CITY OF BAINBRIDGE ISLAND GREENHOUSE GAS EMISSIONS INVENTORY

FINAL FINDINGS REPORT

2019

CASCADIA CONSULTING GROUP, INC.

Cascadia Consulting Group, Inc.
Tel (206) 343-9759
Fax (206) 343-9819
www.cascadiaconsulting.com

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Acronyms

ACS	American Community Survey (from the U.S. Census Bureau)
BOD	Biochemical oxygen demand (a metric of the effectiveness of wastewater treatment plants)
EIA	United States Energy Information Association
EPA	United States Environmental Protection Agency
CO_2e	Carbon dioxide equivalent
GHG	Greenhouse gas (limited to CO_2, CH_4, N_2O, and fugitive gases in this inventory)
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
$MTCO_2e$	Metric tons of carbon dioxide equivalent
MOVES	Motor Vehicle Emission Simulator model (developed by EPA to quantify emissions from mobile sources)
MPG	Miles per gallon
NONROAD	Part of MOVES model developed by EPA to quantify non-road mobile emissions
O&M	Operations and Maintenance
ODS	Ozone depleting substance
PFC	Perfluorocarbon
PSCAA	Puget Sound Clean Air Agency
PSE	Puget Sound Energy
PSRC	Puget Sound Regional Council
SF_6	Sulfur hexafluoride
TCR	The Climate Registry
USDA	United States Department of Agriculture
WARM	Waste Reduction Model (model developed by EPA to quantify solid waste emissions)
WSDOT	Washington State Department of Transportation
WWTP	Wastewater Treatment Plant
VMT	Vehicle Miles Traveled

Executive Summary

Global climate change poses a growing threat and humanitarian climate emergency, and Bainbridge Island shares the responsibility to reduce greenhouse gas emissions (GHG) to stabilize the global climate while preparing for the effects of climate change. The City of Bainbridge Island recently completed a comprehensive greenhouse gas inventory as part of its commitment to reducing emissions and leading on climate action. Greenhouse gas emission inventories quantify the amount of climate pollution produced by an entity—in this case, from the Bainbridge Island community and municipal government operations. As the Bainbridge Island government and community continues to take action to reduce GHG emissions, these inventories will serve as tools for tracking progress and making improvements along the way.

Inventory Approaches

This report describes findings from three distinct inventories:

- A **community inventory** that estimates GHG emissions produced by activities of the Bainbridge Island community, including residents and businesses. The community GHG inventory includes emissions due to energy used to power and heat homes and businesses; fuel used by vehicles running within Bainbridge Island; solid waste that is generated by the community; agriculture activities; fuel use by off-road equipment and vehicles; and others.
- A **municipal inventory** that accounts for the GHG emissions resulting from City of Bainbridge Island government operations. This inventory can help the City understand GHG emissions stemming from various activities associated with municipal operations, including from municipal building and facility operation, transportation, solid waste, wastewater, and refrigerant leakage.
- A **consumption-based inventory** that estimates GHG emissions associated with the *consumption* of food, goods, and services within the community, regardless of their origin. For example, this inventory would not include emissions from the production of locally-manufactured goods that are consumed entirely outside the community; however, it would include emissions associated with the production of goods manufactured in another community but consumed by Bainbridge Island residents, visitors, or businesses. This inventory can be examined in context with the community inventory to paint a more comprehensive picture of community emissions.

This report also presents findings from additional analyses:

- Municipal and communitywide **contribution analyses** that identify key drivers of observed emission trends. For example, analysis calculates the impact that a hotter summer or colder winter may have had on household energy use, and thus, emissions.
- A supplemental **carbon sequestration analysis** that estimates the amount of carbon dioxide that Bainbridge Island trees absorb—or sequester—from the atmosphere on an annual basis (in Appendix).

Inventory Methodology

The GHG inventories summarized in this report account for human-caused emissions of the most prominent and typical greenhouse gases for communities: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). To account for the differences in potency among these gases, all emissions are calculated and reported in units of metric tons of carbon dioxide equivalent ($MTCO_2e$). The inventories were conducted using widely accepted tools and protocols, including the *Local Government Operations Protocol* and *U.S. Community Protocol for Accounting and Reporting of Greenhous Gas Emissions*.

GHG emissions are inventoried by multiplying annual activity data (e.g. electricity consumption) by emission factors (greenhouse gas emissions produced per kWh of electricity). For the municipal operations inventory, we obtained most data from City staff and local documentation such as Puget Sound Energy's (PSE) billing records, records from local wastewater treatment facilities, and fleet vehicle fuel use records. For the communitywide inventory, key data sources included electricity consumption data from PSE, Puget Sound Regional Council (PSRC) modeling outputs for vehicle miles traveled by fuel type, Bainbridge Disposal tonnage records, and Kitsap County Conservation District estimates of agricultural landowners and acreage. Where local data were not available, we referenced and downscaled national data sources such as from the Federal Transit Administration, U.S. Census Bureau, and the U.S. Department of Agriculture.

Inventory Boundaries

The activities and sectors included in GHG inventories are often classified into three "scopes," which represent relative levels of control over an emissions source:

- **Scope 1** emission sources include those directly caused by an organization's actions, such as from owned equipment and facilities.[1]
- **Scope 2** emissions are those indirectly associated with purchased electricity, steam, heating, or cooling.
- **Scope 3** includes all other indirect emissions that are not covered in Scope 2.

The communitywide and municipal inventories for Bainbridge Island included emissions sources from all three scopes: Scope 1, Scope 2, and Scope 3. The inventories included all sources required by the consulted protocols and additional sources, as relevant.

Inventory Years

The inventories summarized in this report cover two representative years, **2014** and **2018**. To provide Bainbridge Island with the most comprehensive, consistent, and relevant information on their GHG emissions, we selected the most recent year available as an inventory year – 2018. For a comparison year, we selected 2014 because no major changes in organizational structure or infrastructure occurred after that year. Additionally, choosing a more recent comparison year increases the likelihood that all needed data are available and derived using consistent methodologies.

[1] Except direct carbon dioxide emissions from biogenic sources.

INVENTORY RESULTS

Community Emissions

The Bainbridge Island community emitted an estimated 233,998 metric tons of carbon dioxide equivalent ($MTCO_2e$) in 2018, or 9.4 $MTCO_2e$ per Bainbridge Island resident. A high-level comparison suggests that this per-capita estimate is consistent with that of Kitsap County (9.9 $MTCO_2e$ per person), and lower than per-capita estimates for the U.S., Washington State, King County, and Bellevue. However, Bainbridge Island's estimated per-capita emissions are almost twice those of Seattle and Tacoma (Figure 6). The majority of Bainbridge Island community emissions stem from consumption of electricity in homes and commercial buildings (Figure 4).

Figure 1. Bainbridge Island communitywide emissions in 2018 (total = 233,998 $MTCO_2e$).

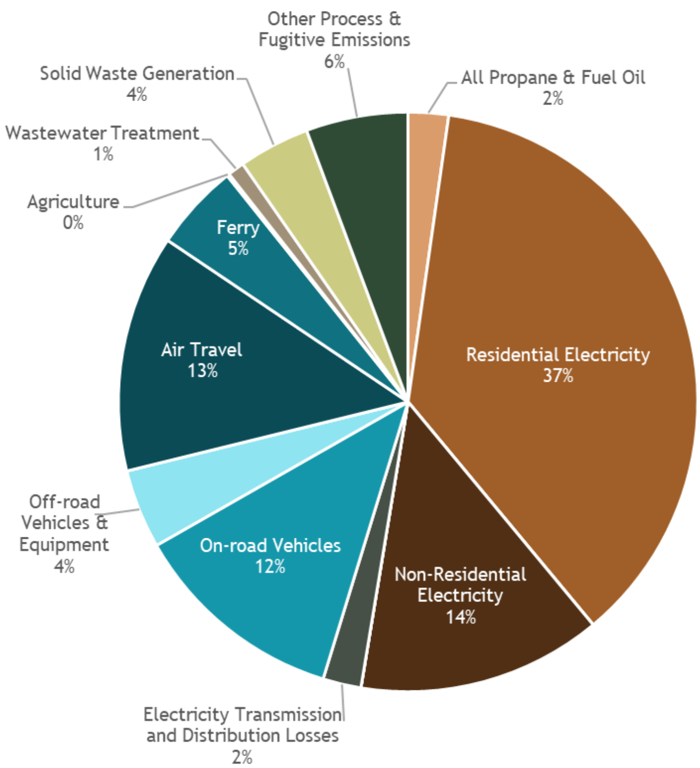
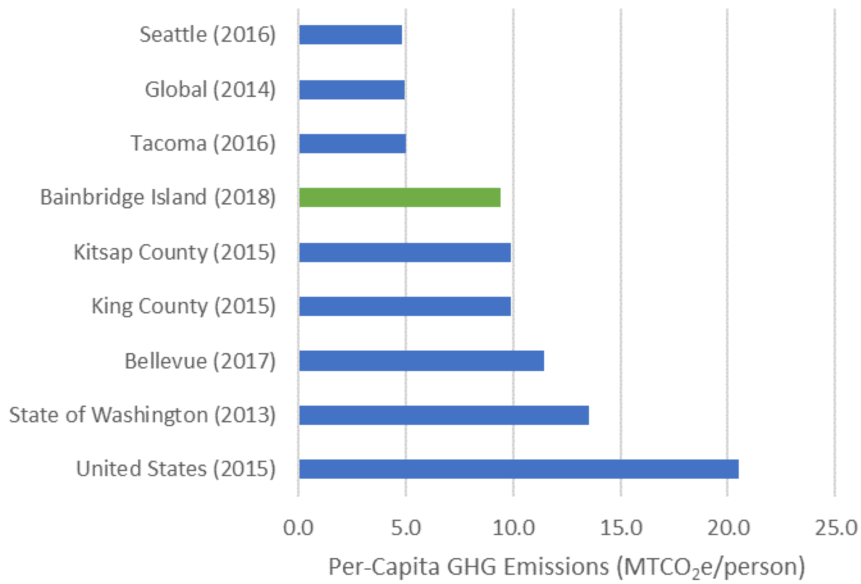
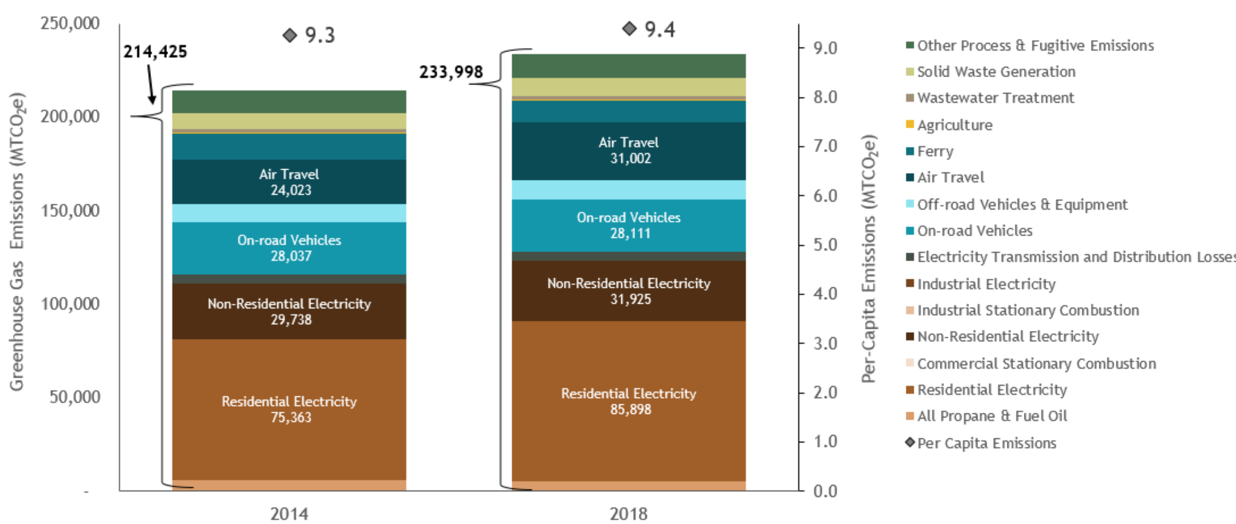


Figure 2. Per-capita GHG emissions comparison.[2]



Overall, communitywide emissions have increased by 9% since 2014 (Figure 5). Per-capita emissions, however, only increased 1% over that period, suggesting that population growth contributed to the observed trends. Changes in electricity fuel source (e.g., renewables versus coal) and growth in employment also pushed emissions upward, while improvements in vehicle fuel economy, reductions in the distance each person drives, and declining per-household and per-business energy consumption on Bainbridge Island softened the extent of those increases.

Figure 3. Bainbridge Island community emissions trends, by year and source.



[2] Other jurisdictions may use different data sets, methods, and years for their GHG emission inventories.

City Government Emissions

Emissions from City of Bainbridge Island activities—which make up about 1% of the total community emissions—increased 11% from 2014 to 2018, totaling 2,291 $MTCO_2e$ in 2018 (Figure 7 and Figure 8). Major emissions sources included facility electricity consumption (60%) and on-road fleet vehicles (17%).

Emissions from municipal facility electricity and on-road fleet vehicles increased 14% and 7%, respectively. Just four facilities accounted for 80% of all facility electricity use in 2018: Bainbridge Island Waste Water Treatment Plant (WWTP), City Hall, Fletcher Bay: Well Field, and Bainbridge Island Public Works Operations and Maintenance Yard. Among the largest emissions decreases were from streetlights and traffic signals improvements.

Figure 4. City operations GHG emissions in 2018 (total = 2,291 $MTCO_2e$).

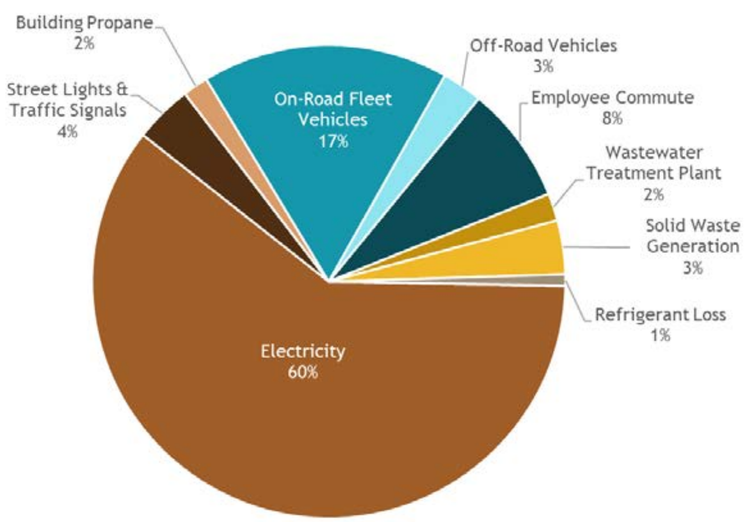
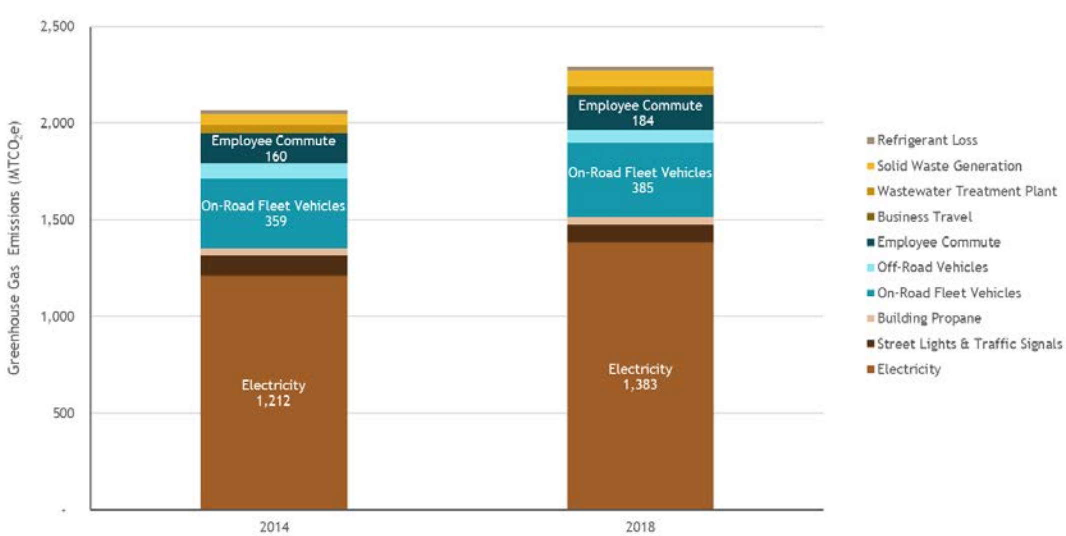


Figure 5. Bainbridge Island city operations emissions trends, by year and source.

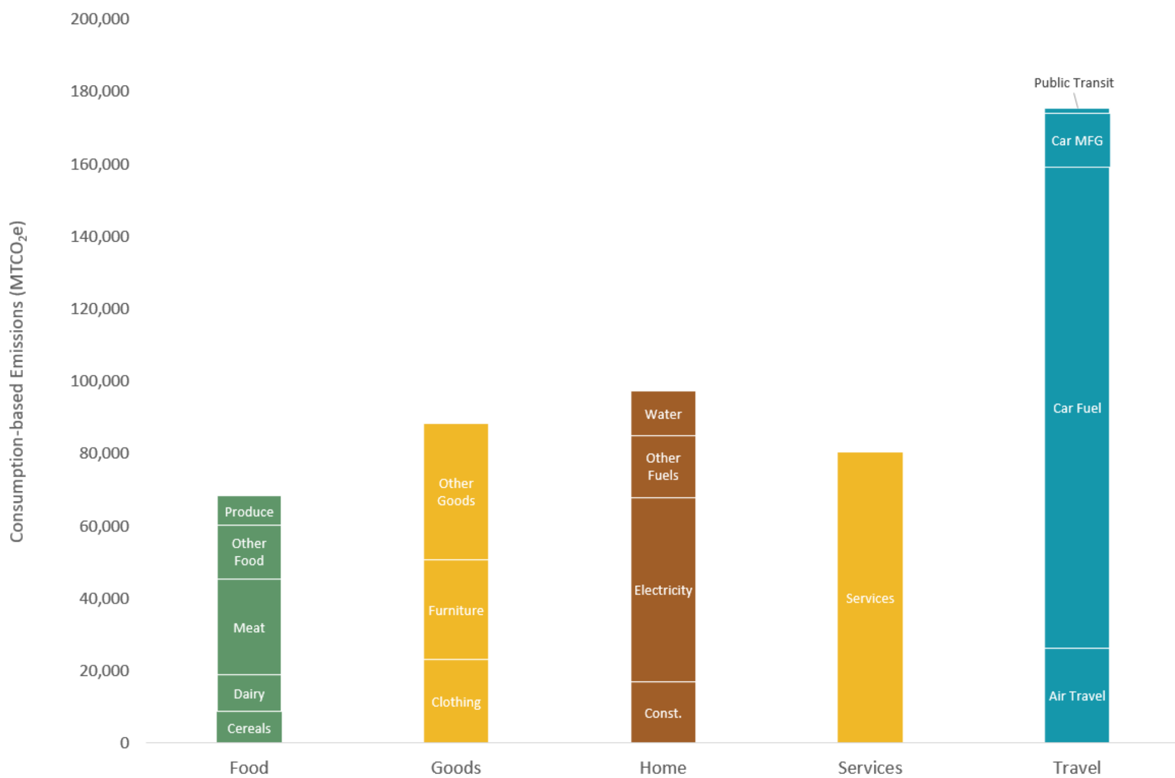


Consumption-based Emissions

The purchasing decisions we make impact the environment. Some types of foods and materials, such as meat and furniture, can carry a significant GHG emissions burden. For example, meat and dairy cows emit methane—a potent greenhouse gas. Residents in Bainbridge Island who consume beef contribute to the emissions from these cows—even if the cows are raised outside the island.

Results from a household-based economic modeling tool suggest that the average Bainbridge Island household emits 52 $MTCO_2e$ a year through their purchasing behaviors.[3] There were an estimated 9,404 and 9,798 households on Bainbridge Island in 2014 and 2018, respectively, indicating that total consumption-based emissions from all households on Bainbridge Island could have reached approximately 510,000 $MTCO_2e$ in 2018. Major drivers include the purchase of meat, furniture, clothing, home energy, and travel-related expenses such as car fuel and air travel.

Figure 6. Consumption-based emissions per Bainbridge Island household.



[3] As indicated from U.C. Berkeley's *CoolClimate* Calculator. Outcomes from the consumption-based inventory analysis are presented at the per-household level because purchasing behavior is typically examined and analyzed at the household—not individual—level.

