Greenhouse Gas Inventory Report for Calendar Year 2010

Thurston County, Washington

August 2013

Version 1.4, Revised December 26, 2013

Presented by the Thurston Climate Action Team

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Author Information and Acknowledgements

This report was developed as a result of Thurston Climate Action Team's (TCAT's) Greenhouse Gas (GHG) Inventory project. Tom Crawford, TCAT board member and treasurer, led the effort on behalf of TCAT, and recruited Robert Coleman, at the time a student in The Evergreen State College's Master in Environmental Studies (MES) program, to serve as intern for 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. Tom is a member of the International Society of Sustainability Professionals.

Robert (Bobby) Coleman holds a bachelor's degree in English from Michigan State University, and a Master of Environmental Studies degree from The Evergreen State College. Bobby also currently serves as the Resource Conservation Coordinator at The Evergreen State College. As intern for TCAT's Greenhouse Gas Inventory Project, Bobby gathered data, developed a set of calculation spreadsheets based on ICLEI's U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions, and wrote the initial draft report for the project.

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 are:

- Graeme Sackrison, Former Mayor of Lacey, TCAT Board Chair
- Jessica Jensen, Jessica Jensen Law, TCAT Secretary and Board Counsel
- Tom Crawford, President, Praxis Northwest, LLC, TCAT Treasurer
- Geoffrey Glass, Director of Facility and Technology Services, Providence St. Peter Hospital, TCAT Board Member

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- Cynthia Pratt, City Council Member, City of Lacey
- Randy Bachtell, Instructor, New Market Skills Center
- David Schaffert, Director, Olympia Thurston County Chamber of Commerce
- Christine Winslow, City Council Member, City of Rainier
- Gary Carlson, City of Yelm

- Angela White, Manager, Olympia Master Builders
- Cathy Wolfe, Commissioner, Thurston County
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- Rich Hoey, Director of Public Works, City of Olympia
- Marylin Ball-Brown, CEO, Generations Credit Union
- Scott Morgan, Sustainability Manager, The Evergreen State College
- Ronnie Kemp, City of Tenino
- Dennis Bloom, Intercity Transit
- Tom Oliva, Council Member, City of Tumwater
- Lon Wyrick, Executive Director, Thurston Regional Planning Council
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- George Barner, Commissioner, Port of Olympia
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- Laurie Pierce, Operations and Facilities Manager, LOTT Clean Water Alliance
- Jessica Brandt, Environmental and Sustainability Manager, InterCity Transit
- Peter Guttchen, Food to Flowers Program Coordinator, Thurston County Public Works

We want to express special gratitude to John Druelinger, former Sustainability Specialist with Thurston County, who shared with us the results and methodology for his draft GHG inventory model for the 2009 calendar year. The information sources and approach he used both guided and inspired us as we began this effort.

Executive Summary

Global and local concern over the growing climate crisis has led the Thurston Climate Action Team (TCAT) to conduct a community based greenhouse gas (GHG) inventory as a foundation for regional climate action planning. Using a community GHG inventory protocol developed by ICLEI USA, TCAT gathered data for the 2010 calendar year from a variety of sources. Energy usage data was provided by Puget Sound Energy, vehicle miles traveled (VMT) data by the Thurston Regional Planning Council, solid waste data by Thurston County, and wastewater data by the LOTT Clean Water Alliance. Results in each of these sectors was obtained for Thurston County as a whole, and for each of the incorporated cities within the county. TCAT then calculated annual GHG emissions for 2010 using conversion formulas contained in ICLEI documentation for its protocol.

Total GHG emissions for the county as a whole, for each incorporated city, and for the unincorporated portions of the county, are presented in Table 1 below.

Table 1: Summary of GHG emissions by Jurisdiction, 2010, in metric tons of carbon dioxide equivalent (MTCDE)

Jurisdiction	**Total GHG Emissions**	**Per Person GHG Emissions**
Thurston County	2,761,800	10.95
Unincorporated Thurston County	1,443,200	10.68
Bucoda	2,047	3.64
Lacey	392,141	9.25
Olympia	564,607	12.15
Rainier	8,734	4.87
Tenino	12,852	7.58
Tumwater	288,540	16.61
Yelm	49,679	7.25

TCAT recommends that these results be presented to elected officials at the county and city levels. These officials, along with other community and business representatives, would use them to set GHG reduction goals, taking into consideration statewide goals established by the legislature, along with the findings and recommendations of the Inter-governmental Panel on Climate Change (IPCC). It is also recommended that a climate action plan be developed and implemented, along with an annual refresh of this inventory. It is proposed that these efforts include broad participation, with the guidance of a steering committee and segment-specific work groups.

Introduction

Over the last thirty-five years, there has been growing concern among scientists about increases in the level of heat-trapping gases in the earth's atmosphere, and related rising of the average temperature on the earth's surface. These changes are generally known as "the greenhouse effect". There is now near-universal consensus among scientists that human activity—including industrialization, deforestation, fossil fuel based transportation, energy production and consumption, and changing land use patterns-- is responsible for these changes.

