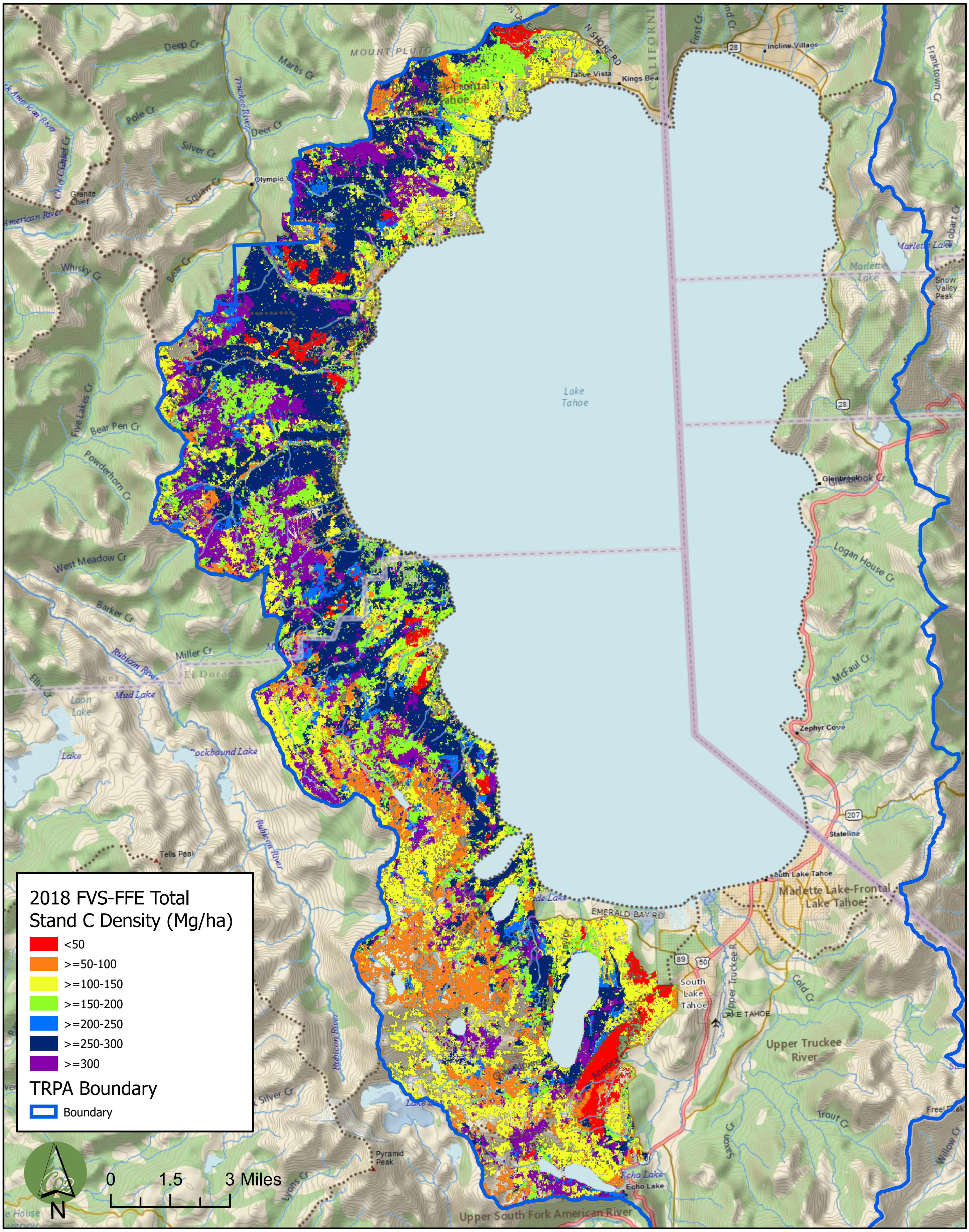


Spatial Informatics Group

AGENDA ITEM NO. VI. B

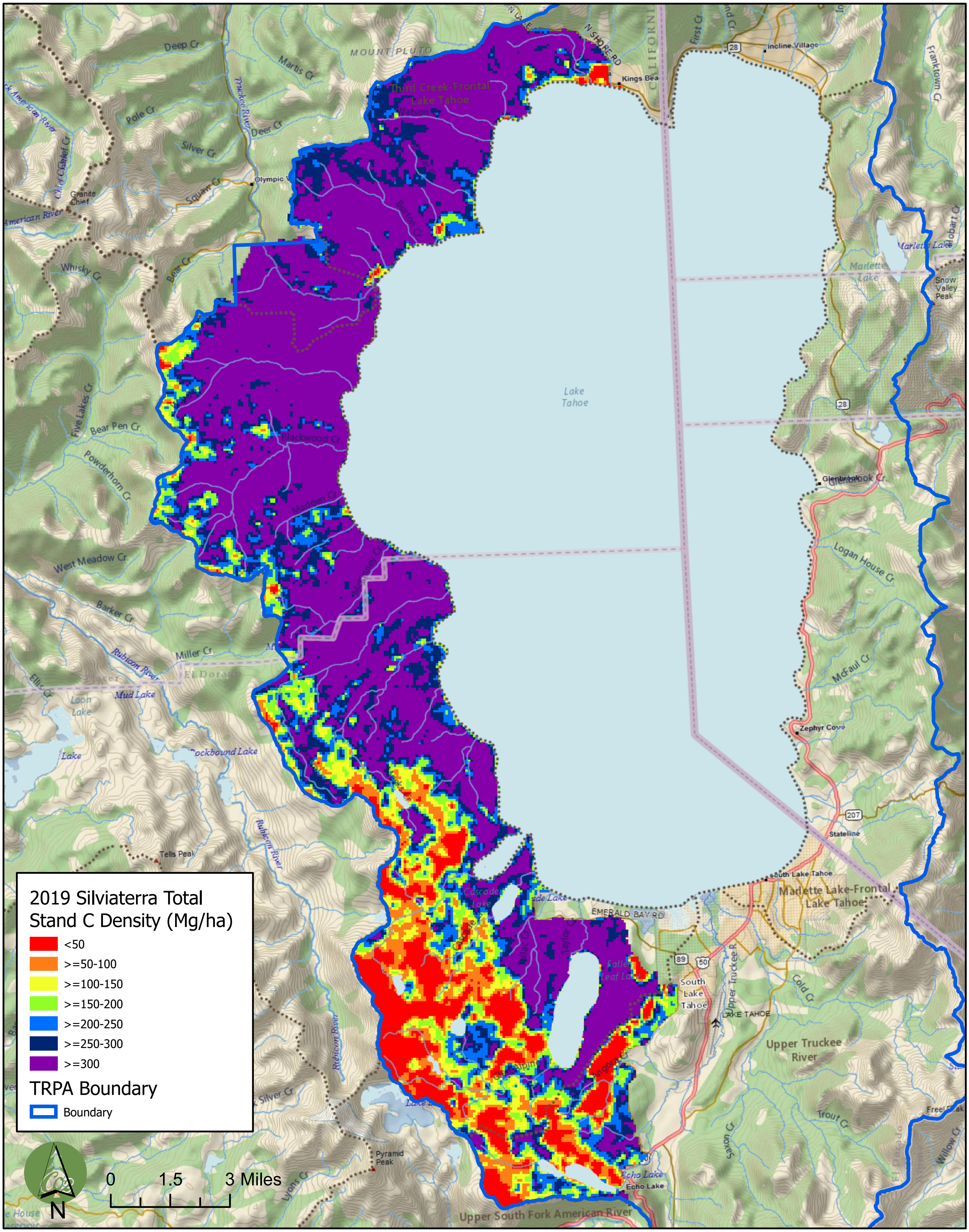


Spatial Informatics Group



