Greenhouse Gas Inventory Report for Calendar Years 2010 – 2016 Final Report

Thurston County, Washington

August 2018

Prepared by the Thurston Climate Action Team

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Acknowledgements

This report was developed as a result of Thurston Climate Action Team's (TCAT's) Greenhouse Gas (GHG) Inventory project. Tom Crawford, TCAT President, led the effort on behalf of TCAT, and recruited Dave Bradley, recently retired from the Department of Ecology, to work on the project.

Tom Crawford is one of the founders of TCAT and has served on TCAT's board since 2009. He holds a bachelor's degree in philosophy from Gonzaga University, and a Master's in Education (M. Ed.) from Eastern Washington University. Tom's background includes work with local and state governments nationwide to improve processes and automated systems, and with Native American communities throughout the Pacific Northwest on community development and educational projects.

Dave Bradley worked for the Department of Ecology for thirty years as a toxicologist and manager in the Toxics Cleanup, Air Quality and the Shorelands and Environmental Assistance Programs. Prior to joining Ecology, Dave worked in Washington DC for an environmental risk assessment consulting firm and the Ralph Nader organization. He holds an undergraduate degree in environmental engineering and a Master's in Toxicology, both from the University of Michigan.

Thurston Climate Action Team's board was instrumental in making this project a reality by defining the greenhouse gas inventory project as a priority for the organization and providing valuable guidance throughout the effort. Current TCAT board members, in addition to Tom, are:

- Scott Morgan, Sustainability Manager, The Evergreen State College;
- Geoffrey Glass, Director of Facility and Technology Services, Providence St. Peter Hospital;
- Dave Watterson, Tenino City Council member; and
- Bill Paulen, President and CEO, Community 1st Credit Union.

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Executive Summary

The Thurston Regional Planning Council's Sustainable Thurston plan — known formally as *Creating Places—Preserving Spaces: A Sustainable Development Plan for the Thurston Region* — includes a priority goal to "move toward a carbon-neutral community." This goal includes recommended emission-reduction targets for the Thurston region:

- Achieve a 25% reduction from 1990 greenhouse gas levels by 2020;
- Achieve a 45% reduction from 1990 greenhouse gas levels by 2035; and
- Achieve an 80% reduction from 1990 greenhouse gas levels by 2050.

A community's ability to take effective action on climate change depends on having information on greenhouse gas (GHG)[1] emissions. Planning for climate action begins with developing a GHG inventory. An inventory enables communities to understand the relative importance of different emission sources and measure progress on achieving emission reduction targets.

The Thurston Climate Action Team (TCAT) prepared this report in order to provide updated[2] information on GHG emissions that will enable regional decision makers to make informed choices about measures to reduce the region's carbon footprint. TCAT compiled data about emission sources for 2010 through 2016 and estimated GHG emissions for those years using internationally-accepted methods for preparing community emission inventories.

Key Findings

- The Thurston region's 2016 carbon footprint was 2,965,754 metric tons reported as carbon dioxide equivalents (MTCO2e). The 2016 emissions were 2% higher than the 2010 emission estimates.
- Per capita emissions in 2016 were 10.9 MTCO2e/person. Per capita emissions fell by 5% between 2010 and 2016 as the county's population rose from 252,624 to 272,700. Per capita emissions in the Thurston region are generally lower than the most recent per capita emissions estimates in Washington (13.7 MTCO2e in 2013) and the United States (20.1 MTCO2e in 2016).
- The Thurston region's per capita emissions were higher than the per capita emissions in several other communities in Washington and Oregon that have prepared greenhouse gas emission inventories. In general, these other communities have (1) higher population densities and more multi-family homes that tend to produce lower per capita building and transportation emissions and (2) cleaner sources of electricity (lower emissions of greenhouse gases per kilowatt-hour) where a larger share of the electricity used by the community is produced from hydropower and wind.
- Built environment emissions associated with the use of electricity and heating fuels represented 58% of the Thurston region's emissions in 2016. Built environment emissions increased by 2% between 2010 and 2016 while per-capita emissions declined by almost 6%.
- On-road transportation emissions represented 38% of the Thurston region's emissions in 2016. On-road

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[1] Greenhouse gases (GHGs) are natural and industrial gases that trap heat and warm the Earth's surface. This report estimates emissions of three GHGs (carbon dioxide, methane and nitrous oxide).

[2] In 2013, the Thurston Climate Action Team (TCAT) published a community-based greenhouse gas (GHG) emission inventory for calendar year 2010. The document was revised in 2014 (TCAT 2014).

emissions increased by 4% while per capita emissions declined by 4% between 2010 and 2016.

- Emissions from waste management activities and agricultural livestock represented 3% and 1%, respectively, of overall emissions in 2016. Waste-related emissions fell by 8% while per capita waste emissions declined by 15% between 2010 and 2016. Agricultural livestock emissions remained fairly constant.
- The Thurston region was able to make meaningful progress on achieving the Sustainable Thurston climate goals between 2010 and 2012 when emissions fell by over 7% during that two-year period. That progress was reversed during the subsequent four years, when emissions rose by almost 10%.
- Achieving the Thurston region's climate goals will require much deeper annual emission reductions than those achieved between 2010 and 2016.

Recommendations

Based on our review of current emission trends, TCAT recommends that the following actions be taken over the next 6-12 months:

1. Climate Action Strategies. Local governments should continue to develop and implement comprehensive strategies for reducing greenhouse gas emissions in the Thurston region while also pursuing on-going efforts to reduce emissions.
2. Standardize Emission Inventory Process. As part of their broader climate action strategies, local governments should prepare and publish annual or biennial emission inventory reports. To support this work, local governments should (1) identify a common set of source categories and (2) adopt common methods for preparing GHG emission inventories.
3. Consistency and Efficiency. Local governments should consider designating one agency (such as the Thurston Regional Planning Council (TRPC)) to prepare annual inventories for all local jurisdictions.
4. Funding. Local governments should provide sufficient funding for preparing up-to-date GHG emission inventories that can be used to measure progress on attaining climate action goals.
5. Evaluate Other Emission Sources. Local governments should evaluate whether to include additional source categories in future inventories. TCAT plans to continue to research methods and data sources for estimating emissions from additional source categories.
6. Evaluate Contributing Factors. Cascadia and Hammerschlag (2017) used a draft tool being developed by ICLEI-USA to mathematically evaluate the various factors contributing to changes in King County emissions between 2008 and 2015. When this tool becomes available for broader use, local governments should consider using it to evaluate trends and the effectiveness of local programs.
7. Land Use Sources and Sinks. Local governments should consider expanding their inventories to include land use emission sources and sinks that absorb carbon dioxide (e.g. forest, agricultural soils). The Environmental Protection Agency (EPA) evaluates both emissions and sinks when preparing the annual US greenhouse gas inventories. They estimated that carbon sinks in the US were equivalent to about 20% of GHG emissions in 2015 (EPA, 2017). Measures to enhance carbon sequestration in soils and trees could be an important part of the Thurston region's

efforts to achieve its 2050 target for reducing GHG emissions.

8. Periodic Review of Methods and Procedures. Local governments should periodically review the methods and procedures for preparing emission inventories taking into account current scientific information, state and federal policies, implementation experience and issues of local interest.

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Introduction

What is the purpose of this report?

The main purpose of this report is to provide updated information on greenhouse gas (GHG) emissions that will enable regional decision makers to make informed choices on measures to reduce the Thurston region's carbon footprint. The report includes:

- Estimated GHG emissions for the Thurston region for the years 2010 through 2016;
- Comparison of the Thurston region's GHG inventory with other community, state and federal GHG inventories; and
- Recommendations to improve future inventories for the Thurston region.

What are the Thurston Region's emission reduction goals?

The Thurston Regional Planning Council's Sustainable Thurston plan — known formally as *Creating Places—Preserving Spaces: A Sustainable Development Plan for the Thurston Region* — includes a priority goal to "move toward a carbon-neutral community." This goal includes recommended emission-reduction targets for the Thurston region:

- Achieve a 25% reduction of 1990 greenhouse gas levels by 2020;
- Achieve a 45% reduction of 1990 greenhouse gas levels by 2035; and
- Achieve an 80% reduction of 1990 greenhouse gas levels by 2050.

The Sustainable Thurston benchmarks are consistent with recommendations by expert scientific panels on the reductions needed to prevent serious climate hazards[3] and recommendations from the Department of Ecology (2016b) for revising existing state laws based on current scientific information.[4,5]

The cities of Lacey, Olympia and Tumwater, along with Thurston County, have committed to completing a regional climate mitigation plan. As this report is being published, each of these jurisdictions is adopting common targets for that regional plan. Those targets are consistent with the Sustainable Thurston targets, and use a more recent baseline year (2015). They are: 45% reduction below 2015 levels by 2030, and 85% below 2015 levels by 2050.

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3 The Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report (IPCC 2013) estimated that a 40-70% reduction below 2010 levels would be needed to limit global warming below 2 degrees C (IPCC, 2013). They also estimated that net global emissions will need to be reduced to zero by the end of the century and that it may even be necessary to eventually take actions to remove CO_2 from the atmosphere.

4 The Department of Ecology (2016b) recommended that the current state reduction limits be revised as follows: By 2020, reduce overall emissions to 1990 levels; by 2035, reduce overall emissions to 40% below 1990 levels; and by 2050, reduce overall levels to 80% below 1990 levels. This recommendation is consistent with limits established by states with active climate programs.

5 In 2018, the Legislature considered, but ultimately did not approve, several bills that would have incorporated Ecology's recommendations into the state's clean air laws. For example, SSHB 1444 would have revised the emission reduction targets in RCW 70.235.020 to incorporate Ecology's recommendations. This bill was not approved by the Legislature.

Table 1: Comparison of Greenhouse Gas Reduction Goals and Benchmarks				
	2020	2030	2035	2050
Thurston Region Climate Mitigation Plan		45% below 2015		85% below 2015
Sustainable Thurston	25% below 1990		45% below 1990	80% below 1990
Current State Law (RCW 70.235.020)	1990 levels		25% below 1990	50% below 1990
Dept. of Ecology (2016b)	1990 levels		40% below 1990	80% below 1990

The Sustainable Thurston reduction goals are also consistent with the reduction goals and benchmarks established by other communities in the Pacific Northwest. For example, the City of Olympia's comprehensive plan states that the City's goal is to reduce GHG emissions to 80% below 1990 levels by 2050 (City of Olympia, 2017).[6] Table 2 provides examples of the goals established by several other local communities in the Pacific Northwest.

Table 2: Comparison of Greenhouse Gas Reduction Goals and Benchmarks				
	2020	2030	2035	2050
Thurston Region Climate Mitigation Plan		45% below 2015		85% below 2015
Sustainable Thurston	25% below 1990		45% below 1990	80% below 1990
City of Ashland, OR	Reduce community emissions by 8%/year until 2050			
City of Bellingham	28% below 2000	40% below 2000		85% below 2000
City of Eugene, OR	Reduce emissions consistent with atmospheric levels below 350 ppm by 2100			
City of Olympia				80% below 1990
City of Seattle	Carbon neutrality (net zero emissions) by 2050			
City of Spokane		30% below 2005		
City of Tacoma				80% below 1990
King County				80% below 2007

A community's ability to take effective action on climate change depends on having information on greenhouse gas (GHG)[7] emissions. Planning for climate action begins with developing a GHG inventory. An inventory enables communities to understand the relative importance of different emission sources and measure progress on achieving emission reduction targets.

What data and methods were used to prepare this inventory?

This report provides a geographic-plus inventory that estimates emissions associated with activities within the Thurston region "plus" emissions associated with producing the electricity used in the community, even though that electricity is

[6] In 2015, the City joined the Compact of Mayors (now the Global Covenant of Mayors for Climate and Energy) and committed to developing a community greenhouse gas inventory (completed), developing emission reduction targets (completed) and developing a climate action plan (ongoing). Following the Trump Administration's decision to leave the Paris Climate Accord, the City committed, along with over 400 other communities, to continue to work to fulfill the US emission reduction commitments (reduce emissions to 26-28% below 2005 levels by 2025).

[7] Greenhouse gases (GHGs) are natural and industrial gases that trap heat and warm the Earth's surface. This report estimates emissions of three GHGs (carbon dioxide, methane and nitrous oxide).

generated outside the Thurston region. This inventory also includes emissions associated with the transportation and disposal of solid waste generated by residents and businesses even though solid waste is currently disposed at a landfill outside the Thurston region.

TCAT prepared this inventory in accordance with the requirements and procedures established by the Global Covenant of Mayors for Climate and Energy (2017).[8] TCAT estimated GHG emissions using the *U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions prepared by the* International Council of Local Environmental Initiatives (US Protocol) published by the International Council of Local Government Initiatives (ICLEI 2013a). This protocol was supplemented by the more recent '*Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories'* prepared by the World Resource Institute (WRI) and C40 Cities and ICLEI (WRI et al, 2014). The US and Global protocols provide an internationally-accepted method that enables comparisons with emission inventories prepared by other cities and counties.

The US and Global Protocols establish a four-step process for estimating GHG emissions:

1. Identify relevant source categories. The Global Covenant of Mayors encourages local governments to include as many emission sources as possible. TCAT developed estimates for the following types of sources:
    - Built Environment (residential, commercial and industrial buildings and outdoor lighting);
    - On-Road Transportation (cars and light-, light medium-, medium- and heavy-duty trucks);
    - Solid Waste (processing, transportation and methane emissions from landfills); and
    - Agricultural Livestock (enteric fermentation).
2. Obtain activity data for source categories. The US and Global Protocols use information on electricity and natural gas use, vehicle miles traveled and other activity measures to develop GHG emission estimates. The TRPC has compiled much of the activity data needed to prepare these estimates:
    - The number of customers and the annual amounts of electricity (kilowatt-hours[9] or KWh) used for residential, commercial and industrial buildings and outdoor lighting between 2010 and 2016;
    - The number of customers and annual amounts of natural gas (therms[10]) used for residential, commercial and industrial buildings between 2010 and 2016;
    - The annual number of vehicle miles traveled (VMT) in Thurston County between 2010 and 2016; and
    - The amount of solid waste generated by Thurston residents and businesses between 2010 and 2016.

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[8] The Global Covenant of Mayors for Climate and Energy is an international alliance of cities and local governments with a shared long-term vision of promoting and supporting voluntary action to combat climate change and move to a low emission, resilient society.

[9] A **kilowatt-hour (KWh)** is a unit of energy measured as 1 kilowatt (1,000watts) of power expended for 1 hour. In 2016, the average residential customer in Thurston County consumed 11,017 KWh. This was slightly higher than the average annual electricity consumption for a U.S. residential utility customer (10,766 KWh) (EIA, 2017b).

[10] A **therm (thm)** is a unit of heat energy equal to100,000 British thermal units (Btu). It is approximately the energy equivalent of burning 100 cubic feet – often referred to as 1 CCF – of natural gas. In 2016, the average residential customer in Thurston County consumed 619 thms. Given the variability in home heating fuels used in the United States, information on the average residential natural gas use is not readily available.

TCAT supplemented the TRPC information with (1) information on the use of other residential heating fuels (fuel oil, liquid petroleum gas[11] (LPG) and wood) from the US Energy Information Administration (EIA) and the US Census Bureau and (2) information on the number of agricultural livestock in Thurston County compiled by the US Department of Agriculture.

3. Identify appropriate emission factors. The US and Global Protocols provided standard emission factors for converting activity data to GHG emission estimates. TCAT supplemented the default emission factors with information from (1) the annual Puget Sound Energy annual emission inventory reports, (2) the 2015 and 2016 United States GHG inventory reports and (3) solid waste composition information from Thurston County Solid Waste.

4. Calculate GHG emissions. TCAT used the web-based ClearPath Community-Scale Emissions Management Software (ICLEI 2013d) to calculate GHG emissions for the Thurston region. Emissions of individual GHGs were converted to metric tons of carbon dioxide equivalents[12] (MTCO2e) using the global warming potentials[13] (GWP) published in *the Intergovernmental Panel on Climate Change's 5th Assessment Report* (IPCC 2013).[14]

How do the updated emission estimates for 2010 compare with the original TCAT estimates?

In 2013, TCAT published a community-based greenhouse gas (GHG) emission inventory for calendar year 2010. Since TCAT prepared the original report, there have been several methodological changes and refinements in the underlying data used in the US and Global protocols.

TCAT used the current methods and data sources to recalculate the GHG emission estimates for 2010. TCAT did this in order to provide a consistent foundation for evaluating the change in emissions between 2010 and 2016.[15]

[11] **Liquid Petroleum Gas (LPG**) is a gas that consists of several flammable hydrocarbons (e.g., propane and butane) that have been liquefied by compression. Also referred to as bottled gas.

[12] In this report, GHG emissions are expressed in terms of metric tons of carbon dioxide equivalent or **"MTCO2e"**. The unit "CO2e" represents an amount of a GHG whose atmospheric impact has been standardized to that of one unit mass of carbon dioxide (CO2), based on the global warming potential (GWP) of the gas.

[13] "**Global Warming Potential**" (GWP) is a measure of a greenhouse gas's ability to absorb heat and warm the atmosphere over a given time period. It is measured relative to a similar amount of carbon dioxide, which has a GWP of 1.0. For example, methane has a GWP of 28 over 100 years. In other words, methane is considered to be 28 times more potent (in terms of methane's impact on global warming) than carbon dioxide.

[14] The "**Intergovernmental Panel on Climate Change"** (IPCC) is a scientific body established by the United Nations Environment Program and the World Meteorological Organization. It periodically reviews and assesses the most recent scientific, technical, and socio-economic work relevant to climate change, but does not carry out its own research. The IPCC was honored with the 2007 Nobel Peace Prize. The IPCC published its most recent report in 2013.

[15] The US Environmental Protection Agency (EPA) uses a similar approach when preparing the annual inventory for US greenhouse gas emissions. EPA noted that "…[e]ach year, some emission and sink estimates in the Inventory are recalculated and revised with improved methods and/or data. In general, recalculations are made to the US greenhouse gas emission estimates either to incorporate new methodologies or, most commonly, to update recent historical data. These improvements are implemented consistently across the previous Inventory's time series …to ensure that the trend is accurate…". (EPA, 2018, p. ES-5)

The updated 2010 TCAT estimate in this report is about 5% higher than the original TCAT 2010 estimate (See Table 3). Important differences between the updated and original 2010 emission estimates include:

- Built Environment: TCAT's updated built environment emission estimate for 2010 is about 17% higher than the original TCAT estimate. This category includes emissions associated with use of electricity, natural gas and other heating fuels. This increase is largely because the emission intensity[16] used to prepare the updated TCAT estimates (obtained from the 2010 annual Puget Sound Energy emission inventory) is higher than the emission intensity used in the original TCAT analysis.
- On-Road Transportation. TCAT's updated on-road transportation emission estimate for 2010 is about 11% lower than the original TCAT estimate. This is largely due to the different assumptions regarding the mix of vehicles (cars, light trucks, etc.). When preparing the updated estimates, TCAT used information provided by the TRPC on the vehicle miles traveled by various types of vehicles. These percentages are different than the default percentages used to prepare the original 2010 emission estimates.
- Solid Waste. TCAT's updated solid waste emission estimate for 2010 is about 63% higher than the original TCAT estimate. This is largely due to the differences in (1) the GWP for methane[17] and (2) the solid waste composition data used in the two analyses.[18]
- Wastewater Treatment: TCAT's updated wastewater treatment emission estimate for 2010 is about 100% lower than the original TCAT estimate. This was largely due to the use of updated formulae and the exclusion of biogenic[19] carbon dioxide emissions.
- Agricultural Livestock. TCAT's updated agricultural livestock emission estimate for 2010 is about 76% higher than the original TCAT estimate. This is largely due to the differences in (1) the GWP for methane and (2) the emission factors for dairy and beef cattle used in the two analyses.[20]

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[16] "**Emission Intensity**" is a measure of the amount of greenhouse gases emitted when generating one kilowatt-hour and is generally expressed in terms of lb/KWh.

[17] TCAT used the GWP value in the 5th Assessment Report to prepare this report. The current GWP value for methane (28) is 33% higher than the GWP value for methane in the 2nd Assessment Report that was used by TCAT to prepare the original 2010 emission estimates.

[18] TCAT used the Solid Waste Characterization Study (Green Solutions, 2014) to calculate a Thurston County emission factor for this updated inventory. The county-specific emission factor is higher than the default emission factor used to prepare the initial 2010 emission estimates.

[19] Biogenic carbon dioxide emissions are defined as emissions that result from the combustion or decomposition of biomass (e.g. wood) that naturally sequester CO_2. The US and Global Protocols specify that CO_2 emissions from the combustion of biogenic materials should not be included in community emission totals.

[20] TCAT used Washington-specific emission factors for dairy and beef cattle published by the EPA (2017) to prepare the updated 2010 emission estimate. The EPA emission factors are higher than the default emission factors used to prepare the initial 2010 emission estimates.