The resulting change in the climate is producing a chain reaction of effects—including rising sea levels, drought, extreme weather events (for example, tornados, hurricanes, floods), loss of glaciers and snow pack, and loss of land and sea ice. Expected effects for the Puget Sound region and for Thurston County include:

- Sea level rise
- Wetter winters
- Drier summers
- Increased disease
- Loss of salmon
- Food supply disruption
- Energy disruption
- Problems with drinking water availability

Scientists have indicated that a safe level of atmospheric greenhouse gases is 350 parts per million (ppm); recent reports indicate levels have reached 400 ppm. This is very alarming, and represents a call to action for all communities across the globe.

Our local communities are responding. Thurston County commissioners, as well as many of the city councils within the county, have over the past ten years established goals and programs for reducing greenhouse gas emissions from their facilities and internal operations. In addition, a variety of activist and volunteer groups have engaged in educational and advocacy programs to reduce GHG emissions in the community while building local resiliency.

One such group is Thurston Climate Action Team. It was founded in 2007 by a group of citizens concerned about the potential impact of global warming and wishing to promote local action to reduce Thurston County communities' carbon footprint. TCAT's founding members include county commissioners and city council members, citizen activists, representatives of key planning entities in the county, business people, the primary energy utility for the county, and the educational community. One of its most significant accomplishments has been collaborating with the local economic development council to obtain funding for and operate a community-wide energy efficiency program.

In 2012, TCAT identified three priority areas for its work:

1. Energy efficiency and distributed generation,
2. Transportation, and

3. A community greenhouse gas inventory for Thurston County.

In order to pursue area number three, in the spring and summer of 2012 TCAT discussed a greenhouse gas inventory project with elected representatives and staff from several local jurisdictions, as well as with its Energy Advisory Committee. TCAT also recruited an intern from The Evergreen State College's Master in Environmental Studies program. Robert Coleman was selected to serve as intern. Throughout the fall and winter of 2012 – 2013, energy usage, transportation, and other data were gathered for use in calculating GHG emissions.

The scope of this study encompasses all activities which produce greenhouse gases throughout the county. It includes all cities as well as unincorporated areas. It is not limited to government operations, but includes emissions produced by all homes, businesses and other entities which exist within the boundaries of the county.

TCAT sees this effort as a first step to setting GHG reduction goals, and setting strategies and projects to achieve those goals. In order to provide a check on progress and to allow correction and redesign of strategies that are not actually helping achieve established goals, it is intended that this inventory be updated annually.

Approach

This section contains three sub-sections: Methodology Chosen, Data Gathering, and Estimate Calculation.

Methodology Chosen

Nationally, the first greenhouse gas (GHG) inventories were completed for companies and other organizations. So initial methodologies developed for conducting this work focused on the needs of those groups. However, communities contribute to greenhouse gas emissions in significantly different ways than do organizations. So when selecting a GHG inventory methodology for this study, it was important to consider these differences. As we started this work, we learned that ICLEI had recently published the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions (i.e., Community Protocol). Because it seemed appropriate to the needs of our communities, and because some local governments in Thurston County have held or currently hold membership in ICLEI, this protocol was selected as the primary guide for estimating community-wide greenhouse gas emissions within the geopolitical boundary of Thurston County Washington.

The Community Protocol is a national standard developed by ICLEI-USA (International Council for Local Environmental Initiatives), now known as Local Governments for Sustainability USA, to inspire and guide U.S. local governments to account for and report on greenhouse gas emissions associated with the communities they represent. The development of the Community Protocol was funded by Pacific Gas and Electric Company, the State of Oregon Department of Environmental Quality, and through a National Science Foundation grant from the Research Coordination Network led by Dr. Anu Ramaswami at University of Colorado Denver. The Community Protocol was vetted by industry experts working in local, state, and federal governments, as well as universities, non-governmental organizations, and private corporations across the United States and Canada. By addressing six internationally recognized greenhouse gases regulated under the Kyoto Protocol (Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulfur hexafluoride (SF6)) across five basic emission types (built environment, transportation and other mobile sources, solid waste, water and wastewater, and agriculture), the protocol can be used to estimate the quantity of GHG emissions associated with community sources and activities during a chosen analysis year.

Data Gathering

The quantity of greenhouse gases emitted for each of the five basic emission types were estimated for 2010 based on the best available data. Electricity and natural gas consumption data from Puget Sound Energy were used to calculate emissions associated with the built environment. The Energy Information Administration's (EIA) State Energy Data System (SEDS) was also used to estimate the use of various fuels and their associated emissions in residential units that do not use natural gas from Puget Sound Energy. Thurston County Solid Waste provided aggregate waste sent to the landfill to calculate emissions associated with solid waste. The United States Department of Agriculture's Agricultural Census of 2007 was used to estimate commercial livestock populations in the county and their associated emissions. Lacey, Olympia, Tumwater, Thurston (LOTT) Clean Water Alliance provided wastewater treatment process and digester gas data for estimates related to wastewater treatment. Data were not available for wastewater processing in other communities within the county. Thurston Regional Planning Council's travel demand model and the Highway Performance Monitoring System (HPMS) database were used to calculate emissions related to on-road vehicles operating within the county. VMT data included trips from outside the jurisdictional boundaries to inside the boundaries, from inside to outside, and from inside to inside. Unincorporated Thurston County included rural Thurston County, city Urban Growth Areas, Grand Mound, and the Nisqually and Chehalis Reservations. Population data for 2010 was obtained from Thurston Regional Planning Council's Profile 2012.

