INVENTORY OF LAKE COUNTY GREENHOUSE GAS EMISSIONS AND SINKS

2019

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Executive Summary

Lake County is a rural county in south-central Oregon with an agriculture and forestry-based economy. In the past few years, renewable energy development has brought economic growth to the area after the decline of lumber production led to a loss of jobs.

This report summarizes the greenhouse gas (GHG) emissions from activities occurring in Lake County in the following sectors: stationary energy, transportation, waste, agriculture, forestry, and other land use. Also discussed are the sequestration abilities of forests, harvested wood products, and cropland, as well as the benefits of numerous renewable energy projects using geothermal, solar, and biomass resources. The inventory was compiled for the year 2019 following the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) created by the World Resources Institute (WRI).

Emissions from stationary energy sources such as electricity, propane, diesel, and firewood were 23% of total 2019 emissions at 91,681 metric tons of carbon dioxide equivalent ($MTCO_2e$). Transportation, which includes on-road and off-road travel as well as aviation and railroad activities, comprised another 21% of emissions with 82,921 $MTCO_2e$. Agriculture produced 48% of the county's emissions in 2019 with 190,340 $MTCO_2e$, most of which can be attributed to methane from the enteric fermentation processes of rangeland cattle. The remainder of the emissions are from the decomposition of solid waste and wastewater (1%) and natural wetland processes (7%). Total emissions from all source categories were 396,082 $MTCO_2e$ in 2019, or 49 $MTCO_2e$ per Lake County resident.

Though agriculture created the most emissions, the production of non-alfalfa hay resulted in estimated sequestration of 26,819 $MTCO_2e$ in 2019 due to the storage of carbon in cropland soils. The natural processes of forests in the western part of the county, along with the storage of biomass in long-lasting harvested wood products, resulted in additional sequestration of 71,045 $MTCO_2e$. These two processes alone offset 25% of Lake County's 2019 emissions. When evaluated as economic sectors and accounting for their sequestration amounts, forestry and agriculture are responsible for 35% of the county's net GHG emissions. This amount is proportional to the 29% estimated contribution of the agriculture and forestry economic sectors to Lake County's total GDP.

The large, utility-scale renewable energy projects in Lake County export electricity to customers that would otherwise consume electricity generated by coal, natural gas, or other fossil fuels. PacifiCorp and Portland General Electric (PGE) purchase the electricity and associated renewable energy credits (RECs) from the majority of solar projects that were generating power in 2019. These projects were estimated to prevent 37,543 $MTCO_2e$ of emissions by eliminating the need for fossil fuel-generated electricity. Though the associated RECs and environmental benefits are owned and used by utilities to meet renewable standards set for utilities in Oregon, the prevented emissions are equivalent to 9% of Lake County 2019 emissions. Small-scale renewable energy systems such as rooftop solar and geothermal heating are also common in the county, and without them, annual emissions would be higher by at least 1,490 $MTCO_2e$.

Four more utility-scale solar projects whose electricity and RECs will be purchased by PGE have started electricity generation and will reach their full operating potential in 2020 and 2021. This corresponds to an additional 65,976 $MTCO_2e$ of emissions prevention in 2020 from two of the projects and 109,281 $MTCO_2e$ in 2021 from all four solar sites. In 2020 renewables prevented emissions equivalent to 26% of Lake County's 2019 greenhouse gas emissions, and in 2021 the additional solar projects are expected to increase that value to 36%. Though the RECs from these new projects will be used by PacifiCorp and PGE to meet Oregon renewable energy requirements, and not for offsetting Lake County emissions, it is still valuable to understand the benefits of the renewable projects developed in the county and how they compare to the emissions produced in the same geographic boundary.

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1. Introduction

1.1. Lake County

Lake County is located in the high desert of south-central Oregon, bordering both California and Nevada. The county spans 8,300 square miles over forests, mountains, juniper shrubland, grassland, and the lakes that it is named for (Figure 1).[1,2] A majority of the land, around 75%, is owned by state or federal government entities such as the U.S. Forest Service (USFS), Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (FWS), and State of Oregon agencies. In 2019 the population of Lake County was 8,080 people, with over 34% of those people residing in the town of Lakeview.[3]

The climate in the county consists of cold winters and warm dry summers, with some snow in the winter and little precipitation in the summer. Lakeview receives 15 inches of precipitation which includes 54 inches of snowfall annually, while Christmas Valley receives only 12 inches of precipitation including 12 inches of snowfall each year.[4] There is a large climate variance between different locations in Lake County based on their distance from the East Cascades mountain range that lies to the west.

The main economic drivers in the county are agriculture (both livestock and hay production), timber harvesting, and government (local, state, and federal). Cattle are raised on rangeland mostly in the southern part of the county, while hay and alfalfa are grown in the north. The only remaining sawmill in the county is located in Lakeview, and the various government agencies employ locals in Lakeview and more remote field offices. Lake County had a GDP of $355 million in 2019.[5]

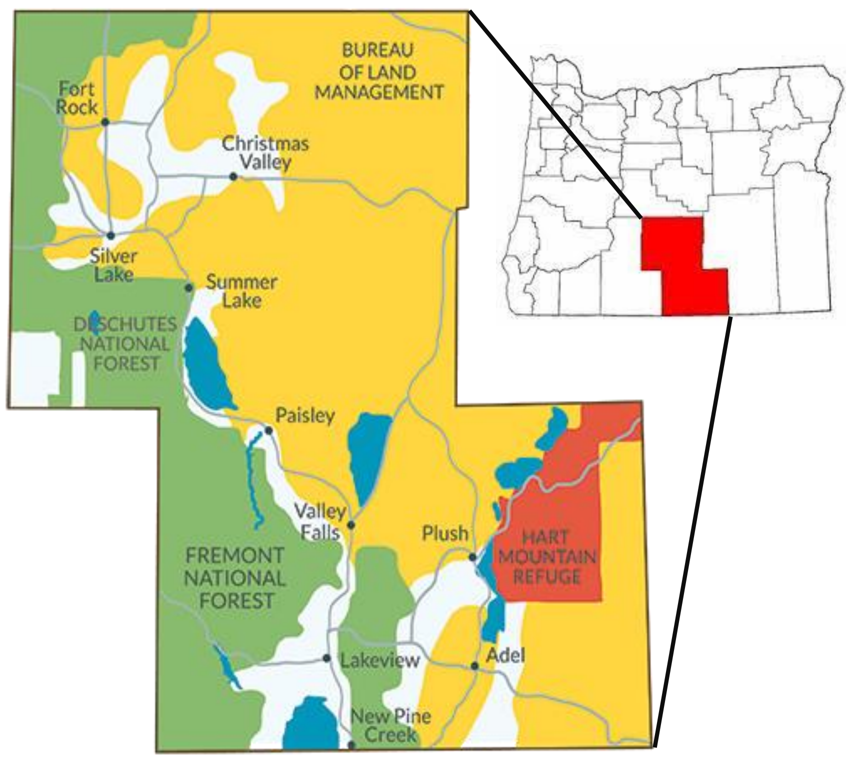


Figure 1. Map of Lake County, Oregon

Lake County also has several renewable energy resources that have boosted the area's economy in recent years, including solar, geothermal, and biomass. Transmission lines from PacifiCorp, the Bonneville Power Administration (BPA), and Portland General Electric (PGE) near Christmas Valley and Lakeview allow expansive solar farms to export energy from Lake County to areas with more dense populations and higher energy consumption.

1.2. Greenhouse Gas Emissions Inventories

Greenhouse gases (GHGs) are gases that trap heat in the atmosphere and, when released in large quantities, contribute to climate change.[6] The purpose of a greenhouse gas emissions inventory is to quantify the amount of these gases that are released via all activities in a certain area and can be performed at local, state, or national levels. Inventories are used to inform decision-making for climate legislation and track progress on preventing or offsetting GHG emissions.

The Oregon Department of Environmental Quality (DEQ) produces a greenhouse gas emissions inventory every five years for the entire state of Oregon. The goal of the inventory is to document changes in emissions from 1990 levels, with goals of a 10% reduction by 2020 and an ambitious 75% reduction by 2050. Because of this, the inventory covers all years since 1990 to show the yearly changes in energy consumption and resulting emissions. As of 2015, Oregon's GHG emissions were up 10% from 1990.[7]

The U.S. Environmental Protection Agency (EPA) creates an annual inventory of GHG emissions and sinks for the entire United States to comply with the United Nations Framework Convention on Climate Change (UNFCCC). Each year the environmental impacts of all sectors since 1990 is analyzed, and results in 2019 showed that emissions increased 2% from 1990 to 2019.[8] The EPA's expansive report is used by the federal government to identify sectors and activities where GHG emissions can be reduced to develop incentives and legislation for energy efficiency, renewable energy, fossil fuel use and more.

The purpose of this inventory is to identify all GHG emissions and sinks, as well as the emissions from the broader region prevented by renewable energy installations, within Lake County in 2019. The analysis of Lake County separate from the full Oregon inventory for the DEQ provides an opportunity for local residents, landowners, employers, and government agencies to understand how each sector consumes energy in a rural community. This inventory assesses the impacts of forest management, agriculture, renewable energy, and more on the amount of GHG emissions released from the county. It will allow for private and government land owners to consider the impact of management practices on climate change and the emissions balance of Lake County and provides concrete data for local decision-making related to GHG emissions. Additionally, this inventory highlights the ability of renewable energy projects to prevent emissions from electricity generation with impacts reaching far from the project area.

While this report only includes a single year of activity in Lake County, it still provides important baseline data about the balance of emissions and sinks. Unlike the DEQ and EPA inventories, it does not address changes in emissions from year to year.

2. Methodology

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) is a set of guidelines that provides requirements for GHG emissions reporting that adhere to the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. The IPCC Guidelines are the international standard for all GHG inventories, and the GPC was created by the World Resources Institute (WRI), a non-profit organization that is a world leader in climate research.

The purpose of the GPC is to standardize the framework used to inventory GHG emissions in cities, counties, and states across the world. It will be used here to encourage a standard for future county GHG emissions inventories in Oregon and the rest of the United States.

The geographic boundary defined for this inventory is Lake County, Oregon and the 12-month time period is the year 2019. The greenhouse gases included in the reporting will be carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The four other GHGs recommended for reporting by the GPC (hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride), are called fluorinated gases and only made up 3% of the total U.S. GHG emissions in 2018. They are mostly released by specific industrial processes, none of which occur in Lake County, and will be omitted from this inventory.

All "Scope 1" emissions (emissions from sources within the inventory boundary) and "Scope 2" emissions (emissions from grid-supplied energy sources) will be included in this report. The use of these specific scopes defined in the GPC allows for easy aggregating of data between other counties in Oregon and eliminates the potential for double-counting emissions if other inventories are created.

Emissions for each sector will be reported in metric tons of carbon dioxide equivalent ($MTCO_2e$) as per the GPC guidelines. CO_2e is a unit of measurement that accounts for the global warming potential of different GHGs.[9] Carbon dioxide (CO_2) has a CO_2e value of 1, all other gases are converted to CO_2e by multiplying by the 100-year global warming coefficient provided by the US Environmental Protection Agency (EPA).

The GPC recommends that inventories differentiate between biogenic emissions (emissions from the combustion of biomass) and all-other anthropogenic (human-caused) emissions. The purpose of this is to avoid double-counting the emissions from this biomass when land-use activities are already listed as sinks or sources of emissions.

All detailed methodologies for each emissions calculation and all required assumptions will be referenced in the appendix, as well as data sources. This ensures full transparency of the inventory whenever it is not related to confidential information. In general, the Oregon DEQ and the U.S. EPA activity protocols and data selection methodologies were used when specific local data for Lake County could not be found.

3. Stationary Energy

Stationary energy is any form of energy that is consumed at a non-moving point source. This includes electricity consumed in the county, the fuel used for heating in residential and commercial buildings, and other fuel use for industrial processes. A summary of the emissions from each of these sources is shown in Figure 2 and each category is discussed in the following report sections.

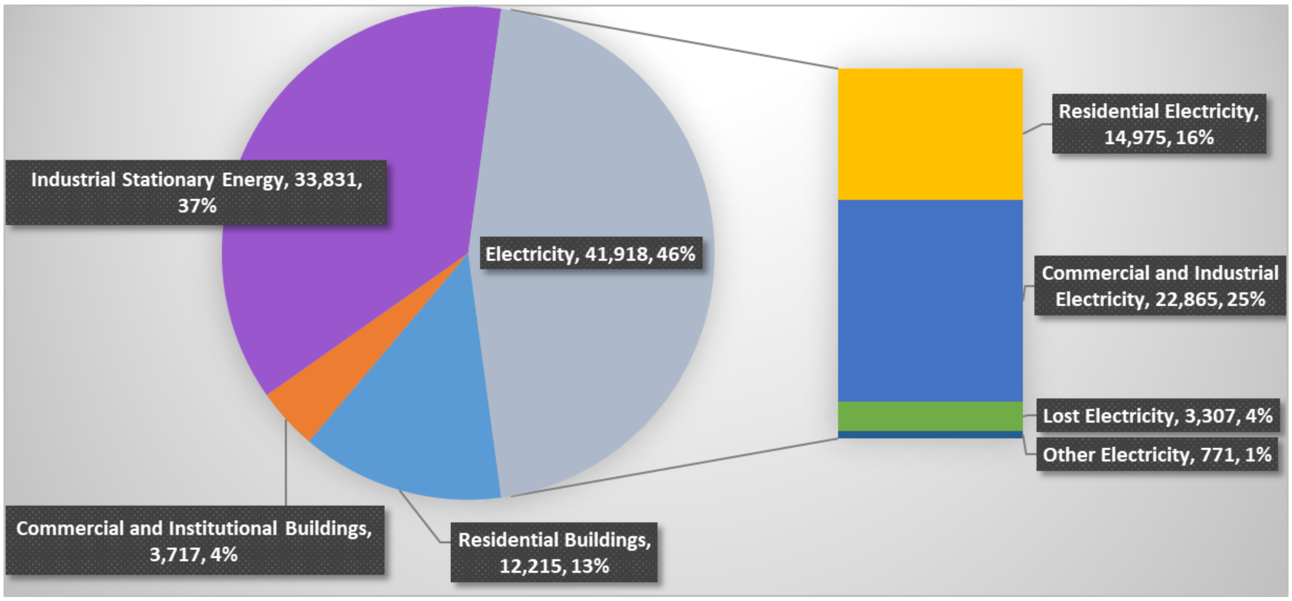


Figure 2. Emissions (MTCO$_2$e) from stationary energy emission sources in Lake County, 2019

3.1. Electricity

Three utilities provide electricity to Lake County. One of these, PacifiCorp (also known as Pacific Power) is an investor-owned utility that services Lakeview, while the other two, Surprise Valley Electrification and Midstate Electric, are electric cooperatives that service the remainder of the county. Surprise Valley and Midstate both purchase electricity, 100% of what they sold in 2019, from the Bonneville Power Administration (BPA). BPA is a nonprofit federal power marketing administration, part of the US Department of Energy, that markets electricity primarily from federal hydroelectric projects and a few nonfederal power plants.

Table 1 details the 2019 electricity sales in Lake County from each utility for the following sectors: residential, commercial and industrial, irrigation, public street lighting, and lost energy. Lost energy from electrical transmission and distribution line losses are listed as Scope 3 emissions in the GPC, and were thus included in the total amount of kilowatt-hours (kWh) consumed in Lake County.

In 2019, PacifiCorp produced 57% of its electricity from coal and 18% from natural gas, both carbon-intensive sources that comprised 75% of the total resource mix.[10] In comparison, BPA's resource mix was 83% hydropower and 11% nuclear – neither of which are carbon-intensive energy sources.[10] The full resource mix for both electricity providers from the Oregon Department of Energy (ODOE) is shown in Figure 3.

Table 1. Electric utilities kWh sales in Lake County, 2019

Sector	PacifiCorp (kWh)	Midstate (kWh)	Surprise Valley (kWh)	Total (kWh)
Residential	19,992,669	42,359,703	16,648,864	79,001,236
Commercial and Industrial	32,470,055	16,222,796	6,793,375	55,486,226
Public Street Lighting	195,652	1,027	20,160	216,839
Irrigation	313,885	6,760,685	11,266,816	18,341,386
Used By Utility	63,720	173,018	576,175	812,913
Lost Energy	4,563,127	3,904,441	4,026,935	12,494,503
Total	57,599,108	69,421,670	39,332,325	166,353,102
Percentage of Total kWh	34.62%	41.73%	23.64%	100%

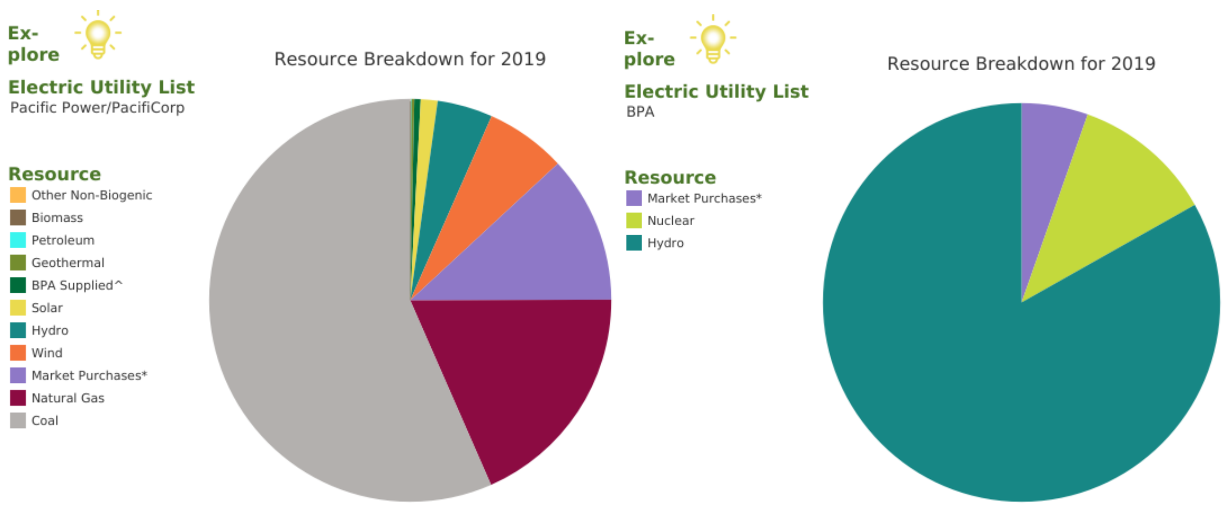


Figure 3. PacifiCorp (left) and BPA (right) fuel resource mixes, 2019

This difference in resource mixes is apparent in the emissions factors reported by PacifiCorp and BPA to the Oregon Department of Environmental Quality (DEQ). The PacifiCorp factor for 2019 was 0.69 $MTCO_2e/MWh$ and the BPA factor was only 0.02 $MTCO_2e/MWh$.[11] This discrepancy in factors alters the proportion of greenhouse gas emissions attributed to PacifiCorp-provided electricity versus that of Midstate and Surprise Valley (Figure 4 and Figure 5).

The breakdown of kWh consumption by utility in the county was 42% Midstate Electric, 35% PacifiCorp, and 23% Surprise Valley Electrification. However, PacifiCorp customers produced 95% of the greenhouse gas emissions from electricity in the county, while Midstate and Surprise Valley customers were only responsible for 3% and 2% respectively. The commercial and industrial sectors produced 55% of emissions from electricity, with residential producing 36% and irrigation, public lighting, and lost energy responsible for the remaining 9%. In total, electricity consumption and losses in Lake County in 2019 emitted 41,918 $MTCO_2e$.

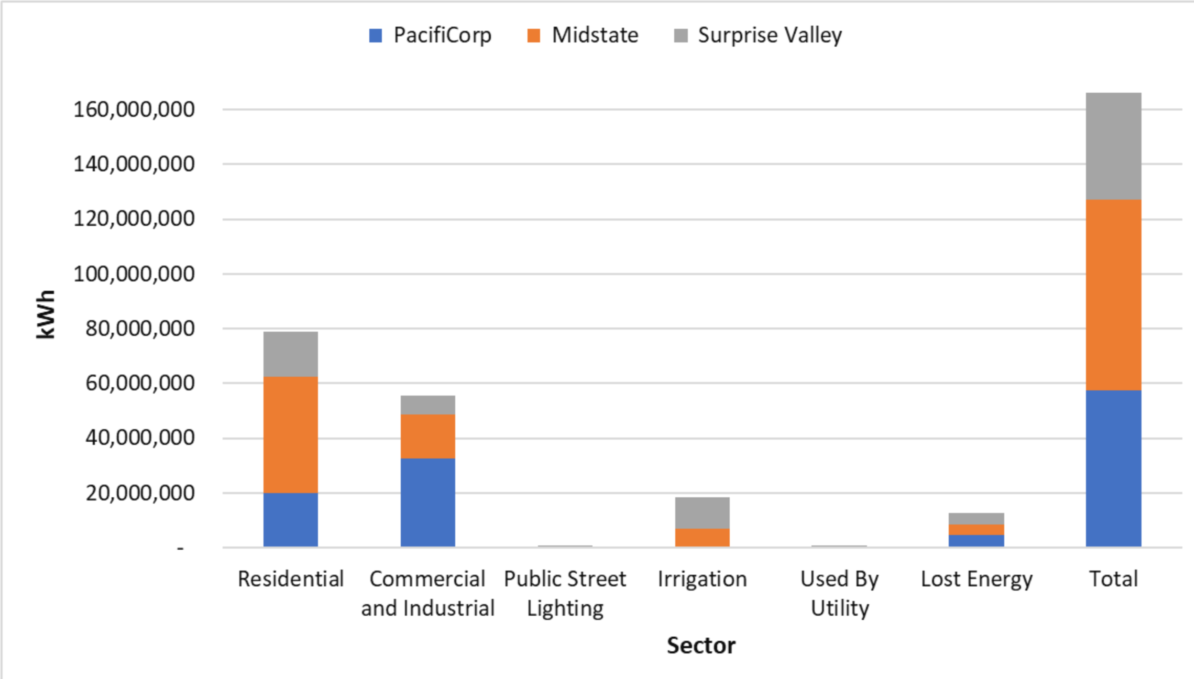


Figure 4. Electricity usage (kWh) by sector and utility, 2019

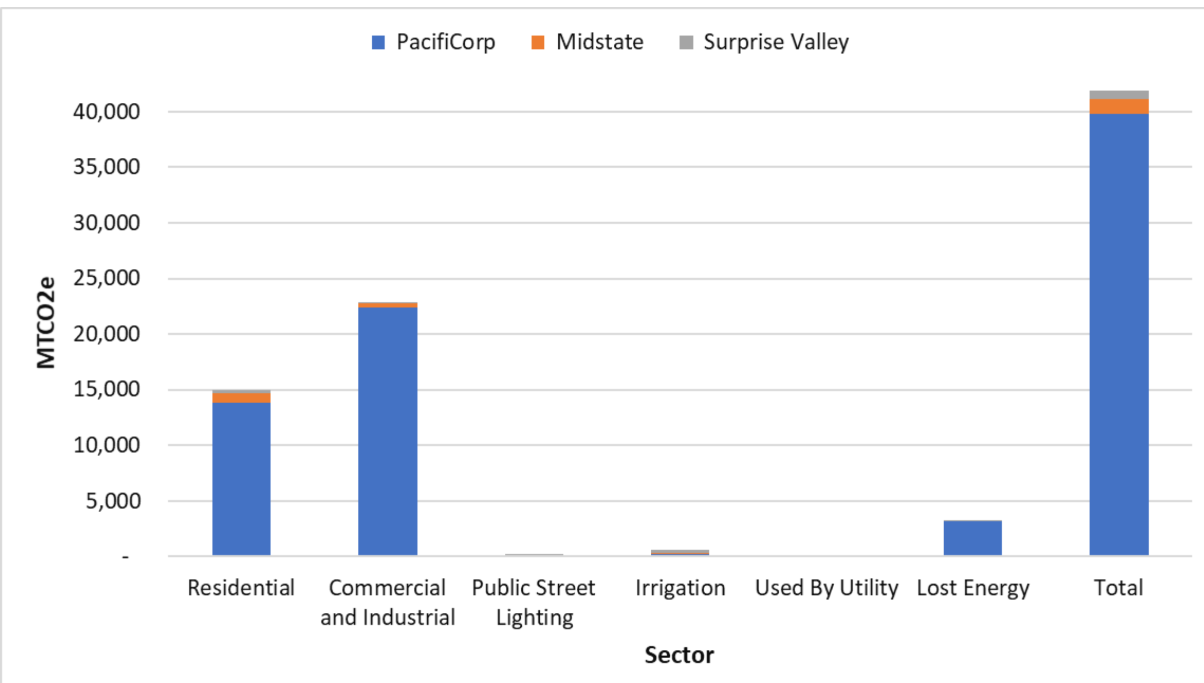


Figure 5. Greenhouse gas emissions ($MTCO_2e$) from electricity usage by sector and utility, 2019

Data on the number of customers serviced wasn't available from all three utilities but was provided by PacifiCorp alone. In Lakeview, 1,815 residential PacifiCorp customers consumed an average of 11,015 kWh per year and emitted 7.6 $MTCO_2e$ annually. In comparison, commercial and industrial customers averaged 75,104 kWh of electricity per year and irrigation customers averaged 19,618 kWh per year. That corresponds to 51.82 and 13.54 $MTCO_2e$ of GHG emissions per customer, respectively.

The Energy Trust of Oregon is the major organization for implementing energy savings measures for electricity reduction in the county. As Energy Trust is funded by investor-owned utilities, they are only able to implement measures for customers of PacifiCorp in Lake County. However, this is not a major obstacle for reducing emissions from electricity use in the county because PacifiCorp's emission factor is much higher than the BPA electricity provided by Midstate and Surprise Valley. In 2019 alone the Energy Trust estimated that they saved over 300,000 kWh of electricity usage through their energy savings measures.[12] These measures are summarized by type and sector in Table 2.[12]

Table 2. Energy Trust energy savings measures implemented in Lake County, 2019

Residential Measures	Number
HVAC	14
Lighting	23
Other	1
Water Heating	46

Commercial Measures	Number
Lighting	8
Weatherization	4

Industrial Measures	Number
Motors	1

However, the lack of access to energy savings funds through the Energy Trust has economic effects on the co-op customers in the county. The Energy Trust estimates that $2,446,300 has been saved on utility bills by their customers from the time the program started until 2019. This is significant considering that 45% of all households in Lake County are considered to be energy burdened, meaning that 45% of households have energy costs that exceed 6% of the household income.[13]

3.2. Residential Buildings

According to the U.S. Energy Information Administration (EIA), 50% of the energy consumed in a residential home is for space heating and air conditioning.[14] Another 20% is used for water heating, and the remainder of household energy use is consumed by other appliances such as cooking appliances, washers and dryers, and electronics.[14] In Lake County, the vast majority of homes use electricity for powering water heaters, stovetops, and air conditioning. This energy usage, along with electricity consumed by washers, dryers, and electronics, is already captured in the electricity analysis. The remaining home energy consumption is from heating, which will be analyzed here.

There are not any natural gas utilities in Lake County, so the fuel mix used for heating homes is quite different than in areas with natural gas access. According to the national Office of Energy Efficiency and Renewable Energy 39% of households in Lake County use electricity for home heating, 24% use fuel oil, and the remaining use either wood or liquified petroleum (LP) gas (Figure 6).[15] Two percent of the homes in the county are listed as having an "other" source of heating; it is assumed that this is either from solar or geothermal energy so these households will not be included in the heating emissions analysis.

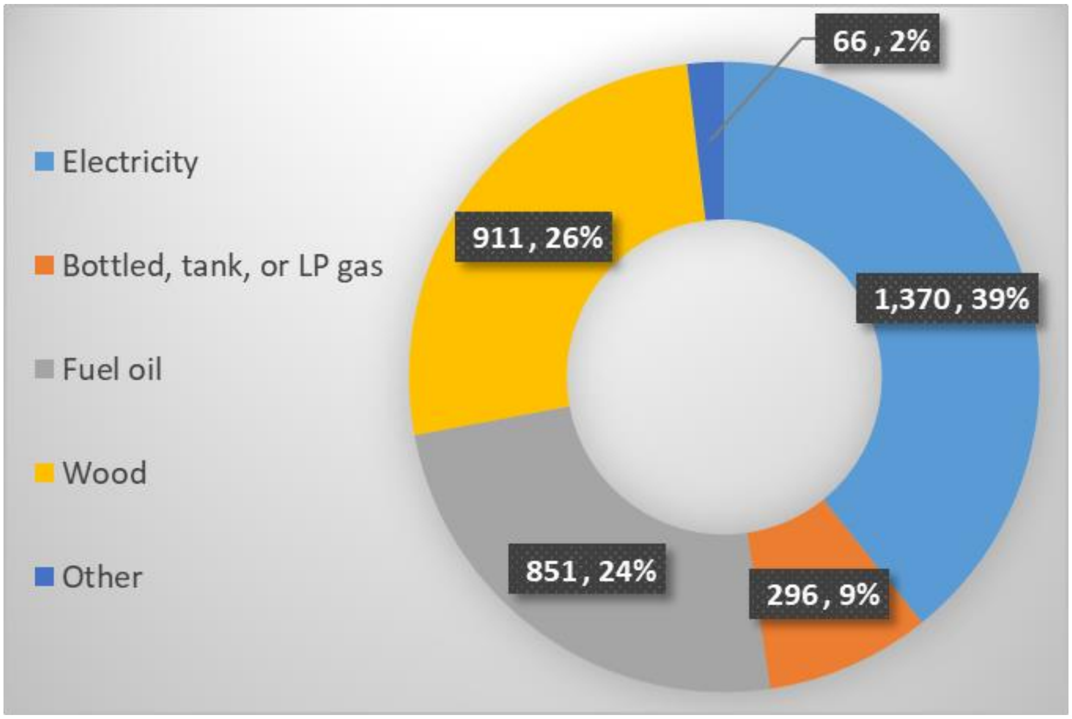


Figure 6. Primary home heating fuel by number of occupied houses in Lake County, 2018

The use of electricity for home heating is already accounted for in the emissions inventory of electricity consumption and will not be discussed here. National average annual energy consumption for home heating by fuel and home age was calculated from the 2015 Residential Energy Consumption Survey (RECS) and applied to homes in Lake County.[16] In 2019, 12,215 $MTCO_2e$ were emitted from household heating that used fuels other than electricity as shown in Table 3. The vast majority of emissions from residential heating are from single-unit homes which make up 94% of occupied housing in the county.