Table 3: Initial and Updated 2010 Thurston County Inventories (MTCO2e)				
	Initial 2010	**Update 2010**	**Change**	**% Change**
Built Environment	1,444,406	1,689,156	244,750	11%
On-Road Transportation	1,221,057	1,089,496	-131,561	-11%
Solid Waste	54,166	88,361	34,195	63%
Wastewater	11,884	135	-11,749	-99%
Agriculture	21,289	37,544	16,255	76%
TOTAL	**2,752,802**	**2,904,692**	**151,890**	**5.5%**

How do the TCAT emission estimates for 2015 compare with the TRPC carbon wedge analysis?

The Thurston Regional Planning Council (TRPC) published a greenhouse gas wedge analysis that explored options for reducing emissions from buildings and on-road vehicles (Clean Energy Transition (CET) and Stockholm Environment Institute (SEI), 2017). As part of that evaluation, CET/SEI estimated emissions for residential, commercial and industrial buildings and on-road vehicle emissions (passenger vehicles and heavy-duty vehicles) for calendar year 2015.

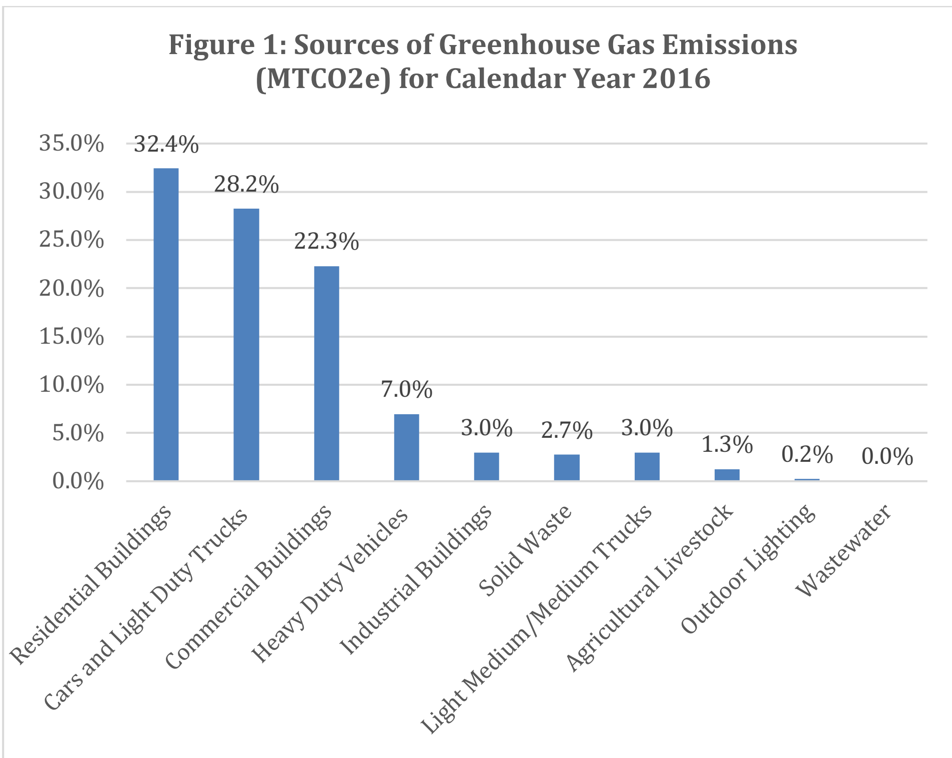
The TCAT emission estimates for buildings and on-road vehicles are 3% higher than the CET/SEI estimates. The two estimates were developed using similar methods and the 3% difference appears to be largely due to differences in how the two analyses took into account emissions associated with the production and distribution of the natural gas used in residential, commercial and industrial buildings.

Overview of the Thurston Region Emission Inventory

This section summarizes (1) the Thurston region's 2016 GHG emission inventory results, (2) how the Thurston region's emissions changed between 2010 and 2016 and (3) how the Thurston region's emissions compare with emissions in other communities. More detailed information on emissions from individual sectors is provided in subsequent sections.

What was the Thurston region's carbon footprint in 2016?

The Thurston region's carbon footprint in 2016 was 2,965,754 MTCO2e. Per capita emissions in 2016 were 10.9 MTCO2e/person. The three largest emission sources in 2016 were residential buildings (32%), cars and light duty trucks (28%) and commercial buildings (22%) (See Figure 1 and Table 4).



Activities taking place in the county can generate GHG emissions both inside and outside the county boundaries. The Global Protocol includes three categories or "scopes" for classifying emissions.

- Scope 1 emissions are greenhouse gases that are emitted by sources located within the county. Scope 1 emissions include emissions from (1) natural gas and other fuels burned in homes and businesses, (2) on-road vehicles, (3) agricultural livestock and (4) wastewater treatment facilities. Scope 1 emissions represented 48% of total emissions in 2016.

- Scope 2 emissions are greenhouse gases emitted as a consequence of the Thurston region's use of grid-supplied electricity even though the electricity is generated outside the region. Scope 2 emissions represented 40% of total emissions in 2016.
- Scope 3 emissions include all other greenhouse gases emitted outside the county as a result of activities that occur within the county. Scope 3 include emissions associated with (1) the disposal of solid waste at the Roosevelt Landfill in eastern Washington, (2) electricity transmission and distribution losses and (3) the production of natural gas and the fuels used to generate electricity. Scope 3 emissions represented 11% of total emissions in 2016

How did greenhouse gas emissions change between 2010 and 2016?

Annual GHG emissions fluctuated up and down between 2010 and 2016 with 2016 emissions being slightly higher (about 2%) than 2010 emissions.

Annual emissions declined by over 7% between 2010 and 2012. This decline was primarily related to (1) reductions in the amount of greenhouse gases emitted per kilowatt-hour when generating the electricity used in the Thurston region, (2) the amounts of vehicles miles traveled; and, to a lesser extent, (3) the amount of solid waste generated by residents and businesses in the Thurston region. (See Figures 2 and 3)

This initial decline was reversed in 2013 and annual emissions increased by almost 10% between 2012 and 2016. This increase was primarily due to (1) increases in the amount of greenhouse gases emitted per kilowatt-hour when generating the electricity used in the Thurston region and, to a lesser extent, (2) an increase in the amount of vehicle miles traveled on roads within the Thurston region.

Per capita emissions in 2016 (10.9 MTCO2e/person) were 5% lower than per capita emissions in 2010 (11.5 MTCO2e/person) as Thurston County's population grew from 252,264 to 272,700. Per capita emissions also fluctuated up and down between 2010 and 2016 in a manner similar to total emissions.

These changes are discussed further in subsequent chapters (Built Environment, Transportation - On-Road Vehicles and Waste).

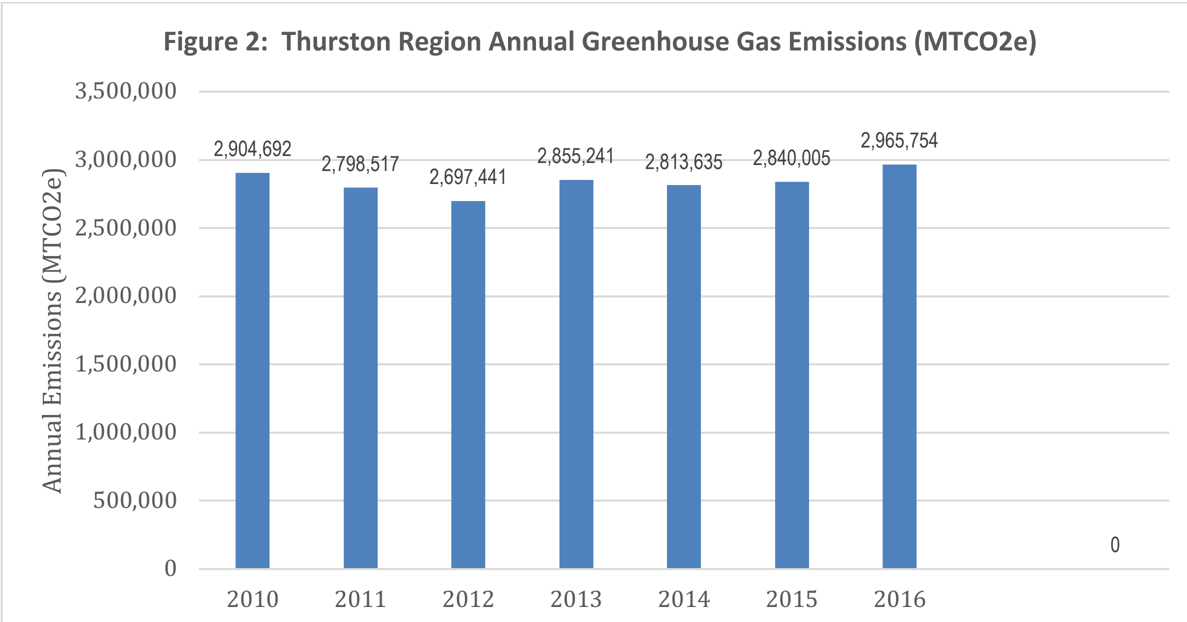


Figure 2: Thurston Region Annual Greenhouse Gas Emissions (MTCO2e)
Annual Emissions (MTCO2e)
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
2,904,692
2,798,517
2,697,441
2,855,241
2,813,635
2,840,005
2,965,754
0
2010
2011
2012
2013
2014
2015
2016

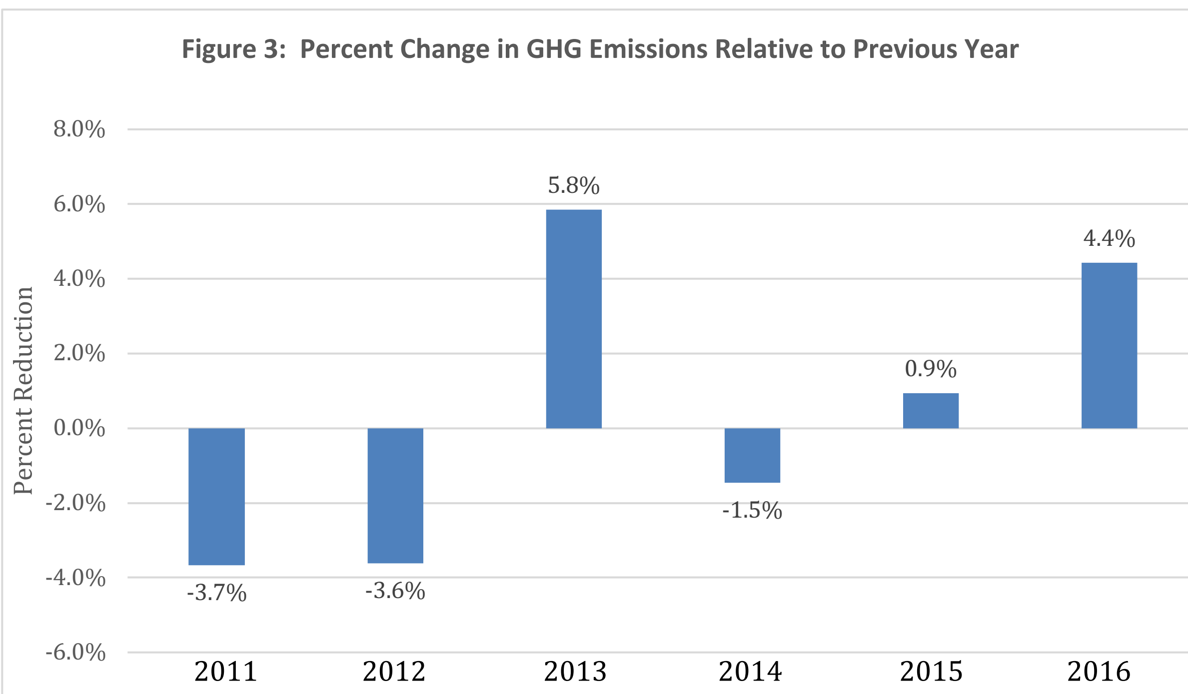
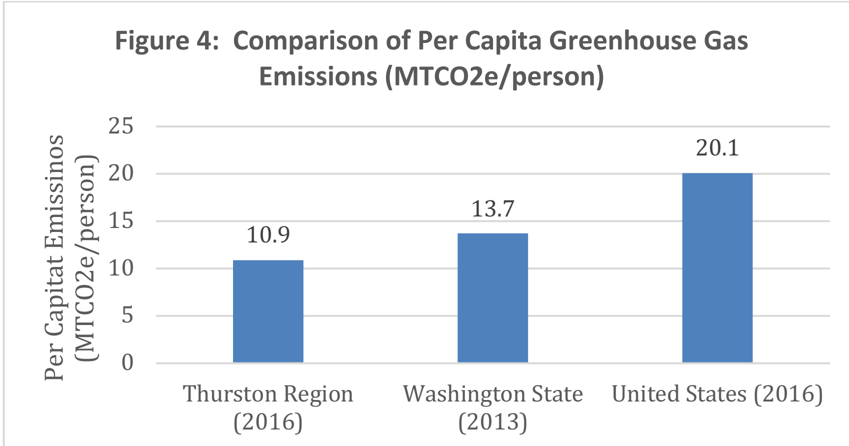


Figure 3: Percent Change in GHG Emissions Relative to Previous Year
Percent Reduction
8.0%
6.0%
4.0%
2.0%
0.0%
-2.0%
-4.0%
-6.0%
-3.7%
-3.6%
5.8%
-1.5%
0.9%
4.4%
2011
2012
2013
2014
2015
2016

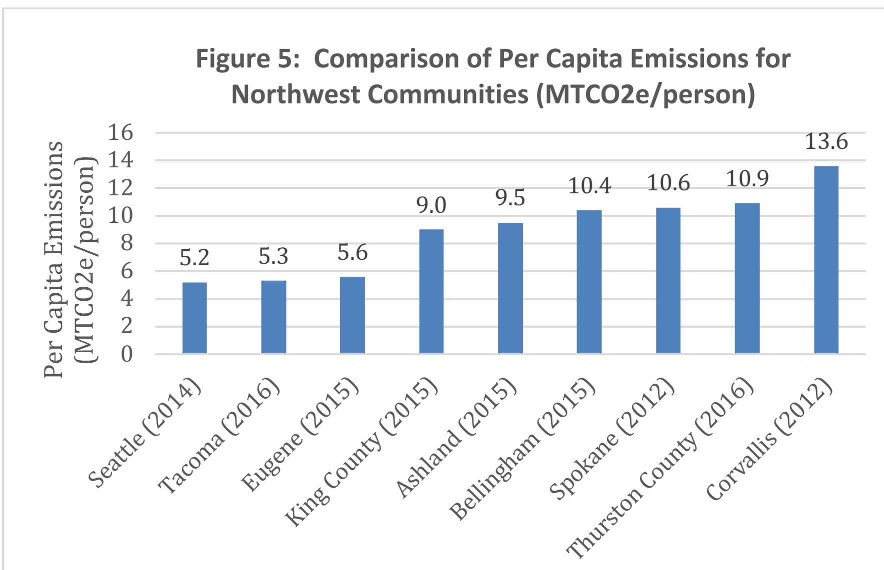
Table 4: Greenhouse Gas Emissions for Thurston County (MTCO2e/yr)				
	2010	**2016**	**Change**	**% Change**
BUILT ENVIRONMENT	**1,689,156**	**1,717,842**	**28,686**	**2%**
Residential	968,971	961,454	-7,518	-1%
Commercial	615,522	661,095	45,572	7%
Industrial	102,230	89,087	-13,536	-13%
Lighting	2,433	6,632	4,167	171%
TRANSPORTATION - On-Road	**1,089,496**	**1,129,198**	**39,702**	**4%**
Cars and Light Duty Trucks	812,905	837,457	24,552	3%
Light Medium/Medium Trucks	84,593	87,696	3,104	4%
Heavy Duty Vehicles	191,998	204,044	12,046	6%
WASTE	**88,496**	**81,233**	**-7,263**	**-8%**
Solid Waste	88,361	81,109	-7,252	-8%
Wastewater	135	124	-11	-8%
AGRICULTURAL	**37,544**	**37,482**	**-62**	**0%**
Agricultural Livestock	37,544	37,482	-62	0%
TOTAL	**2,904,692**	**2,965,754**	**61,062**	**2%**
Per Resident	11.5	10.9	-0.6	-6%

Comparisons to Other Parts of Washington and the United States

Per capita emissions in the Thurston region are generally lower than the most recent per capita emissions estimates in Washington (13.7 MTCO2e in 2013) and the United States (20.1 MTCO2e in 2016). These comparisons should be viewed as a general indicator because (1) the US and Washington inventories include more source categories than the Thurston County inventory and (2) the *U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions* (ICLEI, 2013a) that was used to prepare this inventory differs in certain respects from the methods used to prepare the US and Washington inventories.



Per capita emissions in the Thurston region are generally higher than the per capita emissions reported by other communities in the Pacific Northwest (See Figure 5). In general, these communities have higher population densities and more multi-family homes that tend to produce lower per capita building and transportation emissions. In most cases, these communities also have cleaner sources of electricity (lower emissions of greenhouse gases per kilowatt-hour) where a larger share of electricity is produced from hydropower and wind. This is discussed further in the Built Environment chapter.



While per capita emissions in the Thurston region fell by almost 6% between 2010 and 2016, there were wide variations in year-to-year changes. In general, the reduction in per-capita rates in the Thurston region was not as large as the declines in Washington (2010 through 2013) and the United States (2010 through 2016) (See Figure 6 and Table 5).

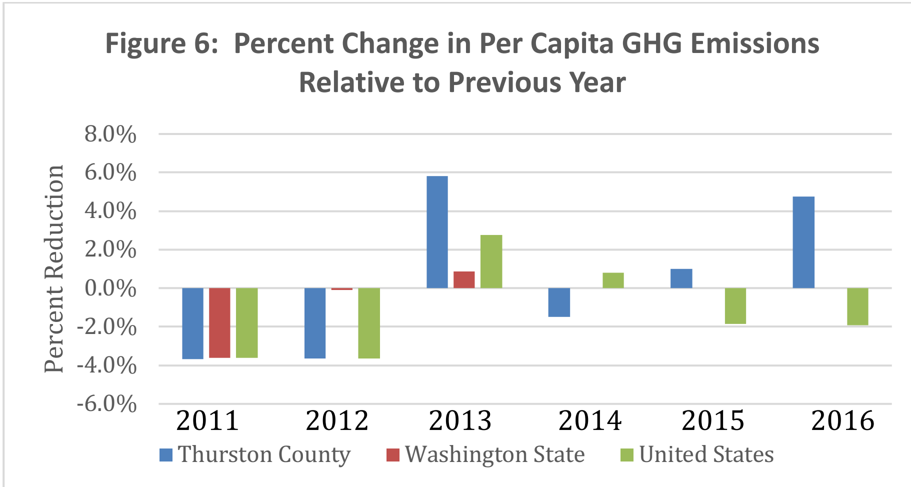


Table 5: Comparison of Per Capita Emission Rates (MTCO2e/person)		
	2010 - 2013	**2010-2016**
Thurston County	-4.7%	-5.6%
State of Washington	-5.1%	
United States	-6.2%	-11.0%

Per capita emissions in the Thurston region declined between 2010 and 2016 at an average annual rate of change of about -0.9% per year. This rate of change falls in the middle of the range of average rates of change for communities that have prepared inventories that span more than one year (See Table 6).

Table 6: Comparison of Trends in Per Capita Greenhouse Gas Emissions

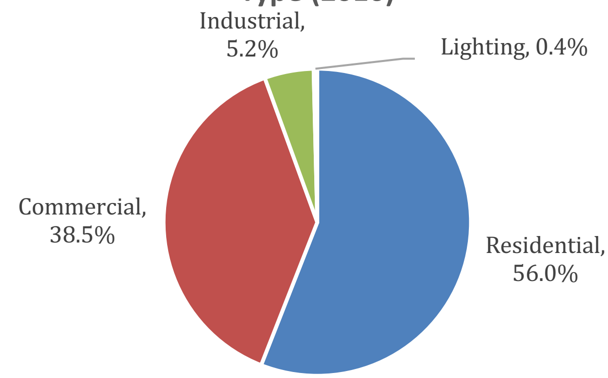
Community	Time Period	Change in per Capita Emissions (%)	Average Change (%/yr)
Ashland	2011 - 2015	-18.0%	-4.5%
Seattle	2008 - 2014	-16.1%	-2.7%
Eugene	2010 - 2015	-12.5%	-2.5%
Thurston Region	2010 - 2016	-5.6%	-0.9%
Tacoma – w/o industry	2012 - 2016	-2%	-0.5%
Spokane	2010 - 2012	0.8%	0.4%
King County	2010 - 2015	5.7%	1.1%
Bellingham	2012 - 2015	10.6%	3.5%

Built Environment

The built environment accounted for the largest portion of the Thurston region's carbon footprint (58%) with 1,717,842 MTCO2e in 2016. Emissions in 2016 were 2% higher than 2010 emissions. Per capita emissions for the built environment in 2016 were 6% lower than 2010 (6.3 MTCO2e/person in 2016 vs 6.7 MTCO2e/person in 2010).