Next Steps

In analyzing the GHG emissions of Bainbridge Island, this report identifies key activities and sectors at both citywide and municipal operations scales that contribute the largest relative amounts of GHG emissions. Drawing from the results in this report, activities and operations can then be targeted for improvement and mitigation. Improving the inventory process, conducting regular inventories, and incorporating these inventory results into decision-making processes will be critical for evaluating progress toward emissions reductions targets and for identifying cost-saving opportunities in the future.

Introduction

This GHG inventory report for the City of Bainbridge Island details estimated GHG emissions from activities within the city of Bainbridge Island. GHG inventories quantify emissions associated with a specific "scope"—or boundary condition—over a specific period. By conducting GHG inventories at regular intervals, they can illuminate trends, accomplishments, and opportunities for improvement. They also hold governments and communities responsible for their impact on the environment and keep organizations on track towards reaching climate action goals.

This report describes findings from three distinct inventories (Figure 10):

- A **community inventory** that estimates GHG emissions produced by activities of the Bainbridge Island community, including residents and businesses. The community GHG inventory includes emissions due to energy used to power and heat homes and businesses; fuel used by vehicles running within Bainbridge Island; solid waste that is generated by the community; agriculture activities; fuel use by off-road equipment and vehicles; and others.
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This report also presents findings from additional analyses:

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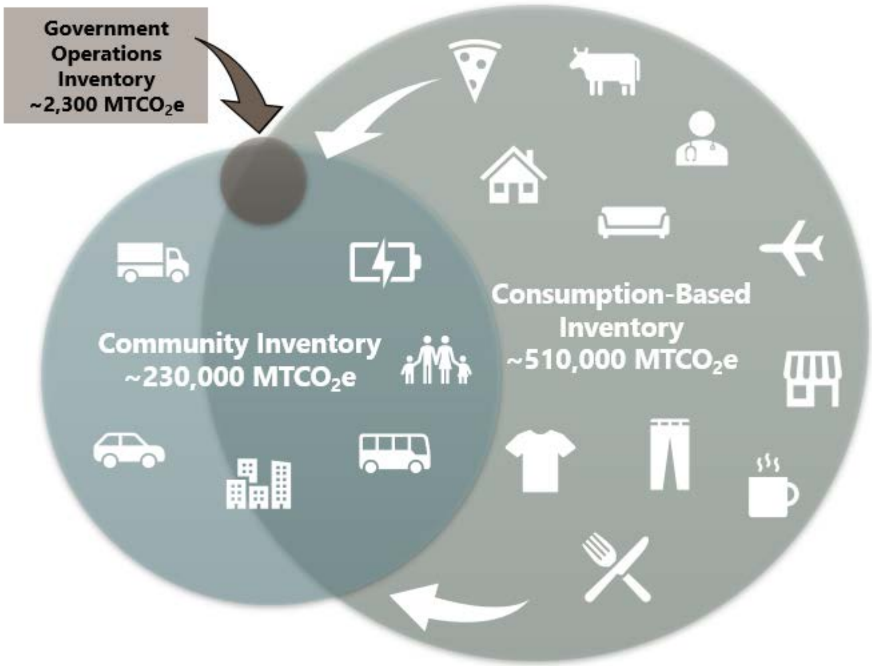
- A supplemental **carbon sequestration analysis** that estimates the amount of carbon dioxide that Bainbridge Island trees absorb—or sequester—from the atmosphere on an annual basis (in Appendix).

Figure 7. Conceptual relationship among community, government, and consumption-based inventories for Bainbridge Island.



GREENHOUSE GAS INVENTORY OVERVIEW

Inventory Methodology

The GHG inventories summarized in this report account for human-caused emissions of the most prominent and typical greenhouse gases for communities: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). To account for the differences in potency among these gases, all emissions are calculated and reported in units of metric tons of carbon dioxide equivalent ($MTCO_2e$). The inventories were conducted using widely accepted tools and protocols, including The Climate Registry's *Local Government Operations Protocol*, ICLEI's *U.S. Community Protocol for Accounting and Reporting of Greenhous Gas Emissions*, and U.C. Berkeley's *CoolClimate Calculator*.

GHG emissions are inventoried by multiplying annual activity data (e.g. electricity consumption) by emission factors (greenhouse gas emissions produced per kWh of electricity). For the municipal operations inventory, we obtained most data from City staff and local documentation such as Puget Sound Energy's (PSE) billing records, records from local wastewater treatment facilities, and fleet vehicle fuel use records. For the communitywide inventory, key data sources included electricity consumption data from PSE, Puget Sound Regional Council (PSRC) modeling outputs for vehicle miles traveled by fuel type, Bainbridge Disposal tonnage records, and Kitsap County Conservation District estimates of agricultural landowners and acreage. Where local data were not available, we referenced and downscaled national data sources such as from the Federal Transit Administration, U.S. Census Bureau, and the U.S. Department of Agriculture.

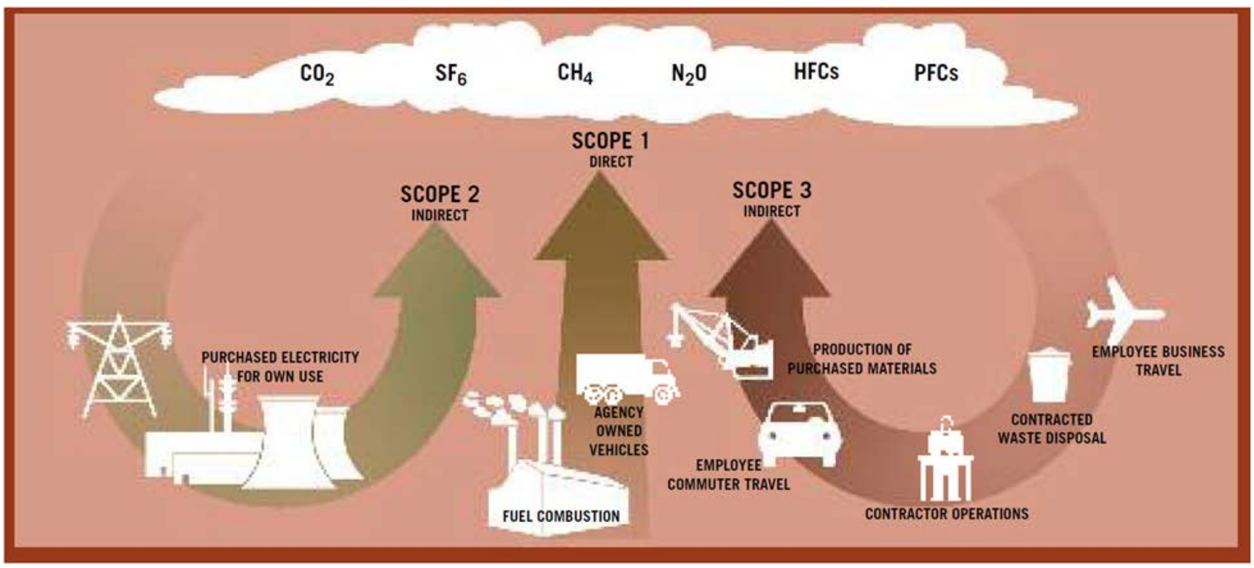
Inventory Boundaries

The activities and sectors included in GHG inventories are often classified into three "scopes," which represent relative levels of control over an emissions source (see Figure 8 and Figure 9):

- **Scope 1** emission sources include those directly caused by an organization's actions, such as from owned equipment and facilities.[4]
- **Scope 2** emissions are those indirectly associated with purchased electricity, steam, heating, or cooling.
- **Scope 3** includes all other indirect emissions that are not covered in Scope 2.

The communitywide and municipal inventories for Bainbridge Island included emissions sources from all three scopes: Scope 1, Scope 2, and Scope 3. The inventories included all sources required by the consulted protocols and additional sources, as relevant.

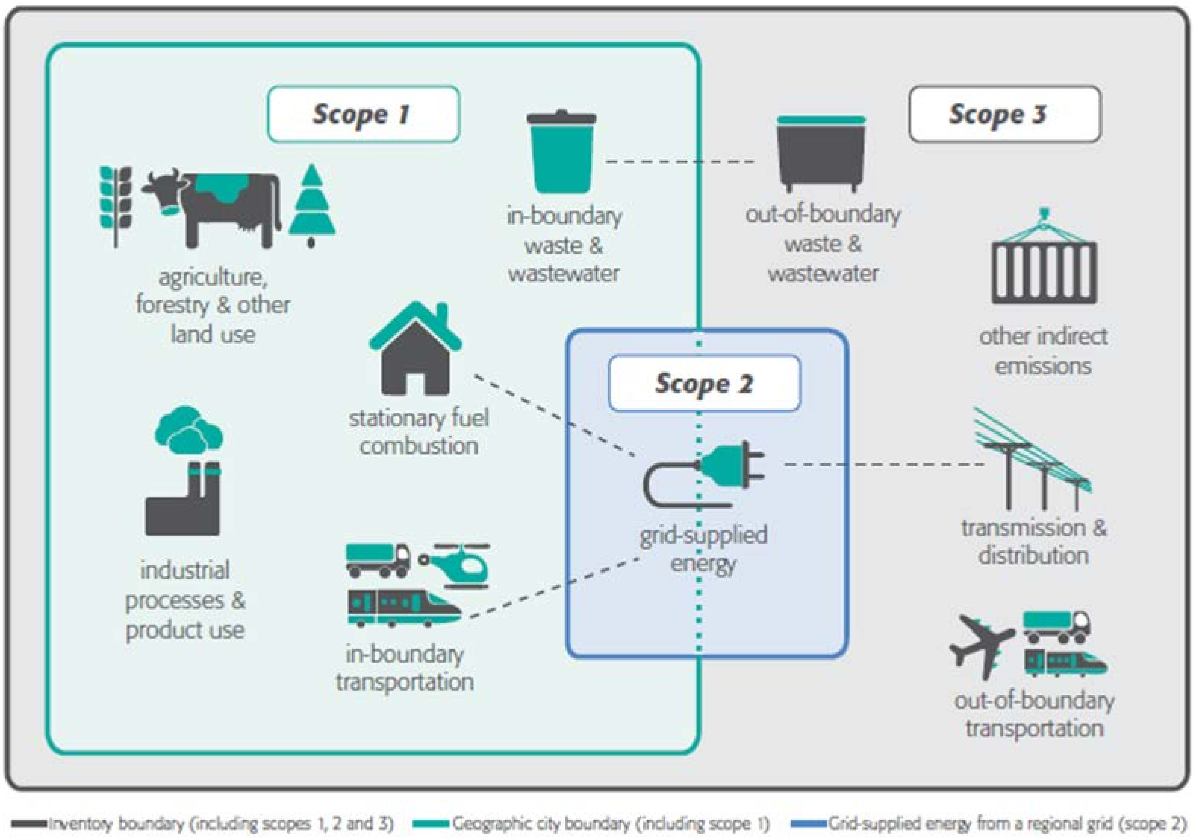
Figure 8. Sources and boundaries of municipal GHG emissions.[5]



[4] Except direct carbon dioxide emissions from biogenic sources.

[5] The Climate Registry. (2010). *Local Government Operations Protocol: For the quantification and reporting of greenhouse gas emissions inventories.*

Figure 9. Sources and boundaries of community GHG emissions.[6]



[6] World Resource Institute (2014). Greenhouse Gas Protocol: *Global protocol for community-scale greenhouse gas emission inventories.*

The tables below summarize sectors included in the municipal and communitywide inventories.

Table 1. Community inventory emissions sources and scope categories.

Emissions Type	Required?	Scope 1	Scope 2	Scope 3
Residential Energy				
Electricity	×		✓	
Propane	×	✓		
Fuel Oil	×	✓		
Commercial Energy				
Electricity	×		✓	
Propane	×	✓		
Industrial Energy				
Electricity	×		✓	
Propane		✓		
Transportation				
On-Road Passenger Vehicles	×	✓		
On-Road Freight Vehicles	×	✓		
On-Road Transit Vehicles		✓		
Off-Road Vehicles and Equipment		✓		
Air Travel				✓
Ferry Travel				✓
Solid Waste, Potable Water, and Wastewater				
Solid Waste	×			✓
Potable Water Use Energy*	×		✓	
Wastewater Treatment	×		✓	
Refrigerant Leakage	×	✓		
Agriculture		✓		

** Potable water use energy—energy associated with treating and distributing potable water systems on the Island (e.g., from pumping stations)—is included in the non-residential energy consumption sector. Energy used for pumping individual wells is included in the residential energy consumption sector.*

Table 2. Municipal inventory emissions sources and scope categories.

Emissions Type	Required?	Scope 1	Scope 2	Scope 3
Buildings and Facility Energy				
Electricity	×		✓	
Propane	×	✓		
Streetlights and Traffic Signals	×		✓	
Transportation				
On-Road Fleet Vehicles	×	✓		
Off-Road Vehicles	×	✓		
Employee Commute				✓
Business Travel				✓
Solid Waste, Potable Water, and Wastewater				
Solid Waste	×			✓
Potable Water Use Energy	×		✓	
Wastewater Treatment	×		✓	
Refrigerant Leakage	×	✓		

Table 3. Consumption-based inventory emissions sources and scope categories.

Emissions Type	Required?	Scope 1	Scope 2	Scope 3
Consumption-Based Emissions				
Household Consumption				✓
City Government Consumption				✓
Upstream Energy				✓

Inventory Years

To provide Bainbridge Island with the most up-to-date information on their GHG emissions, we selected the most recent year available as an inventory year: 2018. For a comparison year, we selected 2014 because no major changes in organizational structure or infrastructure occurred after that year. For example, the wastewater treatment facility update was completed before 2014, so those changes would be reflected in the 2014 inventory, enabling a more apples-to-apples comparison with 2018. Other factors in that deciding the inventory years include:

- **Data availability:** The availability of City data is scarcer further in the past.
- **Data consistency:** Some data were either modeled differently or organized differently in the past (i.e., methodologies changed over the last decade). Having a more recent baseline better ensures more of accurate comparison over time.
- **Relevance:** Choosing a more recent comparison inventory year allows for a more productive assessment of trends over time to inform climate action planning. For example, if the baseline year of 1990 was chosen it would be difficult to understand distinct drivers of changes between 1990 and 2019 due to the many interim changes that occurred within that time frame.

ROADMAP OF THIS REPORT

This report is organized into the following sections to assess GHG emissions associated with Bainbridge Island:

- The **Communitywide Emissions** section presents methodologies and results for community-based inventory.
- The **Communitywide Contribution Analysis** section explores the drivers of communitywide emission trends.
- The **Municipal Operation Emissions** section presents methodologies and results for municipal-based inventory.
- The **Municipal Contribution Analysis** section that explores drivers of municipal operation emission trends.
- The **Consumption-Based Emissions** section presents methodologies and results from the consumption-based inventory.

Each inventory section is organized as follows:

- **Results** section presents GHG inventory results for the study years. The results are quantified and, where relevant, summarized for trends between the two inventory years.
- **Data Sources and Methodology** section details the sources of inventory information by sector, with calculation methodologies, where relevant. The section also describes any data limitations or considerations.

The report concludes with a summary of the major trends across all the inventories and future considerations for climate action planning.

Communitywide Emissions

The communitywide GHG emissions inventory estimates GHG emissions from individuals, businesses, and commercial and industrial processes *within* Bainbridge Island. It also includes emissions associated with some residential and business activities that occur *outside* of Bainbridge Island, such as from electricity generation and solid waste transport to an out-of-state landfill.

Overall communitywide emissions are provided in units of metric tons of carbon dioxide equivalent ($MTCO_2e$). Table 5 below outlines the various emissions sources included in the communitywide inventory, along with their corresponding scope. The table also shows which sectors are required by the *U.S. Community Protocol*.

Table 4. Community inventory emissions and scope categories.

Emissions Type	Required?	Scope 1	Scope 2	Scope 3
Residential Energy				
Electricity	✗		✓	
Propane	✗	✓		
Fuel Oil	✗	✓		
Commercial Energy				
Electricity	✗		✓	
Propane	✗	✓		
Industrial Energy				
Electricity	✗		✓	
Propane		✓		
Transportation				
On-Road Passenger Vehicles	✗	✓		
On-Road Freight Vehicles	✗	✓		
On-Road Transit Vehicles		✓		
Off-road Vehicles and Equipment		✓		
Air travel				✓
Ferry				✓
Solid Waste, Potable Water, and Wastewater				
Solid Waste	✗			✓
Potable Water Use Energy*	✗		✓	
Wastewater Treatment	✗		✓	
Other Process & Fugitive Emissions	✗	✓		
Agriculture		✓		

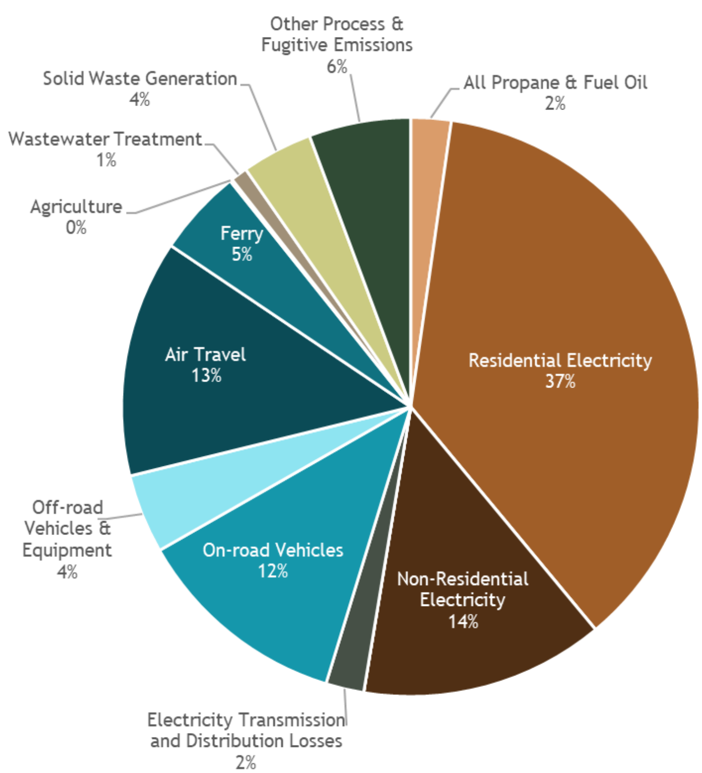
** Potable water use energy—energy associated with treating and distributing potable water systems on the Island (e.g., from pumping stations)—is included in the non-residential energy consumption sector. Energy used for pumping individual wells is included in the residential energy consumption sector.*

RESULTS

Overview

Bainbridge Island's communitywide emissions in 2018 totaled 233,998 $MTCO_2e$—equivalent to 9.4 $MTCO_2e$ per resident. Residential energy (37%) was responsible for the greatest proportion of communitywide emissions, followed by non-residential energy (14%), air travel (13%), and on-road vehicles (12%) (see Figure 11).

Figure 10. Bainbridge Island community emissions by source, 2018 (total = 233,998 $MTCO_2e$)



Communitywide GHG emissions increased by 9% from 2014 to 2018 (see Figure 12, Table 6, and Figure 13). These increases are primarily due to changes in electricity fuel sources (e.g., proportion of coal in the utility fuel mix) and growth in population and employment. Improvements in vehicle fuel economy, reductions in the distance each person drives, and declining per-household and per-business energy consumption all reduced the extent of this increase. Although communitywide emissions have increased by 9%, per capita emissions have increased only slightly—by 1% (see Figure 12).

Figure 11. Bainbridge Island community emissions, by year and source and resident. Major sources are labeled.