Table 3. GHG emissions ($MTCO_2e$) in Lake County from home heating by primary fuel and housing type, 2019

Housing Type	Fuel Oil Emissions ($MTCO_2e$)	Propane Emissions ($MTCO_2e$)	Wood Emissions ($MTCO_2e$)	Total
Single Unit	4,617.79	995.08	6,521.70	12,134.56
Multi-Unit	28.08	6.04	29.08	63.20
RV	3.03	11.24	3.38	17.65
			Home Heating Total:	12,215.42

The emissions from single-family homes by the primary heating fuel used and the year the home was built are shown in Figure 7. The figure also illustrates the number of homes in each age category, showing that emissions are highest for the categories with the most homes.

Wood is the fuel that produced the most emissions from household heating, followed by fuel oil and then propane. However, wood produces biogenic emissions and can be considered a renewable resource. The total amount of anthropogenic emissions from residential heating is then just 5,661 $MTCO_2e$.

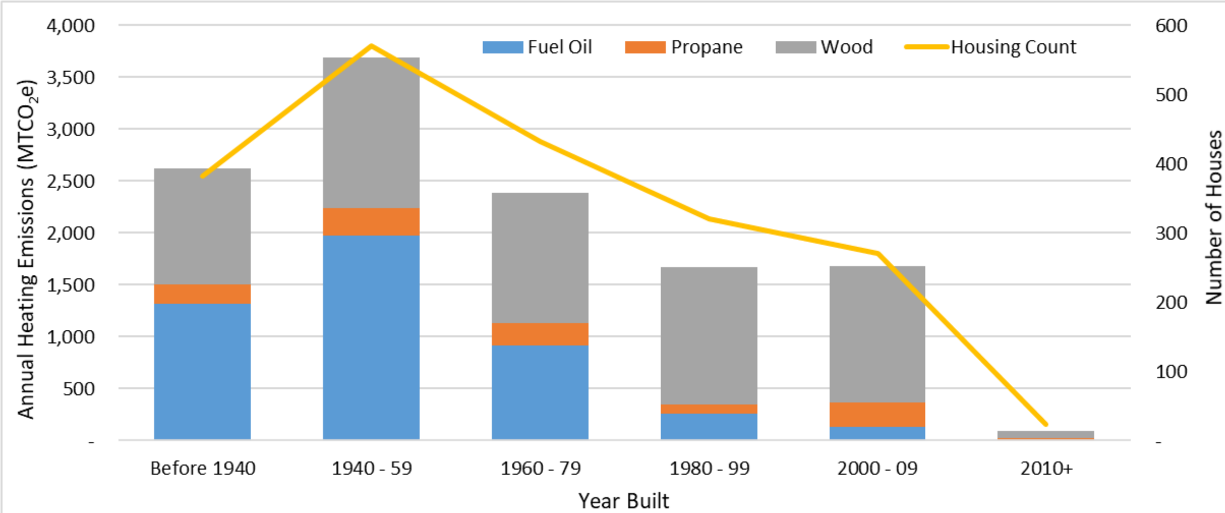


Figure 7. GHG emissions from heating single-family homes by year built (left axis) and fuel used overlayed with the number of single-family homes by year built (right axis)

3.3. Commercial and Institutional Buildings

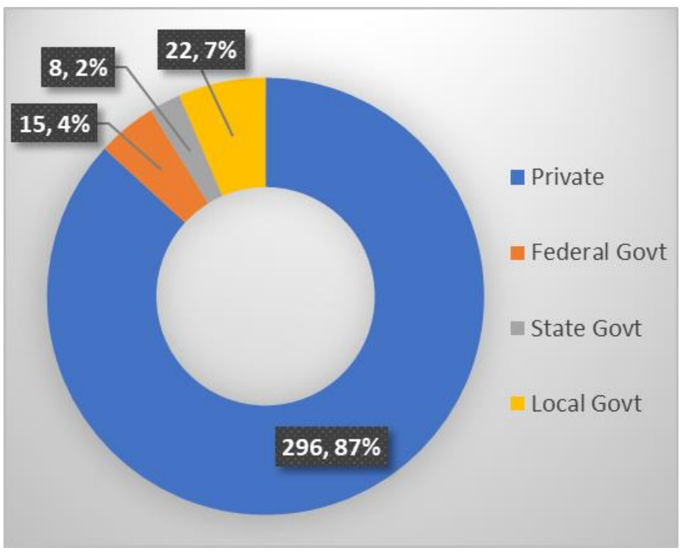


Figure 8. Number of Lake County establishments in each sector, 2019

There were 341 establishments in Lake County in 2019 according to the U.S. Bureau of Labor Statistics (BLS).[17] Private commercial businesses made up 296 of those (87%) while federal, state, and local governments made up the remainder (Figure 8). The private sectors with the most businesses are accommodation and food services, retail trade, and construction. The Bureau of Land Management (BLM), U.S. Forest Service (USFS), Oregon Department of Forestry (ODF), and Oregon Department of Fisheries and Wildlife (ODFW) are some of the state and federal government organizations in the county, and local government entities include public schools and hospitals.

Anderson Engineering and Surveying, Inc. completed a heating study for businesses in downtown Lakeview in June 2011.[18] The study was meant to determine the feasibility of installing a geothermal heating district in the downtown area, and they collected energy usage data for heating from 15 businesses in the process. This data was used to determine the fuels used by commercial and institutional buildings in Lake County, and the amount of energy required per unit area of the building. However, the data is ten years old and doesn't reflect any updates or improvements in heating system efficiencies that have been implemented since then.

Primary data from the heating study was used to find that the average size of a business in Lakeview is 5,390 ft^2 and the average energy consumption for heating commercial and institutional buildings is 0.0408 MMBTU/ft^2 across all primary heating fuel types. 44% of commercial buildings were estimated to use fuel oil for heating, 36% used propane, and the remaining 20% used electricity. The fuel usage and square footage assumptions were applied to all establishments across the county to determine the GHG emissions from propane and fuel oil heating. Emissions from heating with electricity are already included in the electricity section of the report. In total, 3,717 MTCO_2e were emitted in 2019 from heating commercial and institutional buildings with propane and fuel oil (Table 4).

Several of the largest buildings in the county were not included in this analysis because they were retrofitted with geothermal heating to replace fuel oil and propane heating systems. This includes four buildings in the Lakeview school district, the Lake District Hospital, and the Warner Correctional Facility. For more detail on the amount of GHG emissions prevented by these projects see the geothermal renewable energy section of the report.

Table 4. Size, heating fuel usage, and emissions from Lake County commercial and institutional buildings, 2019

Fuel	Building Area (ft^2)	MMBTU	Total Emissions (MTCO_2e)
Electricity	356,547	14,531	N/A
Propane	650,347	26,504	1,673
Fuel Oil	794,367	32,374	2,044
Total	1,801,262	73,408	3,717

3.4. Industrial Stationary Energy

The Oregon DEQ requires all entities that hold an Air Contaminant Discharge Permit (ACDP) or title V operating permit to report their greenhouse gas emissions if they produce 2,500 MTCO_2e or more in a year.[19] In Lake County there are only two such industrial entities: Cornerstone Industrial Minerals and Collins Pine Company. It is assumed that any industrial sources that emit less than the Oregon DEQ minimum reporting limit do not greatly affect the emissions from the county.

Cornerstone Industrial Minerals mines perlite at the Tucker Hill pit near Paisley and processes the ore at a mill in Lakeview.[20] They reported 2,514 MTCO_2e of anthropogenic greenhouse gas emissions in 2019 from stationary combustion of residual oil #5, a heavy fuel oil, for their kiln dryer.[11]

The Collins Pine Company operates a sawmill in Lakeview that processes harvested wood from 97,600 acres of their land in Oregon and California.[21] They reported 30,904 MTCO_2e of biogenic emissions and 413 MTCO_2e of anthropogenic emissions from stationary combustion in 2019.[11] Biogenic emissions are defined by the DEQ as emissions from the combustion of biomass or an industrial process involving biomass. Both the biogenic and anthropogenic emissions reported by the Collins Pine Company are from the burning of wood waste in their boilers used for drying lumber at the mill.

All CO_2 emissions from the wood-burning are classified as biogenic because trees capture CO_2 as they grow and therefore, the net amount of CO_2 in the atmosphere is the same from before the tree grows until after it is burned as fuel. However, CH_4 and N_2O emissions from wood combustion are considered anthropogenic because plants do not sequester either of these greenhouse gases and therefore burning them results in a net increase of CH_4 and N_2O in the atmosphere.

The total anthropogenic emissions from industrial stationary energy use in 2019 were 2,927 $MTCO_2e$ and biogenic emissions were 30,904 $MTCO_2e$.

3.5. Irrigation

According to the Lake County water master and irrigators in the county, the vast majority of irrigation in the county occurs through center pivots or surface irrigation. Almost all of the pumps and motors for center pivot irrigation use electricity as a power source, and their emissions are therefore already included in the electricity section of the report. This means that there is little diesel or other fossil fuel usage for irrigation in the county that needs to be evaluated here.

As shown in Table 1, irrigation consumed 18,341 MWh of electricity in 2019 and produced 577 $MTCO_2e$. There are 89,850 center pivot irrigated acres in the county, resulting in an emission factor of 0.0064 $MTCO_2e$/acre.[22,23] The Natural Resource Conservation Service (NRCS) has programs to improve center pivot irrigation efficiency in the Summer Lake area. Specifically, they are working with irrigators to convert to Low Elevation Spray Application (LESA) or Low Energy Precision Application (LEPA) to reduce water losses and therefore conserve electricity. This program will not only reduce greenhouse gas emissions but will also lower electric bills for irrigators.

4. Transportation

The most common mode of transportation in Lake County is driving on-road vehicles on state highways, county roads, and local roads. There are three main highways in the county: Highway 140 which runs east-west from Klamath Falls to Harney County just before crossing into Nevada, Highway 395 which runs north-south from the northeast corner of the county to California at New Pine Creek alongside Goose Lake, and Highway 31 which enters the northwest corner of Lake County and travels southeast until it meets up with Highway 395 south of Lake Albert. Nearly all of the populated towns in Lake County fall along these highways, the few exceptions being Fort Rock (pop. 72), Christmas Valley (pop. 1,313), and Plush (pop. 95). Other types of transportation include aviation, rail, and off-road transportation. A summary of the emissions from each of these sources is shown in Figure 9 and each category is discussed in the following report sections.

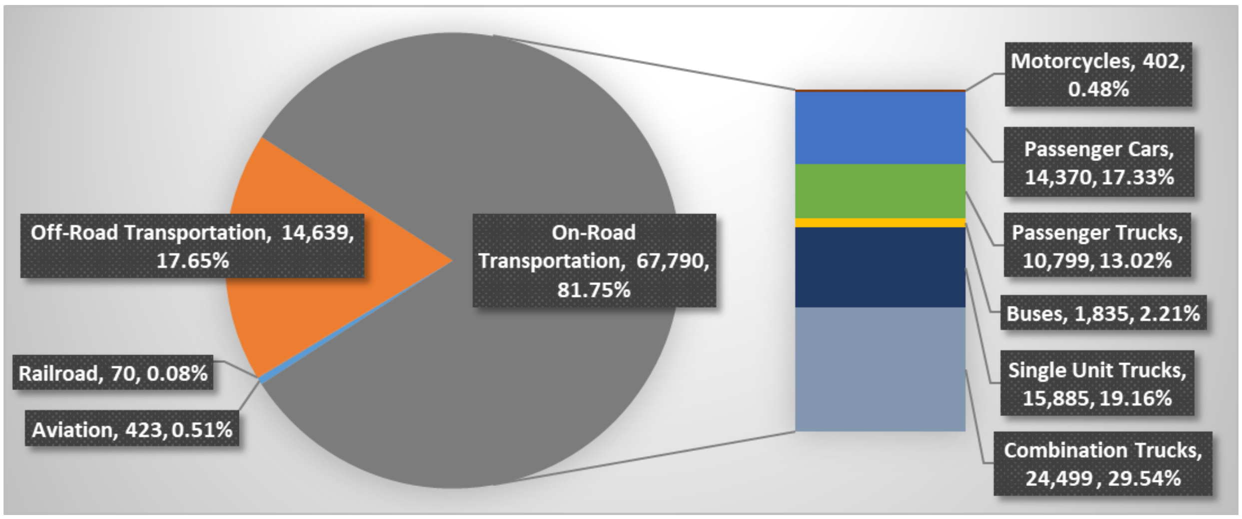


Figure 9. Emissions (MTCO$_2$e) from transportation sources in Lake County, 2019

4.1. On-Road Transportation

On-road vehicle emissions from motorcycles, passenger cars and trucks, buses, and heavy-duty trucks in the county in 2019 were estimated using Oregon Department of Transportation (ODOT) traffic station data and the EPA's MOVES3 model.[24] Heavy-duty trucks include both single unit and combination trucks. The model produced output statistics that can be applied to the year 2019 for this study. The number of passenger vehicle miles traveled (VMT) per day within Lake County is 21.7 miles/capita. The emission factor for passenger cars is estimated at 348 g CO_2e/mi and the emission factor for passenger trucks is around 479 g CO_2e/mi.

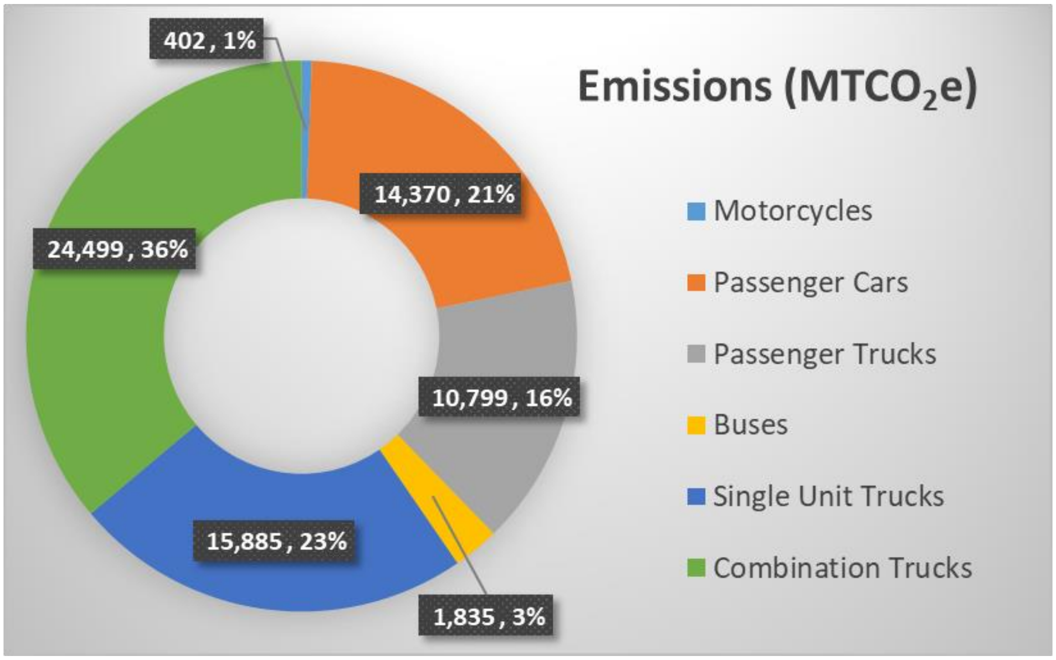


Figure 10. GHG emissions ($MTCO_2e$) from all on-road vehicle types in Lake County, 2019

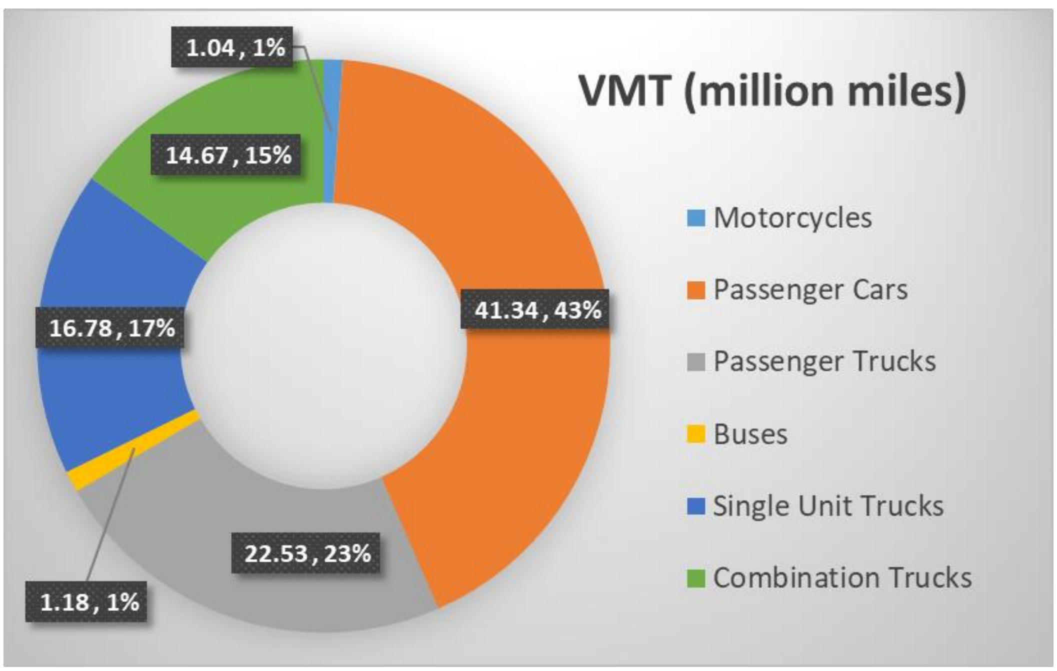


Figure 11. Vehicle miles traveled (million miles) of all on-road vehicle types in Lake County, 2019

The results of the on-road transportation models are illustrated in Figure 10 and Figure 11, which show the differences in emissions and VMT by vehicle class. The total amount of GHG emissions from on-road transportation in 2019 was 67,790 $MTCO_2e$. Although passenger cars and trucks together make up 66% of the 2019 VMT in Lake County, they only produce 37% of the annual GHG emissions. This shows the importance of fuel efficiency when considering emissions from transportation. Heavy-duty trucks, with much lower fuel efficiencies due to the weight of the loads they carry, produced 59% of 2019 on-road transportation emissions.

4.2. Railway

The only railroad in the county is the Goose Lake Railway which stretches from Lakeview to the border of California, about 11 miles long. The train picks up lumber and perlite once a week from Lakeview and runs roundtrip to Perez Junction in California, 220 miles total. In 2019 the Goose Lake Railway consumed about 6,800 gallons of off-road diesel fuel in Lake County, producing just 70 $MTCO_2e$ of GHG emissions.

4.3. Aviation

There were six public airports with flight operations in 2019 in Lake County.[25] The airport with the most operations was the Lakeview airport (LKV) with 6,000 flights; the majority of these departures are from firefighting aircraft sent to areas within and around Lake County during the fire season. There are also a substantial number of layover flights that stop only for refueling at the airport.

The Lakeview airport is the only airport in the county that offers fuel on-site, it sells about 30,000 gallons of Jet A fuel and 15,000 of 100LL fuel each year, including 2019.[26] As shown in Table 5, the burning of this fuel for aircraft operations resulted in 422.97 $MTCO_2e$ of GHG emissions.

Table 5. Calculation of GHG emissions from the three major GHG gases for the fuels sold at LKV, 2019

Fuel	Gallons	Emission Factor (kg CO2/gal)	Emission Factor (g CH4/gal)	Emission Factor (g N2O/gal)	MTCO2e
Jet A	30,000	9.75	0.00	0.30	295.18
Avgas 100 LL	15,000	8.31	7.06	0.11	127.79
				Total:	422.97

4.4. Off-Road Transportation

Off-road transportation includes emissions from forestry, agriculture, recreation, and commercial and industrial equipment that is not included in the on-road or stationary emissions categories. All of the machinery, equipment, and recreational vehicles in this section are powered by diesel, gasoline, or compressed natural gas (CNG) fuel. Recreational activities included in this analysis are the use of snowmobiles, ATVs, and boats. ATV usage is especially common in the Christmas Valley Sand Dunes, an 8,900-acre area of dunes open to vehicle use owned by the BLM. [27] Commercial and industrial equipment includes compressors, generators, welders, power washers, and forklifts. Additionally, the use of construction and mining machinery such as dozers, excavators, loaders, and cement mixers are accounted for in off-road emissions.

Agricultural crop production creates off-road emissions through the use of tractors, mowers, rakes, balers, and more which were all also considered in this analysis. Forestry is another prevalent activity in the county that uses heavy machinery powered by fossil fuels. Chainsaws are used for tree thinning and trucks are driven off-road for thinning activities performed by private entities and the USFS, while larger equipment such as feller-bunchers, processors, and loaders are used for harvesting and commercial thinning.

Off-road transportation GHG emissions from fuel consumption in each category are listed in Table 6 and illustrated in Figure 12. The total off-road emissions in 2019 were 15,676 $MTCO_2e$.

Table 6. GHG emissions ($MTCO_2e$) from off-road transportation

Equipment Type	Emissions (MTCO2e)
Agriculture	9,228
Forestry	993
Commercial	432
Construction	519
Mining	1,519
Industrial	711
Lawn and Garden	610
Recreational	626
Total	14,638

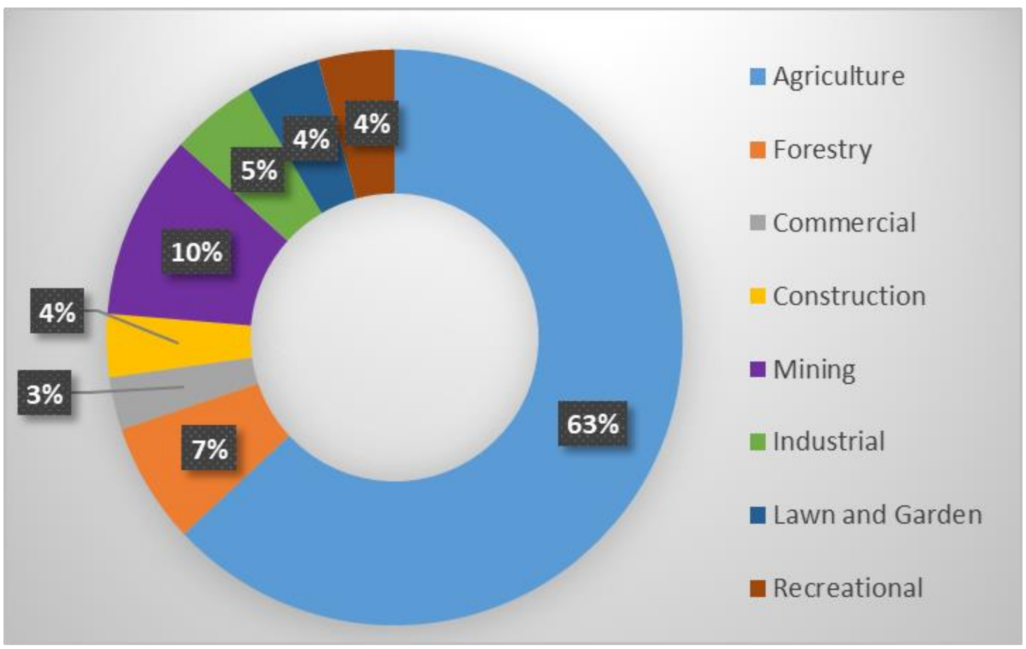


Figure 12. Percentage of total off-road GHG emissions ($MTCO_2e$) by sector

5. Waste

5.1. Landfill

The Thomas Creek Road Landfill is the only active landfill in Lake County, it disposes of municipal solid waste (MSW) and became active in 2019 after the old Lake County Landfill was decommissioned. In 2019 there were 5,398 tons of waste disposed of in the Thomas Creek Road Landfill and an estimated 363 additional tons of waste that were recycled.[28] Lake County recovered 6.3% of the total amount of waste generated, mostly through recycling. The county population was 8,080 people so the waste disposal rate was 1,336 lbs/capita, lower than the state average of 1,569 lbs/capita.[3,29]

Methane is generated from waste in landfills from the anaerobic decomposition of organic matter by bacteria. This process occurs over several years, so waste that was disposed of years ago generates emissions over its lifetime in the landfill. Therefore, the waste disposed of in 2019 likely did not produce significant emissions from anaerobic decomposition that year, but waste disposed of in 2010 did. Disposal data for all years dating back to 1990 was determined from the years provided in the Oregon Waste Generation Report.[29] The EPA's State Inventory Tool for solid waste was used to determine that 3,454 $MTCO_2E$ were generated from methane emissions at the municipal landfills in Lake County in 2019.[30]

5.2. Wastewater

Most residents of Lakeview are connected to the municipal wastewater system that takes wastewater from homes and businesses and treats it in a lagoon and wetland system. Lakeview wastewater treatment plant was updated in 2000; 14-acres of wetlands were added on to finish treatment of effluent after primary treatment in the old lagoons.[31] After the second set of wetlands the effluent enters a chlorination chamber and then a 35-acre irrigation/storage pond. Homes outside of Lakeview use individual septic tanks for wastewater storage and decomposition.

The greenhouse gas emissions produced from municipal wastewater are CH_4 from anaerobic treatment or degradation and N_2O from denitrification.[8] Denitrification is the process of converting nitrate in organic material (mostly from human sewage) in wastewater to nitrous oxide. A summary of the GHG emissions from wastewater in 2019 is provided in Table 7; across all greenhouse gases and treatment types, the emissions were 1,124 $MTCO_2e$.

Table 7. GHG emissions ($MTCO_2e$) from wastewater in Lake County, 2019

GHG	Treatment Type	Emissions (MTCO2e)
CH_4	Septic Tank	518.65
CH_4	Lakeview Facility	136.39
N_2O	All	469.21
	Total	1,124.25

6. Agriculture

The main agricultural activities occurring in Lake County are cattle ranching and hay growing. Altogether agricultural producers generated an estimated $93.9 million from the sale of crops and livestock in Lake County in 2017, which shows the invaluable role agriculture plays in the county's economy.[23] A summary of the emissions from each of these activities is shown in Figure 13 and each category is discussed in the following report sections.

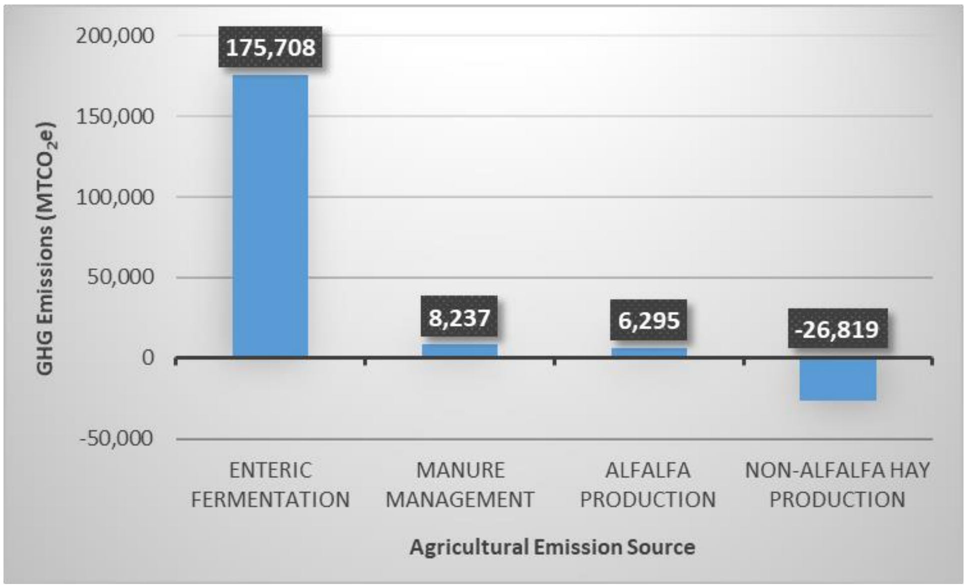


Figure 13. Emissions ($MTCO_2e$) from agricultural sources in Lake County, 2019

6.1. Livestock

The majority of livestock raised in Lake County are rangeland cattle, but there are also a small number of sheep, goats, and horses. There are 225 cattle ranching operations across Lake County.[32] Cattle are grazed on private rangeland as well as on land owned by the Bureau of Land Management. Livestock accounts for around $50 million of the annual county revenue.[23] Some of the cattle in the county, especially in the Goose Lake area, are wintered in California.