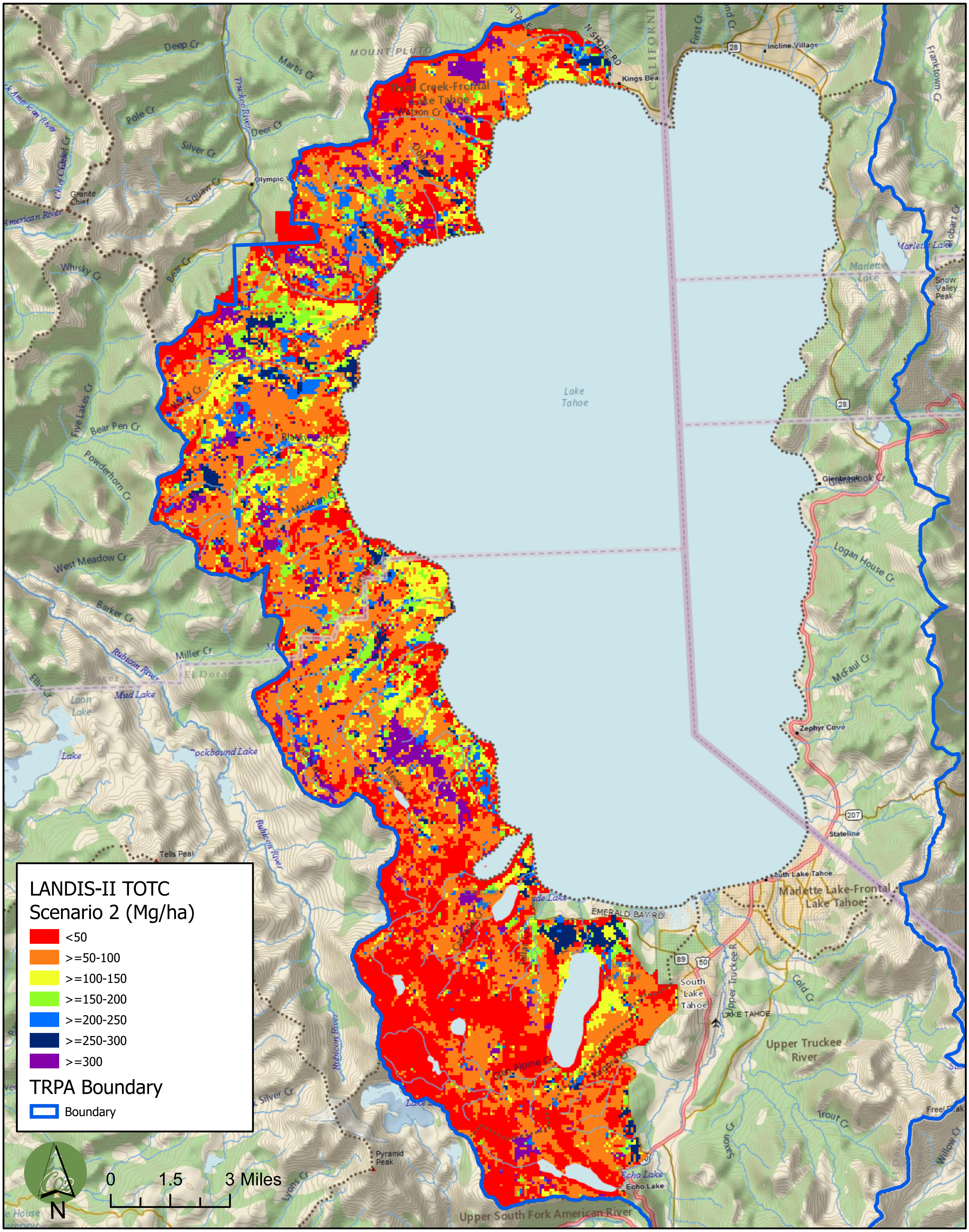
Spatial Informatics Group

AGENDA ITEM NO. VI. B



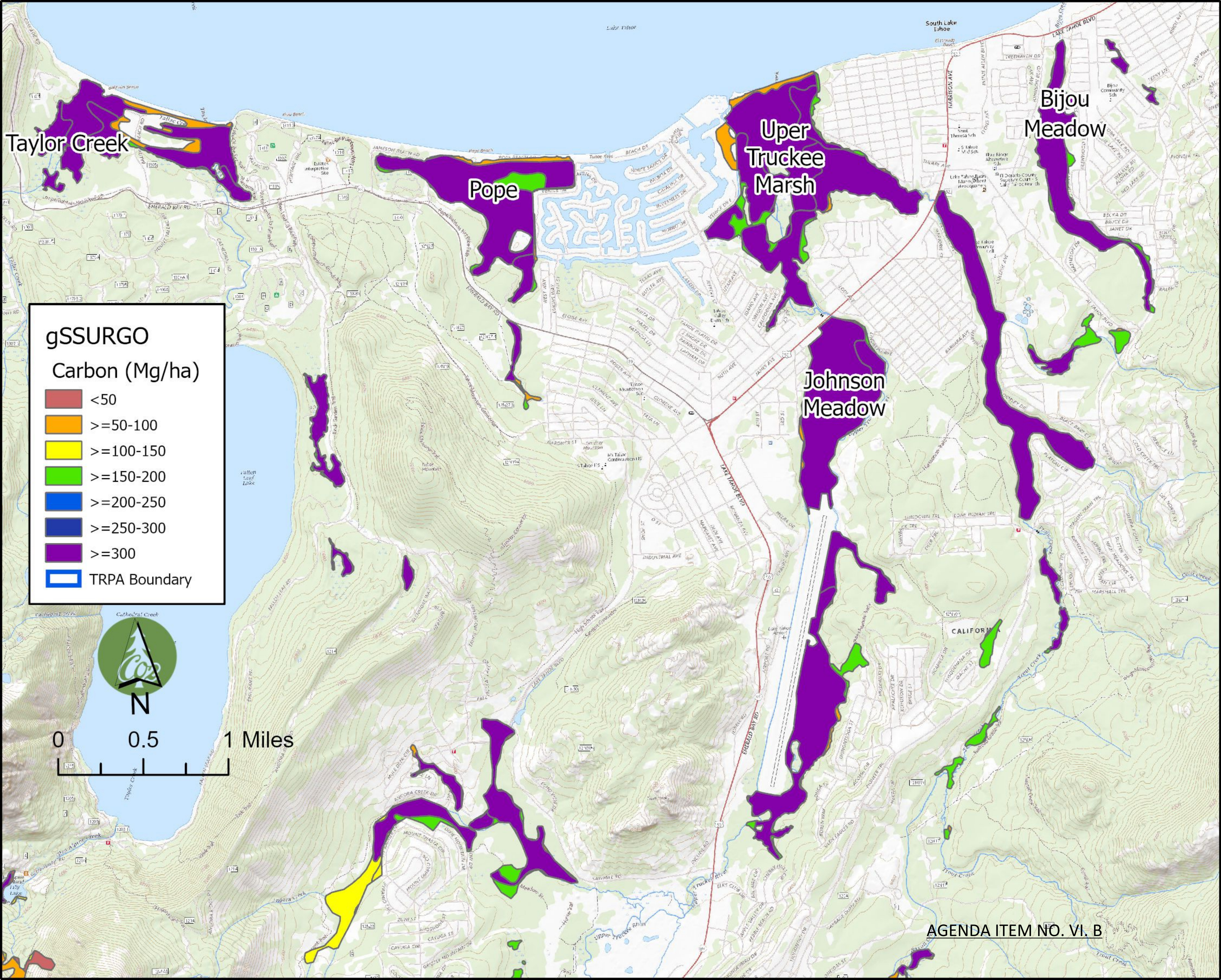
Spatial Informatics Group