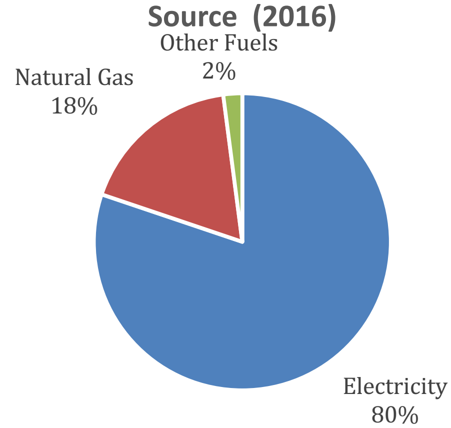
Residential buildings were the largest source of built environment emissions, followed by commercial buildings, industrial buildings and outdoor lighting (See Figure 7).

Figure 7: Built Environment Emissions by Building Type (2016)

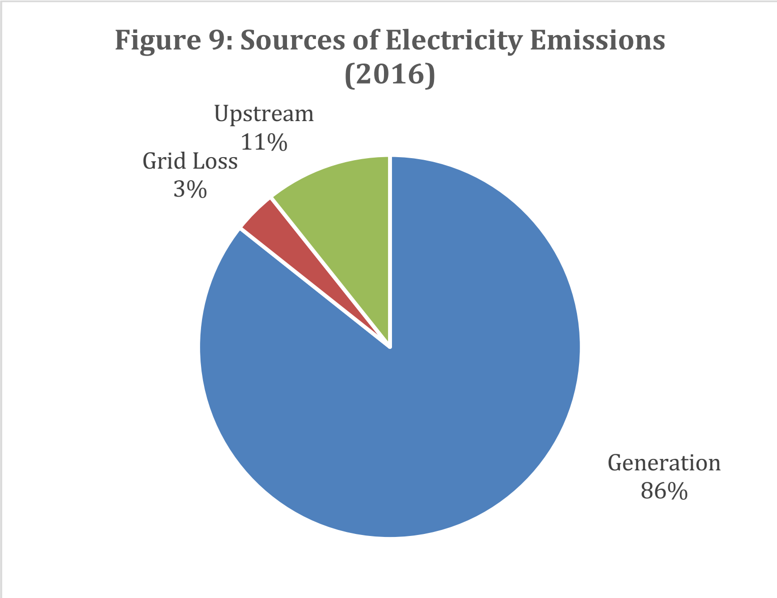


In 2016, the use of electricity accounted for the largest portion of built environment emissions (80%), followed by natural gas (18%). The use of other residential heating fuels (fuel oil, LPG and wood) represented a very small part (about 2%) of built environment emissions in 2016 (See Figure 8)

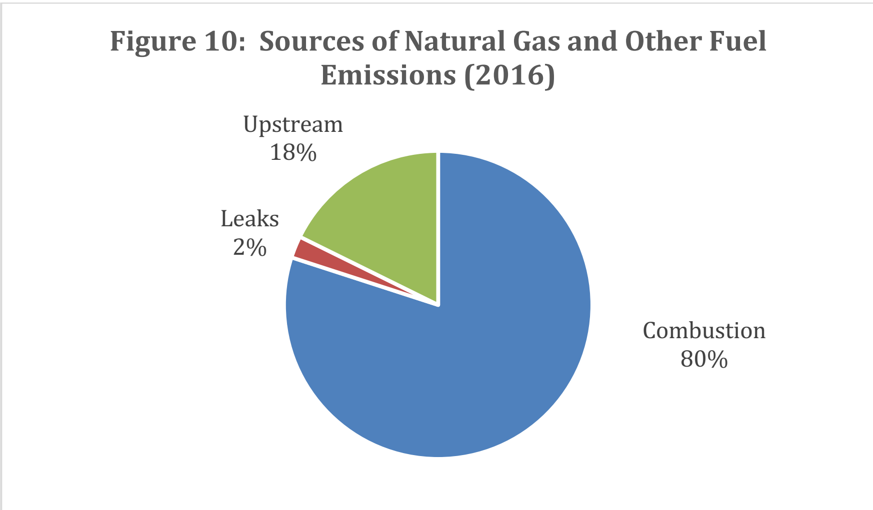
Figure 8: Built Environment Emissions by Energy Source (2016)



Emissions associated with the generation and use of electricity include three components: (1) emissions associated with the generation of the electricity used by Thurston residents and businesses, (2) emissions associated with electricity losses during transmission and distribution; and (3) upstream emissions that occur during the production of the fuels used to generate electricity (upstream emissions). As shown in Figure 9, emissions associated with electricity generation are the largest portion of electricity emissions.



Emissions associated with the generation and use of natural gas and other fuels (fuel oil, LPG and wood) also include three components: (1) emissions from direct combustion; (2) emissions due to leaks during the transmission and distribution of natural gas; and (3) upstream emissions that occur during the production of natural gas and other fuels. As shown in Figure 10, emissions resulting from the direct combustion of natural gas and other heating fuels represents the largest portion of this category.



Key Findings – Residential Buildings

Residential buildings accounted for 32% of the Thurston region's carbon footprint in 2016 (56% of built environment emissions). Emissions declined slightly (-0.8%) between 2010 and 2016 with per capita emissions falling by 8%.

The decline in residential building emissions occurred despite an 8% increase in the emission intensity of electricity provided by Puget Sound Energy in 2016 relative to the emission intensity in 2010.[21]

Factors contributing to the decline in emissions from residential buildings include:

- Efficiency Measures. Puget Sound Energy and local, state and federal governments support energy conservation efforts through a wide range of programs. Thurston region residents appear to be using electricity and natural gas more efficiently than in the past. Residential electricity consumption fell by 2% between 2010 and 2016 while electricity use/customer fell by 9% from 12,048 to 11,017 kWh/customer. This is consistent with the 9% decline in residential electricity sales per capita reported by the Energy Information Administration for the same time frame (EIA, 2017b). Residential natural gas use/customer fell by 14% from 720 to 619 therms/customer between 2010 and 2016.
- Temperature. Warmer weather likely contributed to some of the reduced demand for natural gas and electricity. TCAT found that variations in residential natural gas use between 2010 and 2016 were strongly correlated (correlation coefficient = 0.82) with the variations in annual heating degree days (HDDs).[22] Residential electricity consumption between 2010 and 2016 was also somewhat correlated with the number of annual HDDs (correlation coefficient = 0.48). This is consistent with (1) observations by the Stockholm Environmental Institute (SEI, 2016) and Cascadia and Hammerschlag (2017) when analyzing trends in building-related emissions in the City of Seattle and King County, respectively, (2) EPA's conclusions regarding national emission trends (EPA, 2017 and 2018 and (3) EIA's analysis of electricity usage trends (2017b).[23]
- Grid Improvements. Grid operators reduced transmission and distribution (T&D) losses from 6.8% to 4.2% between 2010 and 2016 (EPA, 2018b). For residential buildings, GHG emissions associated with T&D losses in 2016 were about 13,000 MTCO2e lower than in 2010.
- Heating Fuel Switching. Emissions associated with the use of fuel oil and liquid petroleum gas (LPG) for

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[21] Emission intensity is the amount of greenhouse gases emitted per kilowatt hour (lb CO2e/KWh). The emission intensity of electricity provided by Puget Sound Energy increased from 1.02 lb CO2e/KWh in 2010 to 1.1 lb CO2e/KWh in 2016. (PSE 2017, Table 8-2)

[22] Heating degree day (HDD) is a measurement designed to quantify the demand for energy to heat a building. This measure is based on the assumption that when the outside temperature is 65°F, people don't need to heat their homes in order to be comfortable. For example, a temperature of 60 degrees would represent 5 HDDs. Building heating energy demands are considered to be proportional to heating degree days. Conversely, building cooling needs (fans, air conditioning and dehumidifiers) are considered to be proportional to cooling degree days (CDD). Building cooling needs are expected to increase as average temperatures increase and a higher percentage of homes are built with air conditioning.

[23] The Energy Information Administration (EIA 2017) found that weather is a significant driver in variations in residential electricity sales in many states. EIA found that some of the states with the largest percentage declines in per capita residential electricity sales were also those with the largest declines in winter temperatures between 2010 and 2016. They also noted that the extent to which cold weather influences residential electricity demand depends on heating fuel choices, but many homes use some form of electric heating in winter months. EIA also found that warmer summer weather tends to increase electricity demand as people increase their use of air conditioners, fans, dehumidifiers and other equipment in order to maintain comfortable temperatures. This could become more of a factor in the Thurston region as average temperatures continue to climb over the next century.

home heating fell by 44% and 50% respectively between 2010 and 2016 as households continued to switch to other heating sources.[24] Local trends were consistent with national trends.[25] While there were over 25,000 MTCO2e fewer emissions in 2016 associated with fuel oil and LPG use (relative to 2010), the net reduction in emissions was likely much lower because these households still needed to meet their heating needs through the use of other sources such as natural gas or electricity.

Table 7: Changes in Residential GHG Emissions by Energy Type (2010 – 2016)

	2010	2016	Change	% Change
Residential - Electricity	697,136	724,799	27,663	4%
Per Customer	6.6	6.4	-0.2	-3%
Residential - Natural Gas	211,132	201,117	-10,015	-5%
Per Customer	4.9	4.2	-0.7	-14%
Residential - Fuel Oil	8,620	4,807	-3,813	-44%
Per Household	5.5	5.4	-0.2	-3%
Residential - LPG	44,161	22,191	-21,970	-50%
Per Household	7.3	5.0	-2.3	-32%
Residential - Wood	7,922	8,539	617	8%
Per Household	1.3	1.3	0	1%
Residential - Total	**968,971**	**961,454**	**-7,518**	**-0.8%**
Per capita[26]	**3.8**	**3.5**	**0.3**	**-8%**

Key Findings – Commercial Buildings

Commercial buildings accounted for 22% of the Thurston region's carbon footprint in 2016 (38% of built environment emissions). Emissions associated with commercial buildings increased by 7% between 2010 and 2016, while per capita emissions slightly declined (-0.6%). Most of the increase can be explained by (1) a 4% increase in the total amount of electricity used in commercial buildings and (2) an 8% increase in the emission intensity of electricity provided by Puget Sound Energy in 2016 relative to the emission intensity in 2010.

[24] Heating oil has the highest carbon content of any of the heating fuels used in Washington. The Washington Energy Office recommends oil-heated homes be converted to electric heat pumps (WDOC, 2016). This recommendation is designed to support the state carbon emissions reduction goals.

[25] Information provided in recent EIA Annual Energy Outlook reports indicate that the amount of fuel oil delivered to residential customers fell by over 25% between 2010 and 2016. The amount of propane delivered to residential customers fell by 18% during that time period.

[26] This table includes information on total emissions, per customer emissions (electricity and natural gas) and per household emission (fuel oil, LPG and wood). Per capita emission estimates are also provided in order to facilitate comparisons with other communities.

There were also several factors that mitigated the emission increase from commercial buildings due to the higher electricity consumption and emission intensities:

- Efficiency Measures. Thurston region businesses and governments also appear to be using electricity and natural gas more efficiently than in the past. Per customer emissions associated with commercial natural gas[27] and electricity use declined by 12% and 5%, respectively, between 2010 and 2016. The Department of Ecology (2017) recently reported that estimated statewide emissions from state agency buildings (which make up an important portion of commercial buildings in the Thurston region) fell by 8% between 2014 and 2015.[28]
- Temperature. Annual variations in commercial natural gas use between 2010 and 2016 were strongly correlated with the variations in annual heating degree days (correlation coefficient = 0.79). Variations in commercial electricity consumption between 2010 and 2016 were weakly correlated with the variations in the number of annual HDDs (correlation coefficient = 0.23).
- Grid improvements. Emissions associated with T&D grid losses were over 8,300 MTCO2e lower in 2016 relative to 2010.

Table 8: Changes in Commercial GHG Emissions by Energy Type (2010 – 2016)

	2010	2016	Change	% Change
Commercial – Electricity	507,524	562,531	55,008	11%
Per Customer	37.7	38.2	0.5	1%
Commercial – Natural Gas	107,998	98,563	-9,435	-9%
Per Customer	31.1	27.3	-4	-12%
Commercial – Total	**615,522**	**661,095**	**45,573**	**7%**
Per Capita	**2.44**	**2.42**	**-0.02**	**-0.2%**

Key Findings - Industrial Buildings

Industrial buildings accounted for 3% of Thurston region's carbon footprint in 2016 (5% of built environment emissions). Emissions and per capita emissions associated with industrial buildings fell by 13% and 20%, respectively, between 2010 and 2016. The trend in Industrial emissions is really a tale of two cities:

- Emissions associated with electricity increased by 9%. This reflected a confluence of several factors: (1) an 8% higher emission intensity in 2016 relative to 2010; (2) electricity grid improvements which resulted in less electricity being lost during the transmission and distribution of electricity; and (3) a 3% increase in electricity consumption.
- Emissions associated with natural gas use fell by 75%. Most of the decline occurred between 2013 and 2014 when Industrial natural gas consumption fell by 78%. Based on the number of industrial natural gas and electricity

[27] Natural gas consumption in commercial buildings fell by 9% between 2010 and 2016.

[28] The Department of Ecology report covers government buildings and operations throughout the whole state. The 8% reduction was calculated using information in Tables 4 and 5 of the Ecology report. Emissions from the Department of Corrections were not included because of the wide fluctuations in building emissions between 2013 and 2015.

customers, it appears that one or more large industrial facilities either closed or shifted to other energy sources during this time period.

Table 9: Changes in Industrial GHG Emissions by Energy Type (2010 – 2016)				
	2010	**2016**	**Change**	**% Change**
Industrial - Electricity	75,212	82,061	6,849	9%
Per Customer	357	419	62	17%
Industrial - Natural Gas	27,017	6,633	-20,385	-75%
Per Customer	386.0	112.4	-274	-71%
Industrial - Total	**102,230**	**88,694**	**-13,536**	**-13%**
Per Capita	**0.41**	**0.33**	**-0.8**	**-20%**

Key Findings - Outdoor Lighting

Outdoor lighting accounted for a very small portion (0.4%) of built environment emissions in 2016 (6,600 MTCO2e). Emissions associated with outdoor lighting increased by 170% between 2010 and 2016. Most of the increase can be explained by:

- The number of outdoor lighting customers increased by 470% between 2010 (112 customers) and 2016 (640 customers).
- While there was an increase in the number of lighting customers, customers were using electricity more efficiently with per customer energy use (KWh/customer) falling 55% between 2010 and 2016. For example, the City of Olympia has converted streetlights and traffic lights to LEDs (City of Olympia, 2018).[29]
- The emission intensity of electricity provided by Puget Sound Energy was 8% higher in 2016 relative to the emission intensity in 2010.

This trend is consistent with a recent report that found that lighted areas on the Earth's surface grew by 2.2% per year between 2012 and 2016 (Kyba et al. 2017). The authors theorized that the transition to more efficient lighting technologies (LEDs, smart technology) was being undermined by a "rebound" effect where communities were increasing the use of outdoor lighting to help meet goals for crime safety, traffic and pedestrian safety and outdoor recreation.

[29] At the county level, the increase in electricity use for outdoor lighting has masked steady improvements in lighting efficiency during the 2010 – 2016 time period. At the city level, there is evidence that community efforts to reduce energy demand for outdoor lighting are starting to pay dividends in terms of energy use for outdoor lighting and GHG emissions. For example, energy demand for outdoor lighting in the City of Olympia fell by 44% between 2015 and 2016. GHG emissions associated with outdoor lighting in the City of Olympia fell by 40% during this period.

Comparisons to Other Parts of Washington and the United States

Per capita GHG emissions for Thurston County residential, commercial and industrial buildings were similar to or less than United States per capita GHG emissions.[30]

Table 10: Comparison of Per Capita GHG Emissions (MTCO2e/person)

	Residential	Commercial	Industrial
Thurston County (2016)	3.5	2.4	0.3
United States (2015)	3.2	2.9	4.3

Per capita GHG emissions for residential, commercial and industrial buildings in the Thurston region are generally higher than other Washington and Oregon communities that have completed greenhouse gas inventories.

Table 11: Comparison of Per Capita Emissions for Residential, Commercial and Industrial Buildings (MTCO2/person)

<table>
<tr><th>Community</th><th>Residential</th><th>Commercial</th><th>Industrial</th></tr>
<tr><td>Seattle (2014)</td><td>0.25</td><td>0.32</td><td></td></tr>
<tr><td>Eugene (2015)</td><td>0.63</td><td colspan="2">1.4</td></tr>
<tr><td>Tacoma (2016)</td><td>0.65</td><td>0.43</td><td>0.25</td></tr>
<tr><td>Bellingham (2015)</td><td>2.1</td><td>2.4</td><td>2.4</td></tr>
<tr><td>King County (2015)</td><td>2.1</td><td>2.2</td><td>1.6</td></tr>
<tr><td>Ashland (2015)</td><td>2.1</td><td>1.8</td><td>0.15</td></tr>
<tr><td>Spokane (2012)</td><td>2.8</td><td>2.5</td><td>0.25</td></tr>
<tr><td>Thurston Region (2016)</td><td>3.5</td><td>2.4</td><td>0.27</td></tr>
</table>

Differences in the emission intensities of the electricity used by the different communities accounted for most of the differences in per capita emissions. The emission intensity of the electricity provided by Puget Sound Energy is considerably higher than that of electricity provided to most of the other Northwest communities that have completed emission inventories. The differences in emission intensities are largely due to the differences in the mix of fuels used by various Washington utilities to generate the electricity provided to their customers. PSE uses (1) a higher percentage of coal and natural gas and (2) a lower percentage of hydropower to generate the electricity provided to PSE customers relative to other nearby utilities. Table 12 provides a comparison between the emission intensities for Puget Sound Energy, Seattle City Light and Tacoma Power.

[30] As noted in a previous footnote, these comparisons should be viewed as a general indicator given that the ICLEI methodology differs in certain respects from the methods used to prepare the US and Washington inventories.

Table 11: Annual CO2 Equivalent Total Output Emission Rate	
Utility	**Lb/MWh**
Puget Sound Energy	1,110[31]
Seattle City Light	1.9[32]
Tacoma Power	1.5

Information Used to Estimate Built Environment Greenhouse Gas Emissions

TCAT estimated the emissions associated with the use of electricity by using information provided by Puget Sound Energy on the number of customers and annual amounts of electricity used for residential, commercial and industrial buildings and outdoor lighting (TRPC, 2017b), carbon intensity values published in the annual emission reports prepared by Puget Sound Energy (PSE, 2011 – 2017),[33] information on electricity transmission and distribution loss published by EPA (EPA, 2018b), fuel mix information compiled by the Department of Commerce (WDOC, 2017) and the default emission factors for coal and natural gas production included in the Clearpath software model.

TCAT estimated the emissions associated with the use of natural gas by using information provided by Puget Sound Energy on the number of customers and annual amounts of natural gas used for residential, commercial and industrial buildings (TRPC, 2017b) and the default emission factors included in the Clearpath software model.

TCAT estimated the emissions associated with the use of other residential heating fuels (fuel oil, LPG and wood) by using energy consumption estimates for Washington State published by the United States Energy Information Administration (EIA, 2017a), information from the US Census Bureau on the number of households in Thurston County and Washington State using different types of heating fuels (Census Bureau, 2017), and the default emission factors included in the Clearpath software model.

There are varying degrees of uncertainty associated with the methods, data and assumptions used to prepare GHG emission estimates for the built environment. In general, there is a low amount of uncertainty surrounding the estimates for natural gas and electricity use because of the high confidence in the information about electricity use, natural gas use and emission factors reported by Puget Sound Energy. This contrasts with the emission estimates for other residential heating fuels (i.e., fuel oil, LPG and wood) where there is a large amount of uncertainty because those estimates required numerous assumptions and extrapolations from statewide and national data.

The equations and information sources used to estimate built environment emissions are described in Appendix B.

[31] Table 8-1 in Puget Sound Energy's 2016 Emissions Inventory (PSE, 2017).

[32] The emission intensities for Seattle City Light (SCL) and Tacoma Power were obtained from the Balancing Authority worksheet provided in eGRID 2016 (EPA, 2018b).

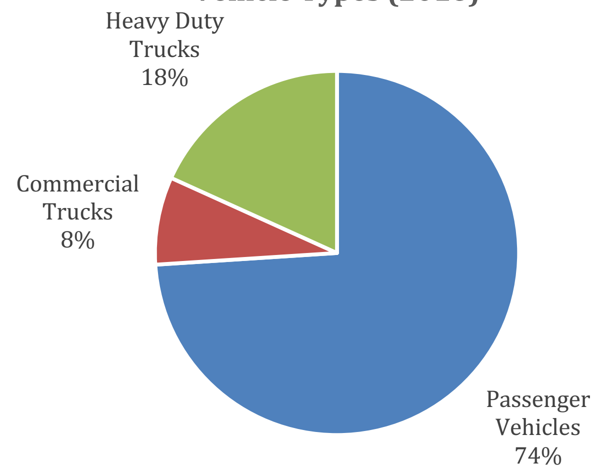
[33] TCAT used the "market-based" calculation method described in the Global Protocol (WRI et al, 2014) which uses utility-specific emission factors to estimate GHG emissions associated with producing the electricity used by a particular community. This differs from the location-specific calculation method that was used to prepare the initial 2010 inventory. Under the location-based calculation method, the average emission intensity for the Northwest Power Pool (NWPP) regional grid compiled by EPA in the eGRID database was used to calculate GHG emissions associated with generating the electricity used in the Thurston region. The average emission intensity for the Northwest Power Pool (NWPP) regional grid in the most recent eGRID publication (655 lbs CO2e/MWh) is about 40% lower than the PSE emission intensity provided in Table 8-1 of the PSE 2016 Emissions Inventory report (PSE, 2017).