Raising livestock produces methane emissions through enteric fermentation and manure management. Although some of the cattle in the county do not reside in the county during the winter months, and therefore do not produce emissions within Lake County during that time, data is not available on what percentage of cattle this applies to. All cattle owned by operations residing in Lake County will have their year-round emissions counted in this analysis.

6.1.1. Enteric Fermentation

Enteric fermentation is the production of methane from microbial fermentation as part of an animal's digestion.[33] Cattle, sheep, and goats in Lake County are ruminant animals that emit the most methane per unit of body mass because of their digestive system. Horses are non-ruminant animals that produce less methane per unit mass, but have a substantial population in the county and are therefore included in the study. The population of each category of livestock in Lake County can be found in Table 8.

Emission factors from the EPA State Inventory Tool were utilized to determine the methane emissions due to enteric fermentation for each type of livestock raised in Lake County (Table 8). The result is an estimated 175.7 thousand $MTCO_2e$ produced in 2019. 68% of the methane emitted by enteric fermentation is from beef cows, and the other 32% is from the remaining cattle population (Figure 14). Less than half a percent of enteric fermentation GHG emissions are from livestock other than cattle. Although ranching operations in the county are highly sustainable for the landscape and ecosystems, the cattle that are grazed tend to produce higher enteric fermentation methane emissions than cattle that are primarily on feed.[34] Cattle in highly productive systems create less methane per unit energy consumed compared to those in less productive ones. However, raising cattle on rangeland leads to fewer emissions from manure as discussed in the next section.

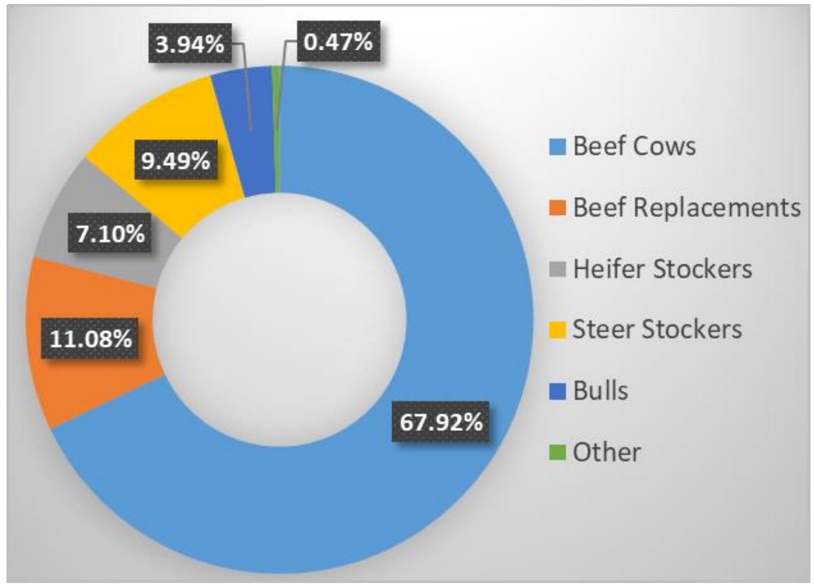


Figure 14. Methane emissions from enteric fermentation by livestock category, 2019

Table 8. Population, enteric fermentation emission factors (kg CH_4/head), and methane emissions ($MTCO_2e$) for all livestock in Lake County, 2019

Animal	2019 Estimated Population (head)	Enteric Fermentation EF (kg CH4/head)	Annual Emissions per Head (MTCO2e/head)	Total Annual Emissions (MTCO2e)
Beef Cows	47,500	100.5	2.513	119,343.75
Beef Replacements	11,712	66.5	1.663	19,471.20
Heifer Stockers	7,696	64.8	1.620	12,467.52
Steer Stockers	10,708	62.3	1.558	16,677.71
Bulls	2,667	103.9	2.598	6,927.53
Sheep and Lamb	623	8	0.200	124.60
Goats	705	5	0.125	88.13
Horses and Ponies	1,351	18	0.450	607.95
			Total:	175,708.39

6.1.2. Manure Management

Livestock manure can produce methane from the anaerobic digestion of organic waste material. Manure deposited on pasture, range, or paddock lands tends to decompose aerobically and produces little CH_4.[30] N_2O can be produced through nitrification and denitrification of N in livestock dung and urine. It can also be indirectly produced from the volatilization of N in manure and the deposition of those gases onto soil or waterways. The other way N_2O is indirectly produced is through runoff and N leaching into surface or groundwater.

The amount of methane and nitrous oxide produced from manure in Lake County is extremely low compared to that of enteric fermentation, given that all cattle are grazed in pastures and rangeland and there are not a high number of other livestock in the county (Figure 15). The sustainable practices used by Lake County ranchers translate into greenhouse gas emissions reductions for manure management. In total, manure from livestock produced 1,865 $MTCO_2e$ of methane emissions and 6,372 $MTCO_2e$ of nitrous oxide emissions in 2019.

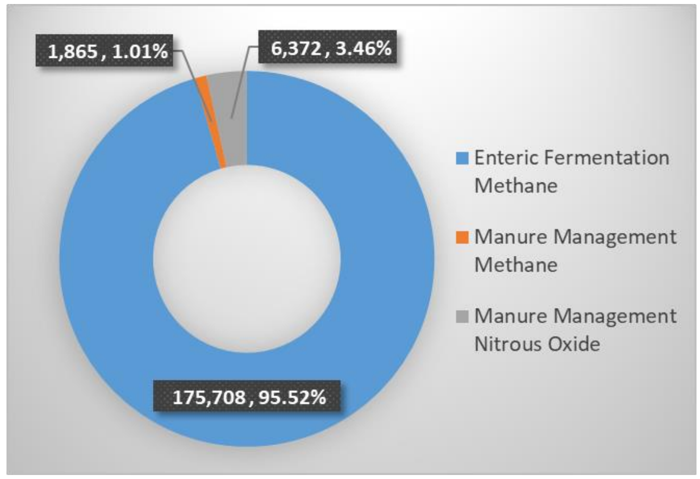


Figure 15. Livestock GHG emissions ($MTCO_2e$) in Lake County, 2019

6.2. Cropland

The main crops grown in Lake County are hay and alfalfa, but there are also a few operations that produce barley, oats, and wheat. Crop sales account for around $45 million in annual revenue.[23] Alfalfa and hay production emits nitrous oxide from plant residue. Nationally, a majority of agriculture emissions come from agricultural soil management.

Soil respiration occurs when aerobic or anaerobic bacteria in the soil release carbon dioxide into the atmosphere. Methane is produced from soil bacteria under anaerobic conditions as well. Nitrous oxide is emitted by the denitrification process. Soil produces the most greenhouse gas emissions under wet conditions because both CH_4 and N_2O are produced at higher rates under anaerobic conditions.[35] Additionally, emissions are increased when the soil is hotter because of increased microbial activity.

Emissions from alfalfa and non-alfalfa hay cropland in Lake County were estimated using the DeNitrification-DeComposition (DNDC) model. With a five-year crop rotation, it was found that alfalfa emits about 235 kg CO_2e/ha each year while non-alfalfa hay sequesters 761 kg CO_2e/ha annually. Table 9 shows that the combined impact is net sequestration of over 20,500 $MTCO_2e$ per year.

Table 9. Annual emissions and sequestration ($MTCO_2e$) from cropland in Lake County, 2019

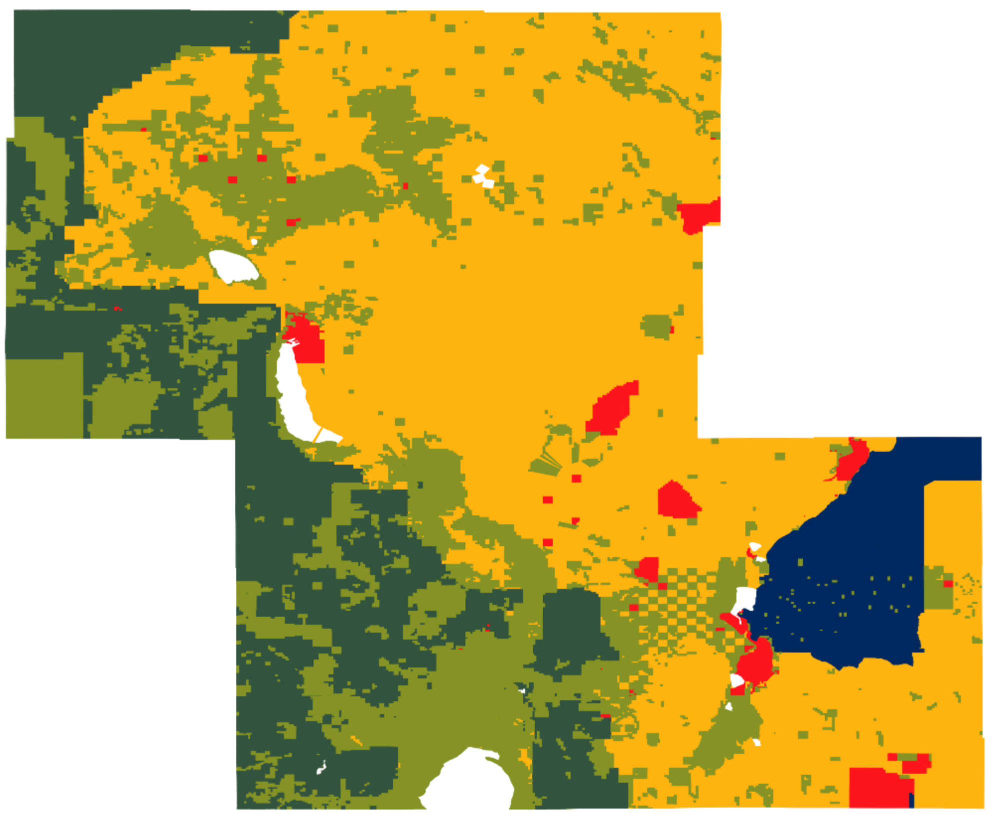
Crop	Area (acres)	Annual Change (kg CO2e/ha)	Emissions (MTCO2e)
Alfalfa Hay	66,190.48	235.00	6,294.79
Hay (non-Alfalfa)	87,085.71	-761.00	-26,819.44
		Total	-20,524.65

The addition of fertilizer varies greatly from year to year based on weather conditions and highly specific soil conditions in each field. Therefore, emissions from fertilizer application for hay production were not included in this report. In 2017, according to the USDA Census of Agriculture, about 39,000 acres of cropland in the county were treated with fertilizer.[23] This means that 24% of cropland is fertilized in Lake County, which could contribute significantly to annual greenhouse gas emissions. In general, increasing soil nitrogen content with manure, fertilizer, or other substances increases the soil respiration rate and N_2O emissions. These effects can be minimized by optimizing the amount of fertilizer use and timing applications for dry periods when the nutrients are not likely to run-off fields.

7. Other Land Use

The main kinds of land use in the 5.35 million acres of Lake County are forest land, grassland, cropland, wetland, and settlements. Emissions from cropland and settlements have already been addressed in previous sections of the report and will not be re-evaluated here. Data from the Lake County Planning Department shows that in 2019 there were only 2,900 acres of approved land use changes; at just 0.06% of the total land in the county, it is assumed that the area of each land use was constant throughout the year. GHG emissions due to these changes will therefore be neglected in the analysis of this report.

The major ownership classes of land in Lake County are shown in Figure 16. The Bureau of Land Management (BLM) owns nearly half of the county's land at 49%, followed by private land at 25% and USFS land at 19%. The land area attributed to each use category is somewhat similar, although rangeland and grassland make up the majority of the county at 65% (Figure 17). Forests are found on 27% of the land, while cropland makes up only 3% of land use. The emissions due to each type of land use not previously analyzed will be provided in the following sections.



	Land Area (acres)
USFW	278,375
BLM	2,600,785
State of Oregon	116,906
Private	1,327,445
USFS	1,026,249

Figure 16. Map of Lake County land ownership

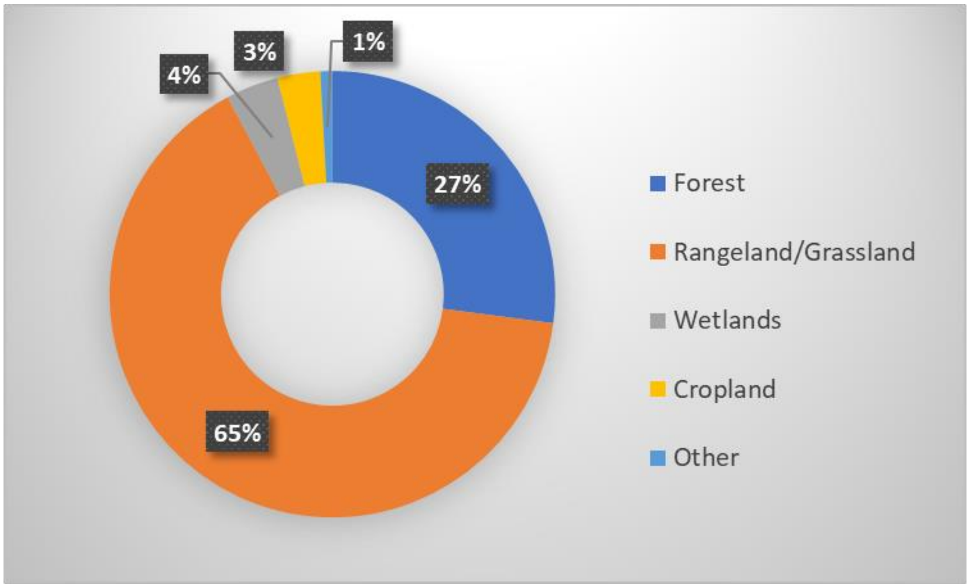


Figure 17. Estimated area in each land use category in Lake County, 2019

7.1. Forest Land

According to the USFS and Oregon Department of Forestry (ODF), there are 1.45 million acres of forest land in Lake County.[36] 174,000 acres are part of the Deschutes National Forest in the northwest corner of the county and 852,000 acres belong to the Fremont National Forest that stretches across the west side.[37] The remaining forest land is privately owned by Collins Pine Company, other commercial forestry operations, or individual landowners. The BLM also owns some forest land, although it is mainly sparse juniper shrubland. The forests of Lake County consist of softwood trees such as lodgepole pine, ponderosa pine, white fir, and juniper. Historical fire suppression has caused an increase in stand density and juniper encroachment into grasslands, as well as a loss of tree and plant diversity. This makes the forests of Lake County prone to wildfire, disease, and further juniper spread.

There are six key carbon pools in any forest: aboveground live (trees, shrubs, saplings, seedlings), belowground live (roots), aboveground dead (standing snags, down wood), belowground dead, litter, and soil organic carbon. The estimated amount of carbon stored in each pool in Lake County is shown in Figure 18, adding up to 112 million metric tons of carbon.[36] The soil has the highest amount of carbon storage at almost three times the amount of carbon stored in aboveground live biomass in trees, which is common for less productive forests east of the Cascade mountain range.

The flux of carbon between these pools and the atmosphere is what leads to GHG emissions or sequestration by the forest. Biomass growth in trees (trunks, branches, roots), shrubs, saplings, and other plants captures carbon from the atmosphere via photosynthesis and stores it in the forest. The decay of litter, dead wood and roots, and soil carbon emits CO_2 via microbe respiration. When the growth of the forest outpaces the rate of decay, the forest will store atmospheric carbon and offset anthropogenic greenhouse gas emissions. However, this sequestration ability decreases as a forest ages and the ecosystem reaches an equilibrium between the growth and death processes.[36]

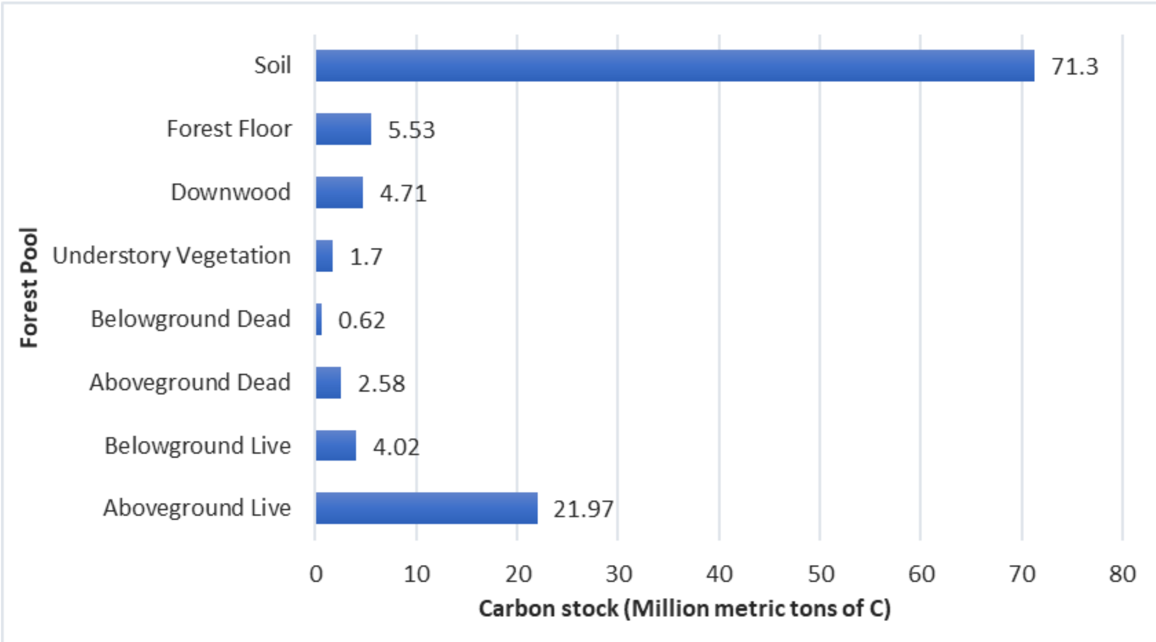


Figure 18. Average amount of carbon (million MT carbon) in each forest pool in Lake County, 2007-2016

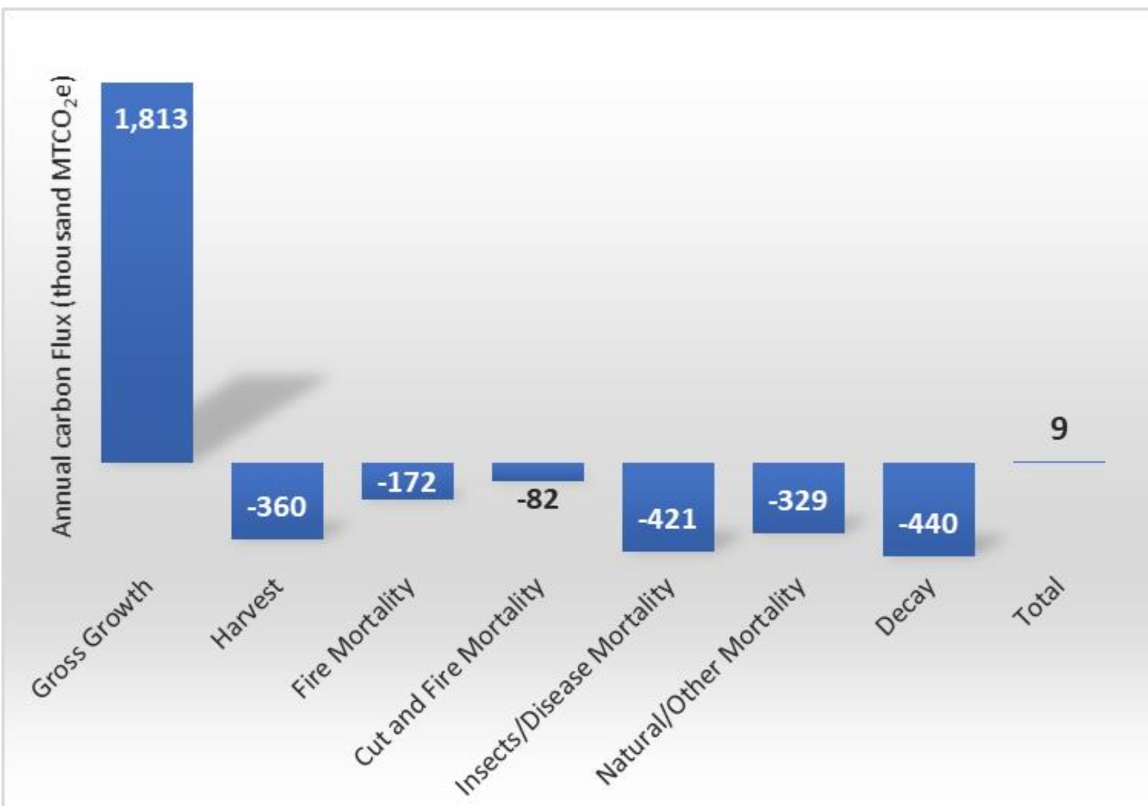


Figure 19. Carbon flux (thousand $MTCO_2e$) from growth, harvest, mortality, and decay annually from Lake County forests, 2007-2016

The annual net carbon sequestration of forests in Lake County is estimated to be 9,000 $MTCO_2e$ from the Oregon Forest Ecosystem Carbon Inventory.[36] This means that the amount of carbon added to the biomass of live trees and shrubs and the amount of carbon sequestered in the soil is greater than the amount of carbon released to the atmosphere from the decay of dead biomass. The total amount of carbon dioxide sequestered by tree and shrub growth annually is estimated at 1.8 million $MTCO_2e$, or 1.25 $MTCO_2e$ per acre (Figure 19). However, this is offset by tree harvesting, mortality, and decay to result in a net sequestration of 0.0062 $MTCO_2e$ per acre. The different types of mortality considered in the report were from fire, cut and fire (meaning thinning and prescribed burning), disease, and natural or other. Although there weren't any major wildfires in Lake County in 2019, the carbon flux due to fire mortality is still included because it is an average over 10 years.

Some of the harvested wood taken from the Lake County forests, as well as forests in northern California, is transformed into long-lived wood products at the Collins Pine Company mill in Lakeview. Collins produces lumber from the softwood species it harvests, and this lumber is assumed to be used for buildings and long-lasting structures. The carbon in the wood of the lumber products created in the county is thus considered to be sequestered and can be removed from the negative flux of harvested trees in the forest inventory. Production from the Collins mill in Lakeview is estimated to have stored 62,045 $MTCO_2e$. This lumber includes harvesting from Collins, some of the other commercial operators in the county, and USFS land. Over time, harvested wood products (HWPs) are discarded and decay in landfills or are burned. Annual emissions from these processes need to be considered when determining net sequestration in HWPs. The Collins mill processes around 1.05% of total Oregon timber harvest, resulting in an annual emission of 181 $MTCO_2e$ from HWPs based on data from a report created by ODF and the USFS.[38] This means that the net annual sequestration from Lake County forests and timber production is 70,864 $MTCO_2e$.

7.1.1. Forest Management

It is assumed that all forest management practices that affect the carbon stocks of the forest are taken into account in the Lake County annual carbon flux values. The report that determined the carbon flux took into account 350 FIA plots across the county from all different locations, landowners, and forest types. Although this number of plots was enough to estimate county-wide carbon trends, there are not enough plots in any one treatment kind for a consistent number of years after treatment to determine the effects of forest management practices in every forest type.

As discussed previously, the USFS owns the vast majority (71%) of forest land in Lake County. Major management practices they perform are piling of fuels, pile burning, precommercial and commercial thinning, and low-intensity underburn. Thinning is a common forestry practice that involves cutting down some trees to increase the growth efficiency of the remaining trees.[39] This efficiency increase is dependent on the maturity and shade tolerance of the remaining trees. Pre-commercial thinning occurs before the trees reach a merchantable size, while commercial thinning occurs on merchantable trees that can be sold for profit. Piling and burning of fuels and underburns are practices that consume excess fuel in forests to prevent major wildfires from spreading quickly and gaining intensity. Table 10 shows the number of acres of each management activity completed in the county in 2019.

Table 10. Area of management practices completed in the Deschutes and Fremont National Forests in Lake County, 2019

Activity	Deschutes area (acres)	Fremont area (acres)	Total (acres)	Percentage of 2019 Management Practices
Animal Damage Control for Reforestation	45	678	723	1.82%
Burning of Piled Material	829	5,135	5,964	15.00%
Commercial Thin	273	1,304	1,577	3.97%
Disease Prevention	-	1,304	1,304	3.28%
Fuel Break	-	359	359	0.90%
Other Stand Tending	-	115	115	0.29%
Overstory Removal Cut	48	-	48	0.12%
Piling of Fuels, Hand or Machine	259	4,589	4,848	12.20%
Plant Trees	45	339	384	0.97%
Precommercial Thin	340	4,333	4,673	11.76%
Range Control Vegetation	1,726	-	1,726	4.34%
Range Cover Manipulation	-	2,000	2,000	5.03%
Range Piling Slash	-	1,937	1,937	4.87%
Rearrangement of Fuels	-	578	578	1.45%
Underburn - Low Intensity (Majority of Unit)	3,644	8,439	12,083	30.40%
Wildfire - Natural Ignition	-	124	124	0.31%
Yarding - Removal of Fuels	-	1,304	1,304	3.28%
Total	7,209	32,538	39,747	100%
Percentage of Lake County NF Area	4.15%	3.82%	3.87%	

The Oregon Department of Forestry (ODF) can perform work in the Fremont-Winema National Forest through a timber and service Special Project Agreement (SPA). The SPAs are available from the Good Neighbor Authority agreement as part of the Federal Forest Restoration Program to increase the speed and scale of restoration on national forest land. In 2019 ODF completed one thinning project on 200 acres in the Fremont National Forest.

The Lake County Umbrella Watershed Council (LCUWC) has been partnering with the USFS, NRCS, LCRI, ODF, and other entities on forest health projects since the 1990s. In 2019 the organization's North Warner Forest Health Project thinned 5,000 acres of forestland on private property with old legacy pine to improve fire resiliency in the heavily fuel-loaded areas. The thinning residue was formed into slash piles that were burned in 2019. The LCUWC also performed a few smaller juniper removal projects.

There are many pockets of juniper woodland across the BLM land in the county. The BLM Lakeview District has been extremely active in removing juniper to restore natural sagebrush steppe habitat for native plant and wildlife species, including sage grouse, bighorn sheep, and pronghorn.[40] Since they began juniper removal activities in the early 2000s, they have treated nearly 80,000 acres in Lake County. In 2019 alone the BLM performed juniper removal on 6,600 acres and pile burning on the leftover fuel from 1,800 acres.

Encroached juniper areas contain an estimated 3.04 metric tons of aboveground juniper biomass per acre.[40] If each ton of biomass contains approximately 0.5 tons of carbon, burning 80% of the removed juniper would result in 4.46 $MTCO_2e$ of carbon dioxide emissions per acre.[40] In 2019, the pile burning of juniper fuel by the BLM contributed 8,028 $MTCO_2e$ to the estimated 82,000 $MTCO_2e$ of emissions from cut and fire tree mortality in the county annually (Figure 19). However, this amount is less than what would be emitted from a dry, high-temperature, severe fire in juniper shrubland.[40]

The Collins Pine Company is the only commercial forestry operation with a mill in Lake County. Their harvesting practice is typically selective harvesting with some small clear cuts or group selections. They also purchase timber sales from the USFS to feed their Lakeview mill. The Collins land in Lake County is certified by the Forest Stewardship Council which indicates that the land is sustainably managed.[41]

The effect of each management practice on forest carbon sequestration depends on individual tree characteristics, stand characteristics, and time since the treatment. This includes factors such as forest age, tree species, dominant stand species, temperature, rainfall, etc. However, typical trends show that thinning initially decreases the carbon stock of the treated section due to the removal of live trees, followed by a recuperation of carbon back to original levels or beyond from improved growth in the remaining trees. Underburns and pile burning create GHG emissions initially but prevent much greater emissions from catastrophic wildfires.

7.1.2. Wildfire

Frequent wildfire is necessary for the health of forests in Lake County, with the ponderosa and lodgepole pine forests historically seeing fire every 15 to 25 years.[42] However, the suppression of wildfire for the past century or so has led to an increase in fuel density and juniper encroachment. This, in turn, increases the frequency and intensity of fires in the area, as has been seen in the Pacific Northwest, California, and across the United States in the past decade. There were no major wildfires in Lake County in 2019, but the effect of wildfire was accounted for in the average annual tree mortality discussed previously (Figure 19).