Data for this inventory were gathered during the months of January and February of 2013, in partnership with Thurston County and the Thurston Regional Planning Council.

Estimate Calculation

Metric Tons of Carbon Dioxide Equivalents (MTCDE) were calculated either directly with an equation supplied by the Community Protocol or by converting individual estimates for each of the three greenhouse gases into Carbon Dioxide equivalents using 100 year Global Warming Potential (Table 2), and summing the three together.

$$MTCDE = [(mt\ CO_2 \times GWP_{CO_2}) + \left(mt\ CH_4 \times GWP_{CH_4}\right) + \left(mt\ N_2O\ \times GWP_{N_2O}\right)]$$

Table 2: One-hundred year Global Warming Potentials (GWP) for greenhouse gases. Carbon Dioxide (CO_2) has a GWP of 1 since it is the baseline unit to which all other greenhouse gases are compared.

Greenhouse Gas	**100 year GWP**
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310

The Community Protocol provides equations (Table 3) that allowed us to use community-based variables for input (Table 4) in order to calculate individual greenhouse gas values or MTCDE for a given emission source or activity. Equations referenced in Table 3 are taken from the source-specific appendices to the Community Protocol; the referenced Appendix is identified for each section of the table. Each equation is in turn described in greater detail in the Appendix, Emission Calculation Details, Figure 11 through Figure 23. Table 4 contains county-wide input values used to calculate emission estimates for the various emission sources and activities. Input values for each city jurisdiction and for the unincorporated sections of the county can be found in the source spreadsheets for these jurisdictions.

Additional details on how these inputs were used to calculate emissions, including specific formulas used, are contained in the Appendix, Emission Calculation Details.

Table 3: Emissions sources and related estimation method used to calculate greenhouse gas emission based on the U.S. Protocol for Community-wide Greenhouse Gas Emission Inventories

Emission Source	Equations Used
Built Environment (BE) Emission Activities and Sources, from Appendix C.	
Emissions from stationary combustion of natural gas in residential, commercial, and industrial units	BE.1.1, Equations BE.1.1.1, BE.1.1.2, BE.1.1.4, BE.1.1.6
Emissions from stationary combustion of fuel oil, propane/LPG, and wood in residential units	BE.1.2, BE.1.1
Emissions from use of electricity in residential, commercial, and industrial units	BE.2.1, Equation BE.2.2
Emissions from electricity transmission and distribution losses	BE.4.1, Equation BE.4.1.1
Upstream emissions from energy use	BE.5.1, Equation BE.5.1.1; BE.5.2A
Solid Waste Emission Activities and Sources, from Appendix E.	
Methane emissions from community-generated waste sent to landfills	SW.4.1
Process emissions associated with landfilling	SW.5
Collection and transportation emissions	SW.6
Agricultural Livestock Emission Activities and Sources, from Appendix G	
Methane emissions from enteric fermentation	A.1
Wastewater and Water Emission Activities and Sources, from Appendix F	
Stationary methane emissions from combustion of digester gas	WW.1.a
Stationary nitrous oxide emissions from combustion of digester gas	WW.2.a

Stationary carbon dioxide emissions from digester gas combustion	WW.3
Process carbon dioxide emissions from the use of fossil-fuel-derived methanol for biological nitrogen removal	WW.9
Transportation and Other Mobile Emission Activities, from Appendix D	
Emissions from passenger vehicles	TR.1.B, Equations TR.1.B.2, TR.1.B.3
Emissions from freight and service trucks	TR.2.A, Equations TR.2.A.1, TR.2.A.2

Table 4: List of user input descriptions, values, and related emission source/activity for Thurston County.

Input Description	Input Value	Emission Source/Activity
Built Environment		
Use of electricity in residential units	1,266,273,211 (kWh)	Consumption of electricity, Transmission and distribution losses, Upstream emissions from electricity use
Use of electricity in commercial units	920,512,299 (kWh)	Consumption of electricity, Transmission and distribution losses, Upstream emissions from electricity use
Use of electricity in industrial units	136,413,709 (kWh)	Consumption of electricity, Transmission and distribution losses, Upstream emissions from electricity use
Use of electricity in street lighting	4,419,884 (kWh)	Consumption of electricity, Transmission and distribution losses, Upstream emissions from electricity use
Use of natural gas in residential units	31,268,416 (therms)	Onsite combustion of fuel, Upstream emissions from fuel use
Use of fuel oil in residential units	248,428* (MMBtu)	Onsite combustion of fuel, Upstream emissions from fuel use
Use of propane/LPG in residential units	26,169* (MMBtu)	Onsite combustion of fuel, Upstream emissions from fuel use
Use of wood in residential units	125,965* (MMBtu)	Onsite combustion of fuel, Upstream emissions from fuel use
Use of natural gas in commercial units	15,994,387	Onsite combustion of fuel, Upstream emissions from fuel