Transportation – On-Road Vehicles

On-road transportation accounted for the second largest portion of Thurston County's carbon footprint (38%) with an estimated 1,129,198 MT CO2e in 2016. On road transportation emissions increased by 4% between 2010 and 2016, while per capita emissions declined by 4%.

Passenger vehicles (cars and light-duty duty trucks) were the largest source of on-road transportation emissions, followed by heavy duty trucks (freight) and commercial vehicles (light medium and medium duty trucks). (See Figure 11).

Figure 11: On-Road Transportation Emissions by Vehicle Types (2016)



Key Findings – Passenger Vehicles

Passenger vehicles represented 91.7%[34] of vehicle miles traveled and 74% of on-road transportation emissions (837,457 MTCO2e) in 2016. Passenger vehicles include passenger cars, light trucks and SUVs that use gasoline and small quantities of diesel.

Passenger vehicle emissions increased by 3% between 2010 and 2016, while per capita emissions declined by 5%. These trends represented the confluence of three main factors:

- Vehicle Miles Traveled (VMT).[35] There was a downward trend in on-road VMT between 2010 and 2012 after which VMT and GHG emissions steadily increased through 2016. The Environmental Protection Agency (2018a) and the Federal Highway Administration (2017) have each discussed the multiple factors influencing VMT and have concluded that national trends in VMT reflect a "…confluence of factors including population growth, economic

[34] Information on the percentage of VMT represented by cars and light trucks was provided by TRPC (2017e). This percentage is consistent with national estimates on the percentage of VMT represented by cars and light duty trucks published in the EIA Annual Energy Outlook reports.

[35] Estimates of vehicle miles traveled in Thurston County include miles driven by non-Thurston County residents in Thurston County (including the large volume of cars and trucks passing through the County on Interstate 5). In 2016, vehicle miles traveled on Interstate 5 represented about 38% of the total vehicle miles traveled in Thurston County (this includes both local and pass-through traffic). It is unlikely that local transportation measures will be able to significantly impact many of the vehicles traveling on Interstate 5..

growth, urban sprawl, and periods of low fuel prices…" All of these factors likely contributed to the variations in annual VMT in Thurston County between 2010 and 2016.

- Fuel Economy. TCAT used information compiled by the US Department of Transportation Bureau of Transportation Statistics (2017) to estimate emissions from passenger vehicles. This information indicates that the average fuel efficiency of US light duty vehicles (existing stock of cars and light-duty trucks) increased by 3% between 2010 and 2015.[36] The improvements in fuel economy were influenced by new vehicle fuel economy standards, light-duty truck share[37] and vehicle turnover.
- Population: The Thurston region's population grew by 8% between 2010 and 2016. This contributed to the overall increase in VMT during this period. The rate of population growth exceeded the growth in VMT which explains why per capita emissions declined while overall emissions increased.

Key Findings – Light Medium- and Medium-Duty Trucks (Commercial Trucks)

Commercial vehicles (light–medium and medium duty vehicles) represented 3.4% of vehicle miles traveled and 8% of on road transportation emissions (87,696 MTCO2e) in 2016. Commercial vehicles include local freight, restaurant delivery and service providers such as electricians, plumbers, etc.

Commercial vehicle emissions increased by 4% between 2010 and 2016, while per capita emissions declined by 4%. Factors contributing to these trends include:

- Vehicle Miles Traveled (VMT). Total VMT declined between 2010 and 2012 after which VMT and GHG emissions steadily increased through 2016.
- Fuel Economy. The US Energy Information Administration reported that average fuel efficiency of light medium and medium duty vehicles increased by 3% and 1%, respectively (Stone and Lynes, 2016). These trends were influenced by new vehicle fuel economy standards and vehicle turnover.
- Population: Thurston County's population grew by 8% between 2010 and 2016 which likely increased the need for commercial services.

Key Findings – Heavy Duty Freight Trucks

Heavy-duty vehicles represented 4.9% of vehicle miles traveled and 18% of on-road transportation emissions (204,044 MTCO2e) in 2016.

Heavy duty vehicle emissions increased by 6% between 2010 and 2016, while per capita emissions remained largely unchanged. Factors contributing to these trends include:

[36] This improvement is slightly below the changes reflected in the information published by the US Energy Information Administration in their Annual Energy Outlook reports. The data compiled by the EIA indicates that average fuel efficiency for the existing stock of light duty vehicles rose from 20.9 mpg in 2010 to 22.4 mpg in 2016 (7% improvement).

[37] The light-duty truck share decreased to about 33 percent in 2009 and has since varied from year to year between 36 percent and 43 percent. Light-duty truck share was about 43 percent of new vehicles in model year 2016 (EPA 2016a). (EPA 2018, pp 2-11& 2-29)

- Vehicle Miles Traveled (VMT). There was a downward trend in on-road VMT between 2010 and 2012 after which VMT and GHG emissions steadily increased through 2016.
- Fuel Economy. The US Energy Information Administration reported that average fuel efficiency of heavy duty vehicles remained essentially unchanged between 2010 and 2016 (6.1 mpg in 2010 vs 6.07 mpg in 2016) (Stone and Lynes, 2017).[38]
- Population: Thurston County's population grew by 8% between 2010 and 2016.

Intercity Transit

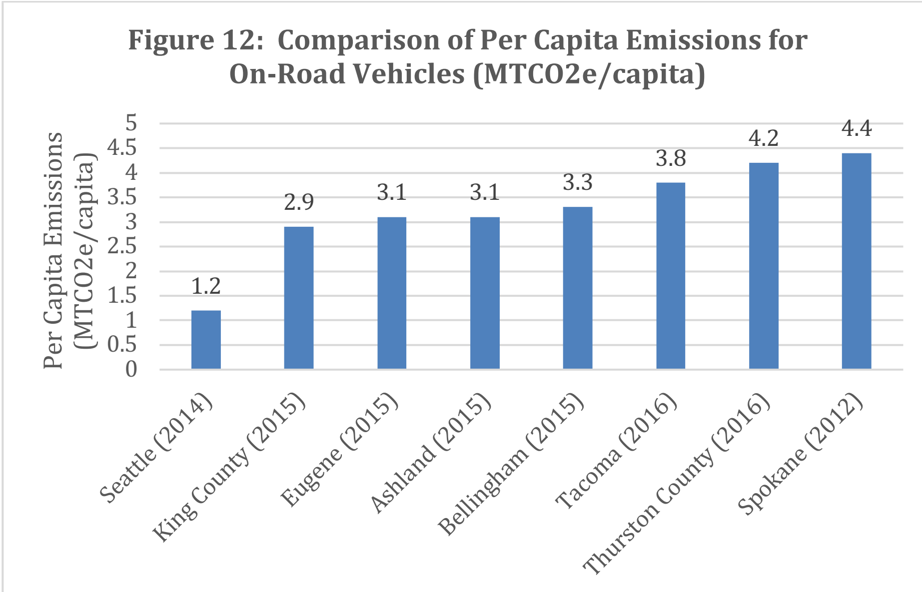
Intercity Transit has an excellent sustainability program that has taken numerous steps to reduce greenhouse gas emissions. Between 2010 and 2016, IT reduced their emissions from approximately 10,000 to 9,200 MTCO2e/year (about an 8% reduction). They achieved these reductions by improving vehicle fuel efficiency and upgrading to efficient lighting in their facilities

TCAT has not separately reported Intercity Transit emissions because the vehicle miles traveled by IT buses and vanpools are included in the county wide VMT totals. The emissions reported in the IT Sustainability Report (IT, 2016) represent less than 1% of the overall county on-road transportation emissions.

Comparisons to Other Parts of Washington and the United States

Current per capita on-road GHG emissions in the Thurston region are similar to the most recent Washington figures for calendar year 2013 (Ecology, 2016a). Both the Thurston region and Washington per capita GHG emissions for on-road transportation are lower than the most recent US per capita rates for calendar year 2015 (EPA, 2018), but higher than those for several Northwest cities that have completed recent GHG inventories. In general, these communities have higher population densities that tend to reduce commuting distances.

[38] Information compiled in the 2013 – 2018 Annual Energy Outlook reports for 2013 through 2018 indicate that the average fuel efficiency for existing stock of freight vehicles rose from 6.7 mpg in 2010 to 7.0 mpg in 2016 (4.5% increase).



Information Used to Estimate On-Road Vehicle Greenhouse Gas Emissions

TCAT estimated on-road transportation emissions by using the vehicle miles traveled (VMT) and vehicle fleet mix information provided by the Thurston Regional Planning Council (TRPC, 2017a and 2017e), gas mileage (miles/gallon) information for cars and light-duty trucks published by the National Highway Transportation Administration (NHTA, 2017), gas mileage information for light-medium-, medium- and heavy-duty trucks published by the Energy Information Administration (Stone and Lynes, 2017) and the emission factors published in the Climate Registry Database.

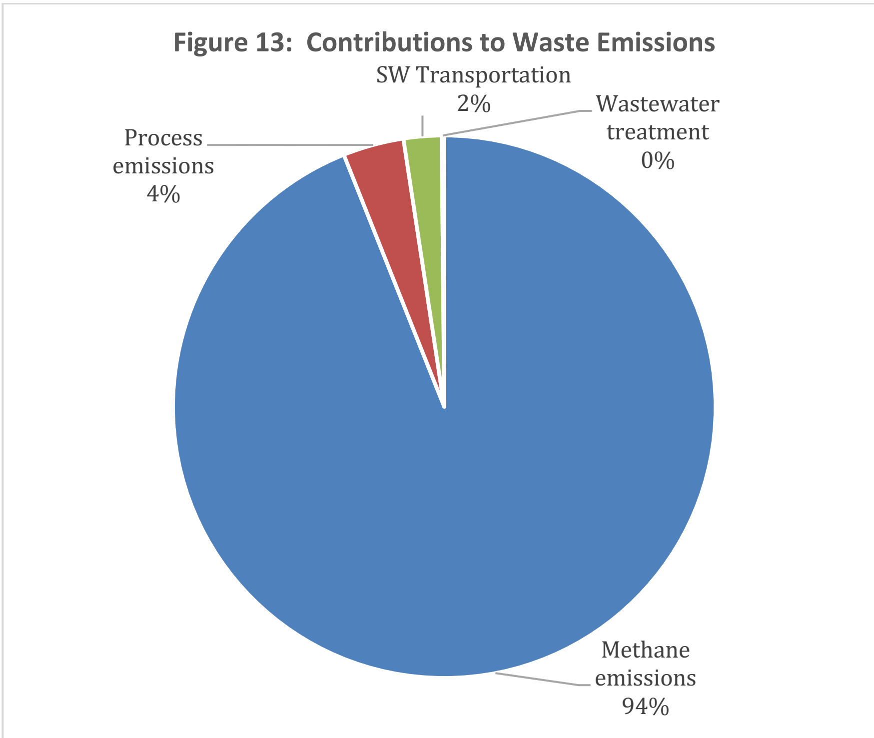
In general, there is a moderate amount of uncertainty surrounding on-road transportation emissions. EPA calculated a 95 percent confidence interval for on-road transportation emissions of -7% (lower bound) to +7% (upper bound). In other words, EPA calculated that there is a 2.5% chance that actual on-road transportation emissions are more than 7% lower than EPA's estimates and that there is a 2.5% chance that actual emissions are more than 7% higher than EPA's estimates. There are additional uncertainties associated with extrapolating the national data (such as fuel efficiency) to the Thurston region. It is unclear whether use of national data will over- or under-estimate the Thurston region's emissions.

The equations and information sources used to estimate on-road transportation emissions are described in Appendix B.

Waste

Emissions from waste management activities represented 3% of the Thurston region's carbon footprint with an estimated 81,233 MTCO2e in 2016. Waste-related emissions fell by 8% between 2010 and 2016 while per capita emissions declined by 15%.

Almost 94% of waste-related emissions in 2016 were associated with methane emissions from the decomposition of community-generated solid waste disposed at the Roosevelt Regional Landfill. Waste processing activities, waste transportation and wastewater treatment contributed 4%, 2% and <<1% of waste-related emissions, respectively.



Key Findings - Solid Waste Management

Solid waste management emissions include:[39]

- Waste Processing. TCAT estimated that waste processing activities emitted 2,948 MTCO2e which represented about 4% of the solid waste-related emissions in 2016. Solid waste is collected by the City of Olympia and Waste

[39] Collection of garbage and recycling is handled by two entities in Thurston County. The City of Olympia collects residential and commercial garbage within the City limits. Waste Connections collects the waste from the rest of the county through contracts with individual cities (Bucoda, Rainier, Tenino and Yelm) or the G-certificate program administered by the Utility Transportation Commission (Lacey, Tumwater, Unincorporated Thurston County). Emissions associated with waste collection are included in the on-road vehicle emission estimates.

Connections and taken to the Waste and Recovery Center at Hawks Prairie where it is combined with waste from two rural drop box facilities.

- Waste Transportation. TCAT estimated that waste transportation activities emitted 1,833 MTCO2e which represented about 2% of solid waste-related emissions in 2016. Waste Connections hauls the waste collected at the Waste and Recovery Center to the Republic Services intermodal transfer station in Centralia WA. Waste containers are then loaded onto trains to be hauled to the Roosevelt Regional Landfill in Klickitat County.
- Waste Disposal. TCAT estimated that methane from the decomposition of community-generated solid waste disposed at the Roosevelt Regional Landfill resulted in the release of 76,328 MTCO2e which represented about 94% of the solid waste-related emissions in 2016.

Table 13: Summary of Changes in Waste Emissions (2010 – 2016)

	2010	2016	Change	% Change
Solid Waste	**88,361**	**81,109**	**-7,252**	**-8%**
Methane emissions	83,958	76,328	-7,630	-9%
Process emissions	2,709	2,948	239	9%
Transportation emissions[40]	1,694	1,833	139	8%
Per resident	**0.35**	**0.30**	**0.05**	**-15%**

Solid waste-related GHG emissions decreased by 7,252 MTCO2e between 2010 and 2016 (-8%) while per capita solid waste emissions fell by 15%.[41] Most of the variations in annual emissions can be explained by variations in the amount of waste generated in the Thurston region. As shown below, landfill waste volumes declined between 2010 and 2012 and then steadily increased reaching the high for the period in 2016. Much of the variation in landfill volumes can be explained by variations in economic conditions and recycling opportunities. Recycled waste volumes have declined recently as the market for recycled materials has grown smaller. Combined landfill and recycled waste volumes have increased more rapidly during the 2014 – 2016 period along with the increased economic growth.

Table 14: Expanded Summary of Changes in Waste Volumes and Emissions (2010 – 2016)

	2010	2011	2012	2013	2014	2015	2016
Total Landfill (tons)	165,191	151,318	146,360	152,162	158,844	168,928	179,733
Per Resident (lbs)	1,268	1,191	1,140	1,170	1,203	1,263	1,318
Total Recycling (tons)	56,291	51,314	57,453	52,780	48,937	45,087	45,776
Per Resident (lbs)	446	404	447	406	371	337	336
Landfill + Recycling (tons)	216,224	202,632	203,813	204,943	207,777	214,015	225,509
Per Resident (lbs)	1714	1595	1587	1576	1574	1601	1654
SW Emissions	**88,361**	**80,940**	**78,287**	**68,679**	**71,686**	**76,238**	**81,109**
MTCO2e/person	**0.35**	**0.32**	**0.30**	**0.26**	**0.27**	**0.29**	**0.30**

[40] Waste-related transportation emissions are associated with (1) transporting solid waste by truck to Centralia where it is loaded on trains and (2) transporting the waste by rail from Centralia to the Roosevelt Regional Landfill.

[41] Much of the 15% decline in per capita emissions reflects a change in the assumptions used to estimate methane emissions from the Roosevelt Regional Landfill. Starting in 2013, TCAT used facility-specific emissions information included in the annual emissions reports that Republic Services submitted to EPA. Estimates for methane emissions was about 10,000 MTCO2e lower in 2013 relative to 2012 emission estimates.

Key Findings - Wastewater Treatment

Emissions from the operation of the main wastewater treatment facility within the county (the Lacey Olympia Tumwater Thurston (LOTT) Clean Water Alliance Budd Inlet Treatment Plant) represent much less than 1% of waste related emissions. These include emissions from (1) burning methane from the onsite digesters and (2) the use of methanol to biologically treat waste.

Wastewater treatment-related GHG emissions decreased by 8% (11 MTCO2e) between 2010 and 2016, while per capita emissions fell by 15% during this period.

Table 15: Summary of Changes in Wastewater Emissions (2010 – 2016)

	2010	2016	Change	% Change
Wastewater	**135**	**124**	**-11**	**-8%**
Digester Gas Combustion	9	11	2	22%
Methanol	126	113	-13	-10%

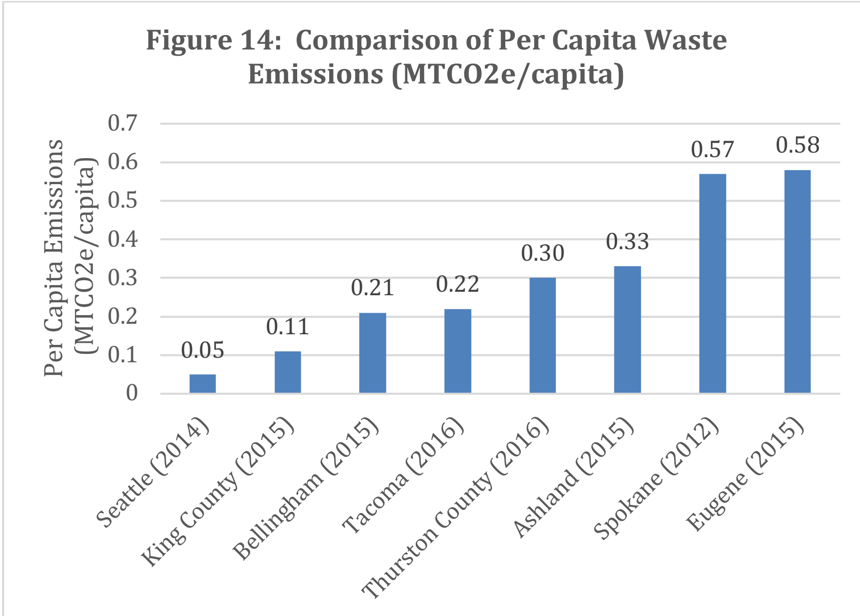
Comparisons to Other Parts of Washington and the United States

Current per capita waste-related emissions in the Thurston region are similar to the US figures for 2016 (EPA, 2018), but lower than the most recent Washington per capita rates for 2013 (Ecology, 2016).

Table 16: Comparison of Waste Per Capita Emissions

Inventory	Year	Total Emissions	Waste	%	Per resident
Thurston County	2016	2,873,437	81,109	2.8%	0.30
Washington State	2013	94,400,000	2,540,000	2.7%	0.37
United States	2015	6,586,700,000	100,800,000	1.5%	0.31

Current per capita waste-related emissions in the Thurston region fall in the middle of the range of per capita waste emissions in several other communities in the Pacific Northwest.



Information Used to Estimate Solid Waste and Wastewater Greenhouse Gas Emissions

TCAT estimated solid waste emissions by using the information on annual solid waste volumes provided by Thurston County Solid Waste (TRPC, 2017c), information on solid waste characteristics published by Thurston County Solid Waste (Green Solutions, LLC, 2014), information on the waste handling practices at the Roosevelt Landfill (EPA 2017b) and default emission factors included in the Clearpath software model.

TCAT estimated wastewater treatment emissions by using information on the average daily digester gas production and fraction of methane in the digester gas provided by LOTT (Peterson, 2017), information on annual methanol use provided by LOTT (Peterson, 2017) and default emission factors included in the Clearpath software model.

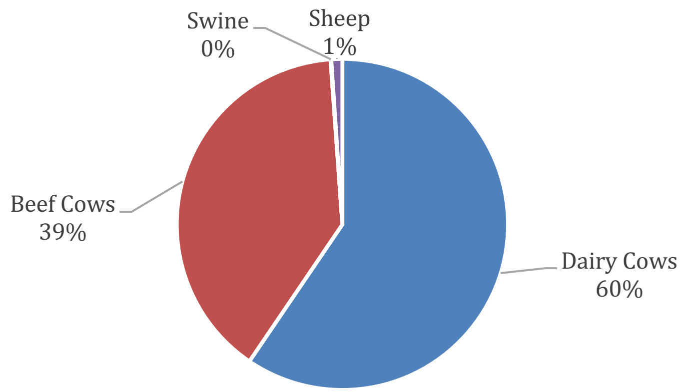
There is a moderate amount of uncertainty surrounding waste emission estimates. EPA calculated a 95 percent confidence interval for methane emissions from landfills of -9% to +9%. In other words, EPA calculated that there was a 2.5% chance that actual methane emissions are more than 9% lower than EPA's estimates and that there is a 2.5% chance that actual methane emissions are more than 9% higher than EPA's estimates.