After a severe fire, forest carbon stocks initially decline and then accumulate over time until the rate of tree growth carbon sequestration passes the release of carbon from decaying dead wood and exposed soil (Figure 20).[36] Shorter fire intervals result in smaller stores of carbon as well as smaller fluxes each year.[43]

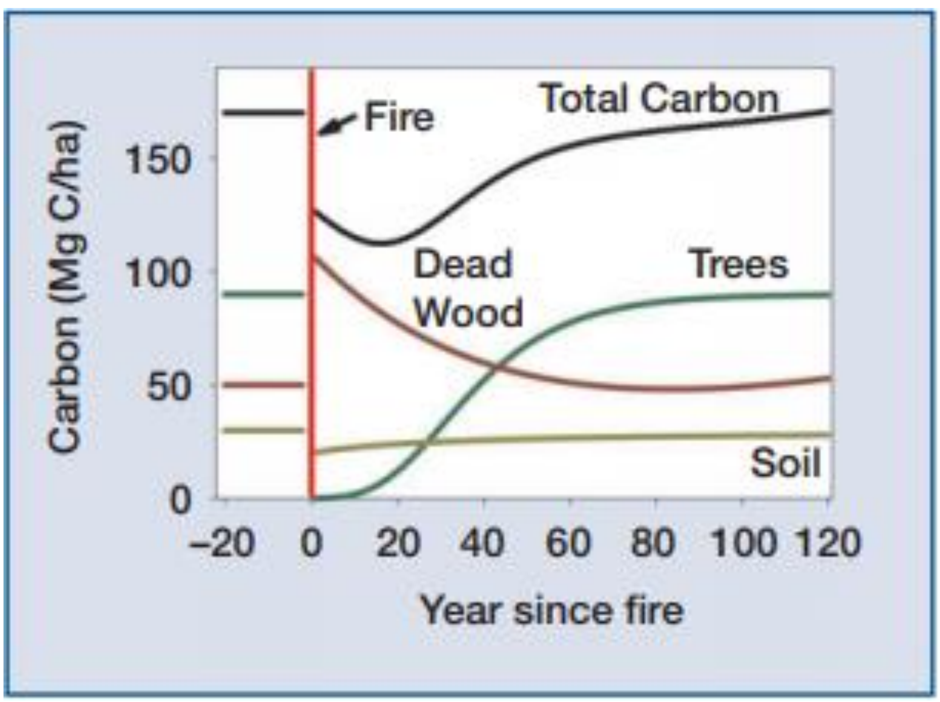


Figure 20. Example of forest carbon stock changes after a wildfire[44]

A low-intensity forest fire in the eastern Cascades consumes about 23% of carbon in aboveground biomass, while a high-intensity fire consumes 35%.[45] For the average forest in Lake County, this corresponds to 30.23 $MTCO_2e$/acre of emissions from a low-intensity fire and 46.34 $MTCO_2e$/acre for a high-intensity fire. Management practices such as underburns and pile burning can be assumed to have produced similar emissions to the low-intensity wildfire estimate. High-intensity fires release a greater amount of GHG emissions into the atmosphere than low-intensity fires and increase the length of time that it takes for the forest carbon sequestration levels to outpace the rate of carbon emissions from decay of the dead wood from the fire.

As mentioned in the previous section, the use of forest management practices such as thinning and burning excess fuels reduces the threat of high-intensity wildfires. The carbon benefits of this have been studied for different forest types, and it is concluded that the impact of severe wildfire on forest carbon stocks is greater than the impact of thinning on ecosystem carbon flux and storage. For example, in ponderosa pine forests it was found that after 10 years an area that had experienced severe wildfire had 42% less carbon stored than the area that had undergone thinning.[46] These carbon benefits vary from stand to stand, but in Lake County forests with frequent fire occurrence, it is likely that thinning and prescribed burns reduce carbon emissions.

7.2. Grassland Remaining Grassland

Emissions from grazed grasslands are included in the manure management section. Insufficient data is available for baseline grassland sequestration or emissions from soil and plant material, therefore only the addition of manure from managed grasslands with grazing will be considered in this report. The Tier 1 calculation protocol from the IPCC states that it is acceptable to assume that base emissions from grasslands are zero.

Natural arid and semi-arid ecosystems, such as the grasslands and shrublands in the central and eastern parts of the county, do not have a high net primary productivity which limits the amount of carbon that they store annually.[47] In addition, differences in rainfall, soil type, and management practices make it difficult to predict this small amount of sequestration for a single year. Over thousands of years, however, the small amount of carbon stored annually adds up to substantial soil carbon pools that are mostly protected from disturbance. This means that conversion of intensively managed cropland to grassland and the reduction of soil erosion in existing grasslands can increase the carbon stored in this ecosystem type in the county.[47]

7.3. Wetlands Remaining Wetlands

Globally, wetlands produce 25% of all anthropogenic and biogenic methane emissions. The majority of wetlands in Lake County are only seasonally flooded and have relatively low organic carbon content. Some are semi-permanently or intermittently flooded and are considered inland mineral wetlands.

Inland mineral wetlands can sequester carbon from undecomposed plant matter that falls to the bottom of the wet or marshy area and is incorporated into the organic matter of the soil. The wetland soils can have an organic matter composition of around 35%, making them a much more substantial carbon pool than typical cropland or rangeland soil.[48] Wetlands emit methane under anaerobic conditions. For the wetlands in Lake County, it is estimated that the annual net flux of GHG emissions from both of these processes is an emission of 0.84 $MTCO_2e$/acre. There were 31,405 acres of semi-permanently and intermittently flooded wetlands in the county in 2019, corresponding to 26,380 $MTCO_2e$ of GHG emissions.

Although wetlands emit more carbon in methane than they sequester, there are a myriad of other environmental benefits that make them important to the county, such as the creation of wildlife habitat and the purification of water. In addition, wetland soils are an important carbon pool as mentioned above. Although the methane emissions are greater than the carbon storage on an annual basis, over time the carbon storage in the soil is substantial. The IPCC guidelines estimate that inland mineral wetlands in cold and dry temperate climates have a storage of 74 tons of soil carbon per hectare. The change of land use from wetland to cropland or rangeland would lead to a release of the majority of the carbon stored in the rich soil and increase emissions greatly.

8. Renewable Energy Generation

Lake County's location, weather, and renewable resources make it an ideal area for renewable energy projects. The county is in the dry and sunny high desert of south-central Oregon, making it optimal for solar energy development. There are also unique geothermal resources in the area. Near Lakeview specifically, the geothermal activity originates along the fault line of the Warner Mountain Range to the east of town. Groundwater across the county is heated along other such fault lines and can provide a source of hot water if it rises close enough to the surface for a well to be drilled. Lastly, overstocked forests in the western part of the county are a vast resource for biomass energy consumption.

8.1. Utility-Scale Solar

The state of Oregon implemented a Renewable Portfolio Standard (RPS) in 2007, a year when only 2% of Oregon's electricity consumption came from renewable resources.[49] The RPS, updated in 2016, requires that 50% of all electricity used in Oregon be provided by renewable energy by the year 2040.[49] This is one of the main drivers of solar energy project construction in Lake County; both PacifiCorp and Portland General Electric (PGE) purchase the renewable energy credits (RECs) from the solar projects to meet their RPS requirements. One REC is given to facilities for each megawatt-hour of renewable energy that is delivered to the grid.

In 2019 there were eight utility solar projects generating electricity in Lake County as detailed in Table 11. Except for OR Solar 6, all of the projects that were active in 2019 were developed by Obsidian Renewables. The electricity and RECs from seven of the projects are purchased by PacifiCorp or PGE. A third-party company called 3 Degrees purchases the RECs from the BC Solar project and sells them to other companies around the country that want to reduce their emissions footprint and claim the environmental benefits associated with the project.[50] Both the Airport and Garrett solar facilities' full generation potential isn't shown here because they came online in December of 2019, their annual production is discussed in the "Current and Future Developments" section.

Monthly net electricity generation, as reported by the U.S. Energy Information Administration (EIA), from four of the largest solar sites is shown in Figure 21.[51] The greatest amount of electricity is produced from June through August, the months with the highest number of sunny days and most direct sunlight. Figure 22 compares the total generation in 2019 for each site with generation for 2018 and 2017 to show annual fluctuations. The 2019 electricity production was comparable to previous years for the BC Solar and OR Solar 6 projects but was lower than past years for Black Cap Solar and Outback Solar. This could be due to weather conditions, maintenance, or other factors.

Table 11. Summary of all utility solar projects in Lake County, 2019

Project Name	Nameplate Capacity (MW)	Location	Developer	REC Owner	Months Active in 2019	2019 Generation (MWh)
Airport Solar	47.3	Lakeview Airport	Obsidian Renewables	PGE	1	1,094
BC Solar	8	Lakeview	Obsidian Renewables	3 Degrees	12	18,568
Black Cap Solar	2	Lakeview	Obsidian Renewables	PacifiCorp	12	3,289
Garrett Solar	10	Lakeview Airport	Obsidian Renewables	PGE	1	227
Lakeview 363	0.363	Lakeview	Obsidian Renewables	PacifiCorp	12	650
Lakeview 500	0.5	Lakeview	Obsidian Renewables	PacifiCorp	12	912
OR Solar 6	10	Lakeview	Origis Energy	PacifiCorp	12	24,446
Outback Solar	4.4	Christmas Valley	Obsidian Renewables	PGE	12	9,483
			Total Utility Solar Generation:			58,669

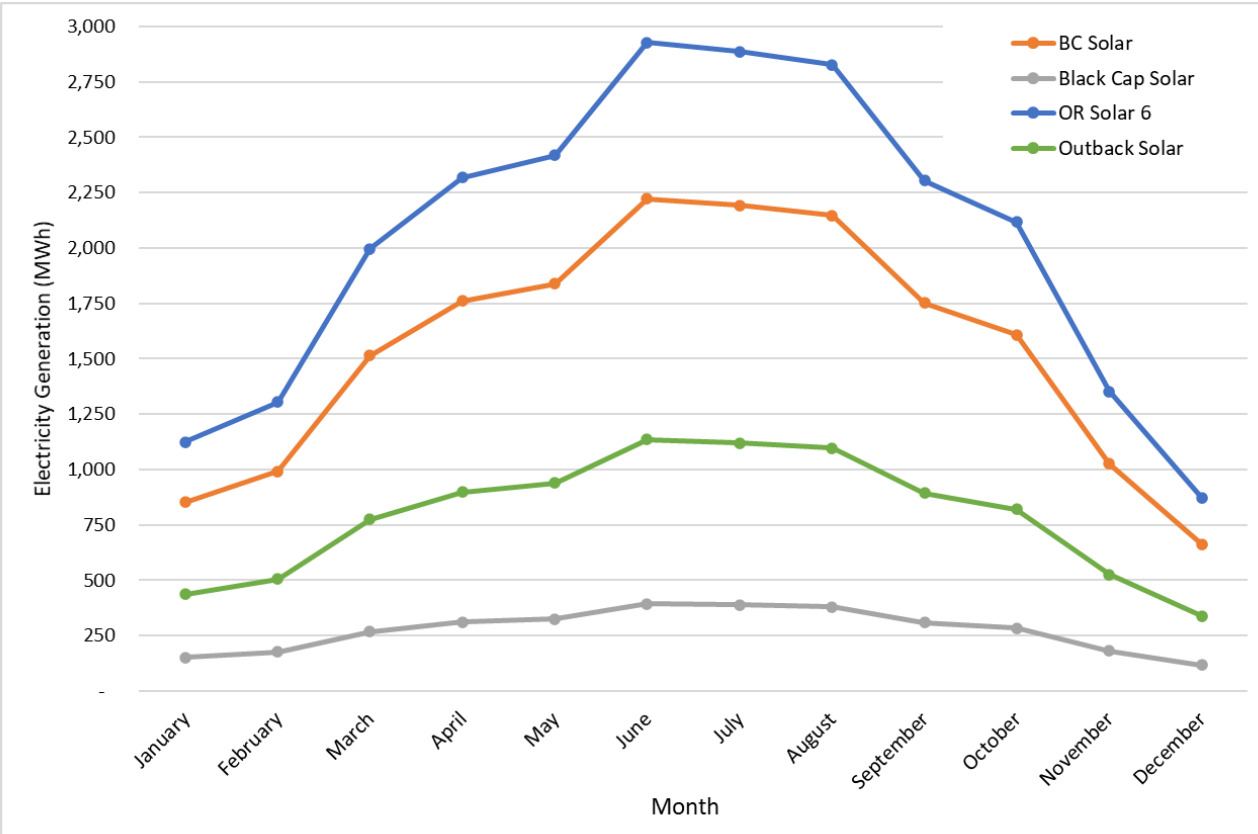


Figure 21. Monthly generation from four utility solar projects in Lake County, 2019

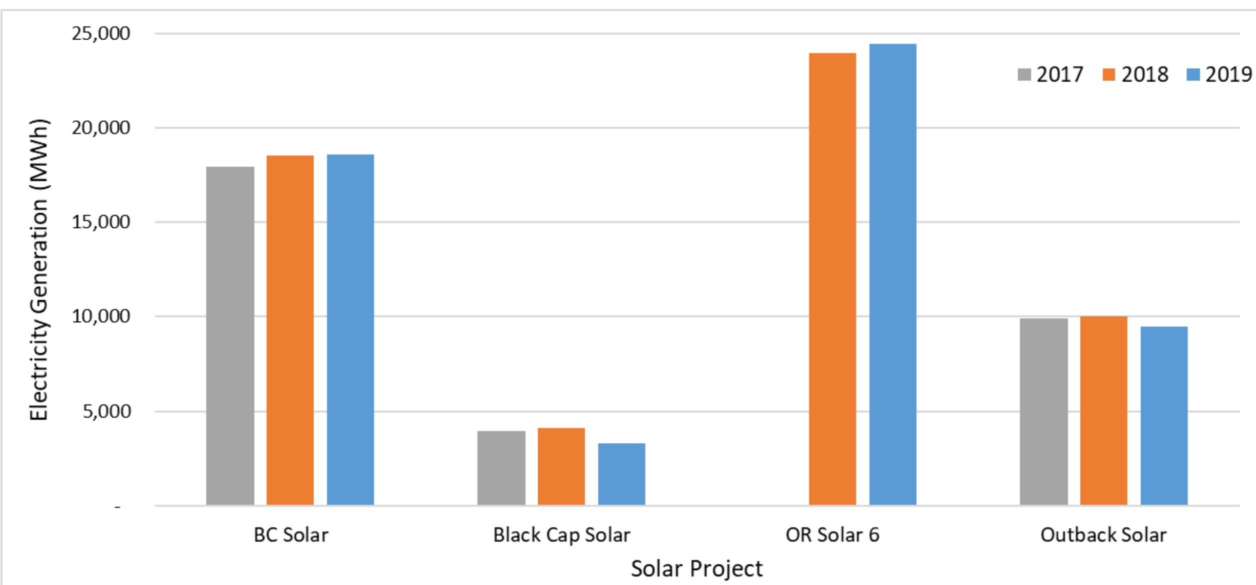


Figure 22. Annual generation from four utility solar projects in Lake County

In order to estimate the amount of greenhouse gas emissions that were prevented by the generation of electricity from solar projects in Lake County, it is important to identify which utility the electricity is serving. PacifiCorp utilizes the electricity from the four projects that they own the RECs for, as well as

BC Solar. These projects all tie into the transmission lines that PacifiCorp owns and serve their customers. The GHG emissions prevented by these projects will therefore be estimated using PacifiCorp's emission factor of 0.69 $MTCO_2e/MWh$ as shown in the "Electricity" section of the report.

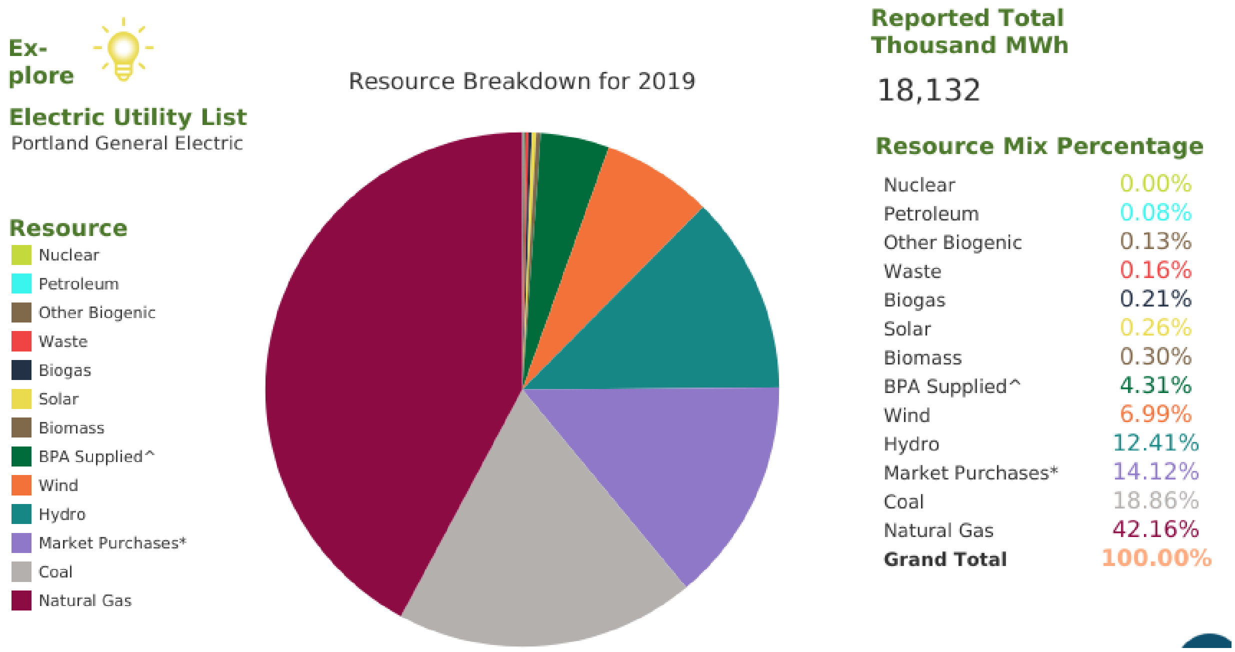


Figure 23. Portland General Electric (PGE) fuel resource mix, 2019[10]

The three remaining solar projects that were active in 2019 have their electricity purchased and RECs owned by PGE. PGE's emissions factor was 0.418 $MTCO_2e/MWh$ in 2019, and their fuel resource mix is shown in Figure 23

Figure 23. Portland General Electric (PGE) fuel resource mix, 2019[10]

.[10,11] Their emissions factor is lower than PacifiCorp's because they have a higher percentage of natural gas and hydroelectric generation with a lower percentage of coal generation, which is more carbon-intensive than any other fossil fuel.[52]

The calculation of prevented emissions is based on either the assumption that the solar projects equally replace electricity generation from all of the fuel resources of the utility, or that it prevents the addition of fuel resources in the existing ratio to the utility's mix. The GHG emissions prevented by each project in 2019 based on the emission factor of the utility it services is shown in Table 12.

Table 12. Prevented emissions for each solar project in Lake County, 2019

Project Name	Electricity Owner	Emission Factor (MTCO2e/MWh)	2019 Generation (MWh)	Prevented Emissions (MTCO2e)
Airport Solar	PGE	0.418	1,094	457
BC Solar	PacifiCorp	0.69	18,568	12,812
Black Cap Solar	PacifiCorp	0.69	3,289	2,269
Garrett Solar	PGE	0.418	227	95
Lakeview 363	PacifiCorp	0.69	650	449
Lakeview 500	PacifiCorp	0.69	912	629
OR Solar 6	PacifiCorp	0.69	24,446	16,868
Outback Solar	PGE	0.418	9,483	3,964
	Total Prevented Emissions:			37,543

8.2. Residential and Commercial Solar

The Oregon DOE had an incentive program for residential solar projects called the Residential Energy Tax Credit program which started in 1977 and ran until the end of 2017.[53] During that time twenty households in Lake County participated in the program.[54] That program has been replaced by a solar and solar plus storage rebate for up to $5,000 for a solar system and $2,500 for an energy storage system.[55] Similarly, the DOE also had a Business Energy Tax Credit program that expired in 2014 and had six commercial participants.

A majority of the benefits from these residential and commercial solar projects are already incorporated into the electricity totals for the county, because the generation from the projects directly replaces utility electricity that would otherwise be required. During peak hours, however, the solar systems may provide more electricity than the household or business is using and some of it may be sent to the grid. This energy that is sent to the grid is tracked by utilities with net metering, but the net metering data from the three utilities in the county was not made available for this report. Therefore, it is assumed that most residential and commercial solar energy is consumed by the household or business upon generation and net metering is neglected.

The number of residential and commercial solar projects by utility service area in Lake County is shown in Table 13, along with their annual generation as estimated by the Oregon DOE.[54] Every year these small-scale solar projects provide electricity that would otherwise be produced and delivered by the utilities, reducing annual emissions by 6.6 $MTCO_2e$.

Table 13. Residential and commercial solar project annual generation and emissions reduction in Lake County by utility

Utility	Number of Residential Solar Projects	Residential Generation (kWh)	Number of Commercial Projects	Commercial Generation (kWh)	GHG Emission Reduction (MTCO2e)
PacifiCorp	-	-	2	8,077	5.57
Surprise Valley	6	11,859	4	11,022	0.46
Midstate	14	28,357	-	-	0.57
				Total	6.60

8.3. Solar Projects for the Community

Several solar projects benefit the community in Lakeview. One of these is the Lakeview 4H solar facility, developed from a partnership between Obsidian Renewables, Lake County 4H, Lakeview School District, and LCRI.[56] This 10 kW array was built in 2013 and is estimated to produce 14,900 kWh of electricity annually for the 4H farm.

The Lake County Feed in Tariff (FIT) Project at the Lake County Fairgrounds is an 18.18kW solar array in Lakeview that serves the local community. It is estimated to produce 27,100 kWh each year. Together these two community-based solar facilities prevent an estimated 29 $MTCO_2e$ of GHG emissions annually.

8.4. Geothermal

The Paisley geothermal plant is a 3 MW facility that is owned by the Surprise Valley Electrification Co-op.[57] However, due to unresolved contracting issues, this power plant has not produced and sold electricity to the grid since May of 2017 according to the EIA.[58] During the time the geothermal plant was in operation, from October 2015 to May 2017, the average monthly generation was 390 MWh and the total lifetime production of the project was 7,403 MWh.[58] This did not significantly reduce greenhouse gas emissions from electricity generation because the estimated emissions factor of the plant was 0.026 $MTCO_2e$/MWh, which is slightly higher than the emissions factor of Surprise Valley electricity in 2019.[59] If the plant was still in operation today, it would not contribute to the reduction of greenhouse gases because it would not lower the emissions factor of the Surprise Valley Co-op. It is not clear why the geothermal plant ceased operation in 2017.

In 2013 the Lakeview School District and Hospital Heating Project replaced outdated heating equipment with geothermal heating infrastructure at five schools and the hospital. Old boilers at each site that altogether consumed 88,150 gallons of #2 fuel oil and 5,456 gallons of propane annually were no longer needed.[60] This resulted in the reduction of GHG emissions by 934 $MTCO_2e$ every year. The project drastically reduced the annual heating cost of the school district and the hospital, and part of the up-front installation cost was covered through the Oregon BETC program.

The last geothermal project discussed here was implemented in 2005 at the Warner Creek correctional facility. The geothermal heating system replaced 8,250 MMBTUs of heating from propane annually.[61] This corresponds to a 521 $MTCO_2e$ GHG emissions reduction. The emissions reduction from both the Warner Creek and Lakeview School and Hospital geothermal projects is accounted for in the stationary energy commercial heating calculations.

8.5. Current and Future Developments

Airport Solar is the largest active solar project in Lake County as of 2021. The full scale of the electricity generated and exported out of the county from the project, as well as the prevention of GHG emissions, was not captured in the 2019 analysis because the site only generated electricity for one month. Garrett Solar was also underrepresented in 2019. Additionally, in 2020 two new projects came online in the Fort Rock area that were developed by Newsun Energy. These four projects are summarized in Table 14 and their predicted annual generation is used to estimate their annual emissions prevention potential. The four new projects combined will prevent almost three times as much annual emissions as the existing projects did in 2019.

The anticipated generation from these projects will greatly increase the amount of renewable energy that is exported from Lake County. In fact, in 2020 the solar facilities produced more electricity than what was consumed in the entire county by 50,000 MWh. The addition of the Fort Rock project's generation for the full year in 2021 will generate an additional 100,000 MWh on top of that. Figure 24 and Figure 25 illustrate the difference in electricity generation from solar energy and the consequent prevention of GHG emissions from 2019-2020 and estimate 2021 values as well.

The development of solar energy facilities in the county is just beginning. Obsidian Renewables has 435 MW of projects in the preconstruction phase, including a 400 MW Obsidian Solar Center project in Fort Rock.[62] Newsun Energy is also developing additional projects in the northern part of the county, anticipating 200-400 MW of new project development within the next few years. Though some of these projects may not move forward, it is clear that Lake County continues to draw interest in new solar development.

In addition to vast amounts of solar development, a unique biomass renewable energy project is also being finalized. Red Rock Biofuels created a facility in Lakeview that will convert 166,000 tons of waste woody biomass into 16.1 million gallons per year of jet and diesel fuels.[63] The facility should be fully operational by Spring of 2021. Lakeview was selected for the project location because of the abundance of waste wood in the forests on the west side of the county, and because of the convenience of highway intersections and the rail system that extends south out of town.

Table 14. Summary of new utility solar projects that generated electricity in Lake County in 2020

Project Name	Nameplate Capacity (MW)	Location	Developer	REC Owner	Annual Generation (MWh)	Expected Emissions Prevention (MTCO2e)
Airport Solar	47.3	Lakeview Airport	Obsidian Renewables	PGE	132,000	55,176
Garrett Solar	10	Lakeview Airport	Obsidian Renewables	PGE	25,837	10,800
Fort Rock North	20	Fort Rock	Newsun Energy	PGE	51,300	21,443
Fort Rock South	20	Fort Rock	Newsun Energy	PGE	52,300	21,861
					Total:	109,281

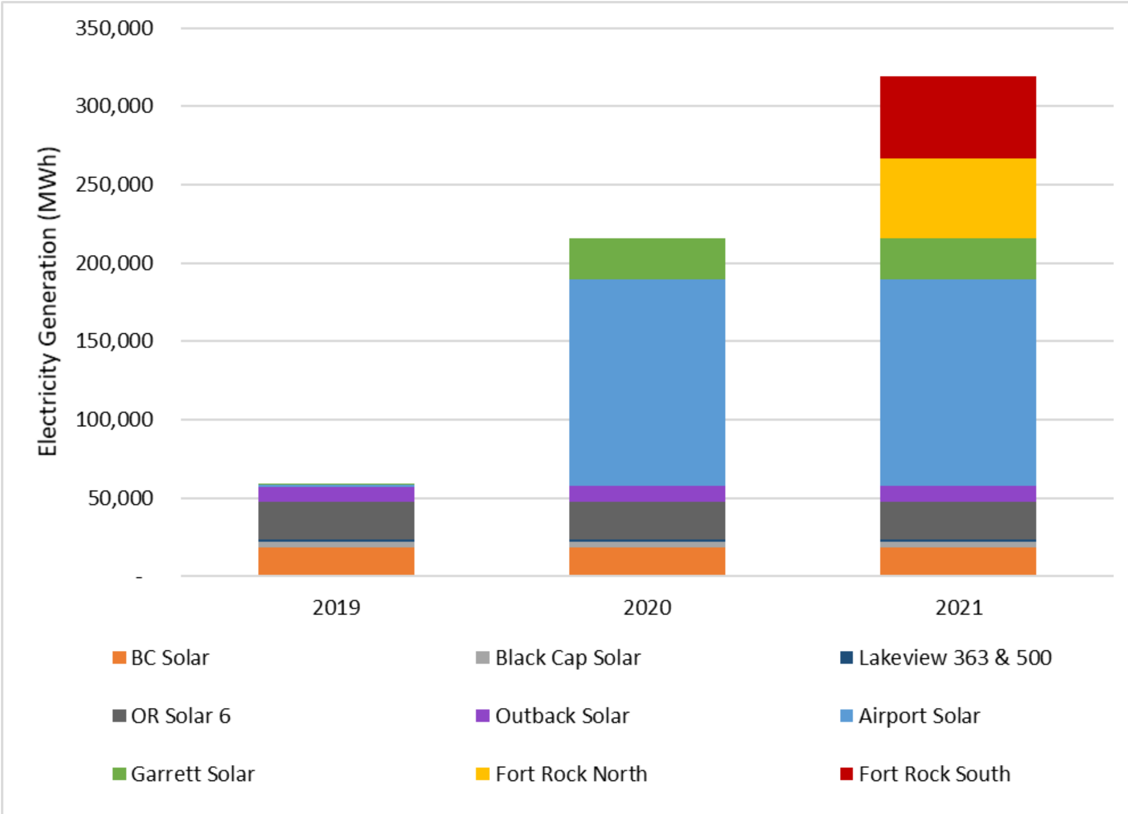


Figure 24. Annual projected electricity generation (MWh) of utility solar projects

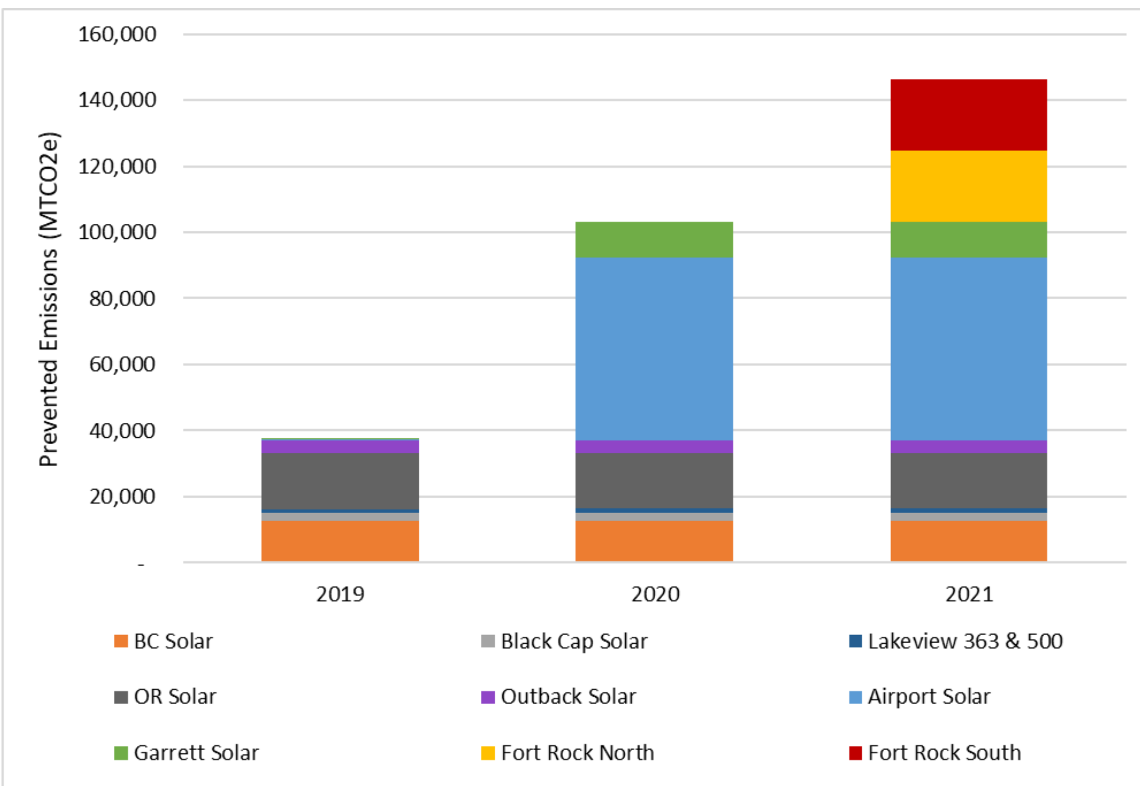


Figure 25. Annual projected GHG emissions prevention ($MTCO_2e$) from utility solar projects

9. Economics of Carbon

9.1. Carbon Credits

Renewable energy credits (RECs) have already been discussed as the environmental benefits associated with a renewable energy project. These credits from solar, wind, and biomass projects are most often used by utilities to adhere to state renewable energy production requirements, but they can also be purchased by third-party companies to offset their own electricity and fuel usage. A larger potential market exists for the sale and purchasing of carbon credits, a more general credit that represents a certain amount of carbon sequestration or GHG emission reduction.