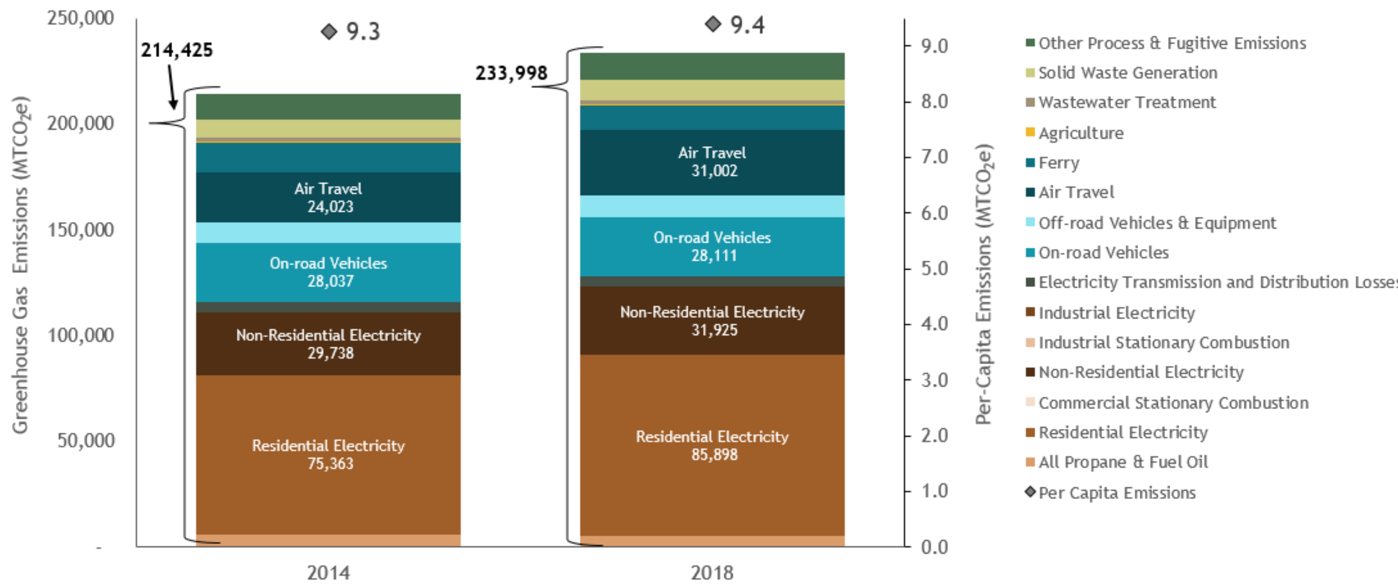
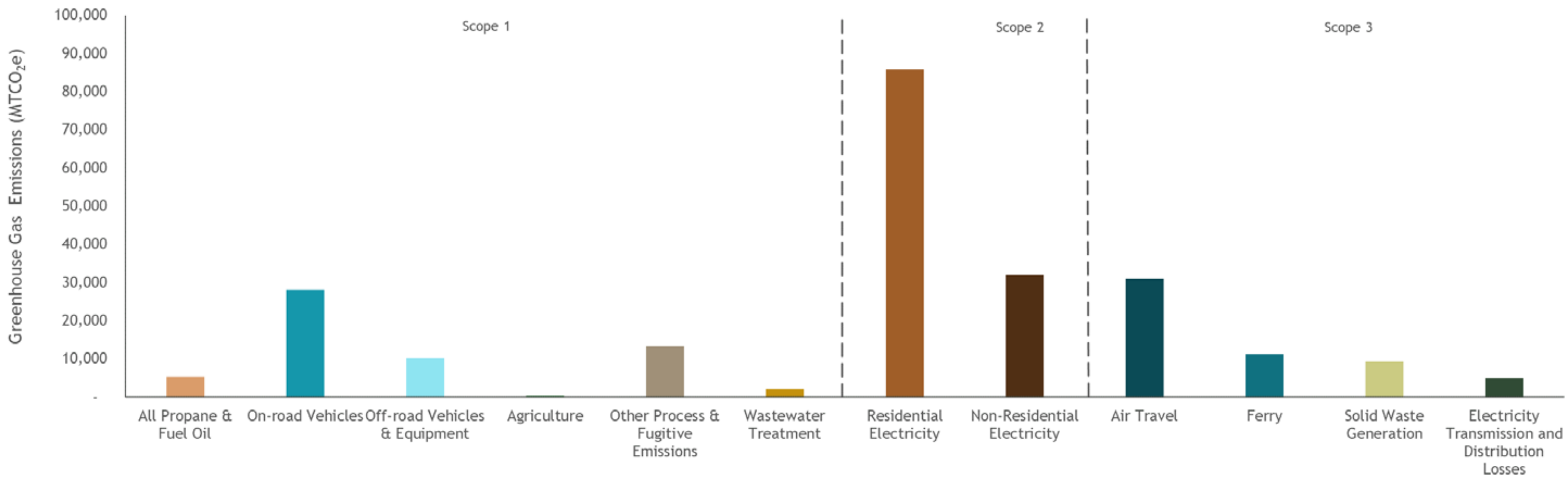


Table 5. Communitywide emissions, by sector.

GHG Emissions by Sector ($MTCO_2e$)	2014	2018	Change	% Change
Residential Energy	**84,885**	**94,810**	**9,925**	**12%**
Electricity	75,363	85,898	10,535	14%
Propane & Fuel Oil (Residential, Commercial, and Industrial)	5,912	5,274	-638	-11%
Losses from transmission & distribution	3,610	3,638	28	1%
Non-Residential Energy	**31,162**	**33,277**	**2,115**	**7%**
Electricity	29,738	31,925	2,187	7%
Losses from transmission & distribution	1,424	1,352	-73	-5%
Transportation	**75,315**	**80,778**	**5,463**	**7%**
On-Road Passenger & Freight Vehicles	27,448	27,330	-118	0%
On-Road Transit Vehicles	590	781	191	32%
Air Travel	24,023	31,002	6,979	29%
Ferry Travel	14,051	11,334	-2,716	-19%
Other Off-Road Vehicles and Equipment	9,204	10,331	1,127	12%
Solid Waste & Wastewater Treatment	**10,503**	**11,470**	**968**	**9%**
Solid Waste	8,369	9,289	920	11%
Wastewater Treatment	48	51	3	7%
Septic Tanks	2,086	2,131	45	2%
Other Process & Fugitive Emissions	**12,209**	**13,332**	**1,123**	**9%**
Agriculture	**351**	**331**	**-20**	**-6%**
Enteric Fermentation	319	297	-22	-7%
Manure Management	33	34	2	5%
TOTAL	**214,425**	**233,998**	**19,574**	**9%**

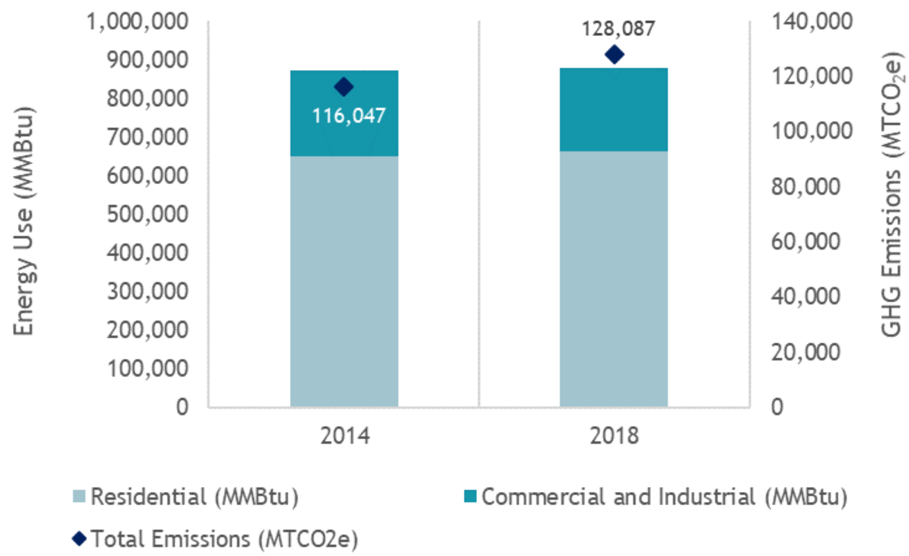
Figure 12. Bainbridge Island community emissions by source and scope, 2018.



Residential Energy

Emissions from residential use of electricity, propane[7], and fuel oil accounted for 41% (94,810 $MTCO_2e$) of total communitywide emissions in 2018, a 12% increase from 2014. Residential electricity use alone makes up 37% of communitywide emissions; it also exceeds non-residential electricity use (see Figure 14).

Figure 13. Community building energy use, by sector and year.



Electricity

Emissions from residential use of electricity increased from 75,363 $MTCO_2e$ in 2014 to 85,898 $MTCO_2e$ in 2018, a 14% change. One contributing factor is that the consumption of electricity increased slightly from 184,865,169 kWh in 2014 to 189,165,563 kWh in 2018, an increase of 2%. Additionally, Bainbridge Island's population increased 8% from 23,135 to 24,891.

Changes in the electricity fuel mix also contributed to increases in residential electricity emissions (see Table 7). Puget Sound Energy (PSE) provides power to Bainbridge Island. Approximately two-thirds of the power is from coal and hydroelectric generation. In 2017, the fuel mix was 38% coal, 33% hydroelectric, 21% natural gas, 6% wind, and 2% nuclear and other sources.[8] In 2014, the fuel mix was 35% coal, 36% hydroelectric, 20% natural gas, 3% wind, and 5% nuclear and other sources. Between 2014 and 2018, Bainbridge Island residents significantly increased their participation in PSE's Green Power Program. The

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[7] Propane amounts were derived from records that do not distinguish between residential, commercial, and industrial use. Therefore, all Bainbridge Island propane usage—regardless of sector—is included within the residential summary of emissions.

[8] Puget Sound Energy. Electricity Supply. www.pse.com/pages/energy-supply/electric-supply (accessed June 27, 2019). The emissions inventory for 2017 was used because the 2018 inventory was not yet available during the time of study.

2018 10% participation rate is among the highest in PSE's service area. However, due to the complexities of the electricity grid, the *U.S. Community Protocol* discourages consideration of renewable energy participation in calculating communitywide GHG inventories (see text box).

Table 6. Puget Sound Energy (PSE) electricity generation fuel mix for 2014 and 2017.[9]

Electricity Generation Fuel Type	2014	2017
Biomass	0%	0%
Coal	35%	38%
Cogeneration	4%	0%
Geothermal	0%	0%
Hydro	36%	33%
Landfill Gas	0%	0%
Natural Gas	20%	21%
Nuclear	1%	1%
Other	0%	0%
Petroleum	0%	0%
Solar	0%	0%
Waste	0%	0%
Wind	3%	6%

Green Power Purchases

Puget Sound Energy allows electricity users to enroll in a Green Power purchasing program to support renewable energy generation in the region. When utility customers enroll in this program, they are not paying for 100% renewable energy to be delivered directly to their home or business, but rather for their utility to buy a certain amount of renewable energy as part of the utility's overall fuel mix. Because utility fuel mixes are used to calculate the GHG emissions of consumed electricity in a community, the renewable energy purchases made through Green Power programs are already included in the emissions calculations of the community GHG inventory. Therefore, accounting for Green Power purchases separately within a GHG inventory risks double-counting the benefits of a renewable energy system.

[9] Puget Sound Energy. Electricity Supply. www.pse.com/pages/energy-supply/electric-supply (accessed June 27, 2019). The emissions inventory for 2017 was used because the 2018 inventory was not yet available during the time of study.

Propane and Fuel Oil

Due to a lack in locally available usage data, consumption of residential propane and fuel oil were estimated using data from local propane sales tax revenues, the U.S. Energy Information Administration (EIA), and 2017 American Community Surveys (ACS). These estimations suggest that emissions from residential use of propane[10] and fuel oil totaled 5,912 MTCO_2e in 2014 and 5,274 MTCO_2e in 2018, an 11% decrease in four years. This decline is primarily due to a decrease in the number of households using those fuel sources, including for cooking and heating.

Electricity Transmission and Distribution Losses

As electricity travels from where it was generated, such as a hydroelectric dam or wind farm, to individual homes, businesses, and other buildings, some of the electricity is naturally lost over power lines and in substations and transformers. The proportion of the total electricity initially generated that is lost through these processes in a given year and region is known as the "grid loss" factor. This grid loss proportion can change from year-to-year based on a number of factors, including weather, transmission distance, power line size, and transmission voltage. Although lost electricity is not ultimately delivered to the consumer, it still results in the emission of greenhouse gases. We estimate that emissions from transmitting and distributing residential electricity to Bainbridge Island residents increased slightly from 3,610 MTCO_2e in 2014 to 3,638 MTCO_2e in 2018—a less than 1% change. These changes are a result of changes to the amount of electricity consumed and the "grid loss" factor of PSE infrastructure.

Non-Residential Energy

The non-residential energy sector includes greenhouse gas emissions from commercial and industrial electricity; losses due to the transmission and distribution of that electricity; and energy associated with treating and distributing potable water (e.g., from pumping stations). Commercial and industrial propane consumption emissions are included within the residential emissions sector, as the source data did not distinguish between different use sectors.

Electricity and Transmission and Distribution Losses

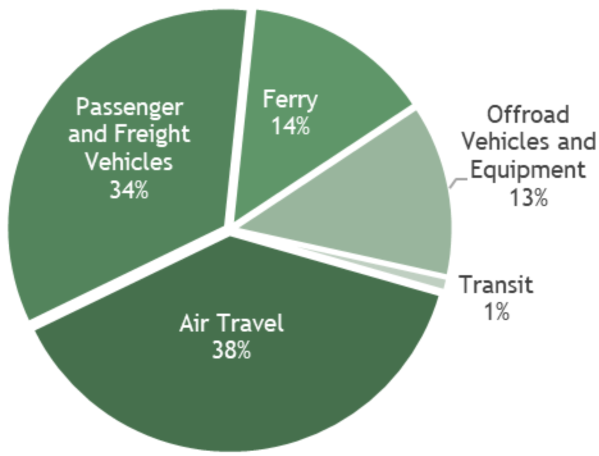
Emissions from commercial and industrial electricity accounted for 14% (31,925 MTCO_2e) of total communitywide emissions in 2018, making it the second-largest source along with air travel. Emissions from commercial and industrial use of electricity increased from 29,738 MTCO_2e in 2014 to 31,925 MTCO_2e in 2018, a 7% change. The increase in emissions can be partially attributed to the increased workforce from 8,224 to 8,943 employees, as well as from changes in the electricity fuel mix(see Figure 14 on page 23) Emissions from non-residential electricity transmission and distribution decreased approximately 5%, from 1,424 MTCO_2e in 2014 to 1,352 MTCO_2e in 2018. These changes are a result of changes in the amount of electricity consumed and the "grid loss factor" associated with PSE infrastructure.

[10] Propane amounts were derived from records that do not distinguish between residential, commercial, and industrial use. Therefore, all Bainbridge Island propane usage—regardless of sector—is included within the residential summary of emissions.

Transportation

Transportation contributed over a third of Bainbridge Island community emissions in 2018, making it the second-largest contributor to the community's greenhouse gas emissions. In 2014, most transportation emissions came from passenger and freight vehicles, followed by air travel. However, in 2018, this trend shifted, with most transportation emissions coming from air travel followed by passenger and freight vehicles (Figure 15). The rapid growth of Sea-Tac Airport explains this shift: there was a 30% increase in landings at SeaTac International Airport between 2014 and 2018.[11]

Figure 14. Community transportation emissions in 2018 (total = 80,778 $MTCO_2e$).



On-Road Vehicles

Most on-road vehicle emissions in Bainbridge Island stem from passenger cars. Downscaled modeling by the Puget Sound Regional Council suggests that passenger vehicles traveled over 69 million miles in Bainbridge Island in 2018 (Table 8 and Figure 16).

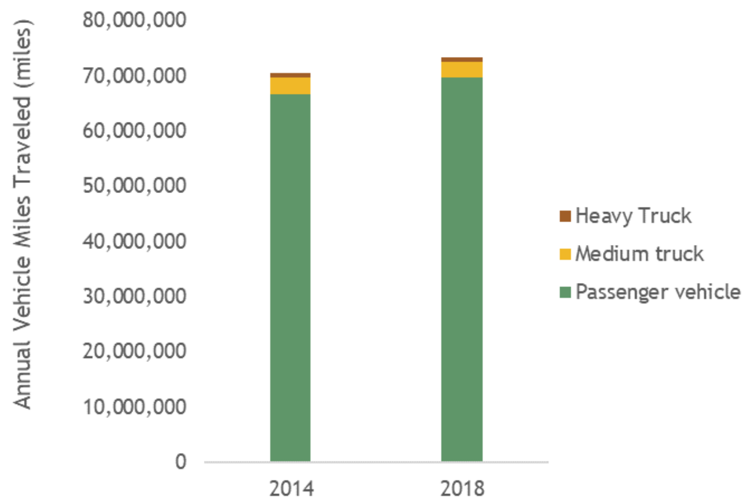
Table 7. Annual vehicle miles estimated for Bainbridge Island.

Type	2014	2018	Change
Passenger vehicle	66,612,870	69,543,904	4%
Medium truck	3,011,067	2,993,763	-1%
Heavy Truck	708,280	708,118	0%
Transit bus*	394,450	397,634	1%

**Miles for transit buses are in annual revenue miles.*

[11] Air travel emissions from Bainbridge residents were attributed by downscaling total fuel use at Sea-Tac Airport to the Bainbridge Island community based on population. More information can be found in the "Data Sources and Methodology" section of this report.

Figure 15. Distribution of on-road vehicle miles traveled, by vehicle type.



Transportation data are typically recorded as vehicle miles traveled, or VMT. VMT is the total number of miles driven by motorized vehicles of specific types. Although the model used to estimate GHG emissions by VMT and vehicle type does not separately note hybrids and electric vehicles, these vehicles are subject to the same emissions standards as conventional gasoline or diesel vehicles. As such, hybrid and electric vehicle VMT are incorporated into the average emissions factors used for each vehicle type and model year, despite not being reported separately from general passenger vehicles.

Despite a 4% increase in VMT for passenger vehicles between 2014 and 2018, emissions from on-road vehicles increased minimally—by 0.3%. The increasing average fuel economy of passenger vehicles accounts for this minimal change (Figure 16).

We estimate that transit vehicle emissions increased 32% between 2014 and 2018, rising from an estimated 590 $MTCO_2e$ in 2014 to 781 $MTCO_2e$ in 2018. As reported by Kitsap Transit to the Federal Transit Administration, annual revenue miles remained relatively constant between the two inventory years—only increasing 1%. This trend suggests that increased transit emissions may be the result of incomplete reporting, decreased fuel economy, and/or increased use of high emitting fuels. The report indicates that Kitsap Transit activities in 2018 included more gasoline use for vanpool vehicles and a shift to liquified petroleum gas for paratransit (demand response) vehicles.

Off-Road Vehicles & Equipment

This inventory categorizes off-road vehicles and equipment into three categories: ferry travel, air travel, and other off-road vehicles and equipment. Other off-road vehicles and equipment includes emissions from vehicles and equipment used for agriculture, construction, lawn/gardening, and recreation such as boating.

Ferry Travel

Emissions from ferry travel decreased from 14,051 $MTCO_2e$ in 2014 to 11,334 $MTCO_2e$ in 2018, an overall decrease of 19%. This decrease is a result of a large reduction in fuel consumption by Washington State ferries traveling the Seattle-Bainbridge Island route. In 2014, we estimate that Bainbridge Island's share of ferry travel accounted for the consumption of 2.7 million gallons of fuel, compared to 2.2 million gallons in 2018.

Air Travel

We estimate that air travel contributed 13% to communitywide emissions, making it the largest source of off-road GHG emissions and second-largest source of emissions overall (tied with non-residential energy). Emissions from air travel increased 29%, from an estimated 24,023 $MTCO_2e$ in 2014 to 31,002 $MTCO_2e$ in 2018. This increase is largely attributable to population growth on Bainbridge Island and a 30% increase in total landings at SeaTac International Airport between 2014 and 2018. Our calculations are based on available jet fuel usage data (from 2015), which were scaled by the proportion of landings at SeaTac International Airport. Bainbridge Island's population and businesses make up approximately 0.5% of the four-county area that SeaTac predominantly serves (King, Kitsap, Pierce, and Snohomish counties).

Other Off-Road Vehicles & Equipment

We estimate that emissions from other off-road equipment accounted for 4% of overall emissions in Bainbridge Island in 2018 (10,331 $MTCO_2e$). Most of these emissions—which are estimated by scaling county-level model outputs to Bainbridge Island based on population—are generated by construction equipment, lawn and garden equipment, and pleasure watercraft.

Solid Waste and Wastewater

Solid Waste

Most emissions from the disposal of solid waste are associated with the release of methane from decomposing waste in the landfill (see Figure 17 and Table 9). Emissions from waste disposal increased from 5,527 $MTCO_2e$ in 2014 to 6,134 $MTCO_2e$ in 2018, an 11% change that is largely due to population growth and associated increases in tons disposed. Based on waste characterization studies from Kitsap County, King County, and Washington State, the composition of waste over time remained relatively constant. Approximately two-thirds of disposed waste is mixed solid waste, and about one-quarter is food scraps.

All of Bainbridge Island's waste is transported off-Island, first in trucks to the Olympic View Landfill in Bremerton then via train to the Columbia Landfill near Arlington, Oregon. We estimate that emissions from waste transportation increased from 2,352 $MTCO_2e$ to 2,611 $MTCO_2e$. This is associated with the rise in waste collected and transported, which grew from an estimated 22,616 tons in 2014 to 25,102 tons in 2018.