Input Description	**Input Value**	**Emission Source/Activity**
	(therms)	use
Use of natural gas in industrial units	4,007,881 (therms)	Onsite combustion of fuel, Upstream emissions from fuel use
Transportation and Other Mobile Units		
Vehicle Miles Traveled estimate	2,341,013,000	Use of fuel in passenger cars
Vehicle Miles Traveled estimate	2,341,013,000	Use of fuel in heavy-duty freight vehicles
Solid Waste		
Tons of waste sent to landfill	165,191 tons	Methane emissions from community-generated waste sent to landfills
Tons of waste sent to landfill	165,191 tons	Process emissions associated with landfilling
Tons of waste sent to landfill	165,191 tons	Collection and transportation emissions
Agricultural Livestock		
Quantity of beef cows	5,165 individuals	Methane emissions from enteric fermentation and manure, direct and indirect nitrous oxide emissions from manure
Quantity of dairy cows	5,451 individuals	Methane emissions from enteric fermentation and manure, direct and indirect nitrous oxide emissions from manure
Quantity of swine	777 individuals	Methane emissions from enteric fermentation and manure, direct and indirect nitrous oxide emissions from manure

Input Description	Input Value	Emission Source/Activity
Quantity of sheep	1,838 individuals	Methane emissions from enteric fermentation and manure, direct and indirect nitrous oxide emissions from manure
Wastewater Treatment		
Digester annual average daily Biogas	138,369 ft^3	LOTT digester emissions
Fraction of CH4 in biogas	70%	LOTT digester emissions
Annual methanol consumption	31,029 gallons	LOTT emissions from methanol use in biological treatment of wastewater

*Values are obtained by scaling-down consumption estimates from the Energy Information Administration's (EIA) State Energy Database System (SEDS)

Results (by Jurisdiction)

Greenhouse gas emissions were calculated for Thurston County as a whole, for each incorporated city within the county, and for the unincorporated portion of Thurston County. Incorporated cities for which greenhouse gas emissions were calculated include: Olympia, Lacey, Tumwater, Yelm, Tenino, Bucoda and Rainier. Those results are presented in each of the sections below. All results are presented as metric tons of carbon dioxide equivalent (MTCDE).

Figure 1 depicts the geography of Thurston County, including the boundaries of the various communities and urban growth areas contained within the county, as of 2010. (Grand Mound and Rochester data was not collected for this study, because they are not incorporated and hence energy usage data was not available from Puget Sound Energy for those communities.)

This map can also be found at the following web site:
http://www.trpc.org/data/Documents/Profile%202010/Map02-CityLimits_UGAs11x17.pdf