California currently has a cap-and-trade program that limits GHG emissions from the major sources that produce 85% of the state's emissions.[64] This legislation created a market for carbon offsets from forestry and other projects so that entities could comply with the emissions limit set by the state. The Oregon state legislature put forth a very similar cap-and-trade bill (SB 1350) in both 2019 and 2020 that was not approved. The exact price of each ton of carbon fluctuates due to supply and demand in a cap-and-trade scenario, while carbon taxes set exact fees for carbon emissions and specify the price of carbon. A carbon tax proposed in Portland, for example, would charge $25 per ton of carbon for all facilities that produce 2,500 $MTCO_2e$ or more annually.[65]

Alternatively, there are also voluntary carbon markets created by companies that want to offset their GHG emissions without being required to do so by local or state governments. Companies purchase credits directly from a project creator (such as a landowner or forestry operation) or through an offset project development firm. Opportunities for Lake County landowners in this voluntary market are discussed in the next section.

9.2. Ecosystem Carbon

Several forest management activities and projects are eligible for carbon credits that can be sold to various companies for environmental compliance or voluntary and ethical reasons. The Collins Pine Company is creating carbon credits with a reforestation project in northern California near Lake County. Green Diamond has a forest restoration project that utilizes forest health thinning and limited logging within Lake and Klamath counties and sold 250,000 tons of carbon removal credits to Microsoft.[66] Microsoft purchased the credits not because of mandatory environmental laws, but as part of a voluntary effort within the organization to be carbon negative by 2030. Forest restoration is a cost-effective way to offset carbon emissions, with a much lower initial cost than renewable energy projects.

The Climate Action Reserve (CAR) has protocols for determining carbon credits from forest management on public and private lands. The carbon sequestration or carbon maintenance of the project must be effective for 100 years, and the forest management practice has to make use of native tree species and have a fully functioning natural ecosystem.[67] These requirements are in place to prevent the implementation of exotic tree plantations that may maximize carbon sequestration at the cost of the native plants and animals. Some examples of eligible activities listed in the report are increasing rotation ages, thinning diseased and suppressed trees, increasing tree stocking in understocked areas, and maintaining stocks. Harvesting is allowed in the project area, but only if it is certified as sustainable and has a long-term management plan. The CAR has also recently added protocols for grasslands, soil enrichment, nitrogen management, and livestock projects available. The Verified Carbon Standard (VCS) and American Carbon Registry (ACR) are other organizations that verify ecosystem carbon credits.

Not only are forests an increasing focus of carbon sequestration projects, but agricultural lands are also emerging as a focal point on the carbon trading market. The NRCS has begun to assist landowners in entering these markets by creating tools like the CarbOn Management Evaluation Tool for Voluntary Reporting (COMET-VR). COMET-VR is a voluntary reporting tool that agricultural producers can use to prove they are sequestering carbon with sustainable land management practices; those carbon credits can then be sold in a voluntary carbon market (just as forest carbon credits are) to provide additional farm income. The NRCS can also award Conservation Innovation Grants (CIGs) for carbon sequestration projects. Another example of increased national interest in funding agricultural carbon sequestration projects is the Healthy Soils Healthy Climate Act that was introduced to the US Senate in April 2021.[68] If passed, the legislation would make $100 million in USDA funds available to producers that increase carbon levels in their soil.[68]

10. Summary and Conclusions

The largest source of emissions in Lake County was agriculture with 190,340 $MTCO_2e$, or 48% of total emissions, in 2019. Stationary energy was the second-largest source comprising 23% of emissions with 91,681 $MTCO_2e$, followed by transportation with 21% and 82,921 $MTCO_2e$. Total emissions from all source categories were 396,082 $MTCO_2e$ in 2019, or 49 $MTCO_2e$ per Lake County resident for the year. Emissions from the burning of fuel alone (excluding those from livestock, waste, and land use) were 174,602 $MTCO_2e$ in 2019.

The activities that resulted in a net sequestration of carbon were crop production and forestry, which together offset 25%, or 97,864 $MTCO_2e$, of Lake County's emissions in 2019. Utility solar project electricity generation prevented 37,543 $MTCO_2e$ of emissions by eliminating the need for fossil fuel-generated electricity. Though the associated RECs and environmental benefits are owned and used by utilities to meet renewable standards set for utilities in Oregon, these prevented emissions are equivalent to 9% of the county's 2019 emissions. Four more utility-scale solar projects will reach their full operating potential in 2020 and 2021. This corresponds to an additional 65,976 $MTCO_2e$ of emissions prevention in 2020 from two of the projects and 109,281 $MTCO_2e$ in 2021 from all four solar sites. In 2020 renewables prevented emissions equivalent to 26% of Lake County's 2019 greenhouse gas emissions, and in 2021 the additional solar projects are expected to increase that value to 37%. These results are summarized in Figure 26.

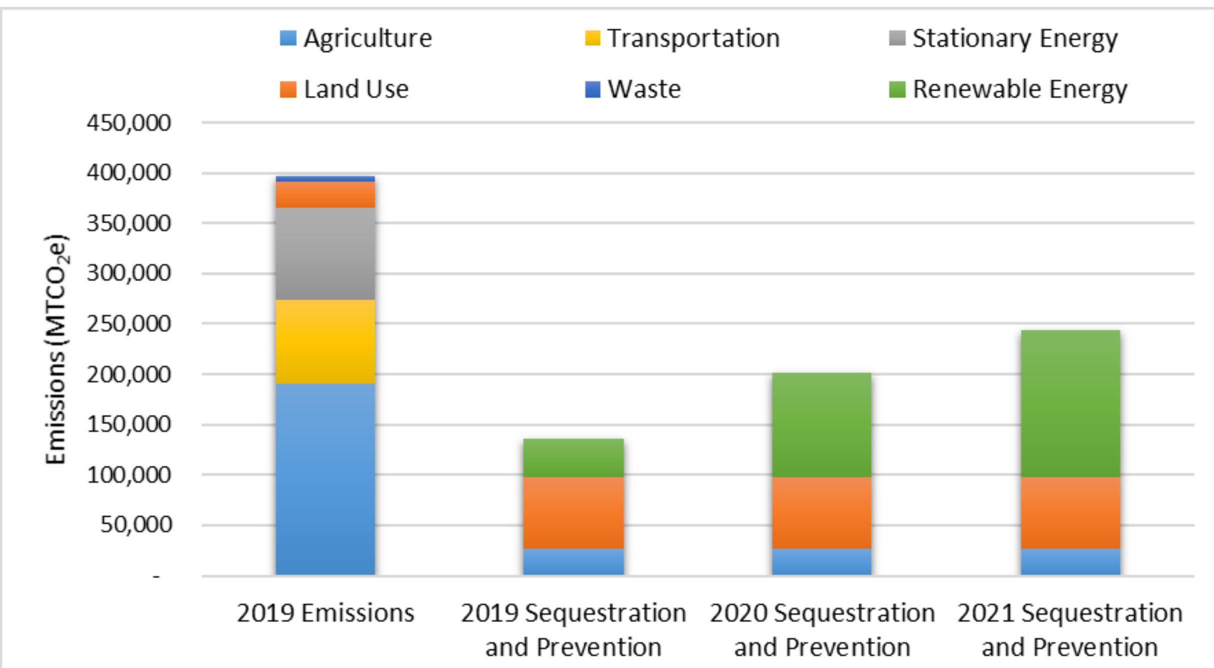


Figure 26. Summary of 2019 emissions and 2019-2021 carbon sequestration and emissions prevention in Lake County by report section

Emission and sequestration data from each section of the report can be grouped into the following sectors: agriculture, commercial, forestry, industrial, residential, transportation, waste, other land use, and renewable energy (Figure 27). With this type of analysis, agriculture was the highest net emitter in 2019 and transportation was the second highest. However, it can be seen that the industrial sector produced 45,328 $MTCO_2e$ from electricity and fuel consumption and is the next largest source of emissions. Residential emissions follow and are nearly equivalent to the estimated emissions from wetlands in the county. A summary of emissions alone from each sector is provided in Figure 28 and a more detailed visualization of the impact of each activity in the county on 2019 emissions is shown in Figure 29.

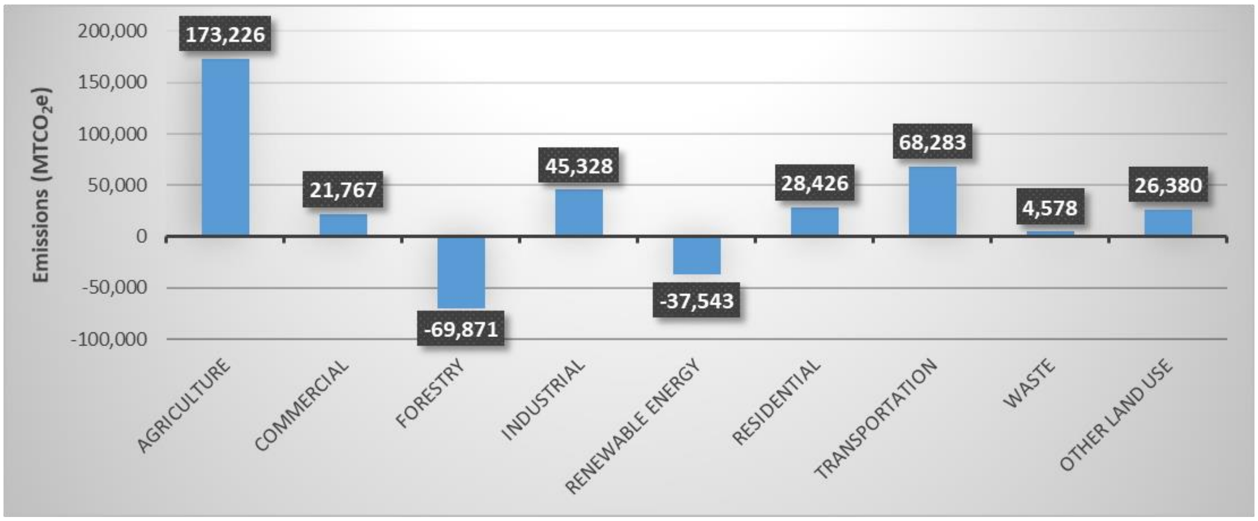


Figure 27. Summary of 2019 emissions, carbon sequestration, and emissions prevention in Lake County by sector

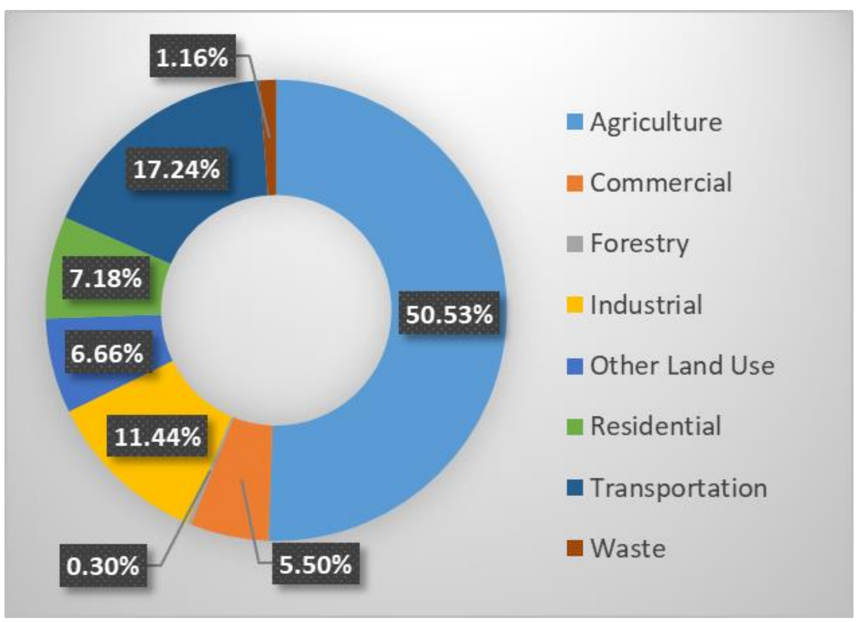


Figure 28. Percentage of GHG emissions alone attributed to each sector, 2019

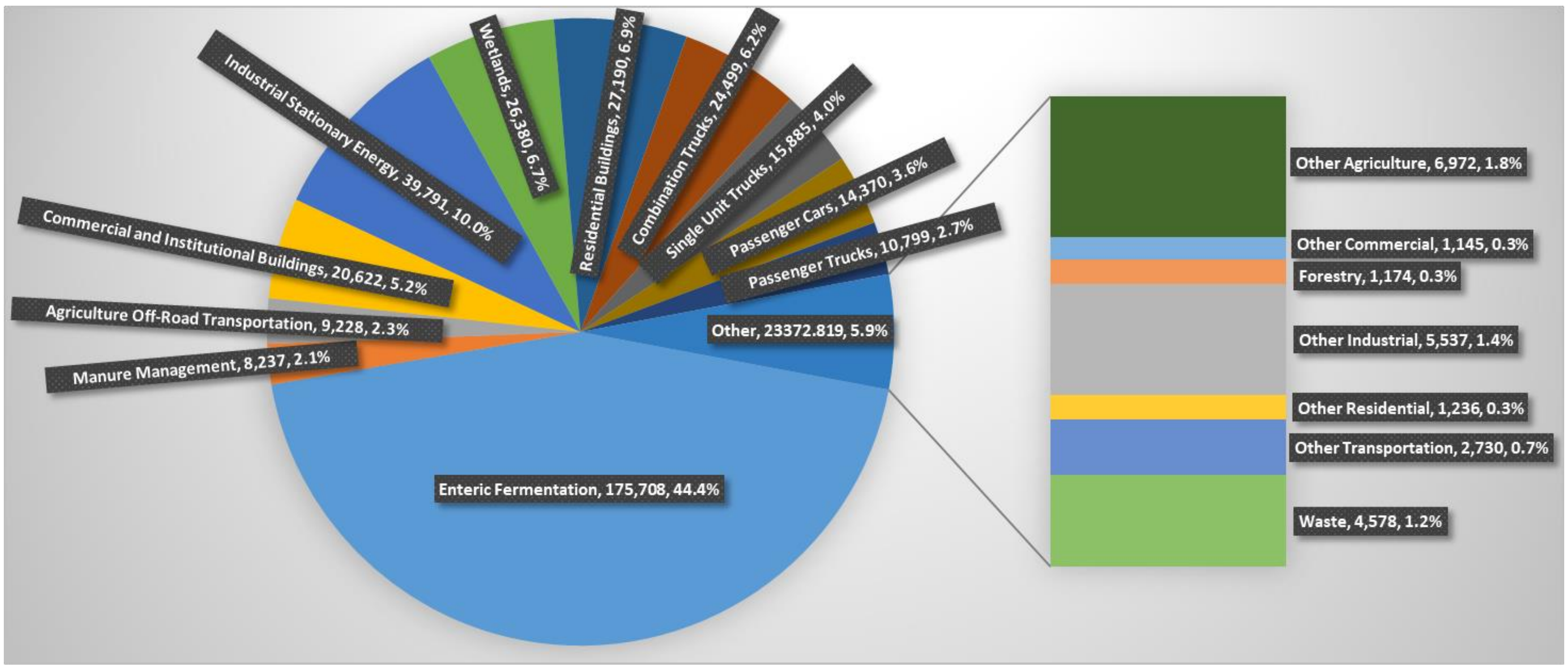


Figure 29. Emissions (MTCO$_2$e) and percentage of total emissions from each activity in Lake County, 2019

According to the Oregon Regional Economic Analysis Project, agriculture and forestry contributed 29% of Lake County's GDP.[69] When separated by economic sector and accounting for sequestration from hay production and harvested wood products, agriculture and forestry were responsible for 34.67% of 2019 emissions. This means that although enteric fermentation and other activities in this sector appear to have a disproportionately large impact on GHG emissions in Lake County, their emissions are in line with their economic contribution to the area.

Carbon sequestration from agriculture and forestry and emissions prevented by renewable energy projects were not greater than Lake County's total emissions in 2019. However, it is clear that through 2021 there are large annual increases in renewable energy impacts due to additional solar projects reaching their full generation potential. Additionally, sequestration and emissions prevention was equal to 77.6% of fuel-burning emissions in 2019, and will exceed 2019 fuel emissions in 2020 and 2021. With the possibility of 800 MW or more of solar project development in the next few years as well as the Red Rock biofuel plant startup, sequestration and GHG emission prevention within Lake County may grow larger than total annual emissions in the near future.

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Appendix A: Stationary Energy Calculations

A.1 Electricity

The county-specific electricity sales data was found directly from the Oregon Public Utility Commission (PUC) statistics book for Surprise Valley and derived from Oregon PUC data for Midstate.[70] The data from the 2019 PUC statistics book could directly be used for Surprise Valley's sales in Lake County because that is the only county that the co-op serves in Oregon. Midstate's reported sales in the statistics book were combined for the four counties in Oregon included in its service area, so a method of estimation for county-specific consumption is detailed below.

The kWh sales for all sectors in the county were 65,344,211 as provided by Jami Steinhauer, the CFO of Midstate, via email.[71] The proportion of Midstate's sales that occurred in Lake County in 2019 across all sectors was found by dividing the provided kWh sales in Lake County by Midstate's total electricity sales from the statistics book. It is assumed that the number provided by Jami Steinhauer does not include any electricity used by the utility in the county or lost energy, it only includes sales to customers. The proportion found was then multiplied by the sales for each sector in the statistics book (as well as utility usage and losses) to estimate Lake County kWh sales by sector from Midstate, as shown in Table A - 1 and Table A - 2.

Table A - 1. Lake County proportion of total Midstate electricity usage, 2019

Oregon kWh sales	Total Lake County kWh	Lake County Proportion of Total
412,329,743	65,344,211	15.85%

Table A - 2. Calculation of Midstate's sales by sector for Lake County, 2019

Customer Type	Oregon kWh	Lake County kWh
Residential	267,294,765	42,359,703
Commercial and Industrial	102,367,774	16,222,796
Public Street and Highway Lighting	6,480	1,027
Irrigation Sales	42,660,724	6,760,685
Total Sales	412,329,743	65,344,211
Used by Utility	1,091,763	173,018
Loss	24,637,486	3,904,441
Total Unsold	25,729,249	4,077,459
Total	438,058,992	69,421,670

PacifiCorp data was provided in the chart shown in Table A - 3 below directly from Todd Andres, the Regional Business Manager of PacifiCorp, via email.[72] The electricity sales in each of the three districts were added together to determine the values for each sector across PacifiCorp's service area in the county. The provided chart does not include the amount of electricity lost or used by the utility in the county, so that was estimated using data from the 2019 PUC statistics book.[70] First the proportion of total PacifiCorp sales that occurred in Lake County was determined (Table A - 4). Then this proportion was multiplied by PacifiCorp's utility usage and lost electricity for all of Oregon to determine the amount attributed to Lake County (Table A - 5).

Table A - 3. PacifiCorp sales in Lake County by sector, 2019

Year to Date 12-2019		
Revenue Class	**kWh**	**Customer Count**
COUNTY CODE - OR 019 LAKE		
1219 LAKEVIEW		
COMMERCIAL SALES	12,694,769	208
INDUSTRIAL SALES	420,739	6
PUBLIC STREET&HIGHWAY LIGHTING	195,280	3
RESIDENTIAL SALES	12,333,718	1,151
District Total	25,644,506	1,368
1220 LAKEVIEW UNINCORPORATED		
COMMERCIAL SALES	11,099,368	187
INDUSTRIAL SALES	8,216,743	20
IRRIGATION SALES	307,064	13
PUBLIC STREET&HIGHWAY LIGHTING	372	1
RESIDENTIAL SALES	7,008,647	603
District Total	26,632,194	824
1451 NEW PINE CRK		
COMMERCIAL SALES	38,436	12
IRRIGATION SALES	6,821	3
RESIDENTIAL SALES	650,304	61
District Total	695,561	76
County Total	52,972,261	2,267

Table A - 4. Lake County proportion of total PacifiCorp sales, 2019

Total Oregon kWh Sales	Total Lake County kWh Sales	Proportion of Total
14,426,083,000	52,972,261	0.37%

Table A - 5. Calculation of PacifiCorp's unsold electricity for Lake County, 2019

Sector	Oregon kWh	Lake County kWh
Used by Company	17,353,000	63,720
Lost	1,242,689,000	4,563,127

Each utility is required to report a carbon equivalent emissions factor that indicates the amount of greenhouse gas emissions (from CO_2, CH_4, NO_2, etc. all combined into $MTCO_2e$) per MWh of electricity created each year. This reporting requirement is set by the Oregon DEQ. PacifiCorp's emission factor was reported as 0.69 $MTCO_2e$/MWh. Midstate and Surprise Valley's emission factors are the same at 0.02 $MTCO_2e$/MWh because they both purchase electricity from BPA. These emission factors are multiplied by the electricity usage of each sector (converted to MWh) to determine the total amount of greenhouse gas emissions for each utility as shown in Table A - 6.

Table A - 6. Greenhouse gas emissions by sector and utility, 2019

Sector	PacifiCorp Emissions (MTCO2e)	Midstate Emissions (MTCO2e)	Surprise Valley Emissions (MTCO2e)
Residential	13,795	847	333
Commercial and Industrial	22,404	324	136
Public Street Lighting	135	0	0
Irrigation	217	135	225
Used By Utility	44	3	12
Lost Energy	3,149	78	81
Total	39,743	1,388	787

Additional figures below supplement those included in the body of the report and can be used to compare electricity consumption versus GHG emissions for different sectors and utilities in the county.