The equations and information used to estimate waste-related emissions are described further in Appendix B.

Agricultural Livestock

Emissions resulting from agricultural livestock contributed about 1% of Thurston County's carbon footprint, an estimated 37,482 MTCO2e in 2016. Estimated emissions remained largely unchanged between 2010 and 2016.

Figure 15: Relative Contributions to Agricultural Livestock Emissions



Key Findings – Agricultural Livestock

Emissions resulting from agricultural livestock contributed around 1% of Thurston County's carbon footprint, an estimated 37,482 MTCO2e in 2016.

Dairy cows and beef cows accounted for 60% and 39%, respectively, of emissions from agricultural livestock. Swine and sheep emissions represented about 1% of estimated emissions.

Livestock censuses are taken every 5 years. Consequently, several decades would be required to reasonably assess emission trends.

Comparisons to Other Parts of Washington and the United States

Agricultural emissions represent 1% of Thurston County's greenhouse gas emissions. This is much lower than the most recent inventories prepared for Washington and the United States which is consistent with demographic differences between Thurston County, Washington State and the United States. It also reflects the fact that the Washington and United States inventories evaluated a wider range of agricultural activities.

Table 17: Comparison of Agricultural Emissions as a Percentage of Total Emissions

	% of Total Emissions
Thurston County (2016)	1%
Washington State (2013)	6.2%
United States (2015)	7.9%

Information Used to Estimate Agricultural Livestock Greenhouse Gas Emissions

TCAT estimated agricultural livestock emissions by using information on the number of livestock in Thurston County published by the US Department of Agriculture (USDA, 2012 and 2017), Washington-specific emission factors published by the Environmental Protection Agency (EPA, 2018a) and default emission factors in the Clearpath software model.

There is a moderate–to-large amount of uncertainty surrounding agricultural livestock emissions. EPA (2017a) calculated a 95 percent confidence interval for methane emissions from enteric fermentation of -11% and 18%, respectively. In other words, EPA calculated that there was a 2.5% chance that actual methane emissions are more than 11% lower than EPA's estimates and that there is a 2.5% chance that actual methane emissions are more than 18% higher than EPA's estimates.

The equations and information sources used to estimate emissions from agricultural livestock are described further in Appendix B.

Source Categories Not Included in This Report

TCAT developed preliminary GHG emission estimates for several additional sources and/or categories that were ultimately not included in the Thurston region Inventory. TCAT also developed preliminary estimates for a consumption-based emission inventory that provides an alternative approach for characterizing the carbon footprint of the Thurston region.

Other Source Categories

TCAT developed preliminary GHG emission estimates for several additional sources and/or categories that were ultimately not included in the Thurston region Inventory. Local agencies may want to consider including some of these categories in future inventory efforts if they determine that tracking progress for additional sources would support community emission reduction strategies. These additional sources and categories are summarized in Table 18 and briefly discussed in the following paragraphs.

Table 18: Summary of Preliminary Emission Estimates for Source Categories Not Included in the Thurston Region Geographic Plus Inventory

Category	MTCO2e	Basis for Preliminary Estimate	Reasons for Not Including
Refrigerants and Fire Suppressants	81,000 - 98,000	Extrapolated using per capita and per household information from the 2015 emission inventory for the City of Ashland, OR.	Lack of county-specific data and large uncertainty.
Residential and Business Air Travel	133,560	ICLEI Equations TR.6.B.1 and TR.6.D.1 using fuel consumption data and passenger surveys provided by the Port of Seattle.	Limited role for local government intervention.
Olympia Airport	2,750	ICLEI Equation TR.6.B.1 using jet fuel and aviation gas data provided by the Port of Olympia.	Limited role for local government intervention and small % of county emissions.
Ships and Boats	3,750	PSMAF emission estimates for 2011 extrapolated to other years using EPA national data.	Limited data, large uncertainty in estimates and small % of county emissions.
Railroads	6,020	PSMAF emission estimates for 2011 extrapolated to other years using EPA national data.	Limited data, large uncertainty in estimates and small % of county emissions.
Emissions From Producing Gasoline and Diesel Fuel	283,000	ICLEI Equation TR.9.1 using on-road transportation emission estimates for Thurston County.	Consistency and comparability with other community emission inventories.

The following paragraphs provide additional background information on these source categories:

- Refrigerants and Fire Suppressants. Refrigerators and fire suppression equipment are important sources of hydrofluorocarbons (HFCs). HFCs are thousands of times more potent than carbon dioxide and are now subject to international requirements.[42] The Cities of Ashland (2015) and Eugene (2017) estimated that 1% of building emissions were associated with HFCs. TCAT developed preliminary estimates for this category by using the per capita and per household emission estimates from the City of Ashland inventory report. TCAT decided not to include these estimates in the Thurston region inventory because data on refrigerant and fire suppressant use in Thurston region are not readily available.

- Residential and Business Air Travel. TCAT estimated that air travel by Thurston County residents was associated with 133,561 MTCO2e in 2016. These estimates were developed using fuel consumption data and passenger surveys for Sea Tac International Airport (Meyn, 2017). Estimated emissions in 2016 were 40% higher than in 2010. This increase is consistent with the 45% increase in SeaTac passengers (POS, 2017) during that time period. These types of emissions have been included in geographic-plus inventories prepared by the cities of Seattle and Ashland and are typically included in consumption-based emission inventories (see below). TCAT decided not to include air travel emissions because they are largely unaffected by local government actions.
- Other Transportation Sources. TCAT developed preliminary estimates for several other transportation sources: (1) Olympia Airport; (2) ships and boats; and (3) railroads. Estimated emissions from these sources represent less than 1% of the Thurston region's carbon footprint. TCAT decided not to include these estimates because of method and data uncertainties and/or their relatively small impact on overall county GHG emission estimates.
    - Olympia Airport. TCAT prepared preliminary emissions estimates using information on jet fuel and aviation gas deliveries provided by the Port of Olympia (Liebel, 2017). In 2016, estimated airport emissions were 2,750 MTCO2e.
    - Recreational and Harbor Vessels. TCAT prepared preliminary emissions estimates using information from the 2011 Puget Sound Maritime Air Forum Air Emissions inventory (PSMAF, 2012).[43] In 2016, estimated emissions from recreational and harbor vessels were 3,750 MTCO2e.
    - Rail Transportation. TCAT prepared preliminary emissions estimates using information from the 2011 Puget Sound Maritime Air Forum Air Emissions inventory (PSMAF, 2012).[44] In 2016, estimated railroad emissions were 6,020 MTCO2e.
- Emissions Associated with Producing Transportation Fuels. TCAT developed preliminary estimates on the amount of GHGs emitted during the production of the gasoline and diesel fuel used in Thurston region's cars and

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[42] In October 2016, negotiators from 197 nations signed an agreement to amend the Montreal Protocol in Kigali, Rwanda. Under the Kigali agreement, these countries are expected to reduce the manufacture and use of hydrofluorocarbons (HFCs) by roughly 80-85% from their respective baselines, before 2045. This phase down is expected to slow the global average temperature rise by up to 0.5^{o} C by 2100.

[43] The PSMAF inventory provides emission estimates for recreational vessels and harbor vessels. TCAT extrapolated the 2011 PSMAF estimates to other years using information on United States recreational vessel GHG emissions (EPA, 2017, Table A-118) and United States ships and non-recreational boats GHG emissions (EPA, 2017, Table -119).

[44] The PSMAF 2011 inventory provides emission estimates for line haul locomotives in Thurston County. TCAT extrapolated the 2011 PSMAF estimates to other years using information on United States freight railroad emissions (EPA, 2017, Table -119).

trucks. The ICLEI (2013a) guidance includes methods for estimating these emissions that translates into fuel production emissions being equivalent to about 25% of the GHG emissions associated with the combustion of gasoline and diesel fuel.[45] These types of emissions are typically included in consumption-based emission inventories (see below). TCAT elected not to include these emissions in the Thurston region inventory in order to maintain consistency and comparability with the initial TCAT inventory and geographic-plus inventories prepared by other jurisdictions. (e.g., Seattle, Tacoma, Bellingham).

Consumption-Based Emission Inventory Estimates

Consumption-based emissions inventories (CBEIs) provide an alternate approach for characterizing a community's carbon footprint. CBEIs provide estimates of the global greenhouse gas emissions that result during the complete life cycle of goods and services consumed in a particular community or geographic area. This includes emissions during pre-purchase activities,[46] use[47] and post-consumer disposal.[48] For example, emissions associated with a household car includes emissions associated with manufacturing the car, producing the steel, aluminum and other materials used in manufacturing the car, transporting the finished car to dealerships, vehicle use, production of the gasoline and diesel fuels used when driving the car and final disposal of the car.

These types of inventories are based on several key premises:

- Purchase and consumption of goods and services is the primary cause of emissions.
- A full accounting of a community's climate impact needs to consider the total life-cycle emissions from cradle (the production phase) to grave (post-consumer disposal).
- Many of the emissions associated with producing the goods and services purchased and consumed in a community occur outside the community, but these emissions have the same effect on the global climate as emissions that physically originate within the community.

Several state and local communities have developed CBEIs:

- The Oregon Department of Environmental Quality has developed methods for estimating consumption-based emissions that they have used to develop a CBEI for the State of Oregon (DEQ, 2018).
- Several Oregon cities have used the information compiled by DEQ to incorporate consumption-based emission estimates into their local GHG inventories.
- King County has developed methods for estimating consumption-based emissions and used those methods to develop a CBEI for calendar year 2015 (Cascadia and Hammerschlag, 2017).

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45 This approach is consistent with the methods used to estimate the overall emissions associated with electricity consumption. These methods include emissions associated with producing the fuels (e.g., coal and natural gas) that are used to produce the electricity used in Thurston County.

46 "Pre-purchase" includes most emissions prior to the point of purchase, including supply chain, supply chain transport, and final assembly and production. For services (including health care), pre-purchase emissions include all emissions associated with providing the service.

47 "Use" includes the life-cycle emissions of fuels and electricity used to power lights, electronics, appliances, and personal vehicles, as well as trace emissions from refrigerants and vehicle lubricants.

48 "Post-consumer disposal" includes the emissions from landfilling and incineration of purchased goods.

- The Washington Department of Ecology (Morris et al., 2007) has developed a tool that can be used to estimate consumption-based emission estimates for Washington State. Ecology used the tool to develop consumption-based estimates for 2005 through 2011, but they have not prepared consumption-based emission estimates for more recent years.

TCAT developed a preliminary CBEI for the Thurston region for calendar year 2015 using information from the Oregon DEQ reports. The preliminary estimate includes emissions from households and governments, but not emissions from business capital and investments.[49]

- Thurston County Households. TCAT estimated that consumption by Thurston County households produced 4,882,000 MTCO2e in 2015.[50] Over two-thirds of household consumption-based emissions are associated with the following five categories: Vehicles and parts (22.6 %); Food and beverages (15.3%); Appliances (12.4%); Services (12.1%); and Healthcare (8.4%).
- Government: TCAT estimated that consumption by Thurston County governments produced 610,000 MTCO2e in 2015.[51]

Characterizing a community's total carbon footprint is not simply a matter of adding the CBEI with the geographic -plus inventory contained in this report. Oregon DEQ found that there is considerable overlap between the emission estimates prepared using a sector or geographic-plus approach and consumption-based emission estimates. Specifically, they estimated that Oregon's sector-based emissions and consumption-based emissions in 2015 were about 63 and 89 million MTCO2e, respectively. The two inventories shared about 38 million MTCO2e in common.[52] Consequently, simply adding together the two estimates would have overestimated the combined statewide GHG emissions by 33%.

Several Oregon cities (cities of Ashland, Corvallis and Lake Oswego) have used the information compiled by DEQ to incorporate consumption-based emission estimates into their local GHG inventories. For example, the city of Ashland estimated that consumption-based emissions associated with the residential consumption of goods and food represented almost 37% of Ashland's GHG footprint during calendar year 2015.

A consumption-based emission inventory could provide a valuable tool for local governments seeking to

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[49] TCAT did not develop a preliminary CBEI for business capital/investment because of the uncertainties associated with extrapolating the Oregon business capital/investment estimates to the Thurston region.

[50] TCAT developed the preliminary CBEI for households using the following information: (1) Average per-household consumption-based greenhouse gas emissions (MTCO2e/HH) by income category was obtained from Table B-4 in ODEQ (2018b); (2) Information on the number of Thurston County households by income category in calendar year 2015 was obtained from the US Census Bureau (2018); (3) Household greenhouse gas emissions were estimated for each income category by multiplying the per household emissions in Table B-4 by the total number of Thurston County households in that income category; and (4) Total household greenhouse gas emissions were estimated by summing emission estimates for all income categories.

[51] TCAT developed the preliminary CBEI for governments by assuming that the relationship between government and household emissions (e.g., government emissions represent 12.5% (1/8) of household emissions) is the same for the Thurston region and the State of Oregon. This relationship is similar to ratio of government and household emissions observed in King County (13.3%). This may underestimate government consumption-based emissions in the Thurston region given that the percentage of the overall workforce represented by government employees is much higher in Thurston County (31% of Thurston County's employed population is classified as government workers by the US Census Bureau) than the State of Oregon (16.2%) and King County (12.4%).

[52] Emissions common to both inventories include emissions from household and government use of energy and waste disposal.

understand the global implications and tradeoffs associated with different control strategies. For example, replacing older vehicles with newer more fuel-efficient ones should take into account the global emissions associated with manufacturing a new vehicle vs the reduced energy consumption/emissions during vehicle use.

TCAT decided not to include the preliminary CBEI estimates in the Thurston region's inventory because (1) lack of readily available local data needed to estimate consumption-based emissions in the Thurston region (2) uncertainties in extrapolating information from other consumption-based emission inventories (particularly for government and business capital/investment), and (3) concerns about overlaps with the source categories included in the Thurston region inventory that could lead to double-counting emissions.

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Recommendations

TCAT plans to present this report to Thurston Regional Planning Council, County Commissioners, and individual city councils, tribal councils and other agencies. Based on our review of current emission trends, TCAT recommends the following steps be taken over the next 6-12 months:

1. Climate Action Strategies. Local governments should continue to develop and implement comprehensive strategies for reducing greenhouse gas emissions in the Thurston region while also pursuing on-going efforts to reduce emissions.
2. Standardize Emission Inventory Process. As part of their broader climate action strategies, local governments should prepare and publish annual or biennial emission inventory reports. To support this work, local governments should (1) identify a common set of source categories and (2) adopt common methods for preparing GHG emission inventories.
3. Consistency and Efficiency. Local governments should consider designating one agency (such as the Thurston Regional Planning Council) to prepare annual inventories for all local jurisdictions.
4. Funding. Local governments should provide sufficient funding for preparing up-to-date GHG emission inventories that can be used to measure progress on attaining climate action goals.
5. Evaluate Other Emission Sources. Local governments should evaluate whether to include additional source categories in future inventories. TCAT plans to continue to research methods and data sources for evaluating additional source categories.
6. Evaluate Contributing Factors. Cascadia and Hammerschlag (2017) used a draft tool being developed by ICLEI-USA to mathematically evaluate the various factors contributing to changes in King County emissions between 2008 and 2015. When it becomes available, local governments should consider using the tool to evaluate trends and the effectiveness of local programs.
7. Land Use Sources and Sinks. Local governments should consider expanding their inventories to include land use emissions sources and sinks that absorb carbon dioxide (e.g. forest, agricultural soils). EPA considers both emissions and sinks when preparing the US greenhouse gas inventory. They estimated that carbon sinks in the US were equivalent to about 20% of GHG emissions in 2015 (EPA, 2017a). Measures to enhance carbon sequestration in soils and trees could be an important part of the Thurston region's efforts to achieve its 2050 target for reducing GHG emissions.
8. Periodic Review of Methods and Procedures. Local governments should periodically review the methods and procedures for preparing emission inventories taking into account current scientific information, state and federal policies, implementation experience and issues of local interest.

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Conclusions

The Thurston Regional Planning Council's Sustainable Thurston plan — known formally as *Creating Places—Preserving Spaces: A Sustainable Development Plan for the Thurston Region* — includes a priority goal to "move toward a carbon-neutral community." This goal includes recommended emission-reduction targets for the Thurston region:

- Achieve a 25% reduction of 1990 greenhouse gas levels by 2020;
- Achieve a 45% reduction of 1990 greenhouse gas levels by 2035; and
- Achieve an 80% reduction of 1990 greenhouse gas levels by 2050.

More recently, the cities of Lacey, Olympia, Tumwater, along with Thurston County, are in 2018 adopting similar targets grounded in a 2015 baseline year: 45% reduction below 2015 levels by 2030, and 85% below by 2050.

TCAT found that the Thurston region was able to make meaningful progress on achieving these goals between 2010 and 2012, when emissions fell by over 7% in 2011 and 2012 (average annual decline of 3.6% per year). That progress was reversed during the subsequent four years when emissions rose by almost 10% (average annual increase of 2.3% per year). One encouraging sign was the 5% decline in per capita emissions between 2010 and 2016.

Achieving the Thurston region's climate goals will require much deeper annual emission reductions than those achieved between 2010 and 2016. Achieving the 2020, 2035 and 2050 reduction goals will require annual reductions that average 13.7%, 4.6% and 5.5%, respectively.[53] For example, achieving the emission reduction targets for 2050 (80% below 1990 levels) would require that annual emission reductions of 5.5% be achieved every year between 2017 and 2050.

Table 19: Estimated Annual Emission Reductions to Achieve Thurston County Climate Goals

Thurston County Climate Goals	GHG Emissions (MTCO2e)	Average Annual Emission Reductions (%)		
		To Achieve Climate Goal	Actual 2010-2012	Actual 2012-2016
Estimated 1990 Emissions	2,196,532			
2020 – 25% below 1990	1,647,399	- 13.7%	- 3.6%	2.3%
2035 – 45% below 1990	1,208,093	- 4.6%	- 3.6%	2.3%
2050 – 80% below 1990	439,306	- 5.5%	- 3.6%	2.3%

The annual reductions required to meet the 2020 reduction goal are well beyond reductions actually achieved on a sustainable basis anywhere in the United States and the rest of the world. Achieving the annual emissions reductions needed to meet the 2035 and 2050 goals will require substantial changes to the region's energy sources and transportation and building energy consumption.

[53] TCAT used a simple exponential model to estimate the average annual emission reductions needed to achieve the Sustainable Thurston climate goals. Key assumptions include: (1) annual reductions would occur every year beginning in 2017 until 2020, 2035 and 2050; (2) estimated reductions are independent of achieving earlier reduction targets; and (3) needed reductions are based on estimated 1990 emissions of 2,196,532 MTCO2e (TRPC, 2017). This emission target is consistent with the assumptions underlying the Thurston County Carbon Wedge Analysis (CET/SEI, 2017).