AGENDA ITEM NO. VI. B



Spatial Informatics Group

AGENDA ITEM NO. VI. B



AGENDA ITEM NO. VI. B

Attachment B

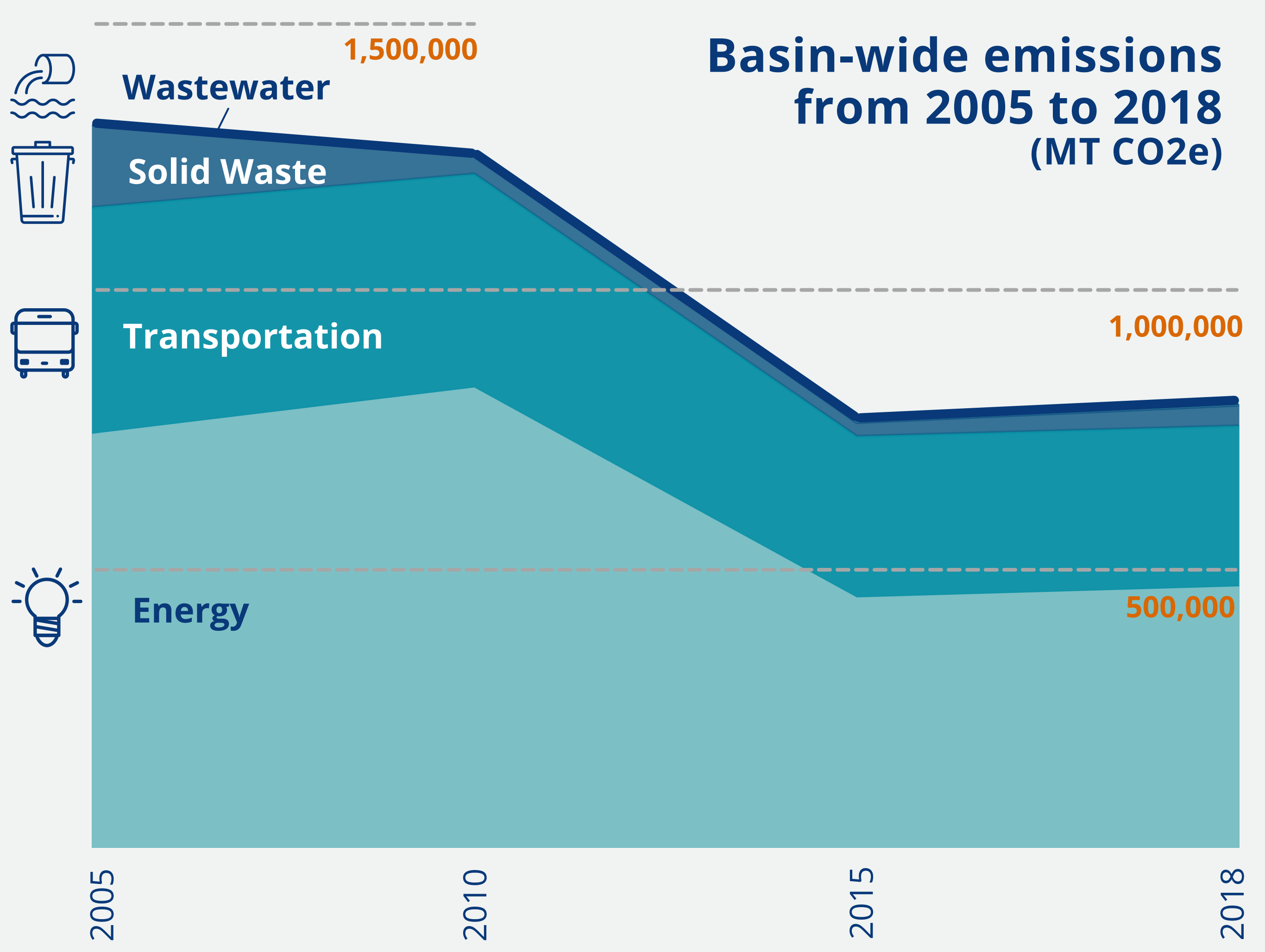