Emissions from equipment used at the landfill to process waste and from yard waste composting make up a nominal proportion of the Island's solid waste emissions. We estimate that the diesel-powered equipment at Columbia Landfill generated 371 $MTCO_2e$ and 412 $MTCO_2e$ in 2014 and 2018, respectively. In 2018, Bainbridge Disposal reported 1,900 tons of yard waste were composted, which generated 132 $MTCO_2e$.

Figure 16. Solid waste emissions in 2018, by source.

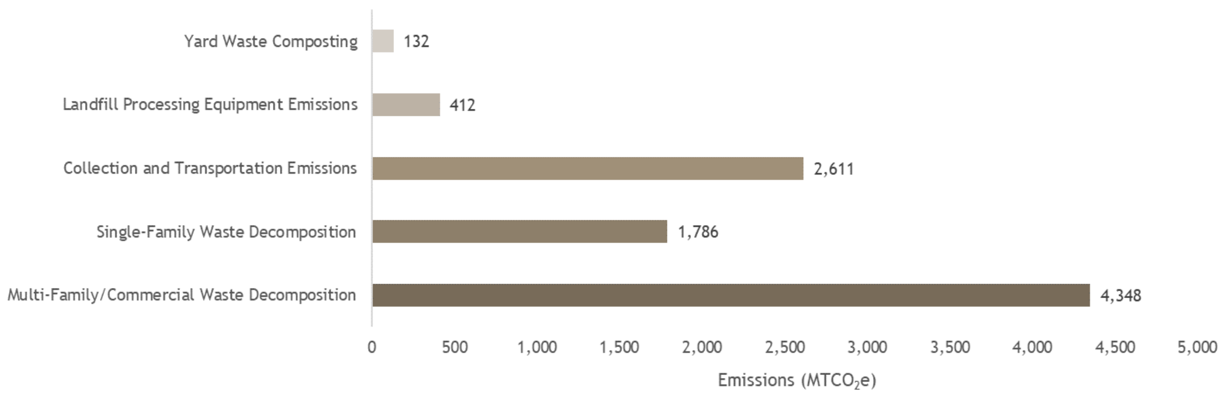


Table 8. Summary of solid waste emissions, by process.

Process	Emissions ($MTCO_2e$)		
	2014	2018	Difference
Solid Waste Disposal & Decomposition	5,527	6,134	+607
Yard Waste Composting	119	132	+13
Collection & Transportation to Landfill	2,352	2,611	+258
Processing with Equipment at Landfill	371	412	+41
Total	***8,369***	***9,289***	***+920***
Process	**Emissions by Weight ($MTCO_2e$/ton waste)**		
	2014	2018	Difference
Solid Waste Disposal & Decomposition	0.244	0.244	—
Yard Waste Composting	0.070	0.070	—
Collection & Transportation to Landfill	0.104	0.104	—
Processing with Equipment at Landfill	0.016	0.016	—
Total	0.344	0.344	—

Wastewater Treatment

The combined emissions from wastewater treatment (process and effluent emissions) and fugitive emissions[12] from septic sources contributed to 1% of communitywide emissions in 2018. This small proportion is associated with an overall 2% increase in emissions from these sources, from 2,134 $MTCO_2e$ in 2014 to 2,182 $MTCO_2e$ in 2018 (see Table 10). This increase is due to population growth and the associated increase in waste generated and processed (calculations for emissions from septic tanks were scaled based on Bainbridge Island population trends and calculating emissions from WWTP also accounted for population growth).

Table 9. Emissions from wastewater treatment and septic tanks ($MTCO_2e$).

Source	Emissions ($MTCO_2e$)			
	2014	2018	Difference	% change
WWTP Process	13	14	+1	+7%
WWTP Effluent	35	37	+2	+7%
Septic Tanks	2,086	2,131	+45	+2%
Total	**2,134**	**2,182**	**+48**	**+2%**

Other Process & Fugitive Emissions

Emissions from other processes and fugitive sources—including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)–contributed 6% of Bainbridge Island's communitywide emissions in 2018.[13] Emissions from HFCs—a common refrigerant used in refrigeration and air conditioning—comprised nearly all of these emissions (99%; 13,234 $MTCO_2e$).

We estimate that emissions from HFCs and PFCs increased 10% between 2014 and 2018, from 12,061 $MTCO_2e$ to 13,237 $MTCO_2e$. This increase is driven by population growth, as emissions were scaled down by population from national-level emissions due to lack of locally available data.

Fugitive emissions from leaks of SF_6 in electricity transmission and distribution operating equipment declined an estimated 36%, from 147 $MTCO_2e$ in 2014 to 95 $MTCO_2e$ in 2018. Our calculations are based on data reported by PSE in their 2014 and 2017 GHG inventories, scaled down to the 1% of customers Bainbridge Island represents within PSE's service area.

Data on process and fugitive sources such as HFC, PFC, and SF_6 emissions at city scales are scarce. The U.S. EPA's 2019 *Inventory of GHG Sources and Sinks* was used as a proxy and the data was scaled to Bainbridge Island's population. Estimating emissions from process and fugitive sources can be highly uncertain. Factors vary between individual pieces of equipment. Even if the leak rate of a piece of equipment has been tracked carefully, that leak rate can change after the leak is repaired or as the

[12] Fugitive emissions are from leaks.

[13] Fugitive emissions are those that are not physically controlled but result from the intentional or unintentional release of GHGs. They commonly arise from the production, processing, transmission, storage and use of fuels or other substances, often through joints, seals, packing, and gaskets. Examples include HFCs from refrigeration leaks, SF_6 from electrical power distributors, and CH_4 from solid waste landfills.

equipment ages. For example, equipment can leak for two or more years before requiring a recharge, so emissions over this timeframe are typically not detected until after they occur.

Table 10. Summary of emissions from other processes and fugitive sources.

GHG	Emissions ($MTCO_2e$)			
	2014	2018	Difference	% change
HFC	12,058	13,234	+1,176	+10%
PFC	3	3	0	0%
SF_6	147	95	-53	-36%
Total	***12,209***	***13,332***	***+1,123***	***+9%***

Agriculture

The Kitsap County agricultural census reported 11,483 and 12,539 livestock animals in 2012 and 2017, respectively. To determine what proportion of livestock animals were on Bainbridge Island during these years, we scaled agricultural census data for Kitsap County to Bainbridge Island based on land area. Using this methodology, we estimate that Bainbridge Island had 803 and 875 livestock animals in 2014 and 2018; representing a 9% increase in animals between the two years.

While the total animal population increased on the Island, we estimate that the number of cattle decreased by 12%. This decline drove estimated reductions in enteric fermentation emissions—the release of methane (CH_4) as livestock digest food—of 7%, from 319 $MTCO_2e$ in 2014 to 297 $MTCO_2e$ in 2018.

Emissions from manure management increased 5%, from 33 $MTCO_2e$ in 2014 to 34 $MTCO_2e$ in 2018, driven by the overall increase in livestock animal population.

Table 11. Agricultural acres and population trends, by livestock.

Animal	Population		
	2014	2018	% change
Horses	98	100	+2%
Sheep	41	82	+100%
Goats	35	44	+26%
Cattle	92	81	-12%
Poultry	517	538	+4%
Swine	20	30	+50%
Total	***803***	***875***	***+9%***

DATA SOURCES AND METHODOLOGY

We followed the *U.S. Community Protocol* (Version 1.1) to complete the communitywide emissions inventory for 2014 and 2018, using the U.S. EPA's *GHG Inventory Sources and Sinks Annexes* for 2014 and 2019 and the IPCC's *5th Assessment Report* (AR5) for updated GWPs and emissions factors where available. All emissions were calculated in ClearPath and were based on verified local data when they were available. When local data were not available, data inputs were scaled down from Kitsap County, King County, or national datasets. Most data were deemed medium quality due to assumptions about local data.

Completing this inventory involved acquiring the following data, summarized in Table 13 and detailed in the followed sections:

- **Activity data** that quantifies levels of activity that generate greenhouse gas emissions, such as vehicle miles traveled, and tons of waste generated.
- **Emission factors** that translate activity levels into emissions.

Data quality is assessed and reported on a High (H), Medium (M), and Low (L) scale in accordance with GHG inventory best practices:

- A *High* rating indicates data are detailed and specific to the local geography
- A *Medium* rating indicates data are more general or modeled with robust assumptions and may not be specific to the local geography, but are downscaled from a slightly broader geography (e.g., state-level)
- A *Low* rating indicates data are highly modeled, uncertain, or a default value was used based on national characteristics.

Table 12. Key data sources for the City of Bainbridge Island's communitywide inventory.

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
Residential Energy				
Electricity	• Overall kWh consumption from the three substations serving the Island • Residential proportion based on sample of customer data in 2014 and 2018	H	• PSE reported emissions factors (PSE Greenhouse Gas Inventory, 2014 & 2017, Table 7.1)	H
Stationary Fuel Combustion	• Local propane sales tax information for Bainbridge Island (2014 and 2018) • EIA's average propane price per gallon of fuel for 2014 and 2018.	M	• Emissions factors provided in ClearPath program	M
Electricity Transmission & Distribution Losses	• See "Electricity" • eGRID Western region grid gross loss percentage (2014 and 2016)	M	• PSE-reported emissions factors (PSE Greenhouse Gas Inventory, 2014 & 2017, Table 7.1)	H

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
Non-Residential Energy				
Electricity	• kWh consumption from the three substations serving the Island • Non-residential proportion based on sample of customer data in 2014 and 2018	H	• PSE reported emissions factors (PSE Greenhouse Gas Inventory, 2014 & 2017, Table 7.1)	H
Electricity Transmission & Distribution Losses	• See "Electricity" • eGRID Western region grid gross loss percentage (2014 and 2016)	M	• PSE reported emissions factors (PSE Greenhouse Gas Inventory, 2014 & 2017, Table 7.1)	H
Transportation				
On-Road Vehicles	• Annual miles traveled, by vehicle and fuel type, provided by EPA MOVES analysis of travel model data, for proportion of Kitsap County VMT occurring in Bainbridge Island • Annual revenue miles traveled and fuel consumption by type provided by National Transit Database for Kitsap County, then scaled down to Bainbridge Island by population	M	• CO_2, CH_4, and N_2O emission factors are defaults from the U.S. Community Protocol	L
Off-Road Vehicles & Equipment	• Emissions by off-road sector and fuel type, along with days of use per year, provided by nonroad module of the EPA MOVES model, for proportion of Kitsap County activity occurring in Bainbridge Island	M	• CO_2, CH_4, and N_2O emission factors are defaults from the U.S EPA MOVES nonroad model	L
Air travel	• 2015 Jet fuel consumption from Port of Seattle, scaled to target years by total landings and to the Island by population/employment	M	• CO_2, CH_4, and N_2O emission factor defaults from ClearPath	H
Ferry travel	• Ferry fuel price, from EIA, and cost, from WSDOT	M	• CO_2, CH_4, and N_2O emission factor defaults from ClearPath	H
Solid Waste and Wastewater				
Solid Waste Generation	• Single-family waste tonnages from Bainbridge Disposal • Multi-family + commercial tonnages estimated from ratio of single-family to multi-family + commercial from 2015-2016 WA Waste Characterization Study, for Kitsap County • Landfill methane collection scenario confirmed "typical" by Columbia Landfill • Annual precipitation from National Weather Service, Arlington, OR	M	• Waste characterizations from 2015-2016 WA Waste Characterization Study, for Kitsap County • Waste characterization was comparable across Port Orchard samples and the Puget Sound-wide data from the aforementioned study; there was also little difference compared to King County compositions, which were assessed as a reference	M

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
Solid Waste Collection & Transportation	• Mass of solid waste from Bainbridge Disposal, with multi-family + commercial estimated from Kitsap County ratio of single-family to multi-family + commercial (see above) • Mileage from Google maps	**M**	• Default EF from ClearPath	**L**
Yard Waste Composting	• Yard waste tonnage from Bainbridge Disposal for 2018; extrapolated for 2014 using 2014:2018 single-family solid waste ratio	**M**	• Default EF from ClearPath	**L**
Landfill Processing	• Mass of solid waste from Bainbridge Disposal, with multi-family + commercial estimated from Kitsap County ratio of single-family to multi-family + commercial (see above) • Fuel type for equipment confirmed by Columbia Landfill	**M**	• Default EF from ClearPath	**L**
Wastewater Treatment Facility	• Wastewater treatment facility processes determined based on desktop research and confirmed with City staff • Population served by wastewater treatment facility estimated by multiplying the number of sewer connections by the average household size from ACS	**M**	• Default EF from ClearPath • CH_4 emissions were not applicable since the system is aerobic	**L**
Septic Tanks	• Population data estimated based on number of septic systems reported to the Department of Health and the number of sewer connections in the community.	**M**	• Default EF from ClearPath • Fugitive emissions calculated using Community Protocol WW.11 Alternative Method for Methane Emissions from Septic Systems if Only the Population is Known	**L**
Refrigerant Leakage				
Refrigerant Leakage from Building Heating and Cooling Equipment, and Fugitive Emissions from Electricity Generation & Transmission	• HFC and PFC tonnage from Annex 6 in U.S. EPA GHG Inventory Sources and Sinks, scaled down to Bainbridge Island population • SF_6 tonnage and customer data from PSE, scaled down to Bainbridge Island customers	**L**	• HFC and PFC GWP from IPCC 5th Assessment Report, with adjustment for climate-carbon feedback • SF_6 100-Year GWP from U.S. EPA GHG Sources and Sinks • Emissions calculated using Community Protocol Alternative Method BE.7.1.A	**H**

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
Agriculture				
Enteric Fermentation and Manure Management	• Animal population and pastureland from USDA Agricultural Census, for Kitsap County • Agricultural acres with livestock on Bainbridge Island and waste management system, from Kitsap County Conservation District • Typical animal mass and B_o from U.S. EPA GHG Inventory Sources & Sinks, 2017 Annexes • Volatile solids and excreted nitrogen from U.S. EPA GHG Inventory Sources & Sinks, 2014 and 2017 Annexes • Methane conversion factors from *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017,* with annual average temperature from Climate Bremerton	**M**	• EF, 100-year GWP for CH_4 and N_2O, and volatilization nitrogen loss from U.S. EPA GHG Inventory Sources & Sinks, 2017 Annexes • EF for nitrogen volatilization and runoff/leaching from U.S. Community Protocol, Appendix G • Indirect N_2O emissions calculated using U.S Community Protocol, Appendix G	**M**

The U.S. Community & Local Government Operations Protocols

The *U.S. Community* and *Local Government Operations* Protocols were built to provide easily applicable and accurate community-level and municipal estimates of GHG emissions. These protocols provide a consistent framework in which to compare emissions from a geographic or operational boundary across time. The *U.S. Community Protocol* was designed for community-scale GHG accounting, making it a valuable tool for counties and cities, and an appropriate choice for the City of Bainbridge Island. The *U.S. Community* and *Local Government Operations* Protocols are widely used, understood, and respected.

These community and municipal inventories follow the *U.S. Community* and *Local Government Operations Protocol* methodologies and deviate from their stated methods only when more precise, local data are available, per Protocol recommendations. The Local Governments for Sustainability (ICLEI) created the *U.S. Community Protocol* in 2013 and the *Local Government Operations Protocol* in 2010. The U.S. Community Protocol requires, at a minimum, reporting of the following five activities: 1) Use of electricity by the community 2) Use of fuel in residential and commercial stationary combustion equipment 3) On-road passenger and freight motor vehicle travel 4) Use of energy in potable water and wastewater treatment and distribution 5) Generation of solid waste by the community. These activities are required because they represent the largest sources of GHG emissions for most communities and are activities that can be impacted by local government actions. The *Local Government Operations Protocol* includes similar reporting requirements with a focus on only those emission sources that are within the government's control and are the result of day-to-day operations.

Residential Energy

- Data on **electricity** use were provided by the utility serving Bainbridge Island, PSE, and for transmission and distribution losses, by eGRID.
- Stationary fuel combustion consisted of residential **fuel oil,** with data from EIA and the number of households from ACS.
- **Propane** usage for residential, commercial, and industrial sectors was estimated using local sales tax data and EIA information on average propane fuel prices per gallon.

Non-Residential Energy

- Data on **electricity** use were provided by the utility serving Bainbridge Island, PSE, and for transmission and distribution losses, by eGRID. PSE does not track commercial and industrial energy separately, hence they were combined in this analysis.

Transportation

- **Vehicle miles traveled** were derived from Puget Sound Regional Council's MOVES analysis of travel model data and account for all mileage within the Kitsap County boundary regardless of trip origin or destination. Emissions for Bainbridge Island are assumed proportional to the share of Kitsap County VMT occurring in Bainbridge Island city limits. Share of average weekday VMT occurring in Bainbridge Island was calculated from 2014 travel model data and includes all vehicle types. Bainbridge Island VMT shares represents all trips to/from Bainbridge Island as well as those driving through the city boundaries. Year 2018 was extrapolated from the rates between 2014 and 2016. The PSRC data reported VMT and emissions for passenger vehicles, medium trucks, heavy trucks, and transit. In ClearPath, we reported medium trucks as light trucks.
- **Annual revenue miles** and **fuel consumption** data for Kitsap County were acquired from the National Transit Database from the Federal Transit Administration. These data were scaled down to Bainbridge Island by population.
- The Port of Seattle supplied **jet fuel consumption** data for SeaTac Airport for 2015, of which 0.5-1% was attributable to Bainbridge Island. SeaTac passenger enplaning surveys and population and employment statistics were used to assign the above fraction of the total airshed emissions to the Bainbridge Island community. This allocation methodology means that communities with more residents and business travelers are assigned a greater proportion of travel-related emissions at SeaTac airport. We scaled 2015 jet fuel usage to 2014 and 2018 based on the total landings in those years.
- **Ferry fuel consumption** was derived from EIA data on diesel fuel price and from WSDOT data on the reported fuel cost for the Bainbridge Island route in fiscal year 2015.
- **Off-road emissions** were calculated from the nonroad module of the EPA MOVES model for 2014 and 2018. The model estimates emissions at the county level, which were then scaled down to Bainbridge Island by population. Emissions include common non-road equipment, including construction, agriculture, lawn/gardening, and recreational equipment.

Ferry Emissions Attribution

Accounting for emissions related to ferry transportation can be complicated by the fact that ferries typically travel between multiple jurisdictions. To simplify the methodology for calculating these emissions, the *U.S. Community Protocol* recommends allocating portions of the total emissions related to ferry transportation according to the number of stops located in each jurisdiction. For example, for the Bainbridge Island-Seattle ferry, this would equate to a 50/50 split of emissions since there is one ferry stop in each city. This is the calculation approach that was used in this community inventory.

However, another possible method for attributing emissions to a particular jurisdiction is by ridership and examining the proportion of ferry riders from each city. To test that the 50/50 allocation was the correct choice for Bainbridge Island, we performed a sensitivity analysis using a ridership-based methodology. Using data reported by Washington State, we assumed that where travelers were heading in the evening on a weekday was likely where they reside. Based on this assumption and available data, we examined the proportion of total ferry travelers that end in Bainbridge Island in the evening versus elsewhere. Using this technique, we deduced that 47% of weekday ferry commuters are residents of Bainbridge Island—a value that is very close to the original 50% estimate.

Given that this proportion strongly aligns with the 50/50 approach recommended by the *U.S. Community Protocol*, we ultimately followed the U.S. Community Protocol attribution approach to align with the robust and established methodology used by other communities in the region.

Solid Waste and Wastewater

- Bainbridge Disposal single-family tonnages and Kitsap County waste characterization data, along with default emissions factors provided in ClearPath, were used to calculate emissions from **waste disposal and composting.** Multi-family and commercial tonnages were not directly available and were estimated using a single-family to multi-family + commercial ratio of 32:68, based on the transfer station survey data collected for the 2015-2016 Washington Waste Characterization Study. Waste characterization was comparable across Port Orchard samples and the Puget Sound-wide data from the aforementioned study; there was also little difference compared to King County compositions, which were assessed as a reference.
- **Landfill emissions** assumed an 82.5% capture rate, based on Columbia Landfill's confirmation of a "typical" collection scenario and ClearPath's associated capture rates.
- Wastewater emission calculations required data from Kitsap County Sewer District #7 and the City of Bainbridge Island **wastewater treatment plants**. City and District staff provided the data.
- Data required for higher quality calculations in ClearPath, such as BOD_5 or population specifically using septic systems (including unpermitted systems), were not available. Therefore, **fugitive septic tank** emissions were estimated based on the number of Bainbridge Island residents not served by a sewer connection.