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References

Cascadia Consulting Group and Hammerschlag LLC. 2017. King County Greenhouse Gas Emissions Inventory. Prepared for King County Washington. Document available at: https://your.kingcounty.gov/dnrp/climate/documents/2015-KC-GHG-inventory.pdf

City of Ashland. 2017. City of Ashland Greenhouse Gas Inventory: Community and City Operations, Results, Analyses and Recommendations. Prepared by the Good Company, February 2017. This document is available at: http://www.ashland.or.us/files/Ashland_GHG_Inventory_Report.pdf

City of Bellingham. 2017. Climate Protection Plan V.1.3 – 2017 Update. This document is available at: https://www.cob.org/Documents/pw/environment/City%20of%20Bellingham%20Climate%20Protection%20Action%20Plan%20%20v1.3.pdf

City of Corvallis. City of Corvallis 2012 Community Greenhouse Gas Inventory Report. This document is available at: https://www.corvallisoregon.gov/publicworks/page/community-greenhouse-gas-inventory

City of Eugene. 2017. Eugene, Oregon Community Greenhouse Gas Inventory: Sector-Based Inventory for 2010 – 2015; Consumption-Based Inventory for 2013. Prepared by the Good Company, February 2017. This document is available at: https://www.eugene-or.gov/2170/Climate-Recovery-Resources

City of Olympia. 2018. Community Indicator Dashboard. This information is available at: http://olympiawa.gov/city-government/codes-plans-and-standards/action-plan/community-indicators.aspx

City of Olympia. 2017. The Olympia Comprehensive Plan. The plan was adopted by Ordinance 6945 on December 16, 2014, and is current through Ordinance 7104, passed October 24, 2017. This document is available at: http://www.codepublishing.com/WA/Olympia/?compplan/OlympiaCPNT.html

City of Lake Oswego. 2012. Community Greenhouse Gas Inventory For Lake Oswego The carbon footprint of residents, businesses and government inside the City of Lake Oswego. Prepared by the Good Company, February 2012. This document is available at: http://welovelakeoswego.com/wp-content/uploads/2011/01/Attach-2a.-Lake-Oswego-GHG-Inventory1.pdf

City of Seattle. 2016. 2014 Seattle Community Greenhouse Gas Emission Inventory. Prepared by the Stockholm Environment Institute for the Seattle Office of Sustainability and the Environment, August 2016. This document is available at: https://www.seattle.gov/Documents/Departments/OSE/2014GHG%20inventorySept2016.pdfCity of Spokane. 2016. Greenhouse Gas Inventory Report for 2010-2012. June 27, 2016. Document is available at: https://static.spokanecity.org/documents/publicworks/environmental/2016/greenhouse-gas-inventory-report-for-2010-2012.pdf

City of Tacoma Office of Environmental Policy and Sustainability. 2017. 2016 Community and Government Operations Greenhouse Gas Emissions Inventory. This document is available at: http://cms.cityoftacoma.org/sustainability/CityofTacoma-GreenhouseGasEmissionsUpdateReport2016.pdf

Clean Energy Transition/Stockholm Environment Institute. 2017. Methodology and Assumptions for Carbon Wedge Analysis with Transportation Scenarios. Memorandum from CET/SEI to Thurston Regional Planning Council (Dated October 13, 2017). This document is available at. http://www.trpc.org/DocumentCenter/View/5016

Erickson, P. and C. Carlson. 2012. Greenhouse Gas Tracking Framework for King County: 2010 Update. This document is available at: http://www.kingcounty.gov/~/media/services/environment/climate/documents/2010_King_County_Core_GHG_Emissions.ashx?la=en

Global Covenant of Mayors for Climate and Energy. 2017. FAQ on a Common Standard for City and Local Government GHG Emissions Inventory Reporting for the Global Covenant of Mayors. Available at: https://www.globalcovenantofmayors.org/about/

Green Solutions, LLC. 2017. Thurston County Solid Waste Management Plan (Preliminary Draft June 2017. Prepared by Green Solutions LLC for Thurston County Public Works Department, June 2017. Document is available at: http://www.co.thurston.wa.us/solidwaste/swac/SWMP.htm

Green Solutions, LLC. 2014. Thurston County Waste Composition Study 2013 - 2014. Prepared by Green Solutions LLC for Thurston County Solid Waste. December 2014. Document is available at: http://www.co.thurston.wa.us/solidwaste/regulations/docs/ThurstonCountyWasteComp2014.pdf

Intercity Transit. 2016. 2016 Sustainability Report. Document available at: https://www.intercitytransit.com/sites/default/files/Sustainability-Report-2016_0.pdf

International Council of Local Environmental Initiatives (ICLEI). 2013a. U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions. This document is available at: http://icleiusa.org/publications/us-community-protocol/

ICLEI. 2013b. Appendix C: Built Environment Emission Activities and Sources. Appendix C of U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Version 1.1). This document is available at: http://icleiusa.org/publications/us-community-protocol/

ICLEI. 2013c. Appendix D: Transportation and Other Mobile Emission Activities and Sources. Appendix D of U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Version 1.1). This document is available at: http://icleiusa.org/publications/us-community-protocol/

ICLEI. 2013d. ClearPath Community-Scale Emissions Management Software.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. This document is available at: http://www.ipcc.ch/report/ar5/syr/

International Panel on Climate Change. 2007. Climate Change 2007: A Synthesis Report. This document is available at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

International Panel on Climate Change. 1996. Climate Change 1995: The Science of Climate Change. This document is available at: https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf

Kyba, CCM, T Kuester, A Sanchez de Miguel, K Baugh, and A Jechow. 2017. Artificially lit surface of Earth at night increasing in radiance and extent. Science Advances (3) 11: 1701528.

Liebel, A. 2017. Email from Amber Liebel (Contract Administrator, Port of Olympia) to Dave Bradley re PR17-52 Bradley RELEASE (September 1, 2017).

Meyn, S. 2017. Email from Stephanie Meyn (Climate Protection Program Manager, Port of Seattle) to Dave Bradley re Jet Fuel Deliveries/Dispensed/Uplift (October 17, 2017)

Morris, J, HS Matthews, F Ackerman, M Morris and R Hlvaka. 2007. The Washington State Consumer Environment Index (CEI): A Summary of the Development of a Tool to Understand and Support Consumer Choices that Have Preferable Environmental Outcomes (Revised Draft). Prepared for the Washington Department of Ecology.

Oregon Department of Environmental Quality. 2018. Oregon's Greenhouse Gas Emissions through 2015: An assessment of Oregon's sector-based and consumption-based greenhouse gas emissions. Document available at: https://www.oregon.gov/deq/FilterDocs/OregonGHGreport.pdf

Peterson, G. 2017. Email from George Peterson (Operations Supervisor, LOTT Clean Water Alliance) to Dave Bradley re LOTT Numbers (September 12, 2017)

Port of Seattle. 2017. Airport Statistics. This information is available at: https://www.portseattle.org/page/airport-statistics

Puget Sound Energy. 2017. Puget Sound Energy's 2016 Greenhouse Gas Inventory. Submitted to PSE by Environmental Resource Management (ERM). November 2017. Document available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Energy. 2016. Puget Sound Energy's 2015 Greenhouse Gas Inventory. Submitted to PSE by Environmental Resource Management (ERM). September 2016. Document available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Energy. 2015. Puget Sound Energy's 2014 Greenhouse Gas Inventory. Submitted to PSE by Environmental Resource Management (ERM). July 2015. Document available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Energy. 2014. Puget Sound Energy's 2013 Greenhouse Gas Inventory. Submitted to PSE by Environmental Resource Management (ERM). August 2014. Document available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Energy. 2013. Puget Sound Energy's 2012 Greenhouse Gas Inventory. Submitted to PSE by AECOM. July 2013. Document available at: :https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Energy. 2012. Puget Sound Energy's 2011 Greenhouse Gas Inventory. Submitted to PSE by AECOM.

August 2012. Document available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Energy. 2011. Puget Sound Energy's 2010 Greenhouse Gas Inventory. Submitted to PSE by AECOM. August 2011. Document available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

Puget Sound Maritime Air Forum. 2012. 2011 Puget Sound Maritime Air Emission Inventory. Prepared by Starcrest Consulting Group, LLC, September 2012. Document available at: https://www.portseattle.org/Environmental/Air/Seaport-Air-Quality/Pages/Puget-Sound-Maritime-Air-Emissions-Inventory.aspx

Sustainable Thurston. 2013. Creating Places Preserving Spaces. A Sustainable Development Plan for the Thurston Region. December 2013. The Environment chapter discusses GHG emission reduction goals and is available at: https://www.trpc.org/DocumentCenter/Home/View/685

Thurston Climate Action Team. 2014. Greenhouse Gas Emissions Inventory for Calendar Year 2010: Thurston County, Washington. Version 1.6, Revised October 6, 2014. This document is available at: http://www.thurstonclimateaction.org/tcat-docs/

Thurston Regional Planning Council (TRPC). 2017a. Transportation: Sustainable Thurston Report Card. Vehicle Miles Traveled (VMT) Information accessed on August 9, 2017 at: http://www.trpc.org/709/Greenhouse-Gas

Thurston Regional Planning Council (TRPC). 2017b. Investment: Sustainable Thurston Report Card. Puget Sound Energy data on electricity and natural gas use accessed on August 31, 2017 at: http://www.trpc.org/693/Energy-Consumption

Thurston Regional Planning Council (TRPC). 2017c. Investment: Sustainable Thurston Report Card. Thurston County data on solid waste volumes accessed on September 2, 2017 at: http://www.trpc.org/694/Solid-Waste

Thurston Regional Planning Council (TRPC) 2017d. Population, Household and Employment Data Tables. Thurston County data on population and households accessed September 8, 2017 at: http://www.trpc.org/480/Population-Housing-Employment-Data

Thurston Regional Planning Council (TRPC) 2017e. Email from Michael Ambrogi (Senior GIS Analyst) to Dave Bradley re: VMT Estimates (August 31, 2017).

United States Department of Agriculture (USDA). 2017. National Agricultural Statistics Service. Information is available at: https://www.nass.usda.gov

United States Department of Agriculture (USDA). 2014. 2012 USDA Census of Agriculture. Document available at: https://www.agcensus.usda.gov/Publications/2012/#full_report

United States Census Bureau. 2017. American Fact Finder. Information is available at: https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

United States Department of Transportation (USDOT). 2017. Average Fuel Efficiency of US Light Duty Vehicles. Table 4-3. Information is available at: https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles

United States Energy Information Administration (EIA). 2017a. Washington State Energy Profile. Accessed September 28, 2017. Document is available at: https://www.eia.gov/state/analysis.php?sid=WA

United States Energy Information Administration (EIA). 2017b. Today in Energy: Per capita residential electricity sales in the U.S. have fallen since 2010. Accessed March 28, 2018. Available at: https://www.eia.gov/todayinenergy/detail.php?id=32212

Stone, David and Melissa Lymes. 2016.. Issues in Focus: Fuel Consumption and Greenhouse Gas Emissions Phase 2 Standards for Medium- and Heavy Duty Vehicles. Document is available at: https://www.eia.gov/outlooks/archive/aeo16/fcghg.cfm

United States Environmental Protection Agency (USEPA). 2018a. Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2016 (Draft). USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-18-001. April 2017. Document available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

United States Environmental Protection Agency (USEPA). 2018b. EPA Emissions and Generation Resources Integrated Database (eGRID). eGRID information for 2010, 2012, 2014 and 2016 are available at: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

United States Environmental Protection Agency (USEPA). 2017a. Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. Document available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

United States Environmental Protection Agency (USEPA). 2017b. GHG Summary Report for Roosevelt Regional Landfill. Available at: https://ghgdata.epa.gov/ghgp/service/html Accessed on November 2, 2017.

Washington State Department of Commerce. 2017. Washington State Electric Utility Fuel Mix Disclosure Reports For Calendar Year 2016. Prepared for the Washington State Legislature. The reports for calendar years 2010 through 2016 are available at: http://www.commerce.wa.gov/growing-the-economy/energy/fuel-mix-disclosure/

Washington Department of Ecology. 2017. Report to the Legislature on Reducing Greenhouse Gas Emissions in Washington State Government. Publication No. 16-02-027. Available at: https://fortress.wa.gov/ecy/publications/documents/1602027.pdf

Washington Department of Ecology. 2016a. Washington Greenhouse Gas Emission Reduction Limits. Report prepared under RCW 70.235.040. Publication No. 16-01-010. Available at: https://fortress.wa.gov/ecy/publications/documents/1601010.pdf

Washington Department of Ecology. 2016b. Report to the Legislature on the Washington Greenhouse Gas Emissions Inventory: 2010 – 2013. Publication No. 16-02-025. Document available at: https://fortress.wa.gov/ecy/publications/SummaryPages/1602025.html

Washington State Office of Financial Management (OFM). 2017. April 1 Official Population Estimates. The 2010 census and yearly estimates for 2011 through 2017 are available at: http://www.ofm.wa.gov/pop/april1/

World Resource Institute (WRI), C40 Cities and ICLEI. 2014. Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories: An Accounting and Reporting Standard for Cities. This document is available at: http://www.iclei.org/fileadmin/user_upload/ICLEI_WS/Documents/Climate/GPC_12-8-14_1_.pdf

Appendices

Appendix A: Geographic and Demographic Data

Thurston County is located at the southern end of Puget Sound. The county has a total area of 774 square miles. This includes 727 square miles of land and 47 square miles (6.03%) of water. It is the seventh smallest county in the state, but the sixth most populous, with 349.4 persons per square mile. The county seat is Olympia, which is also the state capital and the county's largest city.

Population

As of the 2010 census, the county population was 252,264. The Thurston Regional Planning Council (TRPC) estimates that the county's population grew to be 272,700 in 2016. The Office of Financial Management's (OFM's) population information indicates that the growth rate from 2010 to 2016 in Thurston County (8.1%) was faster than the statewide growth rate during that period (6.8%).

State and County Population and Household Information Used to Prepare GHG Emission Estimates							
	2010	2011	2012	2013	2014	2015	2016
Population	People	People	People	People	People	People	People
County	252,264	254,100	256,800	260,100	264,000	267,400	272,700
State	6,724,540	6,767,900	6,817,770	6,882,400	6,968,170	7,061,410	7,183,700
Households	Households	Households	Households	Households	Households	Households	Households
County	108,182	109,272	110,384	111,826	113,281	114,404	115,771
State	2,885,677	2,904,265	2,923,251	2,946,650	2,976,801	3,009,368	3,043,770

Information compiled by the Thurston Regional Planning Council indicates that almost 50% of the County's population (134,890 people) live in a city. Olympia is the largest city with a population of 51,600 people, followed by Lacey (47,540) and Tumwater (23,040). Approximately 30% and 20% of the population live in unincorporated Thurston County and urban growth areas (UGAs), respectively. A small percentage of county residents live on a tribal reservation.

Demographics

Thurston County had a slightly older population than the state in 2016. The percentage of people older than 65 years old in Thurston County (16.5%) was higher than the statewide figure (14.8%). The US Census Bureau also estimated that the percentage of people in Thurston County under 18 years old (21.7%) was slightly less than the statewide percentage (22.4%). Those under five made up 6.1% of Thurston County's population, compared to the state's 6.3%.

In 2016, females represented 51.1% of Thurston County's population, slightly more than that of the state (50.0%). Thurston County is somewhat less diverse than the state. As of July 2016, whites made up 82.4% of its population compared to 80% of the state's population. The percentages of Native Americans, African Americans, Hispanics and Asian Americans are all lower than the statewide percentages.

Educational attainment

Most Thurston County residents age 25 and older (93.6%) are high school graduates, which compares very favorably with 90.6% of Washington State's residents and 87% of U.S. residents over the period 2012-2016. Those with a bachelor's degree or higher made up 33.3% of Thurston County residents age 25 and older compared to 33.6% percent of state residents and 30.3% of U.S. residents.

Employment

The Thurston Regional Planning Council (TRPC) reported that total employment in Thurston County was 145,621 jobs in 2016. The four largest employment sectors in Thurston County are state government (17%); education, health and social services (14%); professional/business services (11%) and retail (11%).

Appendix B: Equations, Activity Data and Emission Factors

This Appendix describes the equations, activity data and emission factors that TCAT used to prepare the GHG emission estimates for Thurston County.

TCAT prepared this inventory using ICLEI's *U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions* (ICLEI 2013a). This protocol was supplemented by the more recent '*Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories'* prepared by the World Resource Institute and ICLEI (WRI and ICLEI 2014). The US and Global Protocols establish a four-step process for estimating GHG emissions:

1. Identify relevant source categories. ICLEI encourages local governments to include as many emission sources as possible. TCAT developed estimates for the following types of sources:
    - Built Environment (residential, commercial and industrial buildings and outdoor lighting);
    - On-Road Transportation (cars and light-, light medium-, medium- and heavy-duty trucks);
    - Solid Waste (processing, transportation and methane emissions from landfills);
    - Agricultural Livestock.
2. Obtain activity data for source categories. The ICLEI Protocol uses information on electricity and natural gas use, vehicle miles traveled and other activity measures to develop GHG emission estimates. The TRPC has compiled much of the activity data needed to prepare these estimates:
    - The number of customers and amount of electricity used for residential, commercial and industrial buildings and outdoor lighting during the 2010 – 2016 time period.
    - The number of customers and amount of natural gas used for residential, commercial and industrial buildings during the 2010 – 2016 time period.
    - The number of vehicle miles traveled (VMT) during the 2010 – 2016 time period.
    - The amount of solid waste generated by Thurston County residents and businesses during the 2010 – 2016 time period.

    The TRPC information was supplemented with (1) information on other residential heating fuels from the US Energy Information Administration and the US Census Bureau, (2) information on the number of agricultural livestock in Thurston County compiled by the US Department of Agriculture and (3) information on annual methanol use and the average daily digester gas production and fraction of methane in the digester gas provided by LOTT wastewater treatment facility.
3. Identify appropriate emission factors. The ICLEI Protocol uses standard emission factors for converting activity data to GHG emission estimates. TCAT supplemented the default emission factors with information from the annual Puget Sound Energy emission reports, the 2015 and 2016 United States inventory reports and solid waste composition information from Thurston County Solid Waste.
4. Calculate GHG emissions. TCAT used the web-based ClearPath Community-Scale Emissions Management Software (ICLEI 2013b) to calculate GHG emissions for the Thurston Region. Emissions of individual GHGs were converted to MTCO2e using the global warming potentials (GWP) published in *the International Panel on Climate Change's 5th Assessment Report* (IPCC 2013).

Built Environment - Electricity Use (Residential, Commercial, Industrial and Lighting)

- CO2, CH4 and N2O emissions associated with electricity use were each estimated using Equation BE.2.2 (shown below). This resulted in three GHG estimates, one for each gas. Estimates for total greenhouse gas emissions from each sector were obtained by summing the estimates for the three individual gases.

$$\text{GHG Emissions (MTCO2e)} = \frac{(\text{Electricity})*(\text{EF})*(\text{GWP})}{2{,}204.6\ (\text{lbs/MT})}$$

Where:

Electricity = Amount of electricity used in residential, commercial and industrial buildings and for lighting (kWh/year)

EF = Emission factor (lb/kWh)

GWP = Global Warming Potential for carbon dioxide (1), methane (28) or nitrogen dioxide (265)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on electricity use in Thurston County was obtained from Puget Sound Energy. This information is shown below and is available at the Thurston Regional Planning Council's (TRPC's) website: http://www.trpc.org/693/Energy-Consumption

Activity Data Provided By Puget Sound Energy							
	2010	2011	2012	2013	2014	2015	2016
	kWh	kWh	kWh	kWh	kWh	kWh	kWh
Lighting (ext)	4,419,884	4,210,561	4,260,253	9,906,493	12,778,793	14,395,639	11,273,368
Residential	1,266,273,211	1,310,060,008	1,269,359,538	1,267,128,962	1,271,598,941	1,241,099,148	1,238,087,439
Commercial	920,512,299	928,324,061	908,332,627	917,983,430	924,184,162	949,560,852	960,903,366
Industrial	136,413,709	136,410,005	143,070,748	136,695,424	113,376,794	119,530,793	140,173,901
	Customers	Customers	Customers	Customers	Customers	Customers	Customers
Residential	105,105	105,786	106,737	122,139	108,945	110,211	112,379
Commercial	13,451	13,671	13,585	10,895	14,240	14,403	14,738
Industrial	211	209	199	205	200	196	196
Lighting	112	110	115	325	591	612	640

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
    - The emission factors for CO2, CH4 and N2O using toe estimate GHG emissions associated with electricity production were obtained from the Puget Sound Energy's Greenhouse Gas Inventories prepared for 2010 through 2016. These documents are available at: https://pse.com/aboutpse/Environment/Pages/Greenhouse-Gas-Policy.aspx

PSE Emission Intensity (All Owned and Purchased Electricity) (lb/KWh)[54]			
	CO2	**CH4**	**N2O**
2010	1.0	6.40E-05	1.60E-05
2011	0.9	5.10E-05	1.50E-05
2012	0.9	4.40E-05	1.50E-05
2013	1.0	5.80E-05	1.50E-05
2014	1.0	6.00E-05	1.60E-05
2015	1.0	5.60E-05	1.60E-05
2016	1.1	6.0E-05	1.5E-05

[54] PSE emission intensity values were obtained from Table 7-1 in the PSE annual GHG inventory reports for 2010 through 2016.

Built Environment - Upstream Impacts of Electricity Losses During Transmission & Distribution

- CO_2, CH_4 and N_2O emissions associated with electricity losses during transmission and distribution were estimated using Equation BE.4.4.1. Estimates for total greenhouse gas emissions from each sector were obtained by summing the estimates for the three individual gases. The following equation was used to estimate emissions of each greenhouse gas:

$$\text{GHG Emissions (MTCO2e)} = \frac{(\text{Electricity})*(\text{Grid Loss Factor})*(\text{EF})*(\text{GWP})}{2{,}204.6\ (\text{lb/MT})}$$

Where:

Electricity	=	Amount of electricity used in residential, commercial and industrial buildings and for lighting (kWh/year)
Grid Loss Factor	=	Percentage of electricity lost during transmission & distribution (%)
EF	=	Emission factor (lb/kWh)
GWP	=	Global Warming Potential for carbon dioxide (1), methane (28) and nitrogen dioxide (265)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on electricity use in Thurston County was obtained from Puget Sound Energy. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC's) website: http://www.trpc.org/693/Energy-Consumption
  - Information on electricity transmission and distribution losses in the Western Grid was obtained from the EPA Emissions and Generation Resources Integrated Database (eGRID). eGRID 2016 includes a grid loss factor of 4.23% for the Western grid. This value was used for 2016. eGRID 2014 includes a grid loss factor of 4.79% for the Western grid. This value was used to prepare estimates for years 2014 and 2016. eGRID 2012 includes a grid loss factor of 5.76%. This value was used to prepare estimates for years 2012 and 2013. eGRID 2010 includes a grid loss factor of 6.84%. This value was used to prepare estimates for 2010 and 2011. This information is available at: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The emission factors for CO_2, CH_4 and N_2O were obtained from the Puget Sound Energy's Greenhouse Gas Inventories prepared for 2010 through 2016. These values are shown above.