Greenhouse Gas Inventory Infographic

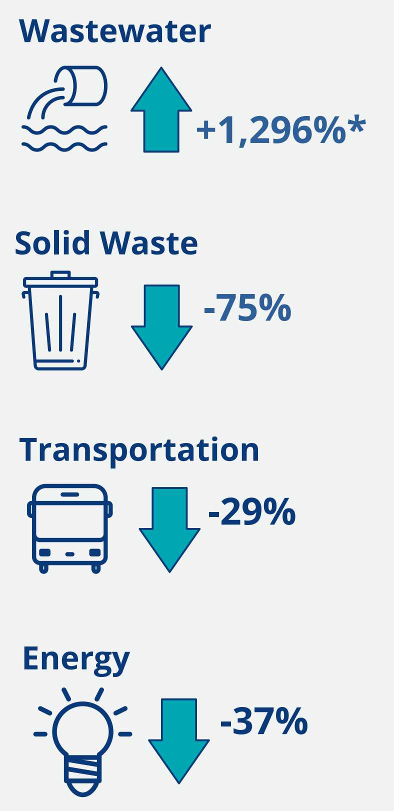
Lake Tahoe Basin
EMISSIONS & SEQUESTRATION

TOTAL 2018 GREENHOUSE GAS EMISSIONS: ~800,000 MT CO2e

Over half of the emissions in the Lake Tahoe Basin come from energy.
Energy + transportation account for **over 95% of total emissions** in the basin.