Other Process & Fugitive Emissions

- Data on **fugitive refrigerant** HFC and PFC emissions at city scales is scarce. We used the U.S. EPA's 2019 Inventory of GHG Sources and Sinks and scaled the data to Bainbridge Island by population. GWP were adjusted to the latest available values in 2014 and 2018, which corresponded to the values in the 4th and 5th Assessment Reports, respectively.
- PSE's greenhouse gas inventories from 2014 and 2017 provided **fugitive electric transmission and distribution** emissions data for SF_6. We scaled the data to Bainbridge Island using PSE customer data.

Agriculture

- The USDA provides publicly available data on the number of animals by county, which was scaled down to Bainbridge Island according to the ratio of livestock to land area. Kitsap County Conservation District provided data on manure management systems. The EPA provides national-level **animal enteric and manure** emissions factors, and state-level emissions factors for cattle.

Considerations

At the time of this inventory, not all communitywide data were available. Many calculations were scaled from national or county estimates by population. ClearPath's default emissions factors were used in cases where local data were not available. There is always a certain level of uncertainty associated with inventories, given constraints in data availability for most communities. However, the goal of performing inventories is to attempt to accurately and precisely account for all sources of emissions using best available data and unbiased methodologies. While ranges of uncertainty are typically not quantified, we strive to use approaches that produce estimates that are neither conservative nor liberal in their leanings, and are based on the most locally-specific and reputable data sources.

A list of data limitations and other considerations specific to Bainbridge Island's communitywide inventory is provided below.

- **Multi-family and commercial solid waste tonnage:** Since tonnage data was not available, we assumed a 32:68 ratio of single-family to multi-family and commercial waste, based on Port Orchard transfer station surveys in 2015.
- **Yard waste composting tonnage:** Bainbridge Disposal data was available for 2018. To derive 2014 yard waste composting tonnage, we calculated the 2018 ratio of single-family tonnage to yard waste composting tonnage and applied the same ratio to 2014 single-family tonnage.
- **2018 VMT:** PSRC data was available for 2014 and 2016. To derive 2018 VMT, we assumed a linear rate of increase from 2014 to 2016 to 2018.
- **2014 and 2018 Annual Revenue Miles:** We scaled Kitsap County data to Bainbridge Island according to population, which may not accurately reflect public transit ridership on Bainbridge Island.
- **Septic tank fugitive emissions:** In the absence of data on BOD_5, we used the U.S. Community Protocol WW.11 Alternative Method to calculate methane emissions when only total population is known.
- **HFC and PFC tonnage:** National data was available for 2014 and 2017 and was scaled down to Bainbridge Island by population. We assumed semiconductor manufacture, and the production of magnesium and aluminum, did not apply to Bainbridge Island and excluded contributions from those sources. The PFC-Substitution of ODS value provided was "does not exceed 0.05"; 0.04 was used as an estimate and may be an overestimate.
- **Air travel:** We were not able to obtain fuel use data for 2018, so the air travel emissions were estimated by using a scaling factor from 2015 fuel use data based on the total landings for 2014 and 2018.
- **Off-road vehicle and equipment:** We used the EPA MOVES model to estimate off-road vehicle and equipment emissions. The model estimates emissions at the county-level; we scaled Kitsap County emissions to Bainbridge Island by population.

These considerations should be taken into account when interpreting findings from this inventory. We also recommend that future inventories seek to address these data limitations, if possible.

COMMUNITY CONTRIBUTION ANALYSIS

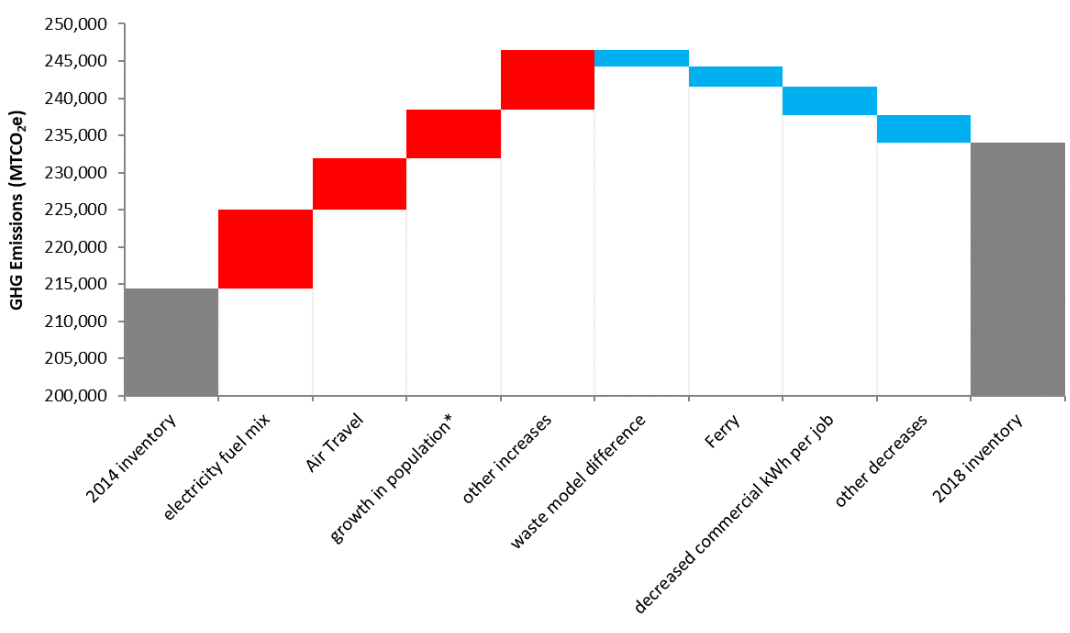
Introduction

In 2014, Bainbridge Island's 23,135 residents and 9,404 emitted approximately 214,425 $MTCO_2e$. In 2018, the population increased 7% (24,891), the number of households increased 4% (9,798), and communitywide emissions increased 9% (to 233,998 $MTCO_2e$). Apart from population growth, what drove that estimated change in emissions? We utilized the *Analyzing Drivers of Change in Greenhouse Gas Emissions Inventories* tool available from ICLEI USA to attribute changes in the community inventories to the economic, social and technological forces that influenced them.[14]

Results

The communitywide contribution analysis highlighted factors that lead to the most significant changes in emissions between 2014 and 2018. The analysis revealed that changes to the PSE electricity fuel mix, increased activity at SeaTac airport (and, thus, higher estimated air travel emissions), and growth in population and employment all contributed to increases in emissions within the community. Conversely, downward forces on emissions included reduced ferry fuel use and more efficient driving and energy use. Figure 18 below shows the influences of the top three drivers on the two inventory years, plus a category labeled "other"—a compilation of contributors illustrated in Figure 19.

Figure 17. High-level summary of major drivers of communitywide inventory increases and decreases.



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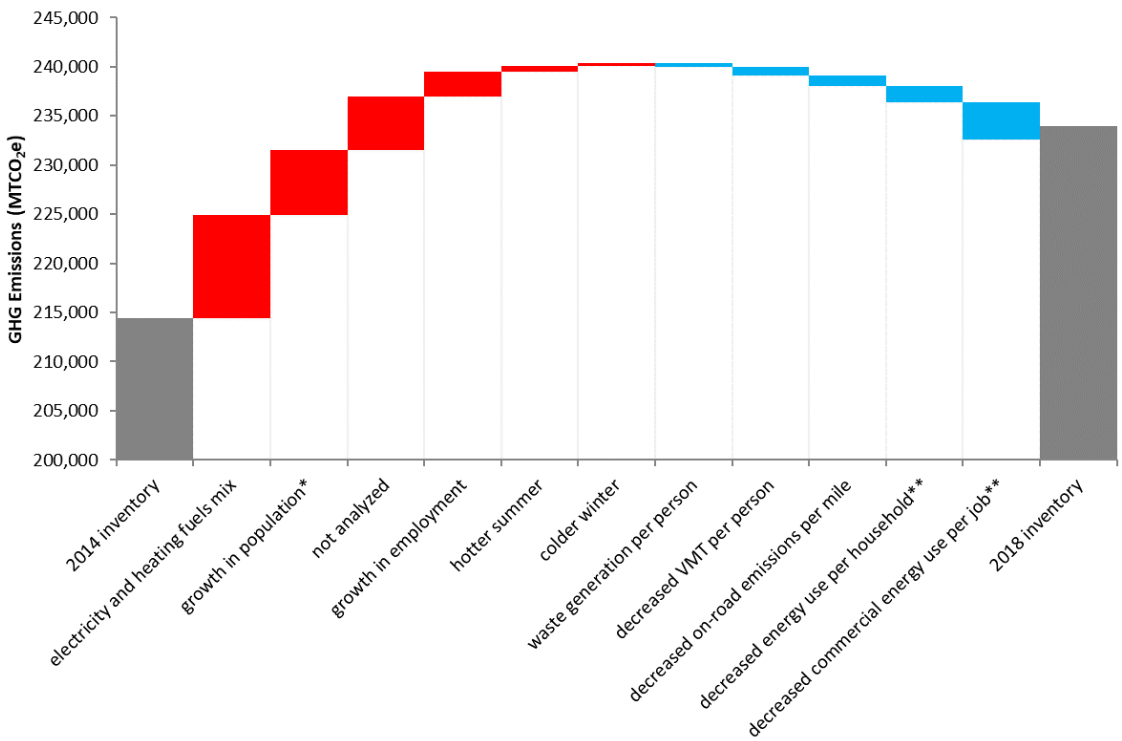
[14] ICELI USA *Analyzing Drivers of Change in Greenhouse Gas Emissions Inventories* tool. http://icleiusa.org/ghg-contribution-analysis/ (Accessed July 1, 2019).

Figure 18. Detailed depiction of major drivers of inventory increases and decreases.



***Includes effects of population on residential energy, VMT and waste generation.*

***After accounting for weather. This change is the net effect of factors that may include occupant behavior, changes to building types and uses, federal appliance standards, utility programs and new electronic devices.*

Specifically, contributors to inventory changes included the following, in order of highest increase to lowest decrease:

- **Electricity fuel mix (+10,542)** describes changes to types of resources used to generate electricity for the community. For example, increased use of renewable sources such as hydroelectricity and solar and wind power would drive emissions *decreases* in the electricity fuel mix. For Bainbridge Island, changes in the PSE electricity fuel mix contributed to *increases* in electricity emissions.
- **Growth in population (+6,581)** includes the impacts of increased housing, driving, and waste generation from Bainbridge Island's growing population. Population grew 7.1% from 23,135 in 2014 to 24,891 in 2018.
- **Not analyzed (+5,418)** describes the emissions from multiple sources—including increases in emissions from off-road vehicles, air travel, agriculture, wastewater, and refrigerant loss—that are not explicitly linked to a variable available in the tool. Due to the calculation

methodology used to estimate emissions from these sources, many of these increases can be linked to population growth, which was used as a scaling factor to estimate emissions.[15]

- **Growth in employment (+2,583)** describes the effect of increased job growth and GDP per person on emissions. Economic growth leads to larger consumption of goods and services, therefore resulting in emissions increases.

- **Hotter summer (+499)** is the increase emissions associated the enlarged strain on various systems due to hotter temperatures during the summer, such as increased electricity and energy consumption for residential and commercial cooling. The summer in 2018 was hotter than in 2014.

- **Colder winter (+366)** is the increase emissions associated with the amplified strain on various systems due to colder temperatures during the winter, such as increased electricity and energy use for residential and commercial heating. The winter in 2018 was colder than in 2014.

- **Waste generation per person (-386)** describes the impacts from change in the amount of waste disposed per person. In Bainbridge Island, the growth of waste generation was slower than that of population, which resulted in reduced per-person waste generation.

- **Decreased VMT per person (-919)** describes changes from people driving more or less in the community. On average, each Bainbridge Island resident drove fewer miles, resulting in emissions decreases.

- **Decreased on-road emissions per mile (-1,061)** represents changes in the amount of emissions per vehicle mile driven. These changes could be due to better driving behavior or more fuel-efficient vehicles.

- **Decreased energy use per household (-1,687)** denotes a decline in the amount of energy used by the average Bainbridge Island household. This change could be due to more energy efficient behaviors or appliances.

- **Decreased commercial energy use per job (-3,754)** incorporates the fact that job growth has increased, but a large conversion of energy efficient standards has been made throughout the commercial sector resulting in a decrease in emissions.

[15] These sources are classified as "not analyzed" because population is used as a scaling factor to estimate emissions for these sources, and therefore population growth is already "baked into" the estimation. Thus, it would be inappropriate to group these sources with the "growth in population" driver.

Municipal Operation Emissions

The municipal operation emissions inventory accounts for the GHG emissions resulting from Bainbridge Island City government operations. Bainbridge Island's government provides a range of municipal services including police, streets, planning, zoning, and general administration services. The City also operates the water and wastewater utilities for a portion of the island.

Table 14 below provides an outline of the various emissions sources included in the municipal inventory, paired with their respective Scope. The table also specifies which sectors are required by the *Local Government Operations Protocol.*

Table 13. Municipal inventory emissions and scope categories.

Emissions Type	Required?	Scope 1	Scope 2	Scope 3
Buildings and Facilities Energy				
Electricity	×		✓	
Stationary Fuel Consumption	×	✓		
Streetlights and Traffic Signals	×		✓	
Transportation				
On-Road Fleet Vehicles	×	✓		
Off-Road vehicles	×	✓		
Employee Commute				✓
Business Travel				✓
Solid Waste, Potable Water, and Wastewater				
Solid Waste				✓
Wastewater Treatment	×	✓		
Refrigerant Leakage	×	✓		

RESULTS

Overview

Bainbridge Island's 2014 municipal-based GHG inventory totaled 2,067 $MTCO_2e$. Municipal emissions in 2018 increased 11% to 2,291 $MTCO_2e$. Major emissions sources in 2018 included facility electricity consumption (60%) and on-road fleet vehicles (17%) (see Table 15).

Transportation and electricity also contributed some of the largest increases in emissions from 2014 to 2018. Municipal facility electricity and on-road fleet vehicles increased by 14% and 7%, respectively. Just four facilities accounted for 80% of all facility electricity use: Bainbridge Island Waste Water Treatment Plant (WWTP), City Hall, Fletcher Bay: Well Field, and Bainbridge Island Public Works Operations and Maintenance Yard. There were a few sectors with decreases in emissions, the largest of which was from streetlight and traffic signal improvements.

Table 14. Municipal GHG emissions by year, sector, and scope.

		GHG Emissions ($MTCO_2e$)	
Sector	**Scope**	**2014**	**2018**
Building Propane	1	40	40
On-Road Fleet Vehicles	1	359	385
Off-Road Vehicles	1	77	63
Refrigerant Loss	1	18	18
Wastewater Treatment Plant	1	40	43
Electricity	2	1,212	1,383
Street Lights & Traffic Signals	2	103	91
Solid Waste Generation	3	59	84
Employee Commute	3	160	184
Business Travel	3	-	-
Total		**2,067**	**2,291**

Figure 19. Municipal emissions, by source and scope, for 2018 (total = 2,291 $MTCO_2e$).

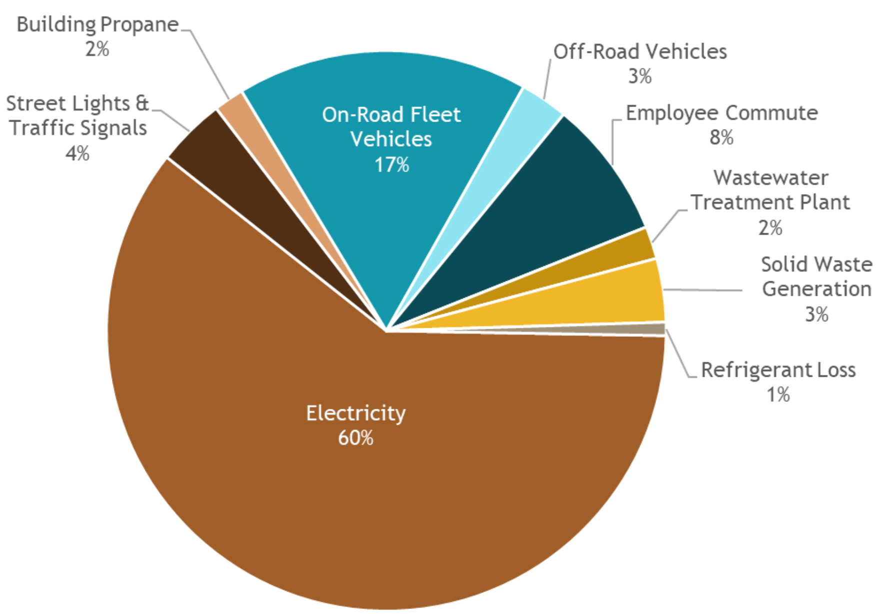
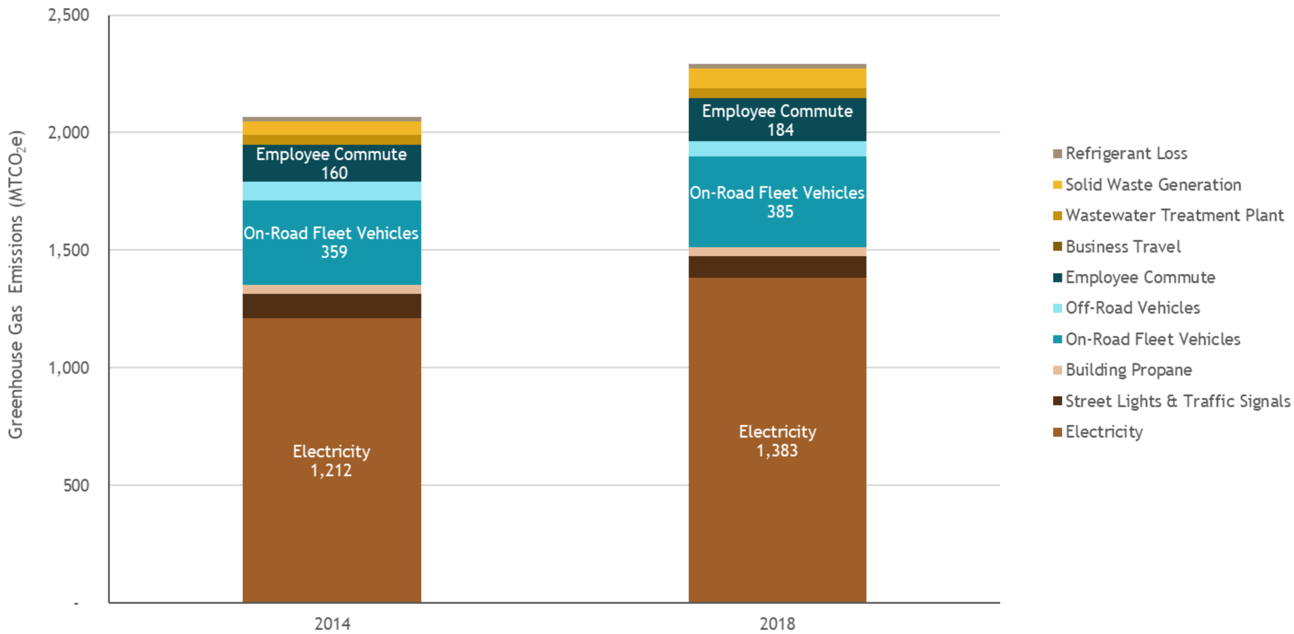


Figure 20. Bainbridge Island municipal emissions, by year and source.

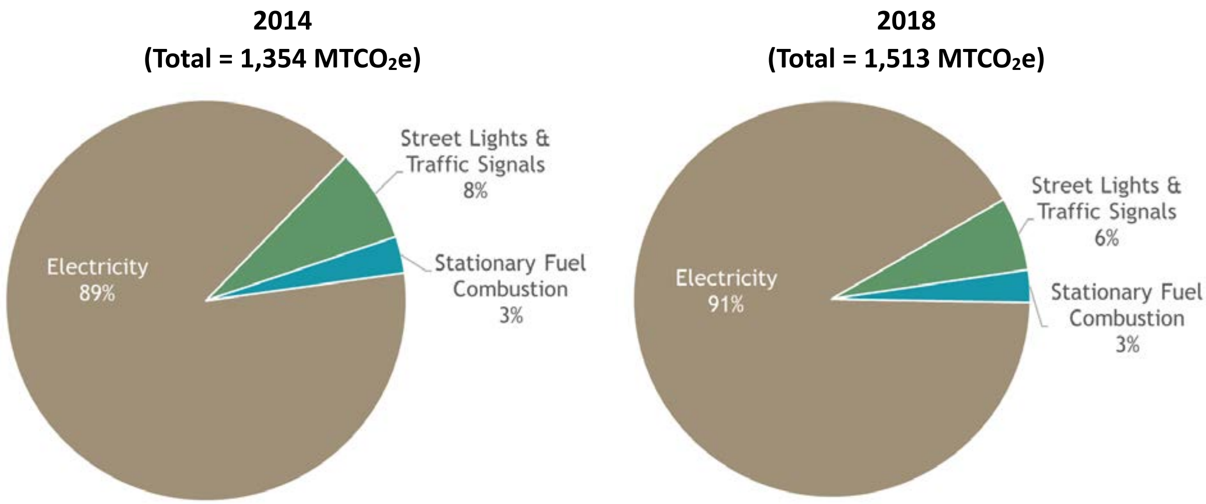


Buildings and Facilities Energy

The City of Bainbridge Island operates several government administration buildings, including City Hall, the Police Station, the Municipal Court, and a maintenance yard, as well as several community spaces, a wastewater treatment facility, and the streetlights and traffic signals throughout the City. This section details the GHG emissions resulting from the consumption of energy at these buildings and facilities. The types of energy consumed at these locations include electricity, provided by Puget Sound Energy, and propane, which is combusted in stationary equipment on-site.