Built Environment - Upstream Impacts of Electricity Use

- Upstream CO2e emissions were estimated using two equations: (1) Equation BE.5.2 was used to estimate the amounts of coal and natural gas used to produce the electricity used in Thurston County; and (2) Equation BE.5.1.1 was used to calculate the upstream CO2e emissions associated with producing the coal and natural gas used to generate the electricity used in Thurston County.
- Equation BE.5.2 used to estimate the amounts of coal and natural gas used to produce the electricity used in Thurston County is displayed below.

Total Primary Fuel Use = (Total Elec. Use)*(Fuel Mix)*(Fuel Type Mix)*(Fuel Generation Pot)

Where:

Total Elec. Use	=	Total annual electricity use including electricity lost during transmission and distribution (kWh)
Fuel Mix	=	Percent of total electricity generated with coal and natural gas (%)
Fuel Type Mix	=	Percent of fuel type from each class of fuels (%)
Fuel Generation Pot	=	Amount of fuel used to generate one kWh (unit/kWh)

- Equation BE.5.1.1 used to calculate the upstream CO2e emissions associated with producing the coal and natural gas used to generate the electricity used in Thurston County is displayed below. Separate calculations were performed for coal and natural gas and then summed to estimate total upstream emissions.

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(Fuel Use)*(CF)*((Emission Factor)*(GWP)}}{\text{1000 (kg/MT)}}$$

Where:

Fuel Use	=	Amounts of natural gas (therms/yr) and coal (MT/year) used to produce the electricity used for lighting and residential, commercial and industrial buildings estimated using Equation BE.5.2.
CF	=	Conversion factor (/MMBTU/therms)
EF	=	Emission factor (kg/MMBTU)
GWP	=	Global Warming Potential for carbon dioxide (1), methane (28) and nitrogen dioxide (265)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on electricity use in Thurston County was obtained from Puget Sound Energy. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC's) website: http://www.trpc.org/693/Energy-Consumption
  - Electricity transmission and distribution losses were estimated using the methods described above.
  - The amounts of different types of primary fuels used to generate the electricity provided by Puget Sound energy were estimated using Equation BE.5.2. and the following information:

    - Information on the percentage of different primary fuels used to produce the PSE generated electricity was obtained from the Washington State Electric Utility Fuel Mix Disclosure Reports prepared annually by the Washington State Department of Commerce. The reports for calendar years 2010 through 2016 are available at: http://www.commerce.wa.gov/growing-the-economy/energy/fuel-mix-disclosure/
    - Information on the percent of various types of coal was obtained from Tables B.15 and B.16 in Appendix C of the US Community Protocol.
    - Information on fuel generation potential of primary fuels was obtained from Table B.17 in Appendix C of the US Community Protocol.
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The default emission factors for natural gas and coal were obtained from Tables B1 (CO_2) and B3 (CH_4 and N_2O) in Appendix C of the US Community Protocol (ICLEI, 2013b).

Built Environment – Emissions from Stationary Natural Gas Combustion (Residential, Commercial and Industrial Buildings)

- The ICLEI guidance includes three equations for calculating greenhouse gas emissions from combustion of natural gas. Separate equations are provided for CO2 (Equations BE.1.1.1), methane (Equation BE.1.1.2) and nitrogen dioxide (Equation BE.1.1.4). Estimates for total greenhouse gas emissions from each sector were obtained by summing the estimates for the three individual gases. The following equation was used to estimate emissions of each greenhouse gas:

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(Fuel Use)*(CF)*(EF)*(GWP)}}{\text{1000 (kg/MT)}}$$

Where:

Fuel Use = Volume of natural gas used in residential, commercial and industrial buildings (therms/year)
CF Conversion factor (MMBTUs/therms)
EF = Emission factor (kg/MMBTU)
GWP = Global Warming Potential for carbon dioxide (1), methane (28) and nitrogen dioxide (265)

- Activity Data Used to Prepare Greenhouse Gas Emission Estimates
    - The Information on natural gas use in Thurston County was obtained from Puget Sound Energy. This information is shown below and is also available at the Thurston Regional Planning Council's (TRPC's) website: http://www.trpc.org/693/Energy-Consumption

Activity Data Provided By Puget Sound Energy							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Natural Gas	**Therms**	**Therms**	**Therms**	**Therms**	**Therms**	**Therms**	**Therms**
Residential	31,268,416	33,971,581	32,609,000	32,216,327	31,220,371	28,309,121	29,785,238
Commercial	15,994,386	17,561,362	17,251,389	16,842,941	15,506,391	14,417,674	14,597,334
Industrial	4,007,880	4,429,061	4,677,417	4,795,796	1,065,303	1,001,325	983,864
Total	51,270,682	55,962,004	54,537,806	53,855,064	47,792,065	43,728,120	45,366,436
Natural Gas	**Customers**	**Customers**	**Customers**	**Customers**	**Customers**	**Customers**	**Customers**
Residential	43,445	44,011	44,672	51,810	46,278	47,054	48,122
Commercial	3,476	3,467	3,452	3,055	3,525	3,530	3,605
Industrial	70	69	70	75	60	60	59

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates were obtained from Appendix C of the US Community Protocol (ICLEI, 2013b).
    - The default emission factor for CO2 in Table B1 (53.02 kg CO2/MMBTU) was used to estimate CO2 emissions for residential, commercial and industrial natural gas combustion.
    - Two default emission factors for CH4 in Table B3 were used to calculate methane emissions: emission factor for industrial natural gas combustion (0.001 kg CH4/MMBTU); and emission factor for residential and commercial natural gas combustion (0.005 kg CH4/MMBTU.

- The default emission factor for nitrogen oxide (0.0001 kg N_2O/MMBTU) was used to estimate emissions for residential, commercial and industrial natural gas combustion..

Built Environment - Upstream Impacts of Natural Gas Use (Residential, Commercial, Industrial)

- Upstream CO_2e emissions associated with producing the natural gas supplied to Thurston County were estimated using Equation BE.5.1.1.

  $$\text{GHG Emissions (MTCO2e)} = \frac{\text{(Fuel Use)*(CF)*(UEF)}}{\text{1000 (kg/MT)}}$$

  Where:

  Fuel Use = Volume of natural gas used in residential, commercial and industrial buildings (therms/year)
  CF Conversion factor used to convert therms to cubic meters (m3/therm)
  UEF = Upstream emission factor (kg CO2e/1000 m3)

- Activity Data Used to Prepare Greenhouse Gas Emission Estimates
  - Information on natural gas use in Thurston County was obtained from Puget Sound Energy. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC's) website: http://www.trpc.org/693/Energy-Consumption
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The default upstream emission factor in Table B13 (445 kg CO2e/1000 m3) in Appendix C of the US Community Protocol was used to prepare GHG emission estimates.

Natural Gas Distribution Leaks

- Appendix C of the US Community Protocol (ICLEI, 2013b) does not include an equation for calculating fugitive emissions associated with the distribution of natural gas. The Clearpath Community-Scale Emissions Management Software Software (ICLEI, 2013d) was used to estimate these emissions using the following information
  - Information on natural gas use in Thurston County was obtained from Puget Sound Energy. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC's) website: http://www.trpc.org/693/Energy-Consumption
  - The default leakage rate (3%) was used to prepare GHG emission estimates.

Built Environment – Emissions from Stationary Combustion of Fuel Oil (Residential)

- CO_2e emissions were estimated using ICLEI Equations BE.1.1.1 (CO_2), BE.1.1.2 (methane) and BE.1.1.4 (nitrogen dioxide). Estimates for total greenhouse gas emissions are obtained by summing the estimates for the three individual gases. The following equation was used to estimate emissions of each greenhouse gas:

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(Fuel Oil Use)*(EF)*(GWP)}}{\text{1000 (kg/MT)}}$$

Where:

Fuel Use = Volume of fuel oil used in residential buildings (MMBTU/year)
EF = Emission factor (kg/MMBTU)
GWP = Global Warming Potential for carbon dioxide (1), methane (28) or nitrogen dioxide (265)

- Activity Data Used to Prepare GHG Emission Estimates
  - Residential fuel oil use in Washington was estimated using statewide information in Table CT4 (Residential Sector Energy Consumption Estimates, 1960 – 2015 Washington) published by the US Energy Information Administration (EIA) (reported in units of MMBTUs). This information is shown below and is available at the EIA website: https://www.eia.gov/state/print.php?sid=WA.
  - The amount of fuel oil used per household was estimated by dividing the annual Washington fuel oil use (expressed in MMBTU) by the number of Washington homes using fuel oil as a heating fuel.
  - Fuel oil use in Thurston County was estimated by multiplying the average amount of fuel oil per Washington household by the number of Thurston County households using fuel oil for home heating. The number of Thurston County households using fuel oil was obtained from the US Census Bureau American Fact Finder. That information is shown below and is available at: http://www.factfinder.census.gov

Activity Data for Fuel Oil Used to Prepare GHG Emission Estimates							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
WA Home Fuel Oil Use (MMBTU)	5,500,000	5,000,000	3,600,000	3,500,000	3,800,000	3,500,000	3,500,000
Thurston Households Using Fuel Oil	1,556	1,585	1,456	1,340	1,140	991	897
WA Households Using Fuel Oil	87,337	81,984	75,844	71,296	66,218	61,754	57,500

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The CO_2, CH_4 and NO_2 emission factors for fuel oil were obtained from the Climate Registry database. That information is available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Built Environment – Upstream Impacts of Stationary Combustion of Fuel Oil (Residential)

- Upstream CO_2e emissions associated with producing the fuel oil supplied to Thurston County were estimated using Equation BE.5.1.1.

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(Fuel Oil Use)*(CF)*(Upstream EF)}}{\text{1000 (kg/MT)}}$$

Where:

Fuel Use	=	Volume of fuel oil used in residential buildings (MMBTU/year)
CF	=	Conversion factor used to convert MMBTU to liters of fuel oil (MMBTU/liter)
UpstreamEF	=	Emission factor (kg CO2e/1000 L)

- Emission Factor Used to Prepare Greenhouse Gas Emission Estimates
  - The default emission factor in Table B13 (492 kg CO2e/1000 liters) in Appendix C of the US Community Protocol was used to prepare GHG emission estimates.
- Activity Data Used to Prepare GHG Emission Estimates
  - Residential fuel oil use in Washington was estimated using statewide information in Table CT4 (Residential Sector Energy Consumption Estimates, 1960 – 2015 Washington) published by the US Energy Information Administration (EIA) (reported in units of mmBTUs). This information is shown above and is available at the EIA website: https://www.eia.gov/state/print.php?sid=WA
  - The amount of fuel oil used per household was estimated by dividing the annual Washington fuel oil use (expressed in MMBTU) by the number of Washington homes using fuel oil as a heating fuel.
  - Fuel oil use in Thurston County was estimated by multiplying average amount of fuel oil per Washington households by the number of Thurston County households using fuel oil for home heating. The number of Thurston County households using fuel oil was obtained from the US Census Bureau American Fact Finder. That information is shown above and is available at: http://www.factfinder.census.gov

Built Environment – Emissions from Stationary Combustion of LPG (Residential)

- CO2e emissions were estimated using the ICLEI Equations BE.1.1.1 (CO2), BE.1.1.2 (methane) and BE.1.1.4 (nitrogen dioxide). Estimates for total greenhouse gas emissions were obtained by summing the estimates for the three individual gases. The following equation was used to estimate emissions of each greenhouse gas:

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(LPG Use)*(EF)*(GWP)}}{\text{1000 (kg/MT)}}$$

Where:

LPG Use = Volume of LPG used in residential buildings (MMBTU/year)

EF = Emission factor (kg/MMBTU)

GWP = Global Warming Potential for carbon dioxide (1), methane (28) and nitrogen dioxide (265)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Residential LPG use in Washington was estimated using statewide information in Table CT4 (Residential Sector Energy Consumption Estimates, 1960 – 2015 Washington) published by the US Energy Information Administration (EIA) (reported in units of mmBTUs). This information is shown below and is available at the EIA website: https://www.eia.gov/state/print.php?sid=WA
  - The amount of LPG used per household was estimated by dividing the annual Washington State LPG use (expressed in MM BTU) by the number of Washington homes using LPG as a heating fuel. Information on the number of Washington households using LPG was obtained from the American Fact Finder. That information is available at: http://www.factfinder.census.gov
  - LPG use in Thurston County was estimated by multiplying the average amount of LPG per Washington households by the number of Thurston County households using LPG for home heating. The number of Thurston County households using bottled tank or LP gas was obtained from the US Census Bureau American Fact Finder. That information is shown below and is available at: http://www.factfinder.census.gov

Activity Data for LPG/Propane Used to Prepare GHG Emission Estimates							
	2010	2011	2012	2013	2014	2015	2016
WA Home LPG/Propane Use (MMBTU)	9,000,000	9,000,000	7,000,000	7,100,000	6,400,000	5,500,000	5,500,000
Thurston Households Using LPG/Propane	6,070	5,892	5,514	5,057	4,725	4,693	4,463
WA Households Using LPG/Propane	89,136	87,321	85,067	84,011	81,356	81,076	79,700

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The CO2, CH4 and NO2 emission factors for LPG were obtained from the Climate Registry database. This information is available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Built Environment – Upstream Impacts of Stationary Combustion of LPG (Residential)

- Upstream CO_2e emissions associated with producing the LPG/propane supplied to Thurston County were estimated using Equation BE.5.1.1.

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(LPG Use)*(CF)*(Upstream EF)}}{\text{1000 (kg/MT)}}$$

Where:

LPG/Propane Use = Volume of fuel oil used in residential buildings (MMBTU/year)
CF = Conversion factor used to convert MMBTU to liters of LPG/Propane (MMBTU/liter)
UpstreamEF = Emission factor (kg CO2e/1000 L)

- Activity Data Used to Prepare GHG Emission Estimates
  - Residential LPG use in Washington was estimated using statewide information in Table CT4 (Residential Sector Energy Consumption Estimates, 1960 – 2015 Washington) published by the US Energy Information Administration (EIA) (reported in units of mmBTUs). This information is available at the EIA website: https://www.eia.gov/state/print.php?sid=WA
  - The amount of LPG used per household was estimated by dividing the annual Washington State LPG use (expressed in MMBTU) by the number of Washington homes using LPG as a heating fuel. Information on the number of Washington households using LPG was obtained from the American Fact Finder. That information is available at: http://www.factfinder.census.gov
  - LPG use in Thurston County was estimated by multiplying average amount of LPG per Washington households by the number of Thurston County households using LPG for home heating. The number of Thurston County households using bottled tank or LP gas was obtained from the US Census Bureau American Fact Finder. That information is available at: http://www.factfinder.census.gov
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The default emission factor in Table B13 (307 kg CO2e/1000 liters) in Appendix C of the US Community Protocol was used to prepare GHG emission estimates.

Built Environment – Emissions from Stationary Combustion of Wood (Residential)

- CO2e emissions were estimated using the ICLEI Equations BE.1.1.2 (methane) and BE.1.1.4 (nitrogen dioxide). Estimates for total greenhouse gas emissions were obtained by summing the estimates for the two individual gases. The following equation was used to estimate emissions of each greenhouse gas:

$$\text{GHG Emissions (MTCO2e)} = \frac{\text{(Wood Use)*(EF)*(GWP)}}{\text{1000 (kg/MT)}}$$

Where:

Wood Use = Amount of wood used in residential buildings (MMBTU/year)
EF = Emission factor (kg/MMBTU)
GWP = Global Warming Potential for methane (28) and nitrogen dioxide (265)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Residential wood use in Washington was estimated using statewide information in Table CT4 (Residential Sector Energy Consumption Estimates, 1960 – 2015 Washington) published by the US Energy Information Administration (EIA) (reported in units of mmBTUs). This information is shown below and is available at the EIA website: https://www.eia.gov/state/print.php?sid=WA
  - The amount of wood used per household was estimated by dividing the annual Washington State wood use (expressed in MM BTU) by the number of Washington homes using wood as a heating fuel. Information on the number of Washington households using LPG was obtained from the American Fact Finder. That information is available at: http://www.factfinder.census.gov
  - Wood use in Thurston County was estimated by multiplying the average amount of wood per Washington households by the number of Thurston County households using wood for home heating. The number of Thurston County households using wood was obtained from the US Census Bureau American Fact Finder. That information is shown below and is available at: http://www.factfinder.census.gov

Activity Data for Wood Used to Prepare GHG Emission Estimates							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
WA Home Wood Use (MMBTU)	9,000,000	9,000,000	7,000,000	7,100,000	6,400,000	5,500,000	5,500,000
Thurston Households Using Wood	6,070	5,892	5,514	5,057	4,725	4,693	4,463
WA Households Using Wood	89,136	87,321	85,067	84,011	81,356	81,076	79,700

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The CH4 and NO2 emission factors for wood were obtained from the Climate Registry database. This information is available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Transportation – Passenger Vehicles (Cars and Light Duty Trucks)

- CO2e emissions were estimated by summing the GHG emissions calculated using two equations: (1) Equation TR.1.B.2 (CO2 emissions) and (2) Equation TR.1.B.3 (CH4 and NO2). These equations are presented in Appendix D: Transportation and Other Mobile Emission Activities and Sources and displayed below.

$$\text{GHG Emissions (MTCO2e for CO2)} = \frac{(VMT)*(\%b)*(EF_f)}{(MPG_f)*(1000\ (kg/MT))}$$

Where:

VMT = The number of vehicle miles traveled in Thurston County (VMT/year).
%b = Percentage of VMT for light duty vehicles.
EF_f = Emission factor for gasoline (8.78 kg CO2/gallon).[55]
MPG_f = Miles per gallon.

$$\text{GHG Emissions (MTCO2e for CH4 and N2O)} = \frac{(VMT)*(\%b)*(EF_f)*(GWP)}{(1000\ g/kg)*(1000\ (kg/MT))}$$

Where:

VMT = The number of vehicle miles traveled in Thurston County (VMT/year).
%b = Percentage of VMT for light duty vehicles.
EF_f = Emission factors for gasoline for both CH4 and N2O (g/mile).
GWP = Global Warming Potential for methane (28) or nitrogen dioxide (265).

- Activity Data Used to Prepare GHG Emission Estimates.
  - Vehicle Miles Traveled (VMT) in Thurston County for years 2010 through 2016 were prepared by the Thurston Regional Planning Council. This information is shown below and is available at: http://www.trpc.org/709/Greenhouse-Gas

VMT Information Used to Prepare On-Road Transportation GHG Emission Estimates							
	2010	2011	2012	2013	2014	2015	2016
Vehicles Miles Traveled	2,341,013,000	2,328,580,000	2,241,171,000	2,303,087,000	2,330,925,000	2,431,638,000	2,473,582,000

  - The percentage of VMT attributed to light duty vehicles (91.8%) was provided in an August 31, 2017 email from Michael Ambrogi (Thurston Regional Planning Council) to Dave Bradley. This value was used for years 2010 through 2016.

[55] GHG emissions were calculated based on an assumption that 100% of light duty vehicles are gasoline-powered. This was done because (1) the TRPC information on percentage of VMT attributed to light duty vehicles is not broken down by fuel type, (2) the Bureau of Transportation Statistics on MPG value for light duty vehicles (short wheel base) is not broken down by fuel type and (3) data included in EPA's 2015 GHG inventory and State Implementation Tool indicate that less than 5% of the VMT for light duty vehicles is attributable to diesel-powered cars or light trucks.

- Miles per gallon estimates for light duty vehicles were obtained from the Bureau of Transportation Statistics (Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles). GHG estimates are based on the MPG values for light duty vehicles (short wheel base) for years 2010 through 2015. MPG values for 2015 were also used to estimate 2016 emissions. This information is available at: https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The CO2 emission factor for motor gasoline (8.78 kg/gallon) was obtained from Table 2 in the Emission Factors for Greenhouse Gas Inventories compiled by the Climate Registry. This information is available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf
  - The emission factors for CH4 and N2O were obtained from Table A-108 in Annex 3 of EPA (2017). This annex is appended to the following document: Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

Transportation – Commercial Vehicles

- CO2e emissions were estimated by summing the GHG emissions calculated using two equations: (1) Equation TR.1.B.2 (CO2 emissions) and (2) Equation TR.1.B.3 (CH4 and NO2). These equations are presented in Appendix D: Transportation and Other Mobile Emission Activities and Sources and displayed below.

$$\text{GHG Emissions (MTCO2e for CO2)} = \frac{(VMT)*(\%b)*(EF)}{(MPG)*(1000\ (kg/MT))}$$

Where:

VMT	=	The number of vehicle miles traveled in Thurston County (VMT/year).
%b	=	Percentage of VMT attributable to commercial vehicles.
EF	=	Emission factor for diesel (10.21 kg CO2/gallon).
MPG	=	Miles per gallon.

$$\text{GHG Emissions (MTCO2e for CH4 and N2O)} = \frac{(VMT)*(\%b)*(EF_f)*(GWP)}{(1000\ g/kg)*(1000\ (kg/MT))}$$

Where:

VMT	=	The number of vehicle miles traveled in Thurston County (VMT/year).
%b	=	Percentage of VMT attributable to commercial vehicles.
EF	=	Emission factors for CH4 and N2O (g/mile).
GWP	=	Global Warming Potential for methane (28) or nitrogen dioxide (265).