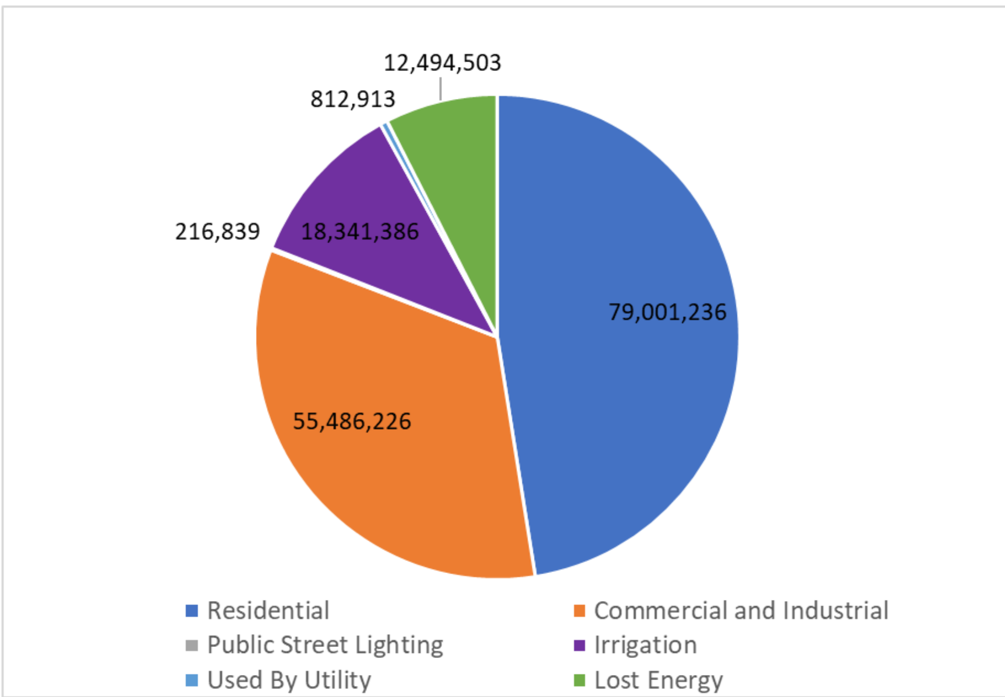

Figure A - 1. Electricity Consumed (kWh) By Sector in Lake County, 2019

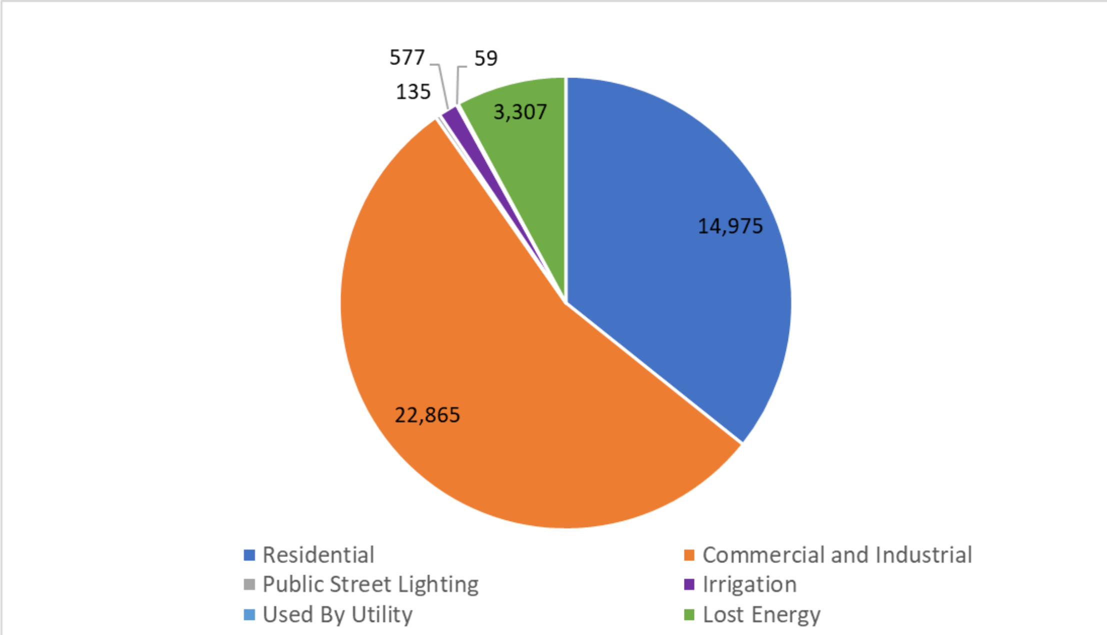

Figure A - 2. Emissions Produced ($MTCO_2e$) By Sector in Lake County, 2019

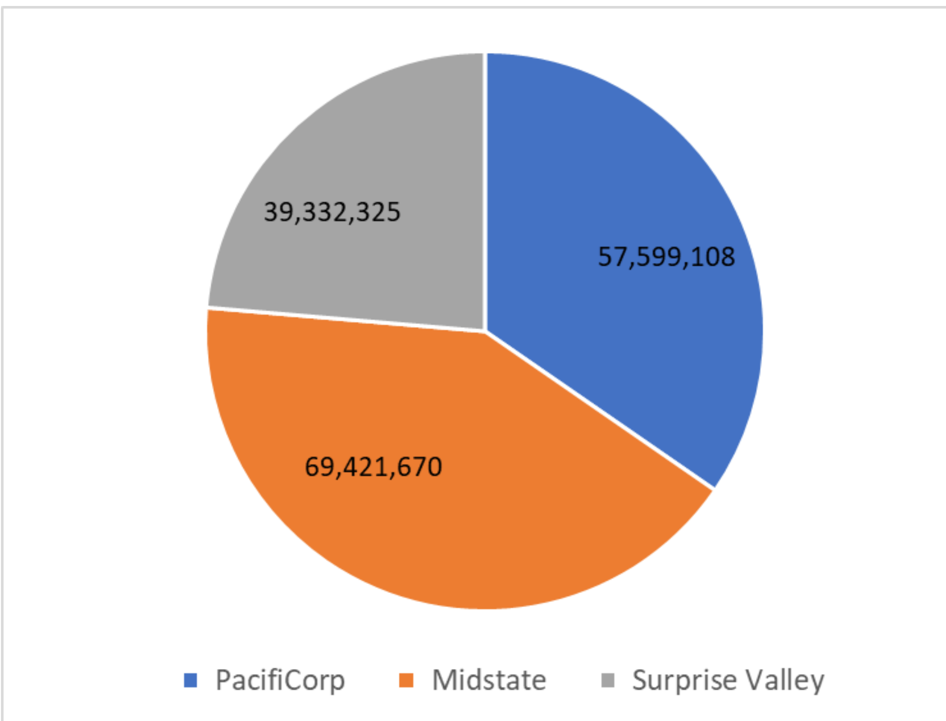

Figure A - 3. Electricity Consumed (kWh) by Utility in Lake County, 2019

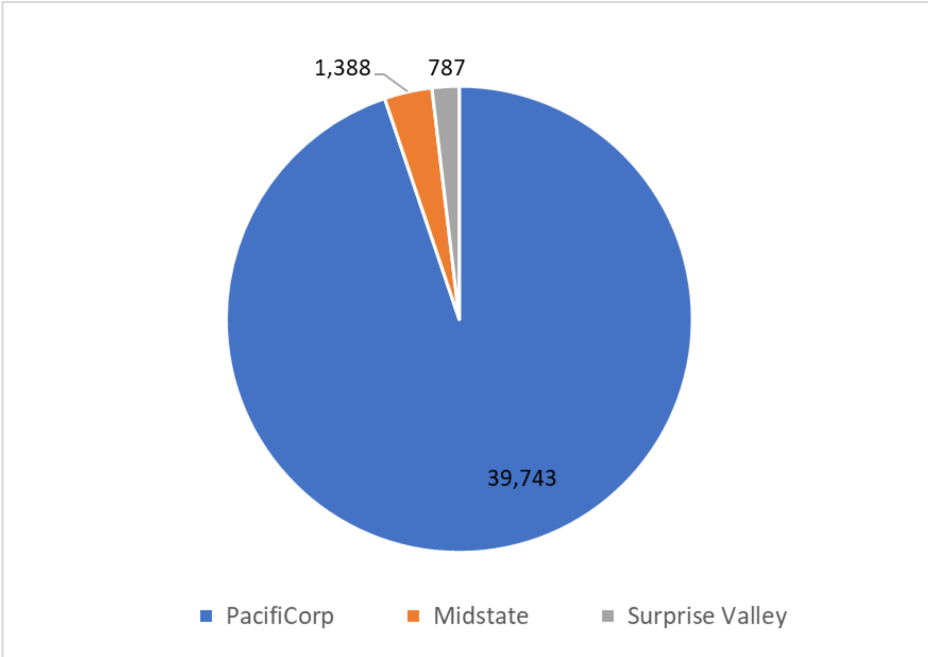

Figure A - 4. Emissions Produced ($MTCO_2e$) by Utility in Lake County, 2019

A.2 Past Report PacifiCorp Re-Calculation

The previous report underestimated the emissions from electricity consumption in Lake County in three ways: 1) miscalculating the emission factor for PacifiCorp electricity; 2) neglecting the electricity used by public lighting and irrigation as well as electricity lost and/or used by the utility; and 3) neglecting the electricity provided by Midstate and Surprise Valley utilities. Electricity sales from Midstate and Surprise Valley were not provided in the initial report, but the PacifiCorp data can be used to properly calculate emissions from that utility in 2009.

The emission factor for PacifiCorp was based on the assumption that all 94% of the electricity produced by fossil fuel was from coal, and that the coal-fired power plants had a 100% conversion efficiency of coal to electricity. Most coal plants are only 40% efficient, which is likely where the biggest discrepancy lies between the emission factor calculated in the report and what PacifiCorp reported to the Oregon DEQ. The previous report found an emission factor of 0.67 lbs CO_2/kWh, which is equivalent to 0.30 $MTCO_2e$/MWh. The actual emission factor for PacifiCorp in 2009 was 0.713 $MTCO_2e$/MWh.

This emissions factor, and the omission of public street and irrigation electricity usage, resulted in an underestimation of GHG emissions from electricity. The final calculated value of residential and commercial/industrial electricity emissions was 15,666 $MTCO_2e$. The actual value is 37,033 $MTCO_2e$, and that is without loss or use by the utility considered. The original report estimated 42.30% of actual emissions.

As a result, the annual emissions per household also need to be adjusted. The first report stated that the annual emissions per household were 3.67 $MTCO_2e$ for PacifiCorp customers, but after recalculation the actual value is 8.61 $MTCO_2e$ of annual emissions. This adjustment of the past report allows for a comparison between electricity usage and emissions from 2009 and 2019 for PacifiCorp customers in Lake County.

The comparison between 2009 and 2019 will neglect any Scope 3 emissions from electricity used by the utility or electricity losses. PacifiCorp customers purchased 960,000 additional kWh in 2019 compared to 2009, an increase that is largely due to the commercial and industrial sector in Lakeview. However, because PacifiCorp's emission factor fell to 0.69 $MTCO_2e$/MWh in 2019 the total emissions were 533 $MTCO_2e$ less than emissions in 2009. Graphs that illustrate this difference can be found in Figure A - 5 and Figure A - 6. The difference in emission factors also resulted in a decrease of annual household emissions for residential customers from 8.61 $MTCO_2e$ in 2009 to 7.60 $MTCO_2e$ in 2019. The commercial and industrial sector instead saw an increase in annual emissions per customer from 44.30 $MTCO_2e$ in 2009 to 51.82 $MTCO_2e$ in 2019 (Figure A - 7).

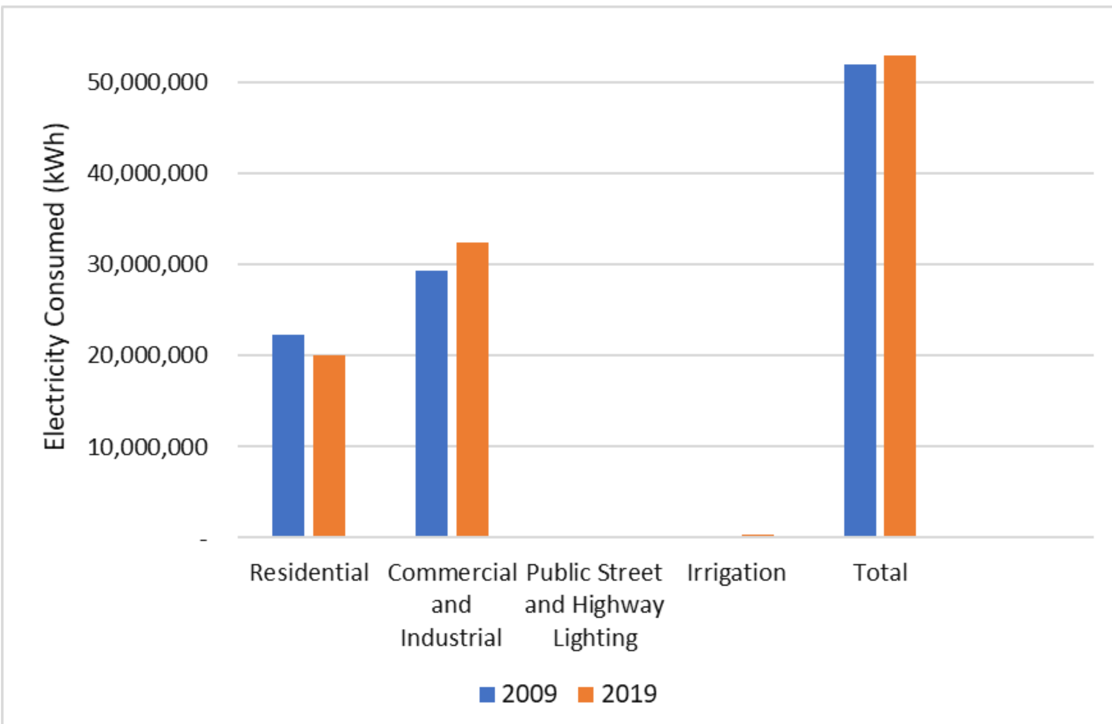

Figure A - 5. PacifiCorp Electricity Consumption (kWh) by Sector, 2009 and 2019

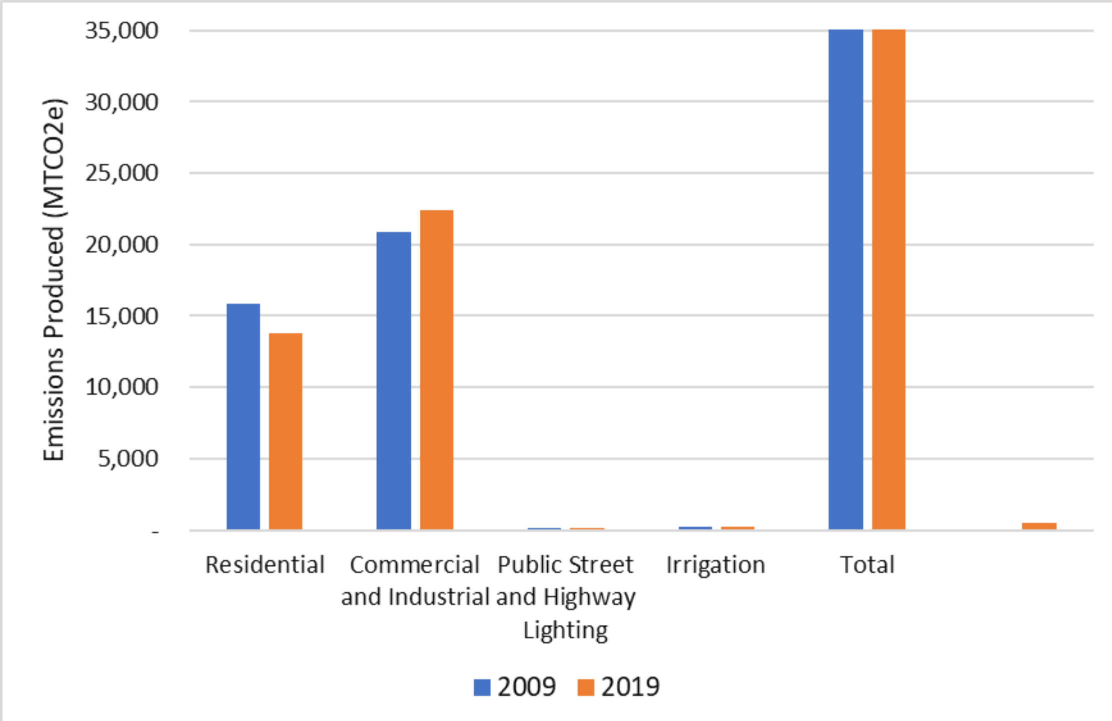

Figure A - 6. PacifiCorp Emissions (MTCO$_2$e) by Sector, 2009 and 2019

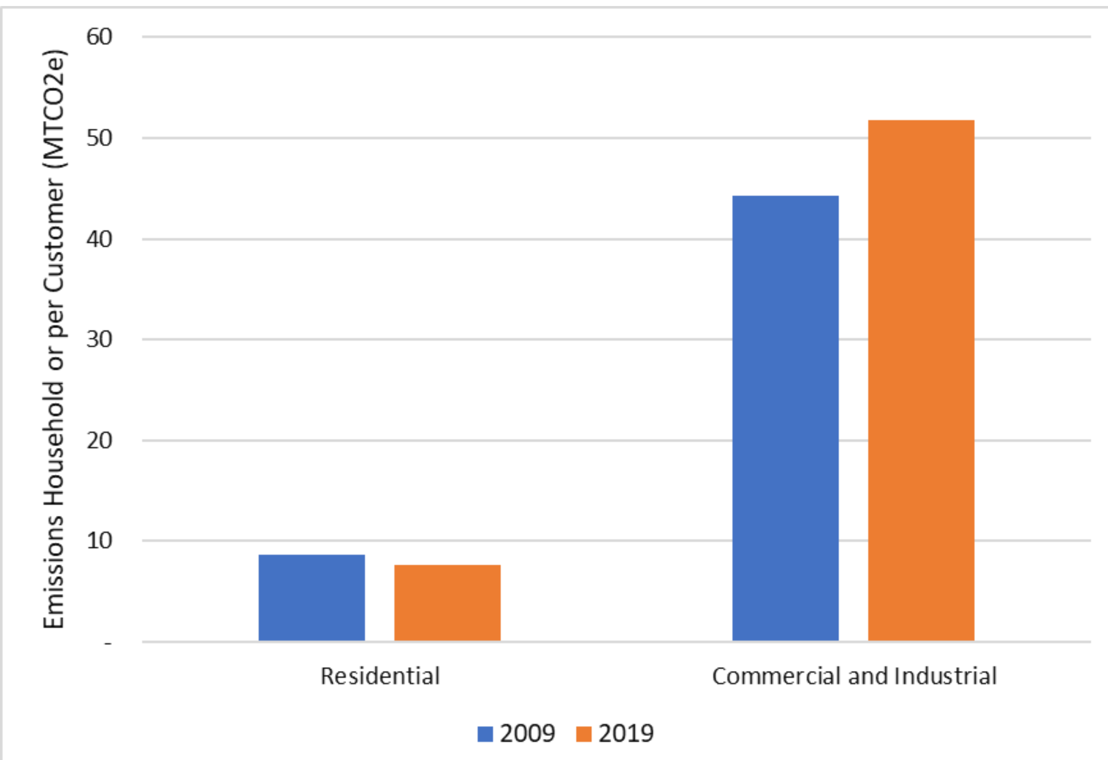

Figure A - 7. PacifiCorp Emissions (MTCO$_2$e) per Household or Customer by Sector, 2009 and 2019

A.3 Residential Buildings

The primary heating fuel used by all occupied households in Lake County was determined using the Low-Income Energy Affordability (LEAD) tool provided by the national Office of Energy Efficiency and Renewable Energy.[15] The LEAD tool was used to generate an output of household heating fuel type by building type and year built for dwellings in the county in 2018.

The national average annual energy usage per unit area (BTU/ft^2) for each fuel type was determined from the EIA's 2015 Residential Energy Consumption Survey (RECS) microdata file.[16] The RECS uses Building America Climate Regions to categorize survey response locations based on heating degree days, average temperatures, and precipitation data. Lake County falls within the "Cold" climate region, so survey responses were only used for this analysis that fell into the "Cold/Very Cold" climate category (CLIMATE_REGION_PUB).[73] Although Lake County falls into the "West" census region and the "Pacific" census division, there weren't enough responses in the division alone to create energy usage constants for every fuel type. Instead, data was used from the "Cold/Very Cold" climate category across the country.

The survey data in this category were then split by primary heating fuel (HEATFUEL) and year built (YEARMADERANGE). The energy usage per unit area for each survey response was determined by adding up all of the energy (in BTUs) required for heating for all fuel types (primary, secondary, and from wood) and dividing by the number of square feet that were heated in the home (TOTHSQFT). The full energy usage, not just that of the primary heating fuel, is used to account for secondary heating. The average per area energy usage was then found for each primary heating fuel and range of years built.

The survey data could not be divided further by housing type (TYPEHUQ) because of a lack of responses for all types, but the determination of energy use per unit area should take into account heating differences for houses of different sizes. Even without division by housing type, there were trends among the emission factors. They were higher for older houses, likely due to poor insulation and older heating systems, and lower for the newer houses. There were also trends by fuel: wood showed the highest amount of energy consumption per area, followed by fuel oil, then natural gas and propane, and finally electricity (Figure A - 8). The differences in energy consumption for each main heating fuel type are likely due to differences in heating system efficiencies.

The average square footage of single-unit homes in Lake County of 1,800 square feet was determined using a sample of 109 single-family houses listed on a real-estate website.[74] The homes were located in all areas of the county, including Lakeview, Christmas Valley, Paisley, Silver Lake, and more. Single-family homes and mobile homes were included. The average square footage of multi-unit homes (apartments) could not be determined for Lake County alone, instead, a national average of 880 square feet was used.[75] The last category that the average area had to be determined for was Boat/RV/Van. Because the LEAD tool only included occupied housing units, it was assumed that RVs make up a majority of the living spaces in this category. The average RV size was estimated at 250 square feet, and the average between the smallest Class C RV size at 190 ft^2 and the largest Class A RV size at 320 ft^2.

For each type of housing, the number of homes in Lake County for each year built category and fuel type (from the LEAD tool) was multiplied by the corresponding annual energy consumption per unit area (from the 2015 RECS data) and by the estimated average square footage of the housing type. This process was only completed for fuel oil, propane, and wood because residential electricity usage has

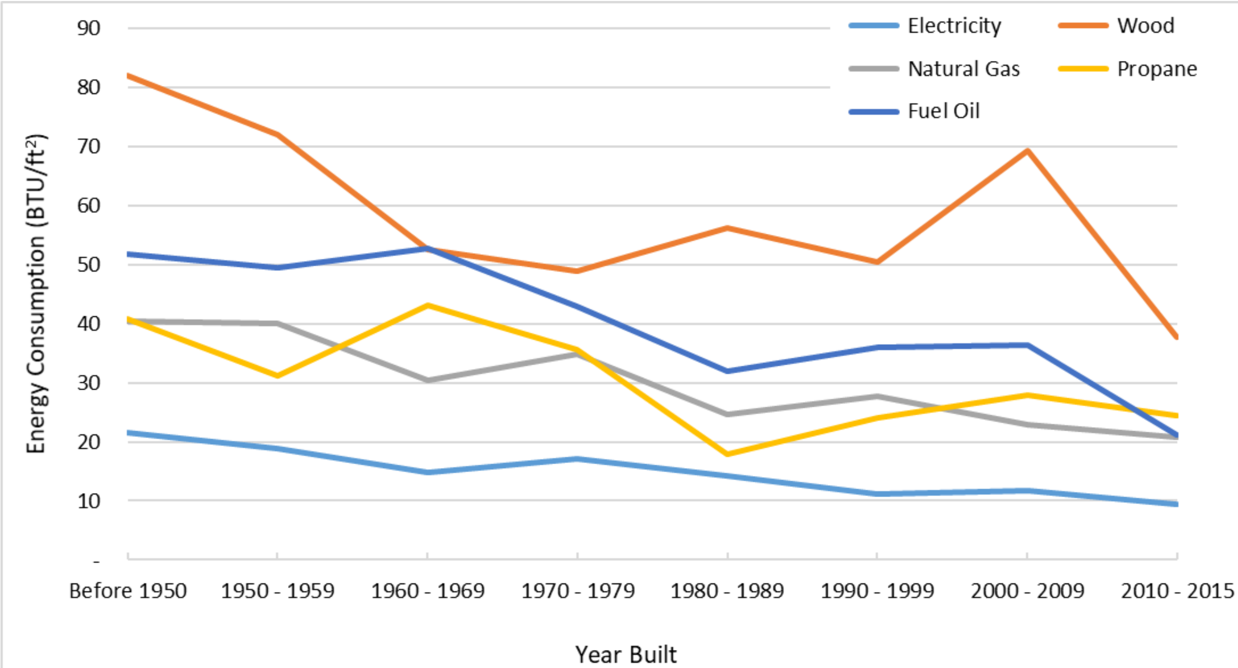

Figure A - 8. Annual energy consumption (BTU/ft²) for homes in "Cold/Very Cold" climates by year built and primary heating fuel, RECS 2015

already been accounted for and "other" heating fuels were neglected. The resulting annual energy consumption (BTUs) was multiplied by 1.00601 to take into account the 0.601% growth in occupied homes from 2018 to 2019. The number of occupied homes in 2018 from the LEAD tool was 3,494, while the U.S. Census American Community Survey (ACS) indicates that there were 3,515 occupied homes in the county in 2019.[76] This adjusted annual energy consumption was multiplied by the EPA emissions factors for CO_2, CH_4, and N_2O for the corresponding fuel.[77] Finally, the amounts of CH_4 and N_2O emitted by household heating were converted to $MTCO_2e$ by multiplying by their 100-year global warming potential (GWP).[77]

A.4 Commercial and Institutional Buildings

The number of establishments in Lake County in 2019 was found from the BLS Quarterly Census of Employment and Wages to be 341.[17] The data tables used were for all industry levels in Lake County and provided average statistics across all quarters in 2019 for each ownership category (private, federal, state, and local).

Data on heating fuel usage by businesses in downtown Lakeview was taken from an Anderson Engineering & Surveying geothermal study for the downtown area.[18] The study collected direct fuel usage from 15 downtown businesses and institutions. The annual fuel usage for each entity was multiplied by the heating value of that fuel (from the EPA) or simply converted to MMBtu units in the case of electricity.[77] The square footage for all 15 of the businesses was also provided, so a per unit area heating energy usage factor could be determined as shown in Table A - 7. This data was collected in 2009, but will still be used for this study with the caveat that improvements in heating system efficiency or changes in fuel type will not be captured in the 2019 emissions estimate for this sector.

Table A - 7. Building square footage and heating requirements in downtown Lakeview

Building Name	S.F.	Heating Fuel	MMBTU Requirement	MMBTU/sqft
Ace Hardware	4,500	Propane	51.40	0.0114
Lake County Chamber of Commerce	3,000	Electricity	197.59	0.0659
OSU Extension	2,176	Electricity	105.99	0.0487
39er Store	4,500	Fuel Oil	104.12	0.0231
Schmink Museum	1,350	Fuel Oil, Electricity	87.75	0.0650
Alger Theatre	4,280	Fuel Oil	372.60	0.0871
Heryford Building - Treasure Valley Community College	1,200	Electricity	56.10	0.0467
Town Hall and Annex	4,500	Electricity	100.04	0.0222
Mario's Restaurant	2,050	Propane	159.38	0.0777
Howard's Health Mart Pharmacy	4,400	Propane	109.71	0.0249
Golden Gem	2,400	Propane	30.38	0.0127
Favell Utley Building	2,400	Propane, Electricity	83.31	0.0347
Marius Building	18,000	Fuel Oil	190.14	0.0106
Arrow Real Estate	1,750	Electricity	38.01	0.0217
Machine Shop	7,280	Propane	496.00	0.0681

Another source of data was the Anderson Engineering & Surveying heating study for the school district and hospital geothermal project.[60] The annual fuel usage for heating and the square footage of the school buildings was provided, so four additional energy per unit area factors were developed for buildings in Lakeview.

The energy factors for all fuel types from both studies were averaged to provide an assumed energy usage of 0.0408 MMBTU/ft^2 in all commercial and institutional buildings in the county. The area of the buildings listed in Table A - 7 as well as 42 additional buildings listed in the downtown heating report were averaged to estimate the typical square footage of establishments in the county as 5,393 ft^2.

To avoid overestimating the amount of fuel used for heating in commercial buildings, the square footage of the schools, hospital, and Warner correctional facility was not used in calculating the average building area. This is because those establishments have areas much larger than the other downtown buildings and assumably the other businesses in the county, ranging from 30,000 – 100,000 ft^2.

The total square footage of all establishments in the county was found by multiplying the average square footage by the number of establishments reported by the BLS. The number of establishments was adjusted to 334 to account for six buildings with known geothermal heating systems. The omission of these buildings from the average area and total area calculations ensured that the full emission reduction benefits of the geothermal heating retrofits are captured in this sector. The total area of all establishments in Lake County is estimated to be 1,801,000 ft^2.

The 15 sites in Table A - 7 were used also to estimate the fraction of Lake County establishments that used each type of heating fuel. This was determined on a per unit area basis rather than per establishment, to show the differences in fuel usage for buildings of different sizes. The results are shown in Table A - 8, with the square footage percentages in the last column being used for the full county analysis. The buildings are categorized by primary heating fuel in the case of multiple heating fuels.

Table A - 8. Heating fuel types by number of businesses and square footage

Fuel	Businesses	% of businesses	Square Footage	% of square footage
Electricity	5	33.33%	12,626	19.79%
Fuel Oil	4	26.67%	28,130	44.10%
Propane	6	40.00%	23,030	36.11%
Total	15	100%	63,786	100%

The estimated percentage of building area heated by each fuel was then multiplied by the total area of businesses in the county. The resulted energy requirements were multiplied by the emissions factors for CO_2, CH_4, and N_2O from the EPA for each fuel.[77] The emissions calculation for electricity was not completed because these emissions were already included in the electricity section of the report. The estimated emissions from heating commercial and institutional buildings with fossil fuels are found in Table A - 9.

Table A - 9. Heating emissions by primary fuel type for commercial and institutional buildings in Lake County, 2019

Fuel	Building Area (ft^2)	MMBTU	Emissions ($MTCO_2e$)
Electricity	356,547	14,531	N/A
Propane	650,347	26,504	1,673
Fuel Oil	794,367	32,374	2,044
Total	1,801,262	73,408	3,717

A.5 Irrigation

The U.S. Geological Survey (USGS) provides estimates of water usage across the United States. For Lake County, data was provided by the USGS estimating the number of acres that were irrigated by sprinkler (center pivot) irrigation and surface irrigation for 2015.[22] The percentage of each irrigation type out of the total irrigation in the county was calculated and applied to the amount of irrigation in Lake County as estimated from the 2017 Census of Agriculture (a more accurate source for agricultural statistics).[23] From the USGS it was found that 64% of the irrigated land used center pivot irrigation. There were 140,327 acres of irrigated land in the county in 2017 according to the census, and using the USGS data it is estimated that 89,850 acres of those acres used center pivot irrigation. It is assumed that there was not a significant difference in the number of acres irrigated in 2019 compared to 2017.

Appendix B: Transportation Calculations

The protocol for calculating transportation emissions in this inventory is known as the geographic or territorial method and is approved for use by the GPC.[9] This method includes all transportation occurring within the boundaries of Lake County in the transportation emissions inventory. There are some transportation methods where emissions within the boundary cannot be directly determined, as will be discussed further.

B.1 On-Road Transportation

The EPA Motor Vehicle Emission Simulator (MOVES3) was used to determine the emissions from on-road transportation in the county in 2019.[24] The scale parameter of the RunSpec was an on-road model at the county scale for an inventory calculation. The time span was all months, days, and hours in the year 2019. The geographic boundary was Lake County, Oregon (41037). The selected on-road vehicle source type and fuel type combinations used in the model are listed in Table B - 1.

Table B - 1. MOVES3 on-road vehicle and fuel type combination selections

Source Use Type	Fuel
Motorcycle	Gasoline
Passenger Car	Diesel
Passenger Car	Ethanol (E-85)
Passenger Car	Gasoline
Passenger Truck	Diesel
Passenger Truck	Ethanol (E-85)
Passenger Truck	Gasoline
Combination Long-haul Truck	Diesel
Combination Short-haul Truck	CNG
Combination Short-haul Truck	Diesel
Combination Short-haul Truck	Gasoline
Other Buses	CNG
Other Buses	Diesel
Other Buses	Gasoline
Single Unit Long-haul Truck	CNG
Single Unit Long-haul Truck	Diesel
Single Unit Long-haul Truck	Gasoline
Single Unit Short-haul Truck	CNG
Single Unit Short-haul Truck	Diesel
Single Unit Short-haul Truck	Gasoline

There are four different road types to choose from in the MOVES3 model, the only one that exists in Lake County is the rural unrestricted access type. Unrestricted access means that there are no ramps required to access the road, whereas restricted access roads would be interstates and freeways with only ramp access. In reality, the roads in downtown Lakeview would be considered urban unrestricted access, but they make up such a small portion of the total road network in Lake County that they will not be analyzed separately.

The model also analyzes emissions from off-network fuel usage, meaning emissions that occur while the vehicles are not moving. These emissions occur from starting vehicles, extended idling, resting evaporative emissions, and more.[78] The pollutant of interest for the model was CO_2 equivalent, which would account for all types of GHG emissions from all processes. According to the model, GHG emissions occur from the following processes: running exhaust, start exhaust, extended idle exhaust, and auxiliary power exhaust.

After selecting these parameters, the model requires many different input data files from the user. Default data provided by the model for Lake County was used for hoteling, idling, starts, vehicle age distribution (for heavy-duty vehicles and motorcycles), vehicle average speed distribution, fuel data, and local weather data files. Age distribution for passenger cars and trucks was taken from ODOT registration data for Lake County.[79] No default data was provided for road type distribution, but this simply required allocating all of the VMT for each vehicle type to rural unrestricted access roads (road type 3). Data on VMT and population for each vehicle source type was also required to be input from the user. This data came from ODOT traffic counts as described below.