In 2018, energy consumption at City of Bainbridge Island buildings and facilities accounted for 66% of total municipal GHG emissions. Building electricity usage accounted for the bulk of emissions, comprising 89% and 91% of the energy sector's emissions in 2014 and 2018, respectively (see Figure 22). From 2014 to 2018, building and facility electricity emissions grew by 14%, primarily due to fluctuations in the electricity utility fuel mix (see *Electricity* section below). The following sections provide greater detail on trends for the three sources of building and facility energy use: electricity, stationary fuel combustion, and streetlights and traffic signals.

Figure 21. Bainbridge Island municipal buildings and facilities energy emissions.



Electricity

Electricity usage contributed the largest portion of GHG emissions within the City's buildings and facilities sector, resulting in the emission of 1,212 $MTCO_2e$ in 2014 and 1,383 $MTCO_2e$ in 2018. Between 2014 and 2018, electricity emissions grew by 14%. However, electricity usage in kWh only grew by 4% within this same time period. This indicates that the growth in emissions between 2014 and 2018 was primarily due to fluctuations in the electricity utility fuel mix (i.e., changes in the proportion of fossil fuel sources used by the utility to generate electricity in a given year) rather than substantial increases in electricity usage.

The two facilities with the greatest electricity usage in both years were the wastewater treatment facility (WWTP) and City Hall. These two facilities also experienced the greatest *reductions* in electricity usage between 2014 and 2018, demonstrating that the City is continuing to make progress on energy efficiency and conservation in the highest consumption facilities (see Figure 23 Figure 24 below). One way the City has reduced electricity usage at City Hall is through on-site solar electricity production: the solar panels at City Hall produced 71,300 kWh and 74,500 kWh of solar electricity in 2014 and 2018, respectively.

Figure 22. Top electricity-using facilities in 2018.

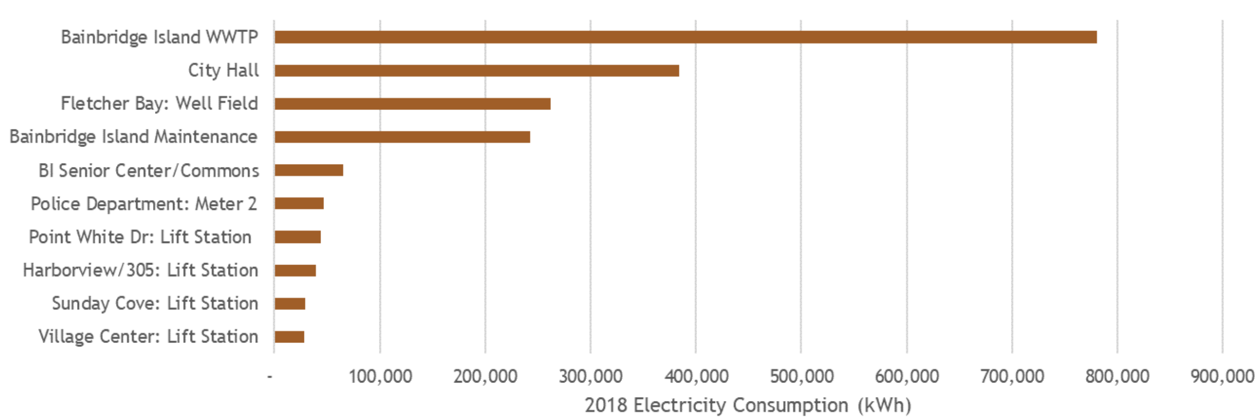


Figure 23. Facilities with the greatest electricity consumption *increases* between 2014 and 2018.

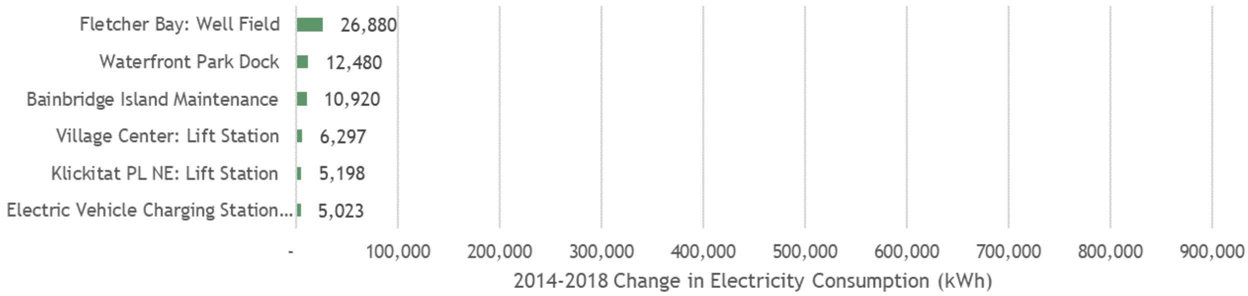
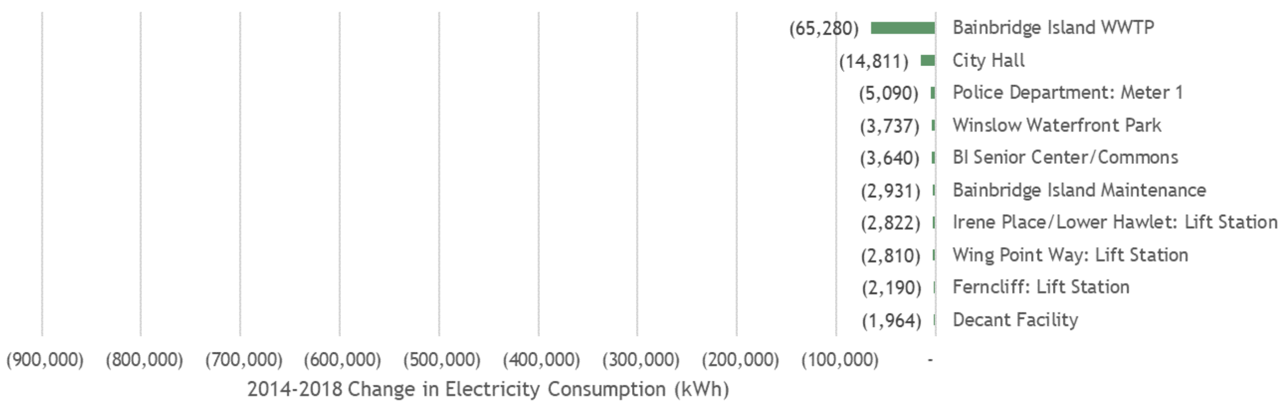


Figure 24. Facilities with the greatest electricity consumption *decreases* between 2014 and 2018.



Stationary Fuel Combustion

Stationary fuel (propane) combustion was the lowest contributor to building-related municipal GHG emissions in both 2014 and 2018. Between both years, emissions remained constant at 40 $MTCO_2e$. The only source for stationary fuel combustion is the Public Works Operations and Maintenance shop, which consumed an estimated 7,077 gallons of propane for heating. The number of gallons consumed remained constant from 2014 to 2018 and therefore resulted in no change in emissions.

Streetlights and Traffic Signals

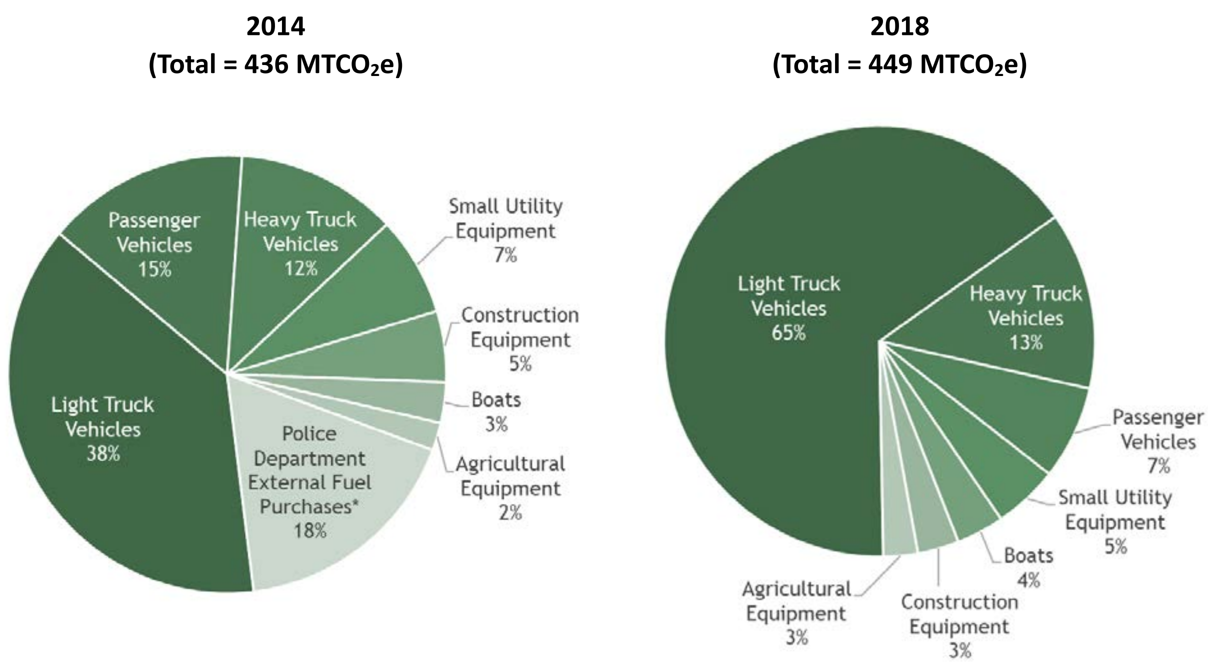
The second largest contributor to GHG emissions 2018 were streetlights and traffic signals. Between 2014 and 2018, the City of Bainbridge Island increased the number of streetlights from 328 to 343. However, the emissions produced and electricity consumed by the streetlights has decreased by 12%. This decrease can be attributed to the City's increased use of energy efficient bulbs.

Transportation

Transportation sector emissions are the third largest contributor to the City of Bainbridge Island's municipal emissions. This section details the GHG emissions resulting from the consumption of gasoline, diesel, biodiesel, and propane in various vehicles. These vehicles are a part of numerous city operations, such as emergency services, landscaping, and government travel.

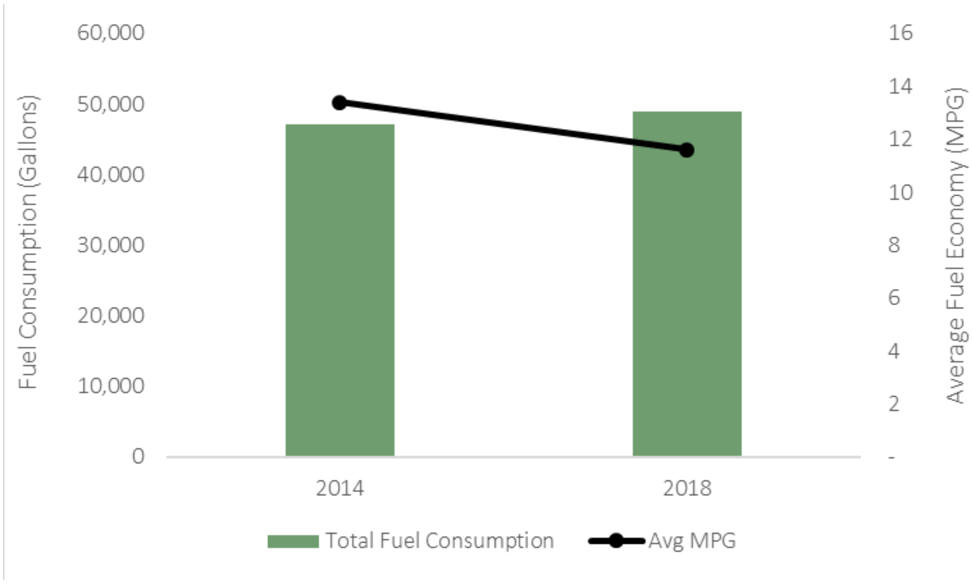
In 2018, the transportation sector contributed 28% of all emissions, totaling 663 $MTCO_2e$. The City of Bainbridge Island utilizes fuel for different vehicles such as boats, pickup-trucks, dump trucks, construction equipment, and patrol vehicles (see Figure 26). Municipal fuel consumption and emissions increased between 2014 and 2018, and there was a small decrease in fuel economy. Between 2014 and 2018, average municipal fuel economy decreased from 13 mpg to 12 mpg (see Figure 27).

Figure 25. City of Bainbridge Island fleet vehicle emissions, by type.



* *Refers to police department fuel purchased outside of O&M. This data is not connected to specific vehicle types.*

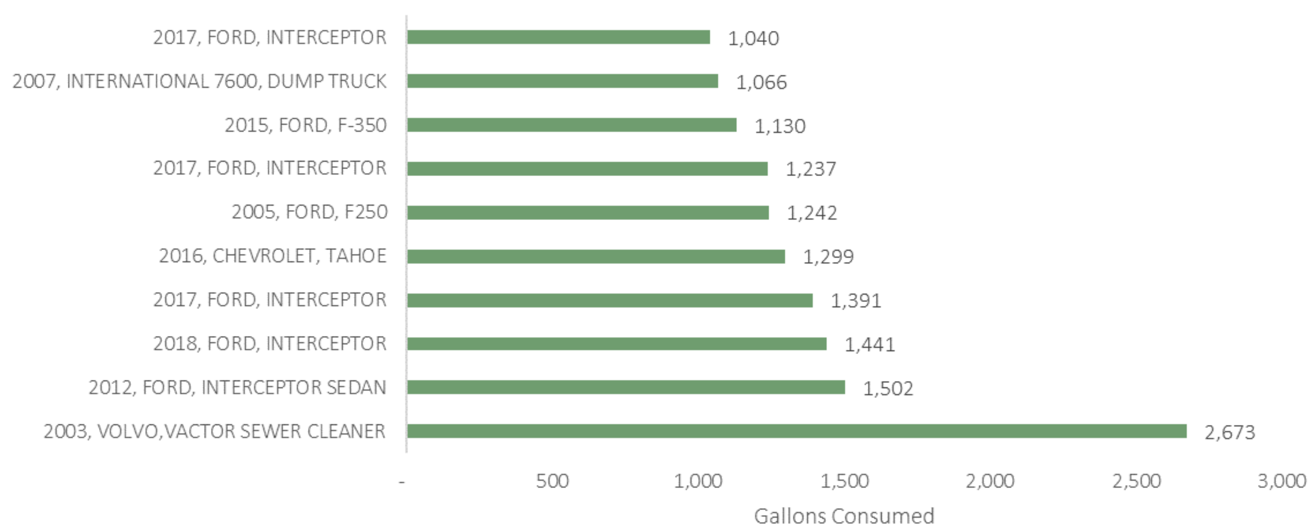
Figure 26. Municipal fleet fuel consumption and average fuel economies, by year.



On-Road Fleet Vehicles

On-road vehicles made up the majority of transportation emissions in 2014 and 2018. Emissions come from on-road fleet vehicles driving on roadways within the community. In 2018, on-road vehicles consisted of 61% of all transportation sector emissions. We estimate that municipal on-road vehicles produced 359 $MTCO_2e$ and 385 $MTCO_2e$ in 2014 and 2018, respectively. The 2003 Volvo Vactor Sewer Cleaner consumed the greatest amount of fuel both years (1,518 gallons of diesel in 2014 and 2,673 gallons in 2018). The Patrol/Interceptor vehicles sector contained the largest number of fuel-consuming vehicles. Figure 28 presents the top-10 fuel consuming vehicles in 2018.

Figure 27. Top 10 fuel-consuming fleet vehicles, 2018.



Off-Road Vehicles

Off-road equipment, such as lawnmowers, boats, and forklifts, contribute another 10% of transportation sector emissions in 2018. There was a 17% reduction in emissions between 2014 and 2018, from 77 $MTCO_2e$ to 63 $MTCO_2e$. Reductions in emissions are from reduced fuel consumption, decreasing from 7,730 gallons in 2014 to 6,474 gallons in 2018.

Employee Commute

Employee commute includes single-occupancy vehicles (SOV), vanpools and carpools. In 2014, employee commuting produced an estimated 160 $MTCO_2e$ from 486,922 VMT. There were 106 full-time equivalent municipal employees, resulting in 1.51 $MTCO_2e$ emitted per employee. The emissions increased in 2018 to 184 $MTCO_2e$. This was a consequence of an increase in VMT to 646,027. In 2018, there were 119 full-time equivalent employees for the city with only a small increase to 1.55 $MTCO_2e$ per person.

Solid Waste and Wastewater

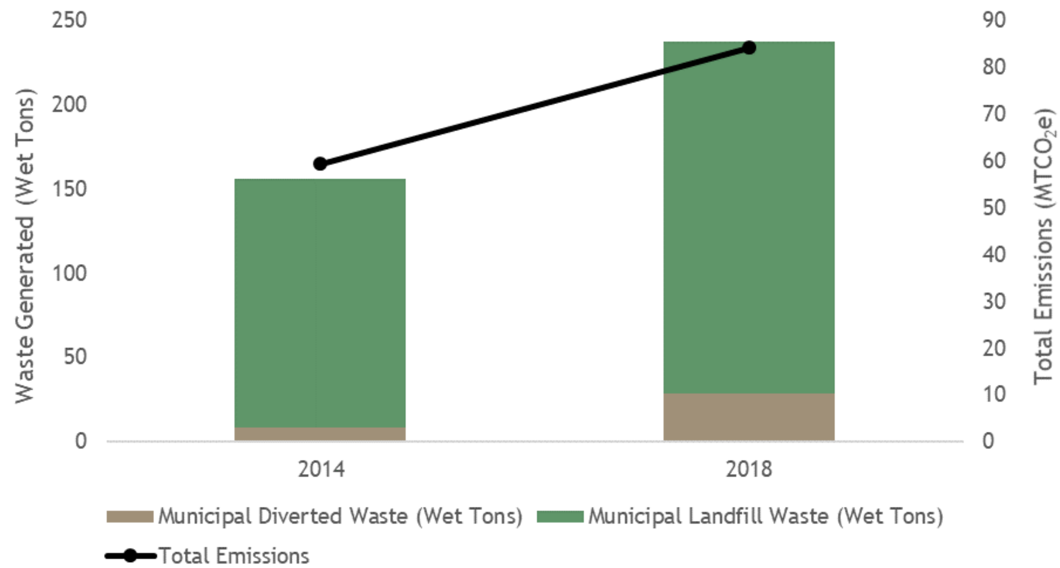
Waste sector includes emissions from solid waste generation and biological process emissions related to wastewater treatment—detailed below.

Solid Waste

Solid waste is comprised of municipal landfill waste and municipal diverted waste (recycling, cardboard, and yard waste). We estimate that emissions from waste increased from 59 $MTCO_2e$ in 2014 to 84 $MTCO_2e$ in 2018. Much of this increase can be attributed to additional service at the Waterfront Park and downtown areas. An increase in foot traffic in the Winslow downtown area, as well as the reconstruction of the Waterfront Park and City Dock, required the installation of more waste receptacles in these areas. We estimate that 147 tons of waste was sent to the landfill in 2014 and that amount increased to 209 tons in 2018.

Between 2014 and 2018, the amount of diverted waste increased from 8.6 tons to 28.8 tons. Yard waste in particular, increased from 2.1 tons in 2014 to 3.9 tons in 2018. This increase in yard waste composting contributed to a slight increase in emissions within the diverted waste category, from 0.15 $MTCO_2e$ to 0.27 $MTCO_2e$ (Figure 29).

Figure 28. Municipal solid waste disposal trends.