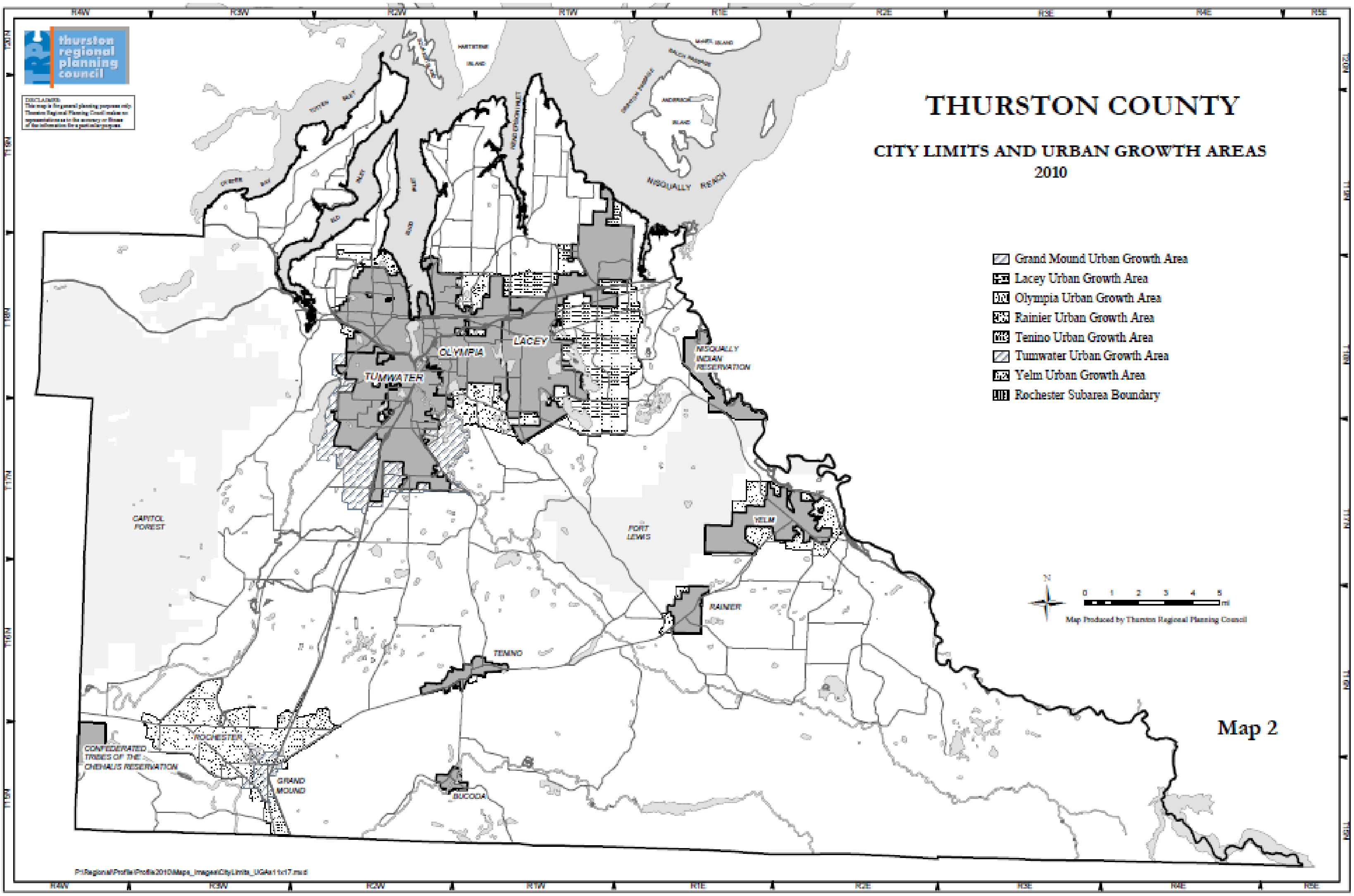

Figure 1: Thurston County Boundaries, City Limits, and Urban Growth Areas

Thurston County

Thurston County is located at the southern end of Puget Sound. As of the 2010 census, its population was 252,264. The county seat is Olympia, which is also the state capital and the county's largest city. According to the U.S. Census Bureau, the county has a total area of 774 square miles, of which 727 square miles is land and 47 square miles (6.03%) is water.

In calendar year 2010, greenhouse gas emissions in all of Thurston County, and from all sources and activities, totaled roughly 2.76 million metric tons of carbon dioxide equivalents (Table 5, Figure 2). This included emissions from the built environment; passenger, heavy-duty, and public transit vehicles; the generation and disposal of solid waste; the primary wastewater treatment facility in the community; and livestock production. The emissions for each of these sources are listed in Table 5 (below) and depicted in Figure 2.

Table 5: County-wide emission source types, quantities, and percentage of total emissions. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE ***	**%**
Built Environment	1,444,406	52%
On-road Vehicles	1,230,054	45%
Solid Waste	54,166	2%
Livestock	21,289	1%
Wastewater Treatment	11,884	0%
Total	2,761,800	100%
Per Capita Emissions	10.95	

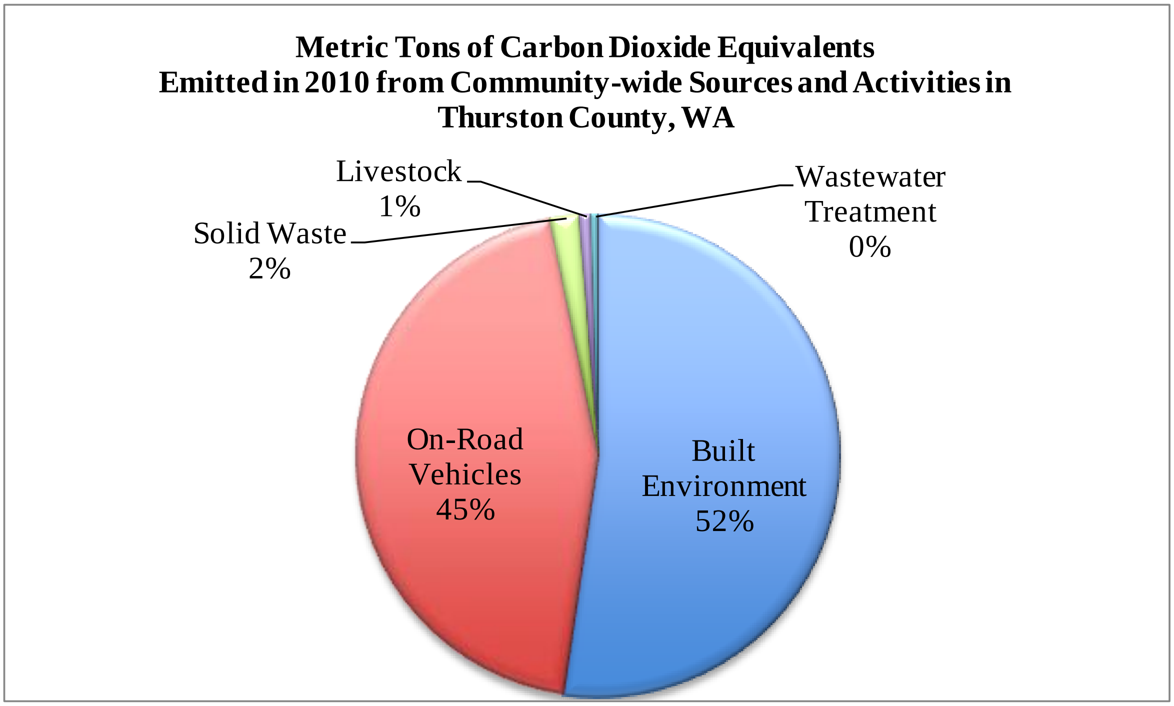

Figure 2: Distribution of county-wide emissions by source.