ODOT has 41 traffic counting stations located along the state highways in Lake County that record the different types of vehicles traveling on the highways.[80] The data from the traffic stations are compiled each year into an annual average daily traffic (AADT) number and the percentages of that traffic that are attributed to the 13 different FHWA vehicle classes (Table B - 2).[81] The same data was also available for 23 traffic counting stations on non-highway roads from the Oregon TransGIS website for 2019.[82]

Table B - 2. FHWA vehicle classifications used by ODOT and their corresponding MOVES3 source type

Class Group	Class Definition	EPA MOVES3 Source Type
1	Motorcycles	Motorcycles
2	Passenger cars	Passenger Car
3	Four tire, single unit	Passenger Truck
4	Buses	School Bus/Other Buses
5	Two axle, six tire, single unit	Single Unit Short-Haul Trucks
6	Three axle, single unit	Single Unit Short-Haul Trucks
7	Four or more axle, single unit	Single Unit Long-Haul Trucks
8	Four or less axle, single trailer	Combination Short-Haul Trucks
9	Five axle tractor semitrailer	Combination Short-Haul Trucks
10	Six or more axle, single trailer	Combination Long-Haul Trucks
11	Five or less axle, multi-trailer	Combination Long-Haul Trucks
12	Six axle, multi-trailer	Combination Long-Haul Trucks
13	Seven or more axle, multi-trailer	Combination Long-Haul Trucks

The estimated population of each source type that travels on each road segment was determined by multiplying the percentage of traffic for that vehicle class by the AADT on that segment. For state highways, where the traffic recorders are located in succession and likely track the same vehicle as it travels through the county, these population estimates were averaged across the segments for each highway and then added together. For the non-state highway traffic counts the estimates were all added together as it is less likely that multiple recorders would count the same vehicle.

The estimated annual VMT of each source class was determined by multiplying the percentage of traffic for each vehicle class by the AADT and the length of the road segment covered by the traffic recorder to estimate the number of vehicle miles traveled. Some of the state highway road sections were extended into neighboring counties which led to an overestimation of VMT. To solve this, the percentage of each vehicle class VMT to total VMT across all highways was calculated and multiplied by the annual VMT on state highways in Lake County as determined by ODOT.[80] The values for the non-state highways could not be adjusted to any larger estimation of off-highway travel, and because of this, the amount of travel in the county is likely underestimated. This underestimation of off-highway travel using the traffic recorder data is not as severe for heavy-duty vehicles as it is for light-duty vehicles because it is likely that the larger vehicles stay on the more heavily trafficked roads.

The population and VMT estimates for the FHWA class groups were aggregated into the categories of motorcycles, passenger cars and trucks, buses, single unit trucks (short and long haul), and combination trucks (short and long haul) as shown in Table B - 2. It was not feasible to determine how many of the buses were school buses, so the FHWA bus category was assigned to the MOVES3 model "other buses" category.

The model run output file showed the GHG emissions and total energy consumption by vehicle category, fuel, and road type (on-road versus off-network) for 2019 in Lake County. Table B - 3 shows a breakdown of the vehicle emissions from the model output by fuel type consumed.

Table B - 3. On-road vehicle emissions ($MTCO_2e$) by fuel type for Lake County, 2019

Vehicle Type	Gasoline Emissions (MTCO2e)	Diesel Emissions (MTCO2e)	CNG Emissions (MTCO2e)	Ethanol Emissions (MTCO2e)	Total Emissions (MTCO2e)
Motorcycles	402	-	-	-	402
Passenger Cars	14,280	83	-	7	14,370
Passenger Trucks	10,344	436	-	19	10,799
Buses	234	1,468	133	-	1,835
Single Unit Short-haul Truck	3,321	12,165	189	-	15,675
Single Unit Long-haul Truck	46	161	3	-	210
Combination Short-haul Truck	0	16,725	409	-	17,134
Combination Long-haul Truck	-	7,365	-	-	7,365
Total	28,628	38,404	733	25	67,790

B.2 Railways

The operations manager at Goose Lake Railway provided the total amount of diesel fuel consumed by the railway in 2019: 68,377 gallons. The total roundtrip distance of the train route is 220 miles, with 22 of those miles within Lake County. That means that 10% of the travel occurs in the county, so it was assumed that 10% of the total fuel is consumed in the county (6,837.7 gallons). The number of gallons consumed in Lake County was multiplied by the CO_2 emission factor for diesel and the CH_4 and N_2O emission factors for diesel locomotives from the EPA.[77] The amount of CH_4 and N_2O produced was multiplied by the corresponding GWPs, and the resulting emissions were 70.48 $MTCO_2e$.

B.3 Aviation

The amount of fuel sold at the Lake County airport in 2019 was a direct estimation from the owner of the airport.[26] Because this was the only type of aviation data available for the county and is likely the most accurate estimation of emissions, the fuel sales method of emission calculation was applied for aviation.[9] The emission factors for the two different types of fuels, Jet A and Avgas 100LL, were taken from the EPA.[77]

B.4 Off-Road Transportation

The majority of off-road transportation emissions were calculated using the EPA MOVES3 Model.[24] The equipment categories of off-road mobile emissions sources selected for the model run were as follows: airport ground support, commercial, construction, industrial, and lawn and garden. The model estimated the emissions from equipment in each category based on population and business data from Lake County. Table B - 4 summarizes the Lake County population (number of vehicles) of each equipment type estimated by MOVES3 and the corresponding greenhouse gas emissions for 2019.

Table B - 4. MOVES3 model off-road equipment population and total emissions ($MTCO_2e$) outputs for some off-road equipment in Lake County, 2019

Equipment Type	Population	Emissions (MTCO2e)
Airport Ground Support Equipment	**0.01**	**0.24**
4-Stroke Airport Ground Support Equipment	0.00	0.01
Airport Ground Support Equipment	0.01	0.23
LPG Airport Ground Support Equipment	0.00	0.00
Commercial Equipment	**268.52**	**432.03**
Air Compressors	7.59	64.34
Gas Compressors	0.03	8.66
Generator Sets	148.47	195.40
Hydro-power Units	0.97	4.40
Pressure Washers	60.33	51.08
Pumps	38.57	50.09
Welders	12.55	58.06
Construction and Mining Equipment	**27.76**	**518.53**
Bore/Drill Rigs	1.51	7.69
Cement and Mortar Mixers	2.79	1.38
Concrete/Industrial Saws	1.21	4.06
Cranes	0.33	16.61
Crawler Tractor/Dozers	0.93	71.90
Crushing/Processing Equipment	0.17	3.07
Dumpers/Tenders	0.35	0.27
Excavators	1.21	72.19
Graders	0.29	17.96
Off-highway Tractors	0.04	7.68
Off-highway Trucks	0.15	61.79
Other Construction Equipment	0.13	7.61
Pavers	0.32	7.52
Paving Equipment	1.38	2.34
Plate Compactors	1.46	0.88
Rollers	0.88	18.51
Rough Terrain Forklifts	1.09	23.34
Rubber Tire Loaders	1.37	79.14
Scrapers	0.16	19.39
Signal Boards/Light Plants	0.62	2.00
Skid Steer Loaders	5.16	33.44
Surfacing Equipment	0.25	1.18
Tampers/Rammers	1.72	0.42
Tractors/Loaders/Backhoes	3.31	48.49
Trenchers	0.91	9.67
Industrial Equipment	**39.07**	**711.15**
4-Stroke AC\Refrigeration	0.06	0.34
AC\Refrigeration	10.97	171.73
Aerial Lifts	3.66	13.93
CNG AC\Refrigeration	0.01	0.08
Forklifts	16.85	394.27
Other General Industrial Equipment	4.32	41.74
Other Material Handling Equipment	0.27	1.80
Sweepers/Scrubbers	2.15	38.51
Terminal Tractors	0.78	48.74

Lawn and Garden Equipment	**3,925.37**	**609.66**
2-Stroke Chain Saws < 6 HP (Commercial)	18.33	10.48
2-Stroke Chain Saws < 6 HP (Residential)	224.18	4.79
2-Stroke Snowblowers (Commercial)	4.98	1.07
2-Stroke Snowblowers (Residential)	185.90	2.32
4-Stroke Snowblowers (Commercial)	5.32	3.09
4-Stroke Snowblowers (Residential)	198.60	6.71
Chippers/Stump Grinders (Commercial)	2.45	33.90
Front Mowers (Commercial)	9.42	21.69
Lawn and Garden Tractors (Commercial)	9.74	44.88
Lawn and Garden Tractors (Residential)	517.94	158.07
Lawn Mowers (Commercial)	38.19	26.04
Lawn Mowers (Residential)	1,405.86	59.24
Leafblowers/Vacuums (Commercial)	26.57	33.17
Leafblowers/Vacuums (Residential)	315.93	4.91
Other Lawn and Garden Equipment (Commercial)	18.53	4.15
Other Lawn and Garden Equipment (Residential)	25.51	5.64
Rear Engine Riding Mowers (Commercial)	1.24	3.03
Rear Engine Riding Mowers (Residential)	75.79	11.79
Rotary Tillers < 6 HP (Commercial)	14.78	15.16
Rotary Tillers < 6 HP (Residential)	145.15	5.38
Shredders < 6 HP (Commercial)	7.75	1.63
Snowblowers (Commercial)	0.01	0.23
Trimmers/Edgers/Brush Cutters (Commercial)	46.71	9.78
Trimmers/Edgers/Brush Cutters (Residential)	601.62	6.96
Turf Equipment (Commercial)	24.85	135.54
Grand Total	**4,260.71**	**2,271.36**

The scale parameter of the RunSpec was a nonroad model at the default scale for an inventory calculation. The time span was all months and days in the year 2019. The geographic boundary was Lake County, Oregon (41037). The pollutants of interest were CH_4 and atmospheric CO_2, which cover the processes of running exhaust, refueling displacement vapor loss, refueling spillage loss, evaporative tank permeation, evaporative hose permeation, and fuel vapor venting. Unfortunately, N_2O was not one of the pollutant options and was not included in the emissions estimation of the model. It is assumed that GHG emissions from N_2O are negligible.

The MOVES3 outputs for forestry and agriculture off-road emissions could not be used because the equipment population was underestimated and the emissions from each vehicle were overestimated. Lake County has greater agricultural and forestry activity per capita than estimated by the model, but the intensity of those activities was overestimated. The model population outputs for recreation using ATVs and snowmobiles were also not used for this analysis, and instead replaced with actual vehicle registration data from Lake County. Recreational boat fuel usage was estimated using an Oregon-specific boating survey. Lastly, mining emissions were calculated directly from activity data for the Tucker Hill mine.

The acres of barley, oats, and winter wheat harvested in the county were taken from the 2017 Census of Agriculture.[23] The harvested acres of alfalfa and other hay were taken from an updated report released by the Northwest Regional Field Office of the National Agricultural Statistics Service for 2017.[83] All crop data was estimated for 2019 based on the change in total Oregon acres for each crop from 2017 to 2019 from the 2021 Oregon Agricultural Statistics Book (Table B - 5).[84] Data on the number of acres treated by various agricultural practices were also taken from the 2017 census and adjusted to 2019 levels based on the estimated percent change (-10.38%) in total Lake County harvested acres from 2017 to 2019 (Table B - 6).[23]

Table B - 5. Calculation of Lake County acres harvested for each crop, 2019

Location	Crop	2017 acres	2019 acres harvested	% Change	2017 Lake County acres	2019 Lake County acres
Oregon	Winter Wheat	690,000	730,000	5.80%	360	381
Oregon	Oats	10,000	9,000	-10.00%	621	559
Oregon	Alfalfa Hay	420,000	400,000	-4.76%	69,500	66,190
Oregon	Hay (excl alfalfa)	665,000	570,000	-14.29%	101,600	87,086
Oregon	Barley	38,000	35,000	-7.89%	134	123

Table B - 6. Calculation of Lake County area of agricultural practices, 2019

Activity	2017 acres	2019 acres
Fertilized Cropland	39,324	35,242
Insecticide	7,447	6,674
Herbicide	44,237	39,645
No-till	752	674

Diesel consumption factors for cultivating and harvesting barley, oats, and winter wheat were provided from the NRCS Energy Estimator for Tillage tool, which estimates diesel consumption from the typical machinery required for each crop type based on local weather data and agricultural practices.[85] This tool did not provide estimates for hay, so instead diesel usage factors per activity per acre from the Farm Energy Analysis Tool (FEAT) were used.[86] These usage factors are averaged from multiple publications and are therefore not specific to Lake County, which makes them less accurate than the values from the NRCS Energy Estimator.

The diesel fuel used per acre for hay production without any additional practices (fertilizer, insecticide, etc.) was assumed to be the same for alfalfa and other hay. Three cuttings for the year are included, and hay transportation distance from the field was estimated at half a mile (Table B - 7). Separate fuel usage factors were determined for tillage (for alfalfa establishment), fertilization, and chemical application. Fuel consumption factors were multiplied by the area of each crop and agricultural practice in the county to determine the total amount of diesel used in agriculture, as shown in Table B - 8 and Table B - 9. It was assumed that alfalfa was re-established every five years, so the number of acres tilled was one-fifth of the total acres of alfalfa. The amount of diesel consumed was multiplied by the emission factors of CO_2, CH_4, and N_2O from the EPA for agricultural equipment; the resulting off-road emissions from agriculture were 9,228 $MTCO_2e$.[77]

Table B - 7. Activities included in diesel usage estimation for alfalfa and hay production, 2019

Approximate Fuel Required for Field		**Hay/Alfalfa/Haylage Base**		**Alfalfa Tillage**		**Fertilization**		**Chemical Treatment**	
		Gallons Used/Ac:	**5.30**	**Gallons Used/Ac:**	**3.39**	**Gallons Used/Ac:**	**0.65**	**Gallons Used/Ac:**	**0.18**
Field Operation	**Diesel (gal/acre)**	**Field Passes**	**Gallons/Acre**	**Field Passes**	**Gallons/Acre**	**Field Passes**	**Gallons/Acre**	**Field Passes**	**Gallons/Acre**
Culti pac	0.72			**1**	0.72				
Chiselplow	1.52			**1**	1.52				
Disc	0.76			**1**	0.76				
Drill	0.40			**1**	0.40				
Fertilizer	0.65					**1**	0.65		
Haul in field+.5 mi	0.20	**3**	0.61						
Haylage blower	0.25	**1**	0.25						
Haylage harvest	1.25	**1**	1.25						
Insecticide	0.18							**1**	0.18
Mow	0.54	**3**	1.63						
Rake	0.24	**3**	0.73						
Square bale	0.42	**2**	0.83						

Table B - 8. GHG emissions from crop management and harvesting in Lake County

Crop	Area Harvested (Acres)	Diesel Usage (gal/acre)	Total Diesel Consumption (gal)	Emissions (MTCO2e)
Barley	123	6.94	854	8.81
Oats	559	4.41	2,465	25.45
Winter Wheat	381	5.54	2,111	21.79
Alfalfa	66,190	5.3	350,807	3,621.55
Other Hay	87,086	5.3	461,556	4,764.86
Total	154,339	-	817,792	8,442

Table B - 9. GHG emissions from additional agricultural practices in Lake County

Practice	Area Treated (Acres)	Diesel Usage (gal/acre)	Total Diesel Consumption (gal)	Emissions (MTCO2e)
Fertilizer	35,242	0.65	22,907	236.48
Insecticide	6,674	0.18	1,201	12.40
Herbicide	39,645	0.18	7,136	73.67
Tillage	13,238	3.39	44,877	463.28
Total	94,799	-	76,122	786

Emissions from off-road transportation related to forestry in Lake County were determined based on fuel usage factors from scientific articles. Harvesting and management fuel inputs on a per unit area and per volume harvested basis were taken from a forest product life-cycle assessment specific to the Pacific Northwest.[87] Although it is focused on wood products from Douglas-fir trees (instead of the ponderosa pines, lodgepole pines, white firs, and cedars found in Lake County), the fuel consumption of the forestry equipment is likely similar when adjusted for volume harvested. Fuel usage for reforestation was taken from a life-cycle report on forest products in the inland Northwest from the Consortium for Research on Renewable Industrial Materials (CORRIM).[88]

The volume of timber harvests that were processed by the Collins Pine Company Lakeview plant in 2019 was provided by the Lakeview project manager. This volume was multiplied by the amount of fuel consumed by ground-based harvesting (in L/m^3) from the Pacific Northwest lifecycle model and converted to gallons of diesel fuel (Table B - 10).[87] The emissions from harvesting are not solely attributed to Collins, as a majority of the wood they processed at the Lakeview mill in 2019 came from timber sales of trees harvested by the USFS.

The USFS performed precommercial thinning and reforestation activities in the portions of the Fremont-Winema and Deschutes National Forests within Lake County. Acreages of each activity were provided directly from the Forest Service Activity Tracking System (FACTS) for 2019. There was juniper thinning that occurred for the North Warner forest health project coordinated by the Lake County Umbrella Watershed Council, as well as by the BLM.[89] Acres of juniper woodland that was thinned by the BLM was provided directly from the BLM GIS specialist for the Lakeview unit in shapefiles.

The area each management activity covered in 2019 was multiplied by the corresponding fuel usage factor to determine the amount of diesel and gasoline consumed (Table B - 11). The precommercial thinning diesel usage factor from trucks and gasoline usage factor from chainsaws (from the Pacific northwest life-cycle assessment) were used for USFS precommercial thinning and all juniper removal activities.[87] USFS reforestation was multiplied by the diesel usage factor specific to national forest planting activity from the inland northwest life-cycle assessment.[88]

The number of gallons of each fuel was multiplied by the emissions factors and GWPs of the three greenhouse gases to determine the total emissions in 2019. For CO_2 production the EPA-provided mobile combustion emission factors for diesel fuel and motor gasoline were used.[77] For CH_4 and N_2O emission factors the EPA-provided values for other non-road vehicles were used because there weren't any factors specific to forestry equipment.

Table B - 10. Emissions ($MTCO_2e$) from fuel used for harvesting of the timber processed at the Collins Lakeview mill, 2019

Entity	Activity	Fuel consumption (gal)	Emissions (MTCO2e)
Collins/USFS	Ground-based harvesting	76,645	789.57

Table B - 11. Emissions ($MTCO_2e$) from fuel used in other management activities in Lake County, 2019

Entity	Activity	Area (acres)	Activity Gasoline Usage (L/ha)	Activity Diesel Usage (L/ha)	Gasoline consumed (gal)	Diesel consumed (gal)	Emissions (MTCO2e)
USFS	Precommercial thinning	4,673	4.21	7.02	2,103	3,507	54.76
USFS	Tree planting	384	0	30	-	1,232	12.69
Umbrella Watershed Council	Tree thinning	5,000	4.21	7.02	2,250	3,752	58.59
BLM	Juniper removal	6,619	4.21	7.02	2,979	4,967	77.56

The number of ATVs in the county was determined by the number of permits sold in 2019 by the Oregon Parks and Recreation Department (found from a public records request). The number of snowmobiles in Lake County was determined from DMV records, as snowmobiles have to be registered. There are only two 9-hole golf courses in Lake County that are both closed in the winter. It is assumed that GHG emissions from golf carts at these courses are negligible.

The EPA MOVES3 model provided an estimation of the GHG emission factor per vehicle per year for Lake County for both ATVs and snowmobiles. These factors were multiplied by the population of each recreational vehicle to determine 2019 emissions (Table B - 12).

Table B - 12. Emissions ($MTCO_2e$) from recreational vehicles in Lake County, 2019

Vehicle Type	Number Registered/Permits Distributed	Emissions Factor (MTCO2e/vehicle)	Emissions (MTCO2e)
ATV	146	0.40	58.40
Snowmobile	99	1.86	184.14

The number of actively registered vessels in Lake County in 2017 was provided by the Oregon Marine Board.[90] This was adjusted by the change in county population from 2017 to 2019 to estimate that 463 vessels were registered in 2019. The 2017 Oregon Motorboat Fuel Use Survey provided average fuel use data for two categories split by boat length: those less than 26 feet and those equal to or greater than 26 feet.[91] The percent ownership of each boat length category was provided for all of Oregon for the survey, and the percentages were applied to the number of registered vessels in Lake County in 2019.

The fuel use survey provided data for both gasoline and diesel fuel consumption per year by vessel. These fuel consumption factors were multiplied by the number of boats in each length category to determine total annual fuel usage, then multiplied by the EPA emission factors for CO_2, CH_4, and N_2O (Table B - 13). The total emissions from recreational boating in Lake County were 383 $MTCO_2e$.

Table B - 13. GHG emissions ($MTCO_2e$) from recreational boat usage in Lake County, 2019

Vessel Type	Oregon %	Lake County Number of Vessels	Avg annual gasoline consumption (gal/vessel)	Avg annual diesel consumption (gal/vessel)	Emissions (MTCO2e)
<26'	95.86%	444	84.09	0.5	333.03
>=26'	4.14%	19	223.3	63.06	50.43
Total	100%	463	-	63.56	383.46

Lastly, emissions from mining activities at the Tucker Hill mine were determined using data from an environmental impact statement created by the BLM for the assessment of continuing mining activities in February of 2019.[92] The hourly fuel consumption and operation hours per year of each piece of heavy machinery is given in the report, as well as the fuel efficiency and VMT of other vehicles used on site. The amount of fuel used was multiplied by the emission factors for construction equipment provided by the EPA.[77]

Appendix C: Waste Calculations

C.1 Landfill

The amount of waste disposed of in the Thomas Creek Road Landfill in 2019 was provided in the 2019 Oregon Material Recovery and Waste Generation Rates Report.[28] The amount of waste disposed of every year since 1990 was also taken from the Oregon Waste Generation Report where data was available and linear interpolation between given years when necessary.[29] There was no waste combustion at the Thomas Creek Road Landfill in 2019 or at the old Lake County landfill during its life, so all emissions came from the anaerobic decomposition of waste.[93]

The EPA State Inventory Tool waste module was used to determine GHG emissions from waste disposed of in the county.[30] A first-order decay model was used to estimate the amount of methane generated from waste that was disposed of in municipal solid waste (MSW) landfills in 2019, as well as the amount of methane generated in 2019 from waste that was disposed in previous years since 1990. The methane generation potential used in the first-order decay equation was 100 m^3 CH_4 per metric ton of waste, from the EPA. The methane generation rate was 0.02 for arid climates such as that in Lake County. The full equation can be seen below.

$$Q_{tx} = A * k * R_x * L_o * e^{-k(T - x)}$$

Where $Q_{T,x}$ = Amount of CH_4 generated in year T by the waste R_x,

T = Current year

x = Year of waste input,

A = Normalization factor, $(1-e^{-k})/k$

k = CH_4 generation rate (yr^{-1})

R_x = Amount of waste landfilled in year x

L_o = CH_4 generation potential

Some amounts of methane are oxidized in the top layer of soil and are not emitted into the atmosphere as CH_4. The EPA estimates that 10% of landfill methane is oxidized, so 10% of the estimated generation from MSW landfills in the county was calculated and subtracted from the total.

C.2 Wastewater

The population of Lake County in 2019 was found from the Portland State University population research center to be 8,080 people.[3] It is assumed that every person living within the town of Lakeview is part of the city's sewer system while everyone outside of Lakeview is assumed to have a septic tank. The population of Lakeview in 2019 was 2,768 people, so 34.25% of the population is estimated to not have a septic tank.

CH_4 emissions from septic tanks were determined by multiplying the population of Lake County that uses septic tanks (5,312) by the emission factor used by the EPA (10.7 g CH_4/day per capita). This was converted to annual emissions then multiplied by the GWP of methane to find that 519 $MTCO_2e$ of methane was emitted in 2019 (Table C - 1).[33,94] CH_4 emissions from municipal wastewater treatment at the facility in Lakeview were determined by multiplying the population of Lakeview by the annual per capita BOD_5 production. BOD_5 is the biochemical oxygen demand of the waste; a default factor for Oregon of 0.09 kg/day per capita was provided by the EPA State Inventory Tool wastewater module.[30] This was converted to annual BOD_5 consumption and multiplied by the maximum CH_4 producing capacity (0.6 kg CH_4/kg BOD) and the methane correction factor for constructed wetlands (0.1) provided by the IPCC.[95] Methane emissions from the Lakeview treatment facility in 2019 were estimated at 136 $MTCO_2e$ (Table C - 2).

Table C - 1. Calculation of CH_4 emissions ($MTCO_2e$) from septic tank wastewater decomposition, 2019

Population	g CH4/person/day	Days/yr	Unit conversion (MT/g)	Emissions (MTCH4)	GWP	Emissions MTCO2e
5,312	10.7	365	0.000001	20.75	25	518.65

Table C - 2. Calculation of CH_4 emissions ($MTCO_2e$) from the Lakeview wastewater treatment plant, 2019

Population	Per capita BOD5 (kg/day)	Days/yr	Unit Conversion (MT/kg)	Emission factor (kg CH4/kg BOD5)	Methane Correction Factor	Emissions (MTCH4)	GWP	Emissions (MTCO2e)
2,768	0.09	365	0.001	0.6	0.10	5.46	25	136.39

N_2O emissions from wastewater treatment and decomposition were determined using the EPA State Inventory Tool.[30] The amount of protein consumed per capita in Oregon was provided by the wastewater module at 44.3 kg/year, with a nitrogen fraction of 16% in the protein and a non-consumption fraction of 1.75. All of these factors were multiplied by the population of Lake County to find the amount of nitrogen in all wastewater produced in 2019. This was multiplied by the nitrous oxide emission factor of wastewater, the fraction of N_2O to N, and the GWP of N_2O to find the annual N_2O emission value of 469 $MTCO_2e$ (Table C - 3).

Table C - 3. Calculation of N_2O emissions ($MTCO_2e$) from the municipal wastewater treatment and decomposition, 2019

Population	Protein (kg/person /yr)	Nitrogen Fraction in Protein (kg N/kg protein)	Fraction of Nitrogen not Consumed	Unit Conversion (MT/kg)	N in domestic wastewater (MT)	Emission Factor (kg N2O/kg sewage N)	N2O/N2	Emissions (MT N2O)	GWP	Emissions (MTCO2e)
8,080	44.3	0.16	1.75	0.001	100.22	0.01	1.571	1.57	298	469.21

Appendix D: Agriculture and Other Land Use Calculations

D.1 Agriculture

Cattle counts in Lake County for January 1, 2019 were found from the 2021 Oregon Agricultural Statistics book.[84] It is assumed that the number of cattle in the county at the beginning of the year is a sufficient estimate of the average number of cattle across the entire year. The statistics book provided data on the total number of cattle (91,000) and beef cows specifically (47,500) in Lake County alone, but not on the other specific age and use categories such as replacement heifers, stockers, calves, and bulls.[84] However, the number of cattle in each category for all of Oregon was provided. The percentages of each non-cow category for all of Oregon were used to estimate the number of cattle in each non-cow category for Lake County alone (Table D - 1 and Table D - 3).

2017 Lake County population data for sheep/lamb, goats, and chickens were taken from the 2017 USDA Census of Agriculture.[23] The change in total population for each animal type for all of Oregon from 2017 to 2019 (from the statistics book) was used to estimate the 2019 Lake County population (Table D - 2).[84] For chickens, this was applied to each subcategory. The remaining livestock categories, horses and turkeys, did not have state-wide totals for 2017 and 2019. Therefore, the population estimate from the 2017 agriculture census was assumed to be sufficient for 2019 for those livestock. Other equines (mules, burros, and donkeys) had an inventory of 20 in the agriculture census but were excluded from the emissions analysis because specific emission factors were not available.

Table D - 1. Oregon non-cow cattle population (1,000 head) and calculation of category percentage at the beginning of the year, 2019

	Replacements	Heifer Stockers	Steer Stockers	Bulls	Calves	Total Non-Cow
Oregon	175	115	160	40	160	650
Percentages	26.92%	17.69%	24.62%	6.15%	24.62%	100.00%

Table D - 2. Oregon livestock inventory (head) changes from 2017 to 2019 and corresponding Lake County population estimate, 2019

Animal	2017 Oregon population	2019 Oregon population	% Change	2017 Lake County pop	2019 Lake County pop
Sheep and Lamb	170,000	175,000	2.94%	605	623
Goats	39,600	40,000	1.01%	698	705
Chickens	2,957,000	2,775,000	-6.15%		
Chickens, Layers				758	711
Chickens, Pullets				84	79
Chickens, Broilers				88	83

D.1.1 Enteric Fermentation

Enteric fermentation emission values for cattle were determined using the EPA's Cattle Enteric Fermentation Model (CEFM) for Oregon. This is a detailed model that specifies cattle age, purpose (beef/dairy), management practice (pasture grazing/feedlot), and animal size. For the other livestock present in Lake County, IPCC Tier 1 default emission factors were used to estimate methane emissions for 2019 (Table D - 3). All of these emission factors were produced by the EPA State Inventory Tool agriculture module and were multiplied by the population of each livestock category to find total methane emissions from enteric fermentation.[30]

Table D - 3. Lake County livestock population, enteric fermentation emission factor, and total methane emissions by animal category, 2019

Animal	2019 Estimated Population (head)	Enteric Fermentation EF (kg CH4/head)	Emissions (MTCO2e)
Beef Cows	47,500	100.5	119,343.75
Cattle Replacements	11,712	66.5	19,471.20
Heifer Stockers	7,696	64.8	12,467.52
Steer Stockers	10,708	62.3	16,677.71
Bulls	2,667	103.9	6,927.53
Sheep and Lamb	623	8	124.60
Goats	705	5	88.13
Horses and Ponies	1,351	18	607.95
		Total:	175,708.39

D.1.2 Manure Management

The EPA State Inventory Tool agriculture module was used to estimate methane emissions from livestock manure management.[30] First, the emissions from cattle (excluding calves) manure management were determined. Less than half a percent of Lake County cattle was on any sort of feed in 2017 according to the USDA Census of Agriculture, so it is assumed that there are not a significant amount of cattle in feedlots in the county and the feedlot categories were left as zero. The population of cattle in each category was first multiplied by the amount of volatile solids (VS) produced per head per year as estimated by the EPA CEFM for Oregon. VS are the organic fraction of all manure solids that oxidize and can produce methane.[8] The VS factor was multiplied by the population to get total VS production per year. The module's default factor for maximum potential methane emissions (m^3 CH_4/kg VS) for cattle in Oregon was used to find the maximum emissions. Lastly, the methane conversion factor (MCF) which indicates the proportion of maximum emissions are realized based on manure management practice was determined. The default factor provided by the module was 1.1% for pastures and rangeland manure deposition in Oregon, but this needs to be updated based on the 2019 refinement of IPCC emissions reporting guidelines. The new MCF value for pasture and rangeland manure management is 0.47% for all climate types. The summary of these emission factors and calculations for cattle manure management emissions is shown in Table D - 4.