Wastewater Treatment

The City owns and operates the Winslow Wastewater Treatment Plant and operates collection for the South Island Sewer System. The Winslow Sewer System serves the historic downtown Winslow area and the South Island Sewer System serves the Lynwood Center, Point White, Pleasant Beach, Emerald Heights, Blakely School, and Rockaway Beach neighborhoods. The collection systems have a combined infrastructure that includes emergency generators, manholes, residential grinder pumps and sewage pump stations.

In 2018, emissions from wastewater treatment totaled an estimated 43 $MTCO_2e$. This was an 7% increase from 2014 when emissions were 40 $MTCO_2e$. This can be attributed to the increase in population served from 4,743 in 2014 to 5,079 in 2018.[16]

Refrigerant Leakage

Leaks in refrigeration systems cause emissions of potent greenhouse gases. These losses can occur in domestic refrigeration, commercial refrigeration, industrial refrigeration, chillers, and residential/commercial air conditioning units. Refrigerant gases differ in their Global Warming Potential (GWP)—the amount of heat a greenhouse gas traps in the atmosphere relative to carbon dioxide. Emissions from R-22 leaks, for example, are especially impactful: they have a GWP 1,760, which means that they are over one thousand times more damaging than carbon dioxide. The City's heating and cooling systems largely use R-22, which we estimate produces 18 $MTCO_2e$ per year.

[16] Service populations were estimated at 25% of the total Bainbridge Island population, as estimated by Bainbridge Island City staff.

DATA SOURCES AND METHODOLOGY

The municipal emissions inventory involved acquiring the following data types, summarized in Table 16 and detailed in the following sections:

- **Activity data** that quantifies levels of activity that generate GHG emissions, such as miles traveled, and kWh of electricity consumed.
- **Emissions factors** that translate activity levels into emissions (e.g., $MgCO_2e$ per kWh).

Data quality is assessed and reported on a High (H), Medium (M), and Low (L) scale in accordance with GHG inventory best practices:

- A *High* rating indicates data are detailed and specific to the local geography
- A *Medium* rating indicates data are more general or modeled with robust assumptions and may not be specific to the local geography, but are downscaled from a slightly broader geography (e.g., state-level)
- A *Low* rating indicates data are highly modeled, uncertain, or a default value was used based on national characteristics.

Table 15. Key data sources for the City of Bainbridge Island's municipal inventory.

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
Buildings and Facilities Energy				
Electricity	• kWh consumption compiled from PSE bills	H	• PSE reported emissions factors (PSE Greenhouse Gas Inventory, 2014 & 2017, Table 7.1)	H
Stationary Fuel Combustion	• Gallons of propane used for heating compiled based on municipal purchasing information provided by O&M	M	• Emissions factors provided in ClearPath program	M
Streetlights and Traffic Signals	• Quantity, type, and wattage of each streetlight and traffic signal transcribed from PSE bills • Installed wattage used to estimate electricity consumption in kWh	M	• PSE reported emissions factors (PSE Greenhouse Gas Inventory, 2014 & 2017, Table 7.1)	H
Transportation				

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
On-Road Fleet Vehicles	• Fuel volumes by vehicle and type, along with annual miles traveled, provided by Public Works staff • Where fuel volumes and miles traveled were unavailable for specific vehicles, the total quantity of fuel purchased was provided (with no vehicle information associated)	H	• CO_2 emission factors provided in ClearPath program • CH_4 and N_2O average emissions factors for each vehicle and fuel type were calculated based on the model year composition of the municipal fleet vehicles • Emissions factors used in these calculations were derived from the EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks (Climate Leadership Resource)	H
Off-Road Vehicles	• Fuel volumes by vehicle and type, along with annual hours of use, provided by Public Works staff • Where fuel volumes were unavailable for specific vehicles, the total quantity of fuel purchased was provided (with no vehicle information associated)	H	• Emissions factors provided in ClearPath program • Emissions factors for off-road vehicle/equipment propane use were missing from the ClearPath program; these emissions were calculated separately using emissions factors derived from the EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks (Climate Leadership Resource)	M
Employee Commute	• $MTCO_2e$ obtained from Commute Trip Reduction survey conducted by WSDOT	M	• N/A; value converted to $MTCO_2e$ by WSDOT	N/A
Solid Waste and Wastewater				
Solid Waste Generation	• Bin sizes, pickup frequency, and waste type were transcribed from solid waste bills • Estimated cubic yards of waste were then converted to tons using EPA solid waste weight conversions • This methodology assumes all waste pickup containers were full	L	• Waste characterizations from King County multifamily and commercial buildings used to estimate Bainbridge Island municipal waste composition • ClearPath default emissions factors used to estimate all future methane emissions resulting from the decomposition of each waste type	L
Wastewater Treatment Facility	• Wastewater treatment facility processes determined based on desktop research and confirmed with city staff • Population served by wastewater treatment facility estimated by multiplying the number of sewer connections (city staff) by the average household size (ACS)	M	• Local Government Operations Protocol equations 10.8 and 10.10 used to calculate N_2O emissions • CH_4 emissions were not applicable since the system is aerobic	L
Refrigerant Leakage				

Sector	Activity Data (AD)	AD Quality	Emissions Factors (EF)	EF Quality
Refrigerant Leakage from Building Heating and Cooling Equipment	• List of heating/cooling equipment provided by city staff • Equipment categorized by type and refrigerant used	L	• Emissions calculated using Equation 6.35 and the default factors in Table 6.4 of the Local Government Operations Protocol	L

Buildings and Facilities Energy

- We acquired **electricity consumption** data by hand transcribing individual monthly PSE electricity bills for the City of Bainbridge Island's municipal operations. City staff photocopied and provided these bills.
- In 2018, gallons of **propane** used to heat the **maintenance shop** were tracked in City records. However, only cost information was tracked in 2014. Based on the comparison of cost information between the two years, City staff estimated the propane use at this facility was the same in 2014 and 2018.
- **Propane usage** in an emergency generator at the Senior Center was omitted from the 2014 and 2018 inventories. In 2014, the generator was not maintained by the City and in 2018 the generator was not used.
- We estimated the total **electricity usage of streetlights and traffic signals** operated by the City of Bainbridge Island by counting the number, wattage, and types of streetlights and traffic signals included in the individual monthly PSE electricity bills. We used Equation 6.15 in the *Local Government Operations Protocol* to convert wattage to estimated electricity consumption in kWh. We assumed an average daily operating time of 12 hours for streetlights and 8 hours for traffic signals.

Transportation

- We categorized the list of **on-road and off-road vehicles** and equipment into standard vehicle types (i.e., passenger car, light-duty truck, heavy-duty truck, etc.) based on provided vehicle descriptions and make/model information. We totaled fuel gallons and vehicle miles traveled by each vehicle category and type of fuel. CO_2 emissions were derived based on usage volumes by type of fuel and ClearPath default emissions factors. CH_4 and N_2O emissions were derived based on miles traveled by vehicle category and fuel type. We used CH_4 and N_2O emissions factors for each vehicle category-fuel type combination originally derived from the *EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks* and modified these factors to reflect the municipal fleet age composition.
- One forklift within the municipal fleet used **propane**. However, propane is not an available fuel type for off-road equipment in the ClearPath program. Therefore, we calculated propane emissions outside of ClearPath using emissions factors derived from the *EPA (2017) Inventory of U.S. Greenhouse Gas Emissions and Sinks.*
- We obtained total emissions (in $MTCO_2e$) associated with **employee commuting** from the *Commute Trip Reduction Survey* conducted by WSDOT.

Solid Waste and Wastewater

- We acquired **waste generation** data by hand transcribing individual monthly Bainbridge Disposal bills for the City of Bainbridge Island's municipal operations. City staff photocopied and provided these bills.
- Waste bills generally indicated the disposal bin volume, the pickup frequency, and the waste stream (i.e., recycling, yard waste, trash, etc.). We assumed that waste bins were full at time of pickup and

that waste described as recycling or cardboard was recycled, waste described as yard waste was composted, and waste described as trash was landfilled. We converted annual volumes of waste by type into tons of waste by type using EPA solid waste weight conversions. We then used King County waste composition information and ClearPath default emissions factors to estimate emissions associated with **waste generation and composting.**

- We estimated **wastewater treatment N_2O emissions** using Equation 10.7 and 10.10 of the *Local Government Operations Protocol.* Population served was estimated by Bainbridge Island City staff. Default nitrogen load information was used since local data was not available.

Refrigerant Leakage

- We acquired a list of **heating/cooling equipment** used in municipal buildings from Bainbridge staff. We did an online search of the equipment models and serial numbers to determine how to best categorize each piece of equipment. Using these categorizations, we estimated emissions from refrigerant leakage using Equation 6.35 and Table 6.4 of the *Local Government Operations Protocol*.

Considerations

There is some degree of uncertainty in any GHG inventory. This uncertainty can come from incomplete data, but it can also result from uncertainty in the methodology or emissions factors used in calculating units of activity (e.g. gallon of fuel, kilowatt-hour of electricity, short ton of solid waste) into CO_2-equivalent emissions. These considerations should inform future inventory and reporting efforts, including prioritization of additional data collection, understanding of inventory results, and in the development of mitigation goals and monitoring systems.

Considerations for the municipal operations inventory include:

- **Electricity consumption:** The hand transcribing of electricity and waste bills introduces a greater potential for human error.
- **Streetlight and traffic signal daily operations:** Assumptions made on average daily operating time could affect electricity consumption amounts.
- **Employee commuting emissions:** WSDOT modeled the *Commute Trip Reduction Survey,* therefore the methodology, such as emissions factors assumed for passenger vehicles, could be different from those used for community passenger vehicles.
- **Municipal vehicle fleet:** Some municipal feel vehicles and equipment are fueled by bulk fuel purchases or mobile fueling tanks. In these instances, we had to estimate vehicle miles traveled and vehicle composition, potentially affecting the CH_4 and N_2O calculations.
- **Solid waste generation:** Disposal frequency can be difficult to determine from solid waste bills—which was the only data available to deduce solid waste disposal amounts. We also lacked data on the amount of waste included in each disposal bin at the time of pickup, we assumed all bins were full. The hand transcribing of waste bills introduces a greater potential for human error.
- **Solid waste characterization:** Bainbridge Island lacked a local waste characterization study, therefore, we applied King County waste characterization data to estimate the relative proportions of different materials in the waste stream. The waste composition for Bainbridge Island may be different than for King County.
- **Wastewater treatment:** Due to limitations in local data availability, the calculations used were default national values based on the treatment method.

MUNICIPAL CONTRIBUTION ANALYSIS

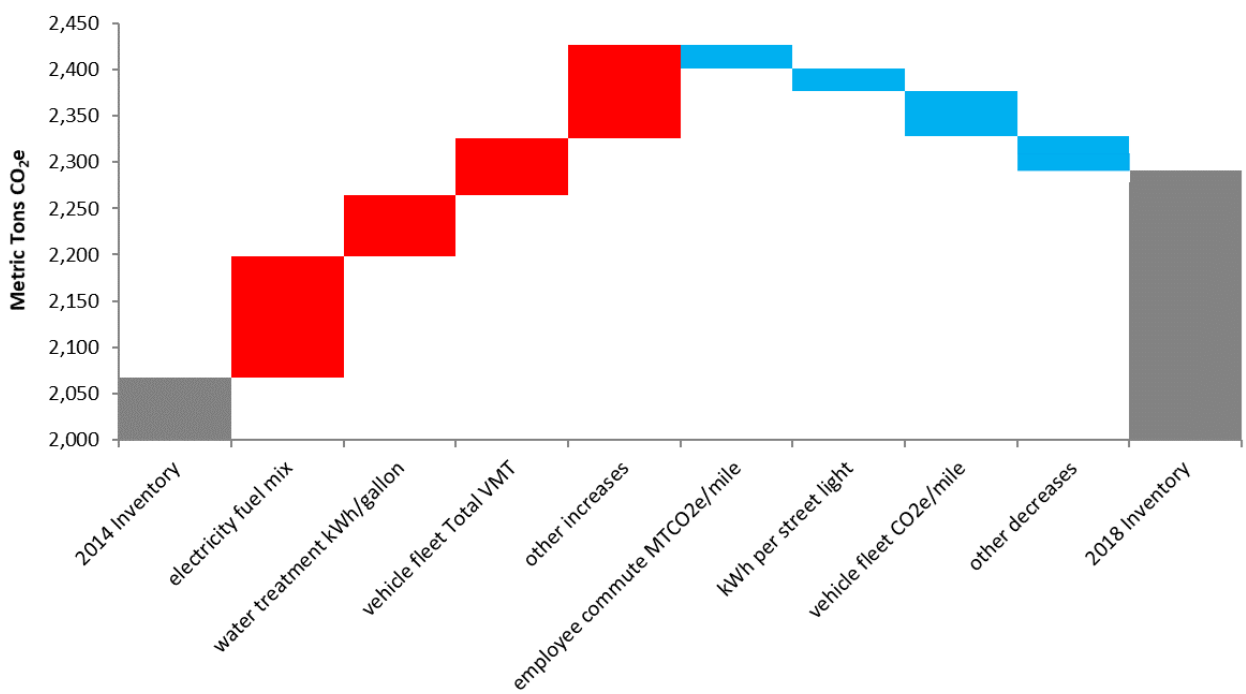
Introduction

In 2014, total municipal emissions were 2,067 $MTCO_2e$. In 2018, total emissions increased to 2,291 $MTCO_2e$, resulting in a 11% (223 $MTCO_2e$) increase from the 2014 inventory. We employed the *Analyzing Drivers of Change in Greenhouse Gas Emissions Inventories* tool available from ICLEI USA to attribute changes in the municipal inventories to the economic, social and technological forces that caused them.[17] The primary goal of this tool is to provide a methodology for discovering the drivers for change between the two inventory years.

Results

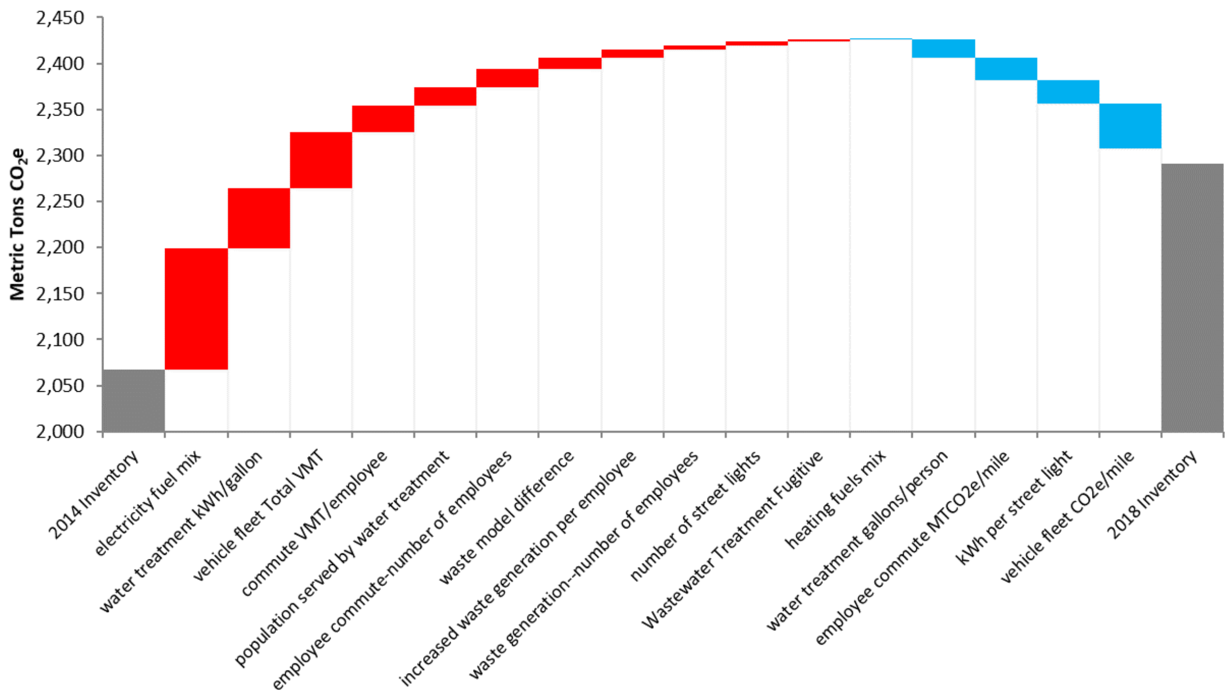
The contribution analysis revealed the factors that led to the net increase in emissions between 2014 and 2018. In summary, a lower-renewables electricity fuel mix as reported by Puget Sound Energy, increased water treatment electricity use, and increased use of fleet vehicles all contributed to emissions increases. Reductions were due to more carbon-efficient employee commuting, more energy-efficient streetlights, and increased fuel economy of the vehicle fleet. Figure 30 shows the influences of major forces on the inventory between 2014 and 2018, and Figure 31 presents a more detailed depiction.

Figure 29. High-level summary of major drivers of government operations inventory increase and decreases.



[17] ICELI USA *Analyzing Drivers of Change in Greenhouse Gas Emissions Inventories* tool. http://icleiusa.org/ghg-contribution-analysis/ (Accessed July 1, 2019).

Figure 30. Detailed depiction of contributions to change for Bainbridge Island government operations GHG emissions.



Contributors to inventory changes included the following, in order from highest increases to lowest decreases:

- **Electricity fuel mix (+131 MTCO$_2$e)** describes changes to types of resources used to generate electricity for the community. For example, increased use of renewable sources such as hydroelectricity and solar and wind power would drive emissions *decreases* in the electricity fuel mix. For Bainbridge Island, changes in the PSE electricity fuel mix contributed to *increases* in electricity emissions.
- **Water treatment kWh/gallon (+66 MTCO$_2$e)** includes changes in the energy efficiency of processing wastewater.
- **Vehicle fleet total VMT (+61 MTCO$_2$e)** describes the increased emissions due to a rise in total vehicle miles traveled for municipally owned vehicles.
- **Other increases (+103 MTCO$_2$e)** is a compilation of changes in: population served by water treatment, number of employees commuting, waste generation per employee, and number of streetlights.
- **Employee commute MTCO$_2$e/mile (-25 MTCO$_2$e)** represents more efficient commuting behaviors, possibly by changes in mode, distance, or vehicle efficiency.
- **kWh per street light (-25 MTCO$_2$e)** incorporates the fact that streetlight and traffic signal numbers have increased, but a large conversion to LED prior to 2018 reduced electricity use and emissions.

- **Vehicle fleet CO_2e/mile (-48 $MTCO_2e$)** is the reduction in emissions associated with reduced gasoline consumption in newer vehicles meeting more stringent federal standards, as well as the retiring of older, less fuel-efficient vehicles.
- **Other decreases (-21 $MTCO_2e$)** includes decreased emissions from changes in the type of heating fuels used and less wastewater produced per-person.

Consumption-Based Emissions

The purchasing decisions we make impact the environment. Some types of foods and materials, such as meat and furniture, can carry a significant GHG emissions burden. For example, meat and dairy cows emit methane—a potent greenhouse gas. Residents of Bainbridge Island who consume beef contribute to the emissions from these cows—even if the cows are raised outside the island. This section presents estimated emissions associated with the purchasing decisions made by Bainbridge Island households.

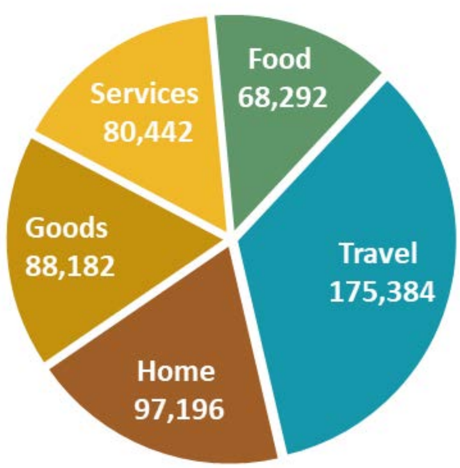
Consumption-based emissions are provided on a *per-household* basis because a household is the economic unit used in the underlying analyses (in other words, the analytical approach is based on household, not individual, purchasing trends and decisions). For example, food and home goods are generally purchased by one person for the use of their entire household.