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in the county (Figure 2). The use of electricity accounts for 60% of built environment emissions, while the use of fuel, primarily natural gas, accounts for roughly 20% (Table 6). Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 10% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 5% and 4% of the built environment total, respectively. The residential sector accounts for the most built environment emissions, followed by commercial and industrial sectors respectively (Figure 3). Street lighting (“lighting”) accounts for a very small portion of emissions within the built environment.

Table 6: County-wide built environment emission source quantities and percentages. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	869,353	60%
Use of Fuel	293,597	20%
Upstream Electricity Use	145,476	10%
Transmission and Distribution Losses	71,373	5%
Upstream Fuel Use	64,606	4%
Total	1,444,406	100%

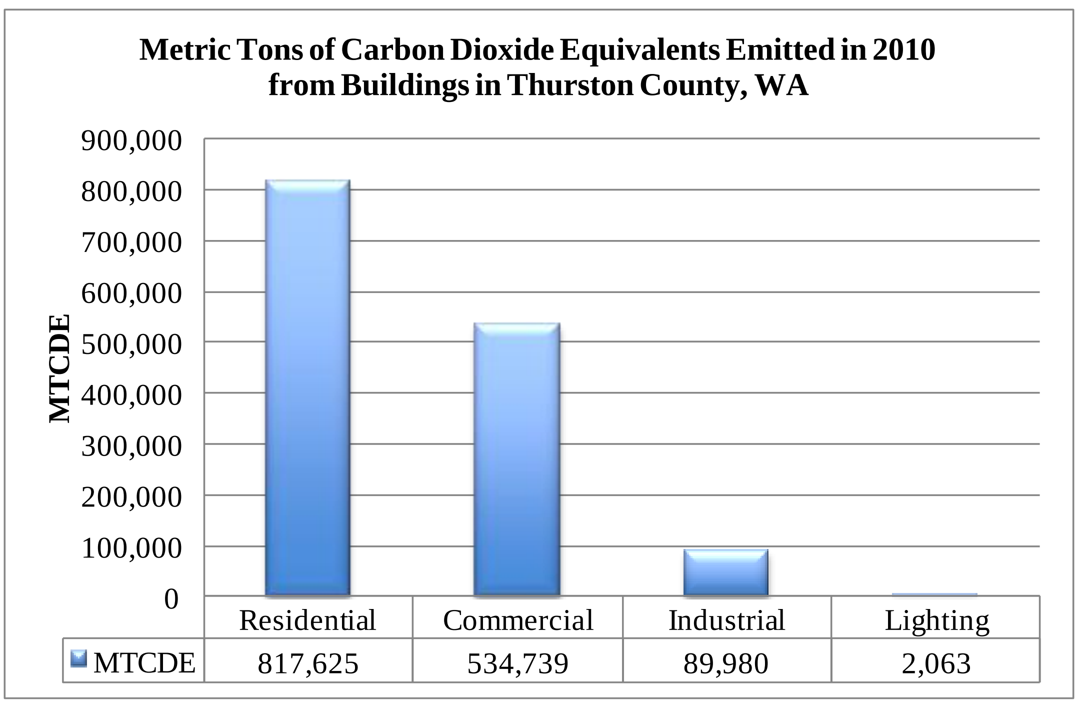

Figure 3: County-wide built environment emissions by structure type. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions account for approximately 44% of total emissions in Thurston County, WA in 2010 (Table 7). Emissions resulting from on-road vehicles operating within the county boundary were larger in passenger vehicles (962,361 MTCDE) than in heavy-duty freight vehicles (258,697 MTCDE). Public transit emissions were the smallest source (8,996 MTCDE). Passenger vehicles account for 78% of emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions, and public transit accounts for approximately 1% of on-road transportation emissions.

Table 7: County-wide on-road vehicle emission source quantities and percentages. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	962,361	78%
Heavy Duty Freight vehicles	258,697	21%
Public Transit (Gasoline)	1,842	<1%
Public Transit (Diesel)	7,154	<1%
Total	1,230,054	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is deposited in a landfill account for 86% of Thurston County's solid waste emissions (Table 8). Emissions associated with the decomposition of this material, and with the equipment used in processing this material, account for 5% of emissions. Rail and truck emissions, separate from on-road vehicle emissions, associated with transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA (4,625 MTCDE) make up the remaining 9% of solid waste emissions.

Table 8. County-wide solid waste emission source quantities and percentages. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	46,831	86%
Transportation emissions	4,625	9%
Process emissions	2,710	5%
Total	54,166	100%

Wastewater Treatment Emissions

Emissions from the operation of the primary wastewater treatment facility within the county (Lacey Olympia Tumwater Thurston (LOTT) Clean Water Alliance Budd Inlet Treatment Plant) were comprised of emissions from burning methane gas from the onsite digesters, and emissions resulting from the use of methanol to biologically treat waste (Table 9) The onsite burning of captured methane gas (digester emissions) produced 99% of emissions, and approximately 1% of emissions were a result of methanol use in the biological treatment of waste.