- Activity Data Used to Prepare GHG Emission Estimates.
  - Vehicle Miles Traveled (VMT) in Thurston County for years 2010 through 2016 were prepared by the Thurston Regional Planning Council. This information is shown above and is available at: http://www.trpc.org/709/Greenhouse-Gas
  - The percentage of VMT attributed to Commercial vehicles (3.3%) was provided in an August 31, 2017 email from Michael Ambrogi (Thurston Regional Planning Council) to Dave Bradley. This value was used for years 2010 through 2016.
  - Miles per gallon estimates for light medium- and medium-duty trucks were obtained the Energy Information Administration (Stone and Lymes, 2017). This information is available at: https://www.eia.gov/outlooks/archive/aeo16/fcghg.cfm
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The CO2 emission factor for motor gasoline (10.21 kg/gallon) was obtained from Table 2 in the Emission Factors for Greenhouse Gas Inventories compiled by the Climate Registry. This information is available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

- The emission factors for CH4 and N2O published in Table 108 Annex 3 of EPA (2017) were used to calculate GHG emissions. This annex is appended to the following document: Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

Transportation – Heavy Duty Vehicles

- CO_2e emissions were estimated by summing the GHG emissions calculated using two equations: (1) Equation TR.2.A.1 (CO_2 emissions) and Equation TR.2.A.2 (CH_4 and NO_2 emissions). These equations are presented in *Appendix D: Transportation and Other Mobile Emission Activities and Sources* and displayed below.

$$\text{GHG Emissions (MTCO2e for CO2)} = \frac{(VMT)*(\%b)*(EF)}{(MPG)*(1000\ (kg/MT))}$$

Where:

VMT	=	The number of vehicle miles traveled in Thurston County (VMT/year).
%b	=	Percentage of VMT attributable to heavy-duty vehicles.
EF	=	Emission factor for diesel (10.21 kg CO2/gallon)
MPG	=	Miles per gallon.

$$\text{GHG Emissions (MTCO2e for CH4 and N2O)} = \frac{(VMT)*(\%b)*(EF)*(GWP)}{(1000\ g/kg)*(1000\ (kg/MT))}$$

Where:

VMT	=	The number of vehicle miles traveled in Thurston County (VMT/year).
%b	=	Percentage of VMT attributable to heavy duty vehicles.
EF	=	Emission factors for diesel for both CH4 and N2O (g/mile).
GWP	=	Global Warming Potential for methane (28) or nitrogen dioxide (265).

- Activity Data Used to Prepare GHG Emission Estimates.
  - Vehicle Miles Traveled (VMT) in Thurston County for years 2010 through 2016 were prepared by the Thurston Regional Planning Council. This information is shown above and is available at: http://www.trpc.org/709/Greenhouse-Gas
  - The percentage of VMT attributed to heavy duty vehicles (4.9%) was provided in an August 31, 2017 email from Michael Ambrogi (Thurston Regional Planning Council) to Dave Bradley. This value was used for years 2010 through 2016.
  - Miles per gallon estimates for heavy-duty trucks were obtained the Energy Information Administration (Stone and Lymes, 2017). This information is available at: https://www.eia.gov/outlooks/archive/aeo16/fcghg.cfm
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The CO_2 emission factor for diesel fuel (10.21 kg/gallon) was obtained from Table 2 in the Emission Factors for Greenhouse Gas Inventories compiled by the Climate Registry. This information is available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf
  - The emission factors for CH_4 and N_2O published in Table 108 Annex 3 of EPA (2017) were used to calculate GHG emissions. This annex is appended to the following document: Inventory of US Greenhouse Gas

Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

Solid Waste – Methane Generation

- Methane emissions associated with community waste disposed at solid waste landfills were estimated using Equation SW.4.1. in Appendix E – Solid Waste Emission Activities and Sources.

  Methane Emissions (MTCO2e) = (1 - CE)*(1 – OX)*M*(EF)*(GWP)

  Where:

  CE = Landfill gas collection efficiency (%)
  OX = Oxidation rate (%)
  M = Annual waste generated and disposed at solid waste landfill (wet short tons/year)
  EF = Emission factor (MT CH4/wet short ton of waste)
  GWP = Global Warming Potential for methane (28)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on Total Waste Generated in Thurston County in 2015 was from the Thurston County Solid Waste. This information is shown below and is available at the Thurston Regional Planning Council's (TRPC) website: http://www.trpc.org/694/Solid-Waste

Solid Waste Volumes (Tons) Used to Prepare GHG Emission Estimates							
	2010	2011	2012	2013	2014	2015	2016
Solid Waste	165,191.00	151,318.00	146,360.00	152,162.00	158,844	168,928	179,733

  - The landfill collection efficiency for Roosevelt Regional Landfill was assumed to be 75%. This is the default value in the ICLEI guidance and is virtually identical to the collection efficiency specified in the 2016 GHG emissions report for the Roosevelt Regional Landfill (USEPA, 2017c)
  - The landfill oxidation rate was assumed to be 10% for years 2010 through 2012. This is the default value in the ICLEI guidance and is consistent with EPA Guidance for estimating methane emissions for solid waste landfills under Subpart HH.
  - The landfill oxidation rate was assumed to be 25% for years 2013 through 2016. Republic Services used this oxidation rate when preparing their 2016 annual GHG report (EPA, 2017c).
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates.
  - The emission factor for Thurston County solid waste was calculated by (1) multiplying the percentage of various types of waste in the waste from Thurston County by the default emission factor for that waste type and (2) summing across waste types.
  - Local waste composition information for Thurston County was obtained from the Thurston County Waste Composition Study 2013 – 2014 (Green Solutions LLC, 2014). The study is available at: http://www.co.thurston.wa.us/solidwaste/regulations/docs/ThurstonCountyWasteComp2014.pdf
  - The default emission factors were obtained from Table SW.5 of Appendix E of the US Community Protocol.

Solid Waste - Process Emissions

- CO_2e emissions associated with processing solid waste were estimated using Equation SW.5. in Appendix E – Solid Waste Emission Activities and Sources.

  GHG Emissions ($MTCO_2e$) = M*EFP

  Where:

  M = Annual waste generated and disposed at solid waste landfill (wet short tons/year)

  EFP = Emission factor for landfill process emissions ($MTCO_2e$/wet short ton of waste)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on Total Waste Generated in Thurston County was obtained from the Thurston County Solid Waste. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC) website: http://www.trpc.org/694/Solid-Waste
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The emission factor for landfill process emissions was obtained from the ICLEI guidance on Solid Waste Emission Activities and Sources.

Solid Waste - Emissions From Truck Transport

- CO_2e emissions associated with transporting solid waste by truck from the Waste and Recovery Center to the Centralia loading facility were estimated using Equation SW.6. in Appendix E – Solid Waste Emission Activities and Sources.

  GHG Emissions (MTCO2e) = M*MT*EFT

  Where:

M	=	Annual waste generated and disposed at solid waste landfill (wet short tons/year)
MT	=	Miles traveled from Waste Recovery Center to Centralia (miles)
EFT	=	Emission factor for transporting solid waste (MTCO2e/wet short ton of waste/mile)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on Total Waste Generated in Thurston County was obtained from the Thurston County Solid Waste. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC) website: http://www.trpc.org/694/Solid-Waste
  - Emissions associated with the collection of solid waste are included in the on-road transportation emission estimates for Thurston County.
  - Thurston County ships county solid waste to Centralia where it is placed on rail cars and transported by train to the Roosevelt Regional Landfill. The distance from the Waste and Recovery Center to the Centralia loading facility is approximately 37 miles.
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The emission factor for transporting solid waste (0.00014 MTCO2e/wet short ton of waste/mile) was obtained from the ICLEI guidance on Solid Waste Emission Activities and Sources.

Solid Waste – Emissions From Railroad Transport

- CO2e emissions associated with transporting solid waste from Centralia to Roosevelt landfill by rail were estimated using Equations TR.3.1 and TR.3.3:

$$\text{Fuel Consumed (gallons)} = \frac{\text{Tons Moved*Length of Track}}{\text{Fuel Efficiency}}$$

Where:

Tons Moved	=	Annual waste generated and disposed at solid waste landfill (wet short tons/year)
Length of Track	=	Distance from Centralia to Roosevelt Landfill (miles)
Fuel Efficiency	=	457 ton-mile/gallon

$$\text{CO2 Emissions (MTCO2)} = \frac{\text{Carbon Content*Fuel Consumed}}{\text{1000 kg/MT}}$$

Where:

Carbon Content	=	Carbon Content of Diesel Fuel (kg CO2/gallon
Fuel Consumed	=	Amount of fuel consumed estimated using Equation TR.3.1 (gallons)

- Activity Data Used to Prepare GHG Emission Estimates.
  - Information on Total Waste Generated in Thurston County was obtained from the Thurston County Solid Waste. This information is shown above and is available at the Thurston Regional Planning Council's (TRPC) website: http://www.trpc.org/694/Solid-Waste
  - Thurston County ships county solid waste to Centralia where it is placed on rail cars and transported by train to the Roosevelt Regional Landfill. The distance from Centralia to the Roosevelt Landfill is approximately 225 miles.
- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - Fuel consumption was estimated using information on national average fuel consumption for all rail freight from the Annual Energy Outlook. At 3.3 ton-miles per thousand BTU (AEO 2010 value) and 138,500 BTU per gallon or 73.15 kg CO2 per MMBTU for diesel fuel, this equates to 457 ton-miles per gallon or 22.17 tons CO2 per million ton-miles.
  - The CO2 emission factor for diesel fuel (10.16 kg/gallon) was obtained from the Carbon Dioxide Emissions Coefficients spreadsheet published by the US Energy Information Administration. This spreadsheet is available at: https://www.eia.gov/environment/emissions/co2_vol_mass.php

Wastewater – Digester Gas Combustion

- The ICLEI guidance includes the following equation for calculating methane and nitrogen dioxide emissions associated with digester gas combustion.

$$\text{GHG Emissions} = \frac{(\text{DigesterGas})*(\text{fCH4})*(\text{BTU})*(\text{FF})*(\text{CF1})*(\text{Days})*(\text{GWP})}{1000\ \text{kg/MT}}$$

Where:

DigesterGas = Standard cubic feet of digester gas produced per day (scf/d)
fCH4 = Fraction of CH4 in gas (%)
BTU = Default heating content of methane (BTU/scf)
CF1 = Conversion from BTU to MMBTU (10-6)
EF = Emission factor (kg CH4 or N2O/MMBTU)
Days = Average days per year (365.25 d/y)
GWP = Global Warming Potential for methane (AR5 = 28) and nitrogen dioxide (AR5 = 265)

- Activity Data Used to Prepare Greenhouse Gas Emission Estimates
  - Information on the average daily digester gas production and fraction methane in the digester gas was provided by George Peterson (LOTT Operations Supervisor) on September 12, 2017.

Information Used to Estimate GHG Emissions Associated With Digester Gas Production							
	2010	2011	2012	2013	2014	2015	2016
Dig. Gas - Ave Daily (ft^3)	138,369	163,673	158,161	172,050	158,624	161,922	167,657
Fraction of CH_4	70%	70%	70%	70%	70%	70%	70%

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The ICLEI guidance document and Clearpath software provide default emission factors that were used to estimate GHG emissions associated with digester gas combustion.

Wastewater - Methanol Use

- CO_2e emissions associated with methanol use were estimated using Equation WW.9.

GHG Emissions = (Methanol Load)*(F)*(MWR)*(GWP)

Where:

Methanol Load	=	Amount of neat chemical used daily (MT CH_3OH/day)
F	=	Factor applied based on wastewater treatment system (anaerobic digestion, F = 90%)
MWR	=	Ratio of the molecular weights for CO_2 to methanol (44.01/32.4 = 1.37)
GWP	=	Global Warming Potential for CO_2 (1)
CF	=	365.25 days per year.

- Activity Data Used to Prepare Greenhouse Gas Emission Estimates
  - Information on methanol use was provided by George Peterson (LOTT Operations Supervisor) on September 12, 2017.

Information Used to Estimate GHG Emissions Associated With Methanol Use							
	2010	2011	2012	2013	2014	2015	2016
Annual Methanol (gallons)	31,029	20,183	36,338	18,908	19,421	29,213	27,776
Daily Methanol (MT/day)	0.28	0.18	0.32	0.17	0.17	0.26	0.25

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The ICLEI guidance document and Clearpath software provide default emission factors that were used to estimate GHG emissions associated with digester gas combustion.

Agriculture – Livestock

- CO_2e emissions were estimated using Equation A.1 in Appendix G: Agricultural Livestock Emission Activities and Sources. Separate estimates were prepared for dairy cows, beef cows, sheep and swine. The following equation was used to calculate methane emissions for each type of livestock.

$$\text{Methane Emissions } (MTCO_2e) = \frac{(\text{Animal Population})*(EF)*(GWP)}{1000 \text{ kg/MT}}$$

Where:

Animal Population = Average annual animal population (head)
EF = Emission factor (kg CH_4/head/year)
GWP = Global Warming Potential for methane (AR5 = 28)

- Activity Data Used to Prepare Greenhouse Gas Emission Estimates
  - The numbers of individual dairy cows, beef cows, sheep and swine in Thurston County were obtained from the livestock inventories compiled by the US Department of Agriculture (USDA, 2007 and 2012). This information is shown below and is available at: https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Livestock/2017/CE_Cat.pdf

Information on Number of Animals Used to Estimate GHG Emissions Associated With Agricultural Livestock

	2010	2011	2012	2013	2014	2015	2016
Dairy Cows	5,165	5,165	5,274	5,274	5,274	5,274	5,274
Beef Cows	5,451	5,451	5,269	5,269	5,269	5,269	5,269
Swine	777	777	644	644	644	644	644
Sheep	1,838	1,838	1,797	1,797	1,797	1,797	1,797

- Emission Factors Used to Prepare Greenhouse Gas Emission Estimates
  - The Washington-specific emission factor for dairy cows (151 kg/head/year) was obtained from Table A-170 in ANNEX 3 Methodological Descriptions for Additional Source or Sink Categories. This annex is appended to the following document: Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015
  - The Washington-specific emission factor for beef cows (100 kg/head/year) was obtained from Table A-170 in ANNEX 3 Methodological Descriptions for Additional Source or Sink Categories. This annex is appended to the following document: Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

- The emission factor for swine (1 kg/head/year) was obtained from Table A-174 in ANNEX 3 Methodological Descriptions for Additional Source or Sink Categories. This annex is appended to the following document: Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015
- The emission factor for sheep (8 kg/head/year) was obtained from Table A-174 in ANNEX 3 Methodological Descriptions for Additional Source or Sink Categories. This annex is appended to the following document: Inventory of US Greenhouse Gas Emissions and Sinks: 1990 to 2015. USEPA, Office of Atmospheric Programs. Washington DC. Publication Number EPA 430-P-17-001. April 2017. This information is available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015

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Appendix C: Detailed Emission Estimates

Estimated GHG Emissions in Thurston County (May 6, 2018) (Reported as MTCO2e/yr calculated using AR5 GWP values)							
	2010	2011	2012	2013	2014	2015	2016
BUILT ENVIRONMENT							
Emissions associated with the use of electricity in lighting(ext) and RCI buildings							
Residential	577,837	538,021	521,193	577,979	580,203	566,223	620,922
Commercial	420,056	381,248	372,957	418,722	421,685	433,216	481,910
Industrial	62,250	56,021	58,744	62,351	51,731	54,533	70,300
Lighting (outdoor)	2,017	1,729	1,749	4,519	5,831	6,568	5,654
Total Electricity Use	**1,062,160**	**977,019**	**954,643**	**1,063,571**	**1,059,450**	**1,060,540**	**1,178,786**
Electricity Transmission & Distribution Losses from electricity use in lighting(ext) and RCI buildings							
Residential	39,524	36,801	30,021	33,292	27,792	27,122	26,265
Commercial	28,732	26,077	21,482	24,118	20,199	20,751	20,385
Industrial	4,258	3,832	3,384	3,591	2,478	2,612	2,974
Lighting (outdoor)	138	118	101	260	279	313	239
Total Electricity T&D Loss	**72,652**	**66,828**	**54,988**	**61,261**	**50,748**	**50,798**	**49,863**
Upstream Emissions from the use of electricity in lighting and RCI buildings							
Residential	79,775	58,521	61,093	76,574	74,226	91,135	77,612
Commercial	58,736	42,001	43,717	55,475	53,947	69,727	60,236
Industrial	8,704	6,172	6,886	8,261	6,618	8,777	8,787
Lighting (Outdoor)	278	189	205	599	746	1,057	707
Total Upstream	**147,493**	**106,883**	**111,901**	**140,907**	**135,537**	**170,696**	**147,343**
Use of natural gas in residential, commercial, and industrial (RCI) stationary combustion equipment							
Residential (Nat Gas)	166,306	180,683	173,436	171,347	166,050	150,566	158,417
Commercial	85,069	93,403	91,754	89,582	82,473	76,683	77,638
Industrial	21,272	23,507	24,825	25,453	5,654	5,314	5,222
Total Nat. Gas Combustion	**272,647**	**297,593**	**290,015**	**286,382**	**254,177**	**232,563**	**241,277**
Natural Gas Leaks During Distribution fir RCU stationary combustion equipment							
Residential	5,425	5,894	5,657	5,589	5,417	4,911	5,168
Commercial	2,775	3,047	2,993	2,922	2,690	2,501	2,531
Industrial	695	768	811	832	185	174	171
Total Nat. Gas Fugitives	**8,895**	**9,709**	**9,461**	**9,343**	**8,292**	**7,586**	**7,870**
Upstream emissions from the use of fuel in RCI stationary combustion equipment							
Residential	39,401	42,808	41,091	40,596	39,341	35,672	37,532
Commercial	20,154	22,129	21,738	21,224	19,540	18,168	18,394
Industrial	5,050	5,581	5,894	6,043	1,342	1,262	1,240
Total Upstream	**64,606**	**70,518**	**68,723**	**67,863**	**60,223**	**55,102**	**57,166**

Use other fuels in residential stationary combustion equipment							
Residential Wood	7,922	11,304	8,205	11,879	11,370	8,539	8,539
Residential (Fuel Oil)	7,288	7,197	5,146	4,898	4,871	4,182	4,065
Residential (LPG)	38,963	38,606	28,845	27,170	23,630	20,239	19,579
Total Use – Other Resid. Fuels	**54,173**	**57,107**	**42,196**	**43,947**	**39,871**	**32,960**	**32,183**
Upstream emissions from the use of other fuels in residential stationary combustion equipment							
Residential (Fuel Oil)	1,332	1,314	939	894	889	763	742
Residential (LPG)	5,198	5,151	3,848	3,625	3,153	2,700	2,612
Total Upstream - other resid. fuels	**6,530**	**6,465**	**4,787**	**4,519**	**4,042**	**3,463**	**3,354**
TOTAL BUILT ENVIRONMENT	**1,689,156**	**1,592,121**	**1,536,714**	**1,677,793**	**1,612,340**	**1,613,708**	**1,717,842**
ON ROAD TRANSPORTATION							
Passenger Vehicles	812,905	812,060	778,235	796,331	812,877	823,257	837,457
Commercial	84,593	83,676	80,778	82,991	83,995	86,944	87,696
Heavy Duty Trucks	191,998	192,083	185,790	191,875	195,168	202,249	204,044
Public Transit	IE	IE	IE	IE	IE	IE	IE
TOTAL ONROAD TRANSPORTATION	**1,089,496**	**1,087,819**	**1,044,803**	**1,071,198**	**1,092,040**	**1,112,450**	**1,129,198**
SOLID WASTE							
Methane emissions	83,958	76,907	74,387	64,624	67,452	71,736	76,328
Process emissions	2,709	2,482	2,400	2,495	2,605	2,770	2,948
SW Transportation	1,694	1,551	1,500	1,560	1,629	1,732	1,833
TOTAL SOLID WASTE	**88,361**	**80,940**	**78,287**	**68,679**	**71,686**	**76,238**	**81,109**
WASTEWATER TREAMENT							
LOTT - Digester Emissions	9	11	11	12	11	11	11
LOTT - Methanol emissions	126	81	144	77	77	117	113
TOTAL WASTEWATER	**135**	**92**	**155**	**89**	**88**	**128**	**124**
AGRICULTURE/LIVESTOCK							
Dairy Cows (individuals)	21,837	21,837	22,299	22,299	22,299	22,299	22,299
Beef Cows (individuals)	15,263	15,263	14,753	14,753	14,753	14,753	14,753
Swine (individuals)	33	33	27	27	27	27	27
Sheep (individuals)	412	412	403	403	403	403	403
TOTAL AG/LIVESTOCK	**37,544**	**37,544**	**37,482**	**37,482**	**37,482**	**37,482**	**37,482**
TOTAL EMISSIONS	**2,904,692**	**2,798,517**	**2,697,441**	**2,855,241**	**2,813,635**	**2,840,005**	**2,965,754**
Population	252,264	254,100	256,800	260,100	264,000	267,400	272,700
Per Capita Emissions	11.5	11.0	10.5	11.0	10.7	10.6	10.9