RESULTS

Overview

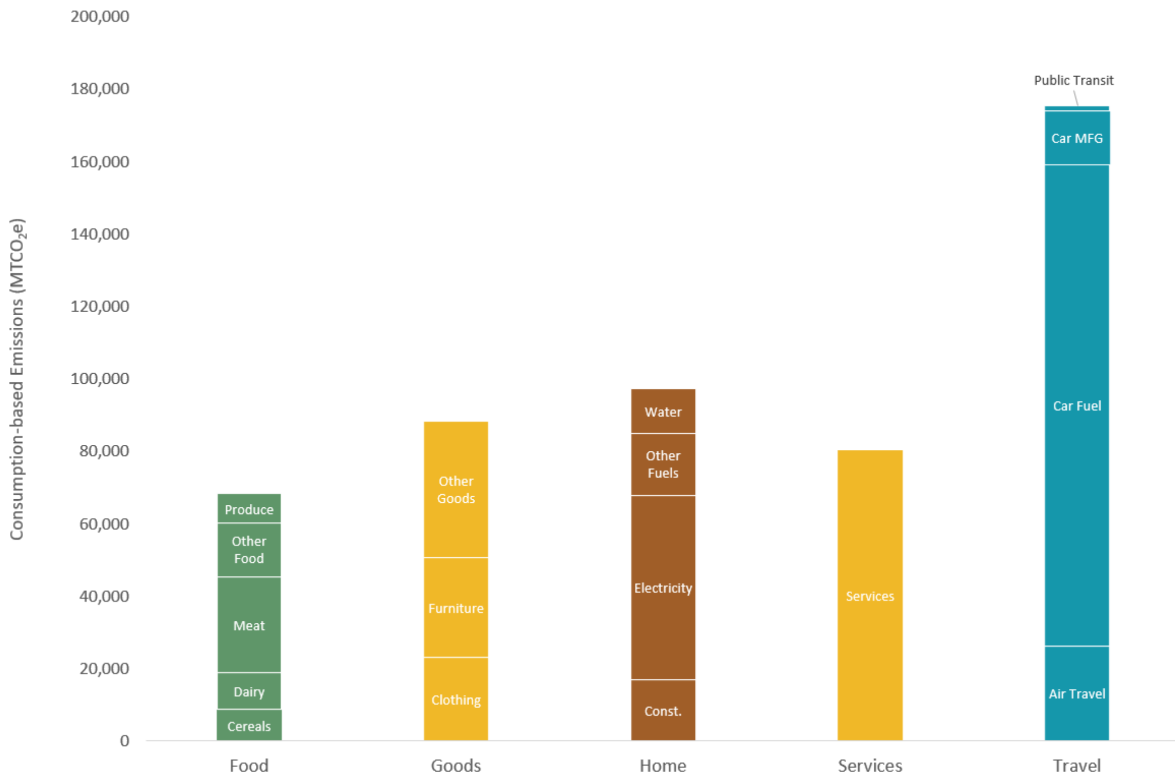
Results from a household-based economic modeling tool suggest that the average Bainbridge Island household emits 52 $MTCO_2e$ a year through their purchasing behaviors.[18] There were an estimated 9,404 and 9,798 households on Bainbridge Island in 2014 and 2018, respectively, indicating that total consumption-based emissions from all households on Bainbridge Island could have reached approximately 510,000 $MTCO_2e$ in 2018. Major drivers include the purchase of meat, furniture, clothing, home energy, and travel-related expenses such as car fuel and air travel (see Figure 32 and Figure 33).

Figure 31. Estimated 2018 consumption-based emissions for Bainbridge Island (total = 509,496 $MTCO_2e$).



[18] As indicated from U.C. Berkeley's *CoolClimate* Calculator. Outcomes from the consumption-based inventory analysis are presented at the per-household level because purchasing behavior is typically examined and analyzed at the household—not individual—level.

Figure 32. Estimated annual individual household consumption-based emissions for Bainbridge Island residents (total = 52 $MTCO_2e$/year).



DATA SOURCES AND METHODOLOGY

Because consumption-based inventories are inevitably coarse in scale compared to other inventory sectors, we used readily available sources to estimate Bainbridge Island's consumption-based emissions. Specifically, we used UC Berkeley's CoolClimate Calculator, which employs an Economic Input-Output Life Cycle Assessment model (EIO-LCA), designed by Carnegie Mellon University, and the Comprehensive Environmental Database Archive to calculate consumption-based emissions. This model employs an economy-wide model of cradle-to-grave emissions of all major greenhouse gases for over 400 economic sectors of the economy.

Considerations

The CoolClimate Calculator largely uses national-level data to estimate emissions associated with purchased goods and services. This means that more locally-specific emissions factors—such as those associated with the electricity we purchase—are not incorporated. For Bainbridge Island, that may mean that the calculator is slightly overestimating household emissions, since the Puget Sound Energy electricity fuel mix is different than the national average. However, the calculator does use regionally-specific economic data to characterize spending habits.

Conclusion and Next Steps

These GHG inventories provide a **solid and informative foundation** for taking climate action:

- The **Bainbridge Island community** now understands its major contributors of GHG emissions—residential electricity, non-residential electricity, on-road vehicles, and air travel—revealing major sectors to focus climate action efforts. Conducting inventories for two years also revealed emissions trends: a 9% increase between the two inventory years as well as increased emissions in almost all sectors. The community could consider approaches for addressing emissions sources that are increasing, such as increasing electric vehicle uptake, incentivizing alternatives to air travel, continuing to increase building use efficiency, and reducing growth. The contribution analysis also provided insight into the underlying drivers of these trends: we learned that continuing to push for lower-emissions electricity sources will be important for lowering Bainbridge Island's climate impact.
- The **City of Bainbridge Island** now understands its key drivers of greenhouse gas emissions—transportation, electricity, and wastewater treatment—which highlight key areas for reduction. The inventories for the two years demonstrated an upward trend in emissions, similar to the community inventory. Between 2014 and 2018, a 11% increase in emissions occurred. The municipal contribution analysis highlighted the drivers of these trends: changes in electricity fuel mix, water treatment operations, and vehicle fleet usage. The City of Bainbridge Island did see small reductions in streetlight and traffic signal use and fleet vehicle fuel economy. The City can consider actions for reducing emissions from increasing sources, such as transferring to a low-carbon electricity fuel mix and decreasing the amount of vehicle travel.
- **Bainbridge Island households** learned the impact of spending habits—an estimated 52 $MTCO_2e$ of emissions per year, on average. The consumption-based inventory also exposed key contributors to that footprint: meat consumption, travel expenses, and the purchase of furniture, clothing, and energy. Bainbridge households could consider behavior changes to lower these emissions, such as switching to a low-carbon diet-which includes more vegetables, fruits and whole grains; utilizing alternative forms of travel; and purchasing second-hand goods.

This foundational work also illuminated opportunities for **improving and expanding future inventories**. We were not able to obtain data related to commercial propane use, for example. The City can continue to work with local propane vendors to start collecting these data and, eventually, begin incorporating this important emissions source into the city's inventory. These and other improvements will not only paint a fuller picture of the community's overall environmental impact but can also motivate businesses and individuals to better understand their personal carbon footprint and identify pathways for reducing that impact.

References

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Appendix: Tree Carbon Sequestration

While inventories focus on emissions of greenhouse gases *into* the atmosphere, vegetation such as trees and grasslands can sequester—or absorb—carbon dioxide *from* the atmosphere. Land use changes, such as development of open and working forest and agricultural lands, can affect this process. To illustrate and better understand this benefit, we sought to quantify the extent to which existing trees in Bainbridge Island sequester carbon from the atmosphere.

It is important to note that while vegetation on Bainbridge Island is taking carbon dioxide out of the atmosphere, this process does not offset or counteract emissions of greenhouse gases from the community, as quantified in the other sections of this report. Such land carbon "offsets" can only be achieved through rigorous and verifiable changes in land management that result in a net increase in carbon sequestration as compared to a pre-established baseline. This analysis does not quantify such activities, but rather offers some insight into the ecosystem services the trees and natural and working forests of Bainbridge Island provide, and the potential losses of services that could result from their development or removal.

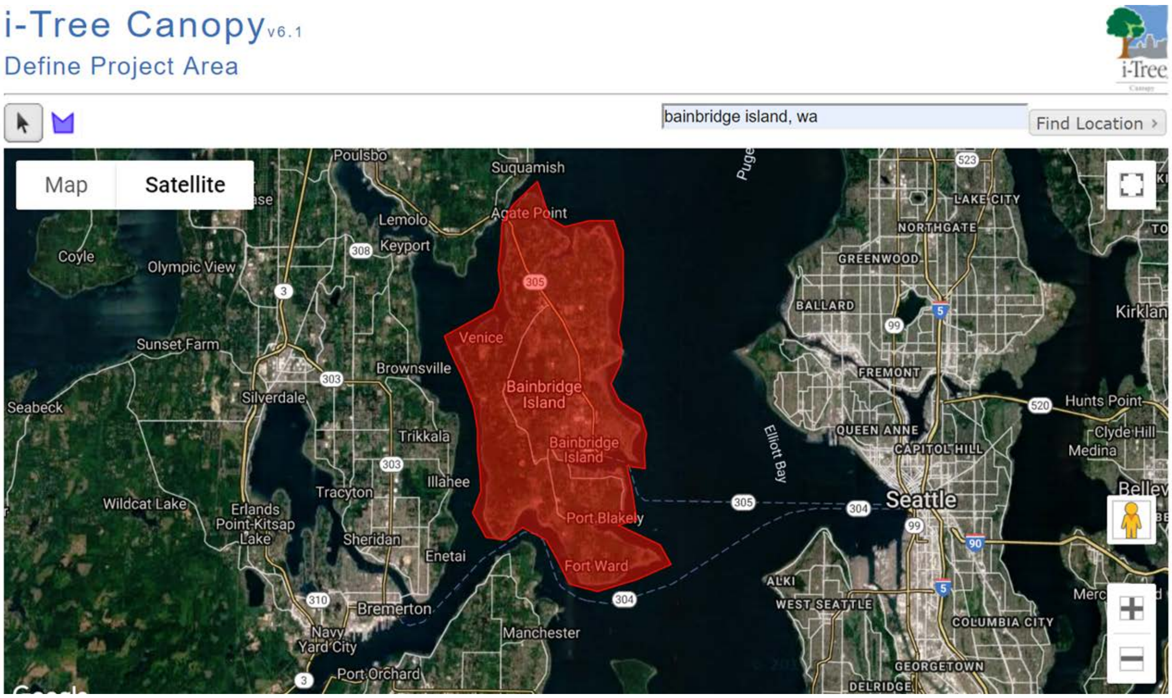
DATA SOURCES AND METHODOLOGY

We utilized the i-Tree Canopy software to estimate annual tree carbon sequestration on Bainbridge Island. The software facilitates a supervised random sampling using Google Maps aerial photography. Specifically, the software walks users through the following steps:[19]

- **Define the project area** using Google Maps aerial photography (see Figure 35).
- **Select project location** using dropdown menus. This step characterizes per-acre carbon sequestration based on anticipated vegetation types (e.g., types of trees) typical in that location. For Bainbridge Island, the selected location was Kitsap County (see Figure 36).
- **Conduct random sampling**. i-Tree Canopy shows a magnified image from the project area with a point identified with crosshairs (see Figure 37). The user then identifies whether the crosshairs are on a tree or "non-tree" area.
- **Repeat random sampling.** The tree/non-tree identification is repeated multiple times to increase statistical precision of the estimated percent tree canopy cover of the project area. For this exercise, we classified 100 random samples.
- **Analyze results.** i-Tree Canopy uses the random sampling to provide an estimate of overall percent tree canopy cover and resultant tree carbon benefits. The estimate carries a level of uncertainty (results are indicated by a mean value +/- one standard error). This uncertainty stems from limitations associated with the sampling approach.

[19] More information regarding the methodology used by i-Tree Canopy can be found at https://canopy.itreetools.org/resources/iTree_Canopy_Methodology.pdf.

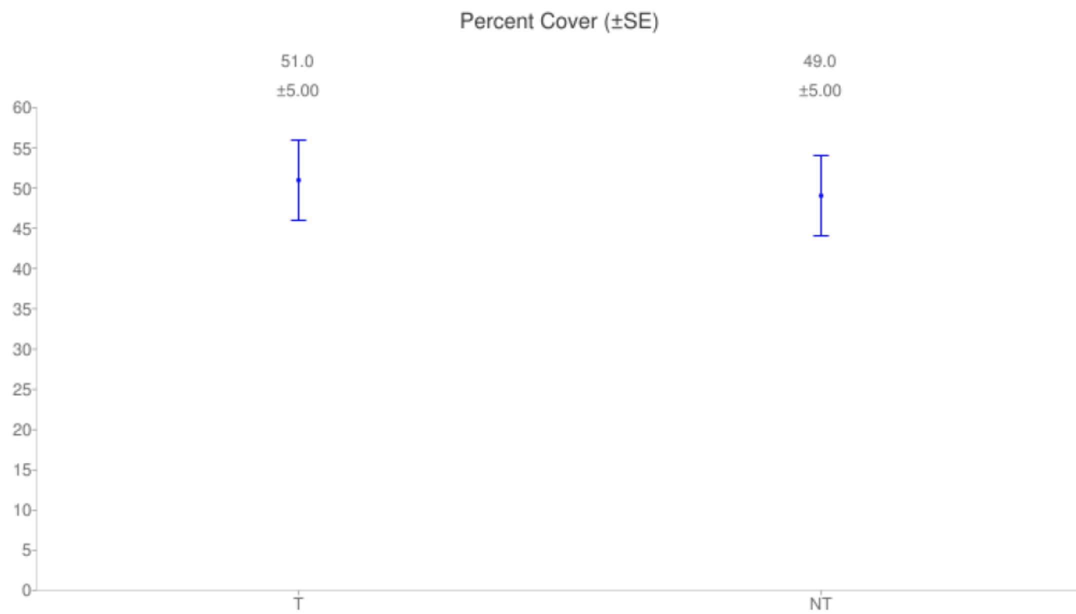
Figure 33. Defining the project area within i-Tree Canopy.



RESULTS

Outcomes from the i-Tree Canopy analysis suggest that 51% of the Bainbridge Island land mass was covered with trees in 2018.[20] Those trees sequester an estimated 58,727 $MTCO_2e$ from the atmosphere every year.[21] This value appears to have decreased slightly since 2014; sampling of historical aerial imagery suggests a tree canopy cover of 55% in 2014 (equivalent to an estimated 63,334 $MTCO_2e$ annual sequestration rate).[22] This change in tree canopy cover would result in an estimated net loss of 4,607 $MTCO_2e$ in carbon sequestration benefits annually.

Figure 34. Estimated tree canopy cover on Bainbridge Island in 2018, using random sampling from the i-Tree Canopy software.[23]



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	51	51.0 ±5.00
Non-Tree	All other surfaces	NT	49	49.0 ±5.00

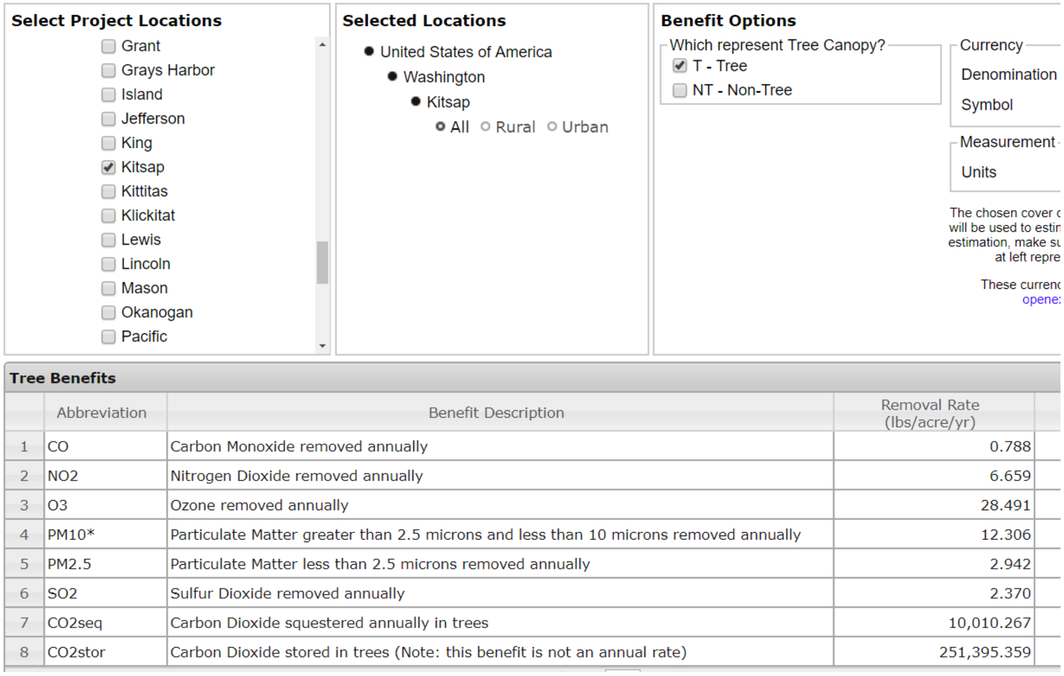
[20] Value depicted as mean estimate, with 95% confidence interval of 41.2% to 60.8%.

[21] Assumes a sequestration rate of 10,010 lbs. CO_2/acre/year. Source: i-Tree Canopy v.6.1.

[22] Value depicted as mean estimate, with 95% confidence interval of 45.3% to 64.7%.

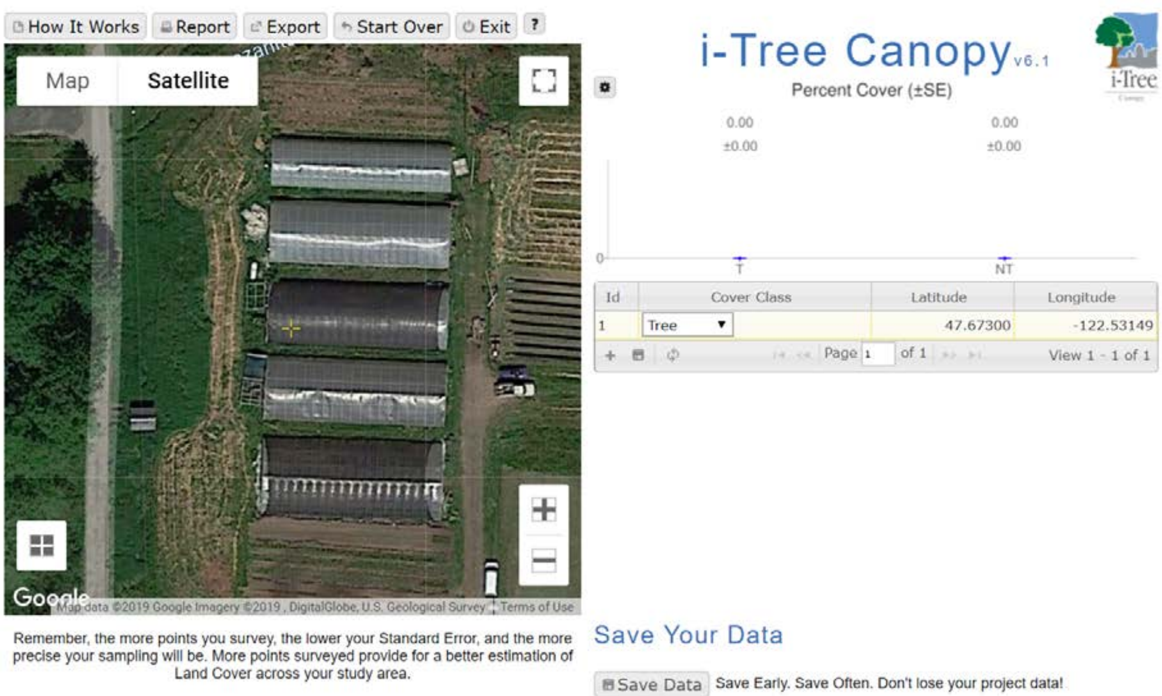
[23] https://canopy.itreetools.org/

Figure 35. Selected project location for the Bainbridge Island study.



	Abbreviation	Benefit Description	Removal Rate (lbs/acre/yr)
1	CO	Carbon Monoxide removed annually	0.788
2	NO2	Nitrogen Dioxide removed annually	6.659
3	O3	Ozone removed annually	28.491
4	PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	12.306
5	PM2.5	Particulate Matter less than 2.5 microns removed annually	2.942
6	SO2	Sulfur Dioxide removed annually	2.370
7	CO2seq	Carbon Dioxide squestered annually in trees	10,010.267
8	CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	251,395.359

Figure 36. Example of random sampling classification exercise.



Considerations

This carbon sequestration analysis represents a high-level estimate of annual land carbon sequestration on Bainbridge Island. Data limitations and other considerations include the following:

- **Omission of non-tree vegetation:** This approach assumes that non-tree vegetation does not sequester carbon, which is not the case. This analysis does not include carbon benefits from non-tree vegetation such as agriculture, pasture, and shrubs.
- **Tree generalization:** This approach does not explicitly differentiate between tree types, but assumes that all trees sequester an average, representative amount of carbon every year.
- **Statistical sampling:** This approach extrapolates a statistical sampling of an area, rather than analyze the area in its entirety, which inevitably results in some level of statistical uncertainty and imprecision.