Table 9. County-wide wastewater emission source quantities and percentages from LOTT Clean Water Alliance Budd Inlet Treatment Plant. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Digester Emissions	11,759	99%
Methanol Emissions	124	1%
Total	11,883	100%

Livestock Emissions

Methane emissions resulting from domesticated animal production within the county boundary were divided among beef cows, dairy cows, sheep, and swine (Table 10). Beef cows accounted for 51% of emissions from domesticated animal production, 48% were from dairy cows, 1% from sheep, and less than 1% from swine.

Table 10: County-wide livestock emission source quantities and percentage. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Beef Cows	10,760	51%
Dairy Cows	10,196	48%
Sheep	309	1%
Swine	24	<1%
Total	21,289	100%

Unincorporated Thurston County

In calendar year 2010 sources and activities producing greenhouse gas emissions in unincorporated Thurston County emitted roughly 1,443,200 metric tons of carbon dioxide equivalents (MTCDEs) (Table 11), including emissions from the built environment, passenger and heavy-duty vehicles, the generation and disposal of solid waste, and livestock production. The built environment generated approximately 606,664 MTCDE (42%), on-road passenger and heavy-duty vehicles produced approximately 786,233 MTCDE (54%), the generation and disposal of solid waste by the community emitted approximately 29,014 MTCDE (2%), and livestock produced roughly 21,289 MTCDE (1%).

Table 11: Unincorporated county emission source types quantities, and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Built Environment	606,664	42%
On-Road Vehicles	786,233	54%
Solid Waste	29,014	2%
Livestock	21,289	1%
Total	1,443,200	100%
Per Capita Emissions	10.68	

Built Environment Emissions

The use of electricity accounts for 64% of built environment emissions in unincorporated Thurston County, while the use of fuel, primarily natural gas, accounts for roughly 16% (Table 12). Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 11% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 5% and 3% of the built environment total, respectively. The commercial sector accounts for the most built environment emissions, followed by the residential sector (Figure 4).

Table 12: Unincorporated county built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Fuel	100,075	16%
Use of Electricity	388,609	64%
Upstream Fuel Use	21,046	3%
Upstream Electricity Use	65,029	11%
Transmission and Distribution Losses	31,905	5%
TOTAL	606,664	100%

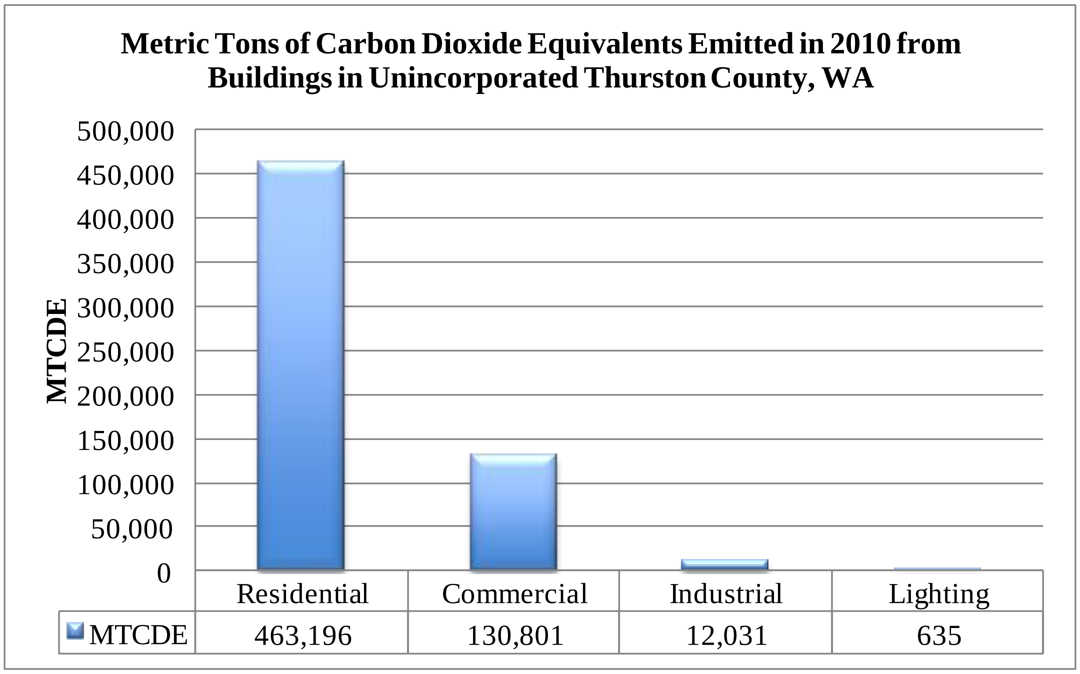

Figure 4: Unincorporated county built environment emissions by structure type. Values in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions account for approximately 54% of total emissions in unincorporated Thurston County in 2010, and are the largest single source of emissions in the region (Table 11). Emissions resulting from on road vehicles operating within the county boundary were larger in passenger vehicles (619,659 MTCDE) than in heavy-duty freight vehicles (166,574 MTCDE). Passenger vehicles account for 79% of emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions. (Table 13)

Table 13: Unincorporated county on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	619,659	79%
Heavy Duty Freight vehicles	166,574	21%
Total	786,233	100%

Solid Waste Emissions

Community-generated waste that is landfilled accounts for 86% of solid waste emissions in unincorporated Thurston County (Table 14). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions (Table 14). Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA makeup the remaining 9% of solid waste emissions.