The methodology for calculating manure emissions from calves and all other livestock is similar, but uses a VS factor that is dependent on animal weight. Typical animal mass (TAM) for each livestock category in Oregon was provided by the module, as well as the VS factor and maximum potential emissions factor. It was assumed that most sheep in Lake County were not on feed, and thus were placed in the "sheep not on feed" category. The default weighted MCF values for chickens and turkeys were used, but the remaining animals that were primarily on pasture or rangeland had an MCF value of 0.47% (the same as cattle). See Table D - 5 for further detail.

Table D - 4. Calculation of methane emissions from cattle manure management, 2019

Animal	Population (head)	VS (kg VS/head/year)	Max Potential Emissions (M3 CH4/kg VS)	Weighted MCF	Emissions (MTCH4)	Emissions (MTCO2e)
Bulls	2,677	1,955.7	0.17	0.0047	2.83	70.69
Beef Cows	47,500	1,891.4	0.17	0.0047	48.53	1,213.14
Beef Replacements	11,712	1,233.6	0.17	0.0047	7.80	195.09
Steer Stockers	10,708	1,120.3	0.17	0.0047	6.48	161.99
Heifer Stockers	7,696	1,233.6	0.17	0.0047	5.13	128.20
					Total:	1,769.11

Table D - 5. Calculation of methane emissions from manure management for all other livestock, 2019

Animal	Population (head)	TAM (kg)	VS (kg VS/1000 kg animal mass/day)	Max Potential Emissions (M3 CH4/kg VS)	Weighted MCF	Emissions (MTCH4)	Emissions (MTCO2e)
Calves	10,708	123	7.7	0.17	0.0047	1.999	49.98
Chickens, Pullets	79	1.8	10.2	0.39	0.171	0.024	0.60
Chickens, Layers	711	1.8	11	0.39	0.171	0.232	5.79
Chickens, Broilers	83	0.9	17	0.36	0.015	0.002	0.04
Turkeys	32	6.8	8.5	0.36	0.015	0.002	0.06
Sheep Not on Feed	623	80	8.3	0.19	0.0047	0.091	2.28
Goats	705	64	9.5	0.17	0.0047	0.085	2.11
Horses	1,351	450	6.1	0.33	0.0047	1.419	35.48
						Total:	96.35

Nitrogen emissions from the addition of manure to rangeland or agricultural soils were also determined using the EPA State Inventory Tool for agriculture and updated IPCC guidelines. The amount of nitrogen excreted by each livestock category was estimated using the population in that category and a nitrogen production rate. Direct emissions were estimated by multiplying the amount of nitrogen from each grazed livestock category by the N_2O emission factor of 0.002 kg N_2O N/kg N from the 2019 updated IPCC guidelines Table 11.1.[96] 0.002 was used for cattle and poultry, 0.003 kg N_2O N/kg N was used for sheep and other animals.

To determine indirect emissions the total amount of nitrogen in the manure was multiplied by the fraction of that nitrogen that will be volatilized into NH_3-N + NOx-N. The IPCC 2019 revision has this fraction at a default value of 0.21 (IPCC Table 11.3). The nitrogen that was volatilized was then multiplied by an emission factor that indicates how much of the volatilized gas was converted to N_2O, from the IPCC 2019 revision the value is 0.005 for dry climates (IPCC Table 11.3). The fraction of nitrogen in manure that is leached in dry climates is assumed to be zero. All of these nitrogen emission amounts were multiplied by the ratio of the molar mass of N_2O to the ratio of N and the GWP of N_2O to determine total nitrous oxide emissions from manure management in $MTCO_2e$ (Table D - 6).

Table D - 6. Nitrous oxide emissions from manure management for each livestock category in Lake County, 2019

Animal	Total K-Nitrogen Excreted (kg)	Pasture, Range, and Paddock Direct Emissions (MT N2O)	Indirect Volatilization Emissions (MT N)	Total N2O Emissions (MTCO2e)
Bulls	183,460	0.37	0.19	262.03
Calves	215,508	0.43	0.23	307.80
Beef Cows	2,809,102	5.62	2.95	4,012.16
Steer Stockers	391,924	0.78	0.41	559.77
Beef Heifers	767,982	1.54	0.81	1,096.89
Pullets	41	0.00	0.00	0.06
Chickens	514	0.00	0.00	0.73
Broilers	26	0.00	0.00	0.04
Turkeys	50	0.00	0.00	0.07
Sheep	8,186	0.02	0.01	15.53
Goats	7,411	0.02	0.01	14.06
Horses	54,366	0.16	0.06	103.11
Total	4,438,570	9	5	6,372

D.1.3 Cropland

The cultivated area for each type of crop was determined using the methodology presented in Section B.4. The estimates for annual emissions/sequestration for alfalfa and non-alfalfa hay were found using the DeNitrification-DeComposition (DNDC) model created by the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire.[97] Daily weather data (temperature maximums and minimums and precipitation) from 2015 to 2019 was used in the model run from the NOAA Climate Data Online (CDO) site for the Poplars weather station in northwest Lake County.[98] This weather station had the most complete daily data for the region where most hay and alfalfa in the county are grown. Details on the DNDC model inputs are provided in Table D - 7.

Information on alfalfa practices was directly provided by hay growers in the county. A total of 18 irrigation events at 2.5cm of water each (for a total of 45cm of water for the growing season) were simulated from March 1st through October 15th. The irrigation was assumed to be center pivot, as that is what most hay growers use in the county. Soil parameters were determined for loamy sand in the Fort Rock/Christmas Valley area based on the NRCS Web Soil Survey.[99] The model was run for five years, the usual length of time that an alfalfa crop can be harvested before replanting is required in the county, and emissions were averaged over those years to estimate 2019 emissions. The average annual emissions for each crop system were multiplied by the number of acres in production in 2019 to determine total annual emissions in Lake County.

Table D - 7. DNDC model inputs and final results for alfalfa and non-alfalfa hay crop systems

DNDC Model Parameters	Alfalfa	Non-Alfalfa Hay
Latitutude	43.2644	43.2644
Simulated Years	5	5
Weather Data	Poplars 2015-2019	Poplars 2015-2019
Atm NH3 concentration	0.06	0.06
Atm CO2 concentration (ppm)	410	410
Soil Land-use	Dry grassland/pasture	Dry grassland/pasture
Texture	loamy sand	loamy sand
Clay fraction	0.06	0.06
Soil pH	8	8
SOC at surface soil (kg C/kg soil)	0.05	0.05
Initial N concentration at surface soil (mg N/kg) nitrate	0.5	0.5
Initial N concentration at surface soil (mg N/kg) nitrate	0.05	0.05
Microbial activity index	0.5	0.5
Slope	2	2
Soil salinity index	0	0
Years of cropping system	5	5
Years of a cycle within this cropping system	5	5
Crop	Legume Hay	Perennial Grass
Year 1 plant	20-Feb	20-Feb
Harvest Date	31-Dec	31-Dec
Harvest Year	1	1
Fraction of leaves+steams left in field	1	1
Year 1 tillage	22-Feb	22-Feb
Tilling method	Ploughing w/ disk or chisel, 10cm	Ploughing w/ disk or chisel, 10cm
Fertilization All Years	None	None
Irrigation Index All Years	18 Irrigation Events	18 Irrigation Events
First Cut	9-Jun	9-Jun
Second Cut	9-Aug	9-Aug
Third Cut	15-Oct	15-Oct
Cut fraction	0.8	0.8
Avg annual emissions (kg CO2e/ha/yr)	235	-761.4

D.2 Land Use

The acreages of each ownership type were provided by the BLM GIS data specialist for the Lakeview District. The area of forest land in Lake County was provided by the Oregon Forest Ecosystem Carbon Inventory Report.[36] Cropland area was provided by the 2017 Census of Agriculture.[23] The area of wetlands across the county was found from the FWS National Wetlands Mapper; only palustrine emergent seasonally, semipermanently, intermittently, or permanently flooded wetlands were included in the analysis.[100] Lastly, the amount of wetlands on BLM, FWS, State of Oregon, and non-forest and non-cropland private land was subtracted from the total for each ownership class to determine the amount of rangeland and grassland in the county.

D.2.1 Forest Land

The total number of acres of forest land in Lake County was provided by the Oregon Forest Ecosystem Carbon Inventory: 2001-2016 produced by the Pacific Northwest Research Station of the USFS and ODF.[36] The acres of both the Fremont-Winema and Deschutes National Forests in Lake County were provided in the USFS 2019 Land Areas Report.[37]

The average carbon stocks of each major forest pool for Lake County alone were provided in Table 4.13b (Forest land carbon stock in Mmtons C by county, 2007-2016) in the Oregon Forest Ecosystem Carbon Inventory.[36] The annual carbon flux in each pool and the overall annual flux were provided in Table B9.2 (Average annual carbon (CO2e) flux in live trees from growth, harvest, mortality) in the inventory as well.[36] Although the values were averaged over years 2001-2016, it is assumed that the inventory and flux amounts are similar in 2019 as they were in previous years. A follow-up report will begin production in 2022 that includes all of the remeasured plots and is expected to increase the precision of the carbon estimates.

The production approach was used to determine the amount of carbon sequestered from harvested wood products created in the county. The 2019 log volume used at the Collins Lakeview mill was provided by the project manager for the Lake County area. The amount of carbon sequestered was determined by estimating the specific gravity and carbon content of wood across all species harvested by Collins in the area. The specific gravities of incense cedar, lodgepole pine, ponderosa pine, and white fir trees were determined from a report published by the USFS Forest Products Laboratory and averaged to produce a specific gravity estimate for all wood products.[101] All tree types were assumed to have a carbon fraction of 0.5, as is common practice for carbon estimation in biomass.[36] Conversion from carbon to carbon dioxide was achieved by multiplying by the atomic weight of carbon dioxide (44) divided by the atomic weight of carbon (12).

The emissions from the burning and decays of harvested wood products (HWPs) were taken into account based on the amount of timber harvest processed at the Collins Lakeview mill compared to the amount harvested across the state of Oregon. The amount processed in 2019 and 2018 was compared to the Oregon totals from the same years, provided by the Forest Industry Research Program at the University of Montana, and averaged.[102] Although this is not indicative of Lake County's historical amount of timber harvest processed, it was the only data available. With this methodology, it is estimated that the Lakeview mill processes 1.05% of Oregon timber harvest. The Oregon Harvested Wood Products Carbon Inventory completed for ODF and the USFS estimates that the Oregon HWP pool emitted 17.2 $MTCO_2e$/yr from 2001-2016.[38] It is assumed that this annual emission estimate applies to the year 2019 as well. Lake County's contribution to these annual emissions is assumed to be equivalent to the proportion of Oregon timber harvest processed in the county, which is 1.05% or 181 $MTCO_2e$/yr. The carbon sequestered in the wood products was added to the net annual flux of Lake County forests and the emissions from wood product decay were subtracted from that total to produce the final 2019 carbon sequestration from forestry of 70,864 $MTCO_2e$.

The acres of forest management practices performed in Lake County in 2019 by the USFS were provided directly from the Forest Service Activity Tracking System (FACTS) database, which tracks all activity performed by the organization across all national forests. The ODF 2019 activity information was provided directly from the Klamath and Lake District federal forest restoration coordinator. Data on LCUWC forest management actions was taken from the organization's 2019 annual report.[89] GIS maps of BLM juniper treatment and pile burning were provided by the Lakeview district BLM GIS Coordinator.

D.2.2Wetlands

The sequestration rate of wetlands was taken from a peer-reviewed article that examined the carbon accumulation in the soil of wetlands around Klamath Lake. Those wetlands are somewhat similar to those found in Lake County and experience similar weather patterns (warm summers, cold winters).

The study found a sequestration rate of 105 g C/m^2, or 1.55 $MTCO_2e$/acre.[48] The rate of methane emission from wetlands similar to the mineral wetlands of Lake County was taken from the Blue Carbon Calculator created by the Massachusetts Division of Ecological Restoration.[103] The calculator estimates that 0.177 MT C/ha are released in methane from inland freshwater mineral wetlands each year, an equivalent of 2.39 $MTCO_2e$/acre.

Combining the annual sequestration rate of carbon in the soil organic material with the emission rate of CH_4 from soil microbes results in a net emission of 0.84 $MTCO_2e$/acre. There are 31,405 acres of semi-permanently and intermittently flooded wetlands in Lake County according to the FWS wetland mapper.[100] There are large areas of seasonally flooded wetlands in the county as well, but they could not be included in this analysis due to a lack of information on GHG fluxes from these sorts of temporary wetlands. In total, Lake County wetlands release 26,054 $MTCO_2e$ each year.

Appendix E: Renewable Energy Calculations

E.1 Utility Solar

Monthly data for each of the six solar projects in Table E - 1 was retrieved from the US EIA electricity data browser.[51] The annual total generation for 2017-2019 was found by adding together all of the monthly totals for that year (when available). The annual generation of the Lakeview 363 and Lakeview 500 projects was provided directly from Obsidian Renewables.[104]

Table E - 1. Monthly electricity generation (MWh) in 2019 for six solar projects and the annual totals from 2017-2019

Month	Airport Solar	BC Solar	Black Cap Solar	Garrett Solar	OR Solar 6	Outback Solar
January	-	853	151	-	1,123	436
February	-	991	176	-	1,305	506
March	-	1,515	268	-	1,995	774
April	-	1,761	312	-	2,318	899
May	-	1,838	326	-	2,419	939
June	-	2,223	394	-	2,927	1,135
July	-	2,192	388	-	2,886	1,120
August	-	2,147	380	-	2,826	1,096
September	-	1,751	310	-	2,305	894
October	-	1,608	285	-	2,117	821
November	-	1,027	182	-	1,353	525
December	1,094	662	117	227	872	338
2019	1,094	18,568	3,289	227	24,446	9,483
2018	-	18,530	4,113	-	23,954	10,013
2017	-	17,907	3,966	-	-	9,903

The amount of GHG emissions prevented by the solar projects was found by multiplying the emissions factor for the corresponding utility, as shown in Table 12, with the 2019 electricity generation.

E.2 Residential and Commercial Solar

The number of residential and commercial solar projects in the county and their electricity generation was found from the Oregon Solar Dashboard from the Oregon DOE.[54] The dashboard consists of a map that shows every residential, commercial, and utility solar project in the state. A spreadsheet was made of every project shown in Lake County on the dashboard, and based on the location on the map it could be determined what utility service area the project was in. The majority of the residential and commercial projects on the map were included because they were part of the RETC or BETC programs.

The dashboard provided annual generation for each project, which was added up for each utility and multiplied by the emission factor of that utility to determine the emissions reduction value for all of the projects.

E.3 Community Solar

The program PVWatts from the National Renewable Energy Laboratory (NREL) was used to estimate the annual electricity output from the larger community solar arrays.[105] First the location of the solar site was specified as “Lakeview, OR”, the PVWatts program provided the corresponding latitude and longitude. For the Lakeview 4H farm project, 10 kW was entered as the system size, the module type was kept as standard, and the array is fixed (open rack). The system losses, tilt, and azimuth were all left as default values. The same parameters were kept for the Lake County FIT project calculation, except for the DC system size which was changed to 18.18 kW. The program provided the estimated annual generation from the given information, and the prevention of GHG emissions for each project was found by multiplying the output by the PacifiCorp emission factor (because the projects were both in Lakeview). The results are provided in Table E - 2.

Table E - 2. PVWatts results for the Lake County community solar projects and corresponding emissions prevention ($MTCO_2e$)

Solar Project	Rated Capacity (kW)	PVWatts Estimated Annual Generation (kWH)	GHG Prevention (MTCO2e)
Lakeview 4H	10	14,907	10.29
Lake County Solar FIT	18.18	27,098	18.70
		Total	28.98

E.4 Geothermal

The average monthly generation and total project generation for the Paisley geothermal plant were determined from the reported monthly net generation on the EIA website.[58] The estimated emission factor when the plant was in operation combined data from two EIA state data tables: “U.S. Electric Power Industry Estimated Emissions by State” and “Net Generation by State by Type of Producer by Energy Source”.[59] The first provided emissions (in $MTCO_2e$) by year, state, producer type, and energy source, while the second provided generation (in MWh) for the same criteria. By narrowing down the tables to geothermal energy production in the years 2015-2017 in Oregon by electric utilities, the only generation – and therefore emissions – were from the Paisley geothermal project. The annual emissions were divided by the annual generation to determine emission factors for each year (Table E - 3).

Table E - 3. Paisley Geothermal Plant emission factors, 2015-2017

Year	State	Producer Type	CO2 (Metric Tons)	Net Generation (MWh)	Emission Factor (MTCO2e/MWh)
2015	OR	Electric Utility	45	1,710	0.0263
2016	OR	Electric Utility	109	4,129	0.0264
2017	OR	Electric Utility	41	1,567	0.0262

The greenhouse gas reduction calculation for the Lakeview School District and Hospital Heating Project first required finding the quantity of fuel used before the geothermal heating system was installed. This data, shown in Table E - 4, was found from the geothermal heating study completed by Anderson Engineering and Surveying which analyzed the annual heating needs of all of the school buildings and the hospital.[60]

Table E - 4. Lakeview School District and Hospital Geothermal Heating project fuel use before the geothermal retrofit

Location	Propane Fuel Use (gallons)	#2 Fuel Oil Fuel Use (gallons)
Lakeview High School	-	13,422
Ag and Wood Shop	5,456	-
Fremont Elementary School	-	4,462
Daly Middle School	-	16,050
Hay Elementary	-	9,216
Hospital	-	45,000
Total	5,456	88,150

Once the amount of fuel used every year was determined, it was multiplied by the emission factor for the fuel for each major greenhouse gas. The emissions factors for the two fuels for carbon dioxide, methane, and nitrous oxide were taken from the EPA and are listed in Table E - 5.[77] The gallons of propane and #2 fuel oil were multiplied by their respective emission factors to find the total for each greenhouse gas. Then grams of CH_4 and grams of N_2O were converted to kg and multiplied by their 100-year global warming potential (GWP) as provided by the EPA.[77] Finally, the emissions for each gas were added and divided by 1,000 to get the total amount of emission reduction in $MTCO_2e$ listed in Table E - 6.

Table E - 5. Fuel emission factors for the three main greenhouse gases

Fuel	kg CO2/gal	g CH4/gal	g N2O/gal
Propane	5.72	0.27	0.05
#2 Fuel Oil	10.21	0.41	0.08

Table E - 6. Emissions reduction from replacing boilers requiring fuel with geothermal heating, $MTCO_2e$

Fuel	Gallons	kg CO2	g CH4	g N2O	MTCO2e
Propane	5,456	31,208	1,473	273	31.33
#2 Fuel Oil	88,150	900,012	36,142	7,052	903.02
				Total:	934.34

The emissions reduction from the Warner Creek geothermal project was calculated in the same way as detailed above for propane fuel.

E.5 Current and Future Developments

Annual generation estimates for the Airport and Garrett solar projects were provided from Obsidian Renewables directly.[104] Estimates for both of the Fort Rock projects were provided from Newsun Energy.[106] The prediction for the amount of GHG emissions that would be prevented by each project was calculated as detailed in the "Utility Solar" section of the appendix.

The annual generation predictions for the existing solar projects for 2020 and 2021 were the averages of the generation from 2017-2019. The annual GHG emissions prevention for each project for 2020 and 2021 were also calculated using that average.

Appendix F: Data Discussion, Quality, and Improvements

F.1 Stationary Energy

The largest improvement needed to correct electricity emissions assumptions is the breakdown of Midstate electricity per sector for Lake County alone, similar to what PacifiCorp provided. This would eliminate the estimation of electricity consumption by sector, and what is likely an overestimation of residential, commercial, and industrial energy consumption and an underestimation of irrigation electricity use.

Heating oil and propane sales data from the local fuel provider would greatly help to correct the estimation of residential and commercial heating energy usage. The use of national residential fuel consumption factors is not specific to Lake County and may not reflect the patterns of the county residents. Alternatively, a survey could be created to better understand the heating needs of Lake County homes. Even without fuel sales data, commercial heating energy usage could be better estimated with updated surveying of the businesses in Lakeview and the rest of the county.

F.2 Transportation

All state and national inventories use fuel sales data to estimate emissions from transportation. The same goes for cities that have a special fuel tax that they keep track of. None of this applies to Lake County, as ODOT does not track the amount of fuel sold or distributed on a county-by-county basis and the county does not have a fuel tax that would require it to track that information either. The local fuel provider that owns all of the gas stations was not able to disclose gallons sold for 2019.

The MOVES3 and VisionEval models are very detailed and take into account local variables such as weather and vehicle fuel efficiencies. However, even the best model does not provide as much data as fuels sales records would. None of the models for vehicle traveling, starts and stops, speed and age distributions, etc. will matter for GHG inventories if the actual amount of fuel used is given. The fuel sales emission calculation method is straightforward and allows for simple aggregation of emissions across several counties. This is especially true for a rural county where transportation trends may vary from national or regional surveys.

Transportation emissions are one of the most important parts of local emissions inventories as it is often most feasible for local governments to implement changes in this sector. The tracking of fuel sales on a more granular level (not just county but city sales) would allow for more accurate baseline estimations as well as tracking of local legislation impacts.

F.3 Agriculture

Livestock emissions could vastly be improved by a complete survey of the ranching industry in Lake County. This survey could include cattle weights, monthly population, nutrient intake, and more to produce a more accurate emissions estimation for both enteric fermentation and manure management.

Cropland emissions were based on the DNCD model run with just a single soil type that is the most common in the northern part of Lake County where hay and alfalfa are grown. The estimation of emissions and sequestration from cropland could be greatly improved by running a longer simulation to indicate the true length of time that alfalfa has been cultivated in the county. In addition, more accurate irrigation application dates for each year could be used to refine the model outputs. Fertilization wasn't accounted for because of the large variation in application rates and times, but more complete data on fertilization would improve the model output as well.

F.4 Other Land Use

The forestry section of the report could be improved by a more recent forest ecosystem carbon inventory. The Oregon report used in this analysis was for the years 2001-2016, but the USFS and ODF plan on releasing another report for 2001-2020. This would give a more accurate idea of the effect of recent management practices (since 2016) on the annual carbon flux in Lake County forests.

Wetland emissions estimates could be improved with data from studies in Lake County on emissions fluxes in the different kinds of wetlands for each different soil and climate type. Using one emission factor for all wetlands areas is not highly accurate considering the differences in wetland composition across the county.

F.5 Report Data Summary

As required by the GPC, a summary of the data for each emissions sector is included in Table F - 3. Notation keys indicate data limitations and exclusions and are explained in Table F - 1. There is also a data quality analysis for each sub-sector's activity data and emission factor based on how specific each item is to the report boundary area. A description of quality categories high, medium, and low are shown in Table F - 2.

Table F - 1. Notation keys as provided by the GPC[9]

Notation key	Definition	Explanation
IE	Included Elsewhere	GHG emissions for this activity are estimated and presented in another category of the inventory. That category shall be noted in the explanation.
NE	Not Estimated	Emissions occur but have not been estimated or reported; justification for exclusion shall be noted in the explanation.
NO	Not Occurring	An activity or process does not occur or exist within the city.
C	Confidential	GHG emissions which could lead to the disclosure of confidential information and can therefore not be reported.

Table F - 2. Data quality categories provided by the GPC[9]

Data quality	Activity data	Emission factor
High (H)	Detailed activity data	Specific emission factors
Medium (M)	Modeled activity data using robust assumptions	More general emission factors
Low (L)	Highly-modeled or uncertain activity data	Default emission factors

Table F - 3. Summary of data collected for each sector and subsector in Lake County, 2019

GHG Emissions Source	Scope	Notation Keys	Report Section	Data Quality		Explanatory Comments
				AD	EF	
Stationary Energy						
Residential Buildings						
Emissions from fuel combustion within the city boundary	1		Residential Buildings	M	M	
Emissions from grid-supplied energy consumed within the city boundary	2		Electricity	H	H	
Commerical and institutional buildings and facilities						
Emissions from fuel combustion within the city boundary	1		Commercial and Institutional Buildings	M	M	
Emissions from grid-supplied energy consumed within the city boundary	2		Electricity	H	H	
Manufacturing industries and construction						
Emissions from fuel combustion within the city boundary	1		Industrial Stationary Energy	H	H	
Emissions from grid-supplied energy consumed within the city boundary	2		Electricity	H	H	
Energy industries						
Emissions from energy used in power plant auxiliary operations within the city boundary	1	NO				There are no fossil fuel electricity generating units in the county
Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	2		Electricity	H	H	
Agriculture, forestry, and fishing activities						
Emissions from fuel combustion within the city boundary	1	NO				Stationary fuel combustion for these activities is negligible, all off-road transportation fuel usage is included in the transportation section. Almost all irrigation in the county uses electricity, not diesel
Emissions from grid-supplied energy consumed within the city boundary	2		Electricity/Irrigation	H	H	
Non-specified sources						
Emissions from fuel combustion within the city boundary	1	NO				Remaining stationary energy combustion is negligible, generators and other equipment are included in off-road transportation
Emissions from grid-supplied energy consumed within the city boundary	2	NO				All electricity consumption in Lake County falls into the categories above
Fugitive emissions from mining, processing, storage, and transportation of coal						
Emissions from fugitive emissions within the city boundary	1	NO				There are no emissions from these activities in the county, the only mine is a perlite mine which has no associated fugitive emissions
Fugitive emissions from oil and natural gas systems						
Emissions from fugitive emissions within the city boundary	1	NO				There are no oil or natural gas pipelines in the county
Transportation						
On-road transportation						
Emissions from fuel combustion on-road transportation occuring within the city boundary	1		On-Road Transportation	M	M	
Railways						
Emissions from fuel combustion for railway transportation occurring within the city boundary	1		Railways	H	M	
Waterborne navigation						
Emissions from fuel combustion for waterborne navigation occurring within the city boundary	1	IE	Off-Road Transportation	M	M	
Aviation						
Emissions from fuel combustion for aviation occurring within the city boundary	1		Aviation	H	M	
Emissions from portion of transboundary journeys occurring outside the city boundary	3		Aviation	H	M	
Off-road transportation						
Emissions from fuel combustion for off-road transportation occurring within the city boundary	1		Off-Road Transportation	M	M	

Waste						
Solid waste disposal						
Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	1		Landfill	H	M	
Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps outside the city boundary	3	NO				Almost all of the residents of Lake County are serviced by the Lake County garbage disposal service
Biological treatment of waste						
Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	1	NO				All municipal solid waste is disposed in the landfill
Emissions from solid waste generated within the city boundary that is treated biologically oustide the city boundary	3	NO				Almost all of the residents of Lake County are serviced by the Lake County garbage disposal service
Incineration and open burning						
Emissions from solid waste generated and treated within the city boundary	1	NO				All municipal solid waste is disposed in the landfill
Emissions from solid waste generated within the city boundary but treated outside of the city boundary	3	NO				Almost all of the residents of Lake County are serviced by the Lake County garbage disposal service
Wastewater treatment and discharge						
Emissions from wastewater generated and treated within the city boundary	1		Wastewater	M	M	
Emissions from wastewater generated within the city boundary but treated outside of the city boundary	3	NO				All wastewater is treated in residential septic tanks or the Lakeview wastewater treatment facility
Industrial Processes and Product Uses (IPPU)						
Emissions from industrial processes occurring within the city boundary	1	NO				There are no large manufacturing plants in the county besides those discussed in the stationary energy section
Emissions from product use occurring within the city boundary	1	NE				Product use emissions are assumed to be negligible due to the small population of the county
Agriculture, Forestry, and Other Land Use (AFOLU)						
Emissions from livestock within the city boundary	1		Livestock	H	M	
Emissions from land within the city boundary	1		Cropland, Other Land Use	H	M	
Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	1		Cropland, Other Land Use	H	M	