Emissions decreased from 2005 to 2018, but slightly increased from 2015 to 2018.

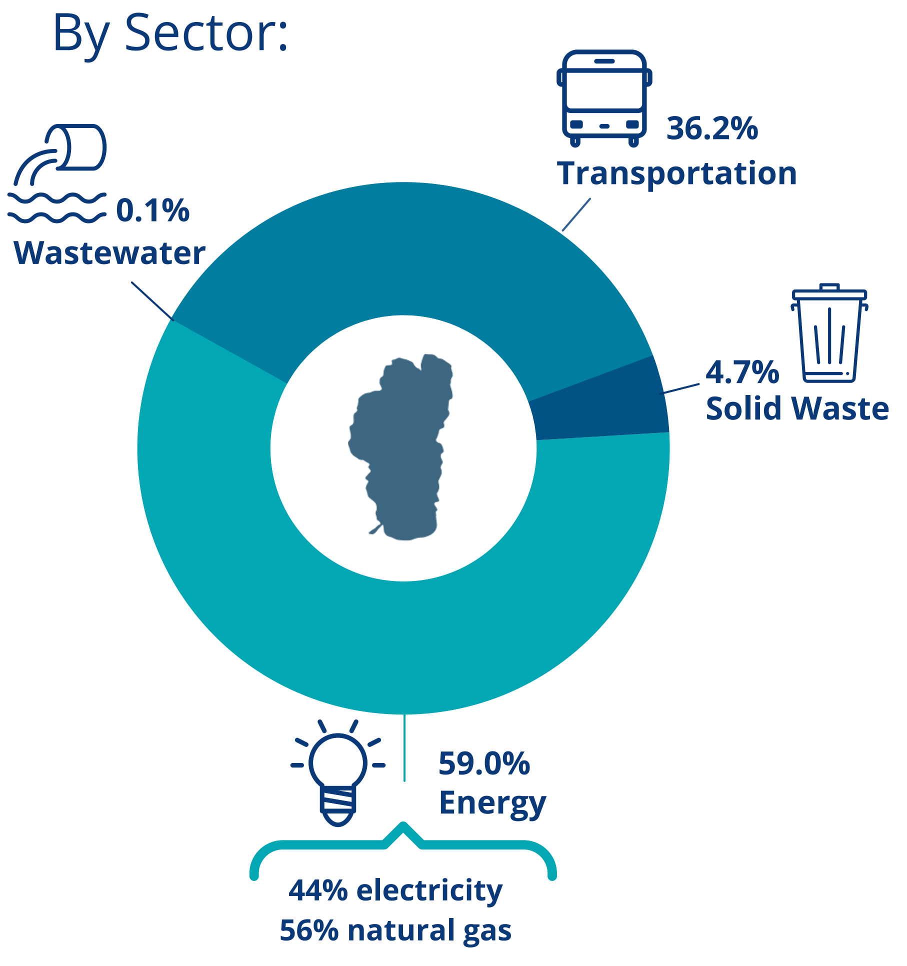




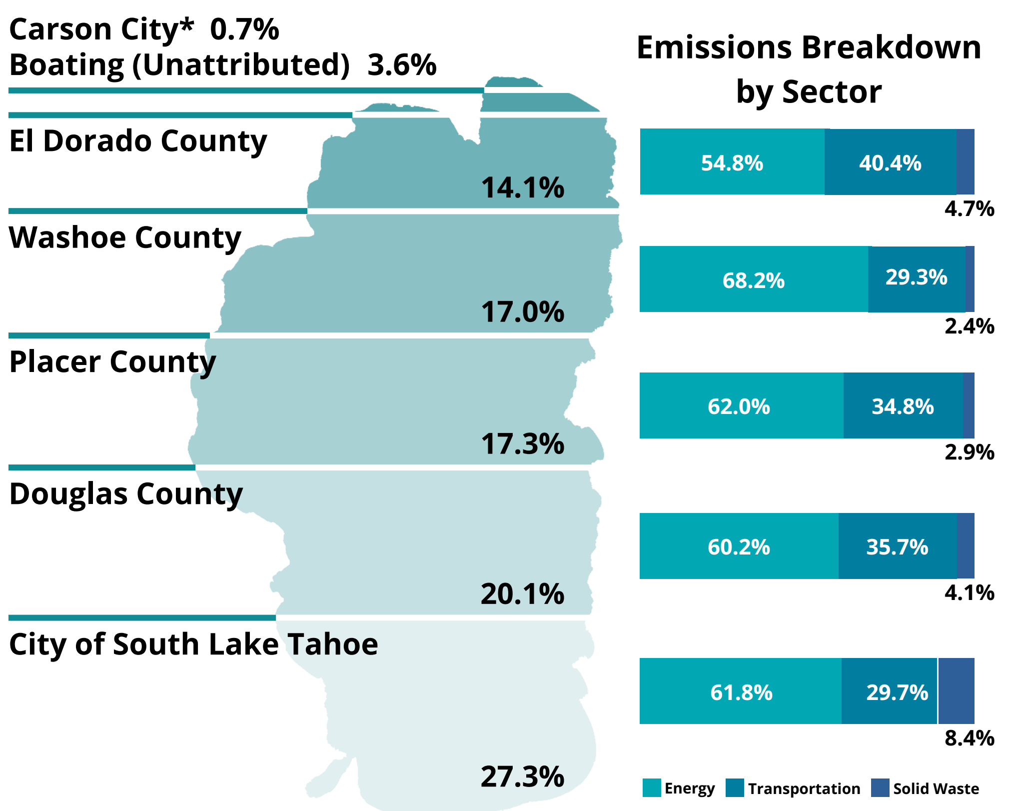
*The sizable increase in wastewater is due to new methodologies that account for additional emissions. As 2015 and 2018 wastewater was only 0.1% of total emissions, the large relative increase did not skew total emissions levels.

2018 EMISSIONS BREAKDOWN

By Sector:



By Jurisdiction:



*The rural portion of Carson City's emissions (within the Tahoe Basin) all come from the Transportation sector.

2014-2018 CARBON SEQUESTRATION

Forest Sequestration in the Tahoe Basin:

Resilient forests are carbon sinks.
Fire-suppressed forests are carbon sources.

175,000 acres of healthy forests sequestered:
300,000 to 900,000 MT CO2e per year
(2014-2018 average)

Carbon Sequestration is an emerging science

The wide range in carbon values for the Tahoe Basin is a result of the variation in forest carbon model outputs, as well as unknown meadow condition status.

Meadow Sequestration in the Tahoe Basin:

Meadows sequester more carbon per acre than forests, but meadows are a diminishing resource as they dry out and are converted into forests.

5,000 acres of meadows could have sequestered
up to 40,000 MT CO2e per year OR emitted -30,000 MT CO2e per year
(2014-2018 average)

Meadows have the potential to play a very important role in carbon sequestration.

REDUCING EMISSIONS IS CRUCIAL

If no further action is taken to continue reducing emissions, overall emissions in the basin are forecast to increase 5.7% by 2045.

CARBON ACCOUNTING BALANCE (2018)

Emissions

Built Environment | Transportation | Solid Waste | Wastewater

-800,000 MT CO2e

Sequestration

Forests | Meadows

+300,000 to +1,000,000 MT CO2e*

NET BALANCE=
-500,000 to +200,000
MT CO2e*

*The wide range in 2018 carbon sequestration values for the Tahoe Basin is a result of the variation in forest carbon outputs compared in this analysis, as well as unknown meadow condition status.

SIERRA BUSINESS COUNCIL | Spatial Informatics Group | CALIFORNIA TAHOE CONSERVANCY | TAHOE REGIONAL PLANNING AGENCY

trpa@trpa.gov | www.trpa.gov | (775) 588-4547