Table 14: Unincorporated county solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	25,085	86%
Transportation emissions	2,478	9%
Process emissions	1,451	5%
Total	29,014	100%

Livestock Emissions

Methane emissions resulting from enteric fermentation of livestock within the county-boundary were divided among beef cows, dairy cows, sheep, and swine (Table 15). Beef cows accounted for 51% of emissions from livestock production, 48% from dairy cows, 1% from sheep, and less than 1% from swine.

Table 15: Unincorporated county livestock emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Beef Cows	10,760	51%
Dairy Cows	10,196	48%
Sheep	309	1%
Swine	24	<1%
Total	21,289	100%

Bucoda

Bucoda is located in the southern portion of Thurston County, about 17 miles south of Olympia, along Old Highway 99. With a 2010 population of 550, it covers only 0.4 square miles.

In calendar year 2010 sources and activities producing greenhouse gas emissions in Bucoda emitted roughly 2,047 metric tons of carbon dioxide equivalents (MTCDEs) (Table 16), including emissions from the built environment, passenger, and heavy-duty vehicles, and the generation and disposal of solid waste. The built environment generated approximately 1,636 MTCDE (80%), on-road passenger and heavy-duty vehicles produced approximately 290 MTCDE (14%), and the generation and disposal of solid waste by the community emitted approximately 121 MTCDE (6%). Per capita emissions for 2010 in Bucoda were estimated at 3.64 MTCDE.

Table 16: Bucoda emission source types quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Built Environment	1,636	80%
On-Road Vehicles	290	14%
Solid Waste	121	6%
Total	2,047	100%
Per Capita Emissions	3.64	

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in Bucoda. The residential sector accounts for the most built environment emissions. The use of electricity accounts for 78% of built environment emissions, while the use of fuel, accounts for 3% (Table 17). Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 13% of built environment emissions. Emissions from electricity transmission and distribution losses account for 6% of built environment emissions.

Table 17: Bucoda built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	1,272	78%
Upstream Electricity Use	213	13%
Transmission and Distribution Losses	104	6%
Use of Fuel	47	3%
Total	6,288	100%

On-road Vehicle Emissions

On-road vehicle emissions account for approximately 14% of total emissions in Bucoda in 2010, and passenger vehicles are the second largest single-source of emissions city-wide (**Table 18**). Emissions resulting from on road vehicles operating within the county boundary were larger in passenger vehicles (229 MTCDE) than in heavy-duty freight vehicles (61 MTCDE). Passenger vehicles accounted for 79% of emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions.

Table 18: Bucoda on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	229	79%
Heavy Duty Freight vehicles	61	21%
Total	290	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is landfilled account for 86% of Bucoda’s solid waste emissions (Table 19). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions. Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County

Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA makeup the remaining 9% of solid waste emissions.

Table 19: Bucoda solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	333	86%
Transportation emissions	33	9%
Process emissions	19	5%
Total	385	100%

Lacey

Lacey is located in the northern part of Thurston County, bordering Olympia to the west. Lacey population in 2010 was 42,393. The city has a total area of 16.51 square miles (42.76 km2), of which, 16.06 square miles is land and 0.45 square miles is water.

In calendar year 2010 sources and activities producing greenhouse gas emissions in Lacey, WA emitted roughly 392,141 metric tons of carbon dioxide equivalents (MTCDEs) (Table 20). This included emissions from the built environment, passenger, heavy-duty, and public transit vehicles, the generation and disposal of solid waste, and the primary wastewater treatment facility in the community. The built environment generated approximately 240,697 MTCDE (60%), on-road passenger and freight vehicles produced approximately 137,599 MTCDE (35%), the generation and disposal of solid waste by the community emitted approximately 9,103 MTCDE (2%), and emissions related to the primary wastewater treatment facility within the county serving Lacey total approximately 4,742 MTCDE (1%). Per capita emissions for Lacey were 9.25 MTCDE.

Table 20: Lacey emission source type quantities, and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Built Environment	240,697	61%
On-Road Vehicles	137,599	35%
Wastewater Treatment	4,742	1%
Solid Waste	9,103	2%
Total	392,141	100%
Per Capita Emissions	9.25	

Unique among the jurisdictions included in this inventory, Lacey conducted a community wide greenhouse gas inventory for calendar year 2005. At that time, Lacey had a population of 33,705 and its emissions were 345,202 metric tons of carbon dioxide equivalent. This represents a 14% increase in overall community GHG emissions between 2005 and 2010, significantly lower than its 26% growth in population. With per capita emissions for 2005 at 10.24, these figures point to a 10% reduction in Lacey's per capita emissions during that five year period.

The numbers reported in Lacey's 2005 greenhouse gas inventory may have used slightly different calculations; for example, they may not have included upstream electricity and fuel use as part of the built environment calculations. For a more accurate picture of Lacey's GHG emissions trends, these calculations should be examined in greater detail, and any necessary adjustments made to ensure an accurate comparison between 2005 and 2010 emissions.

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in the city of Lacey (Table 20). The residential sector accounts for the most built environment emissions, followed by the commercial and then industrial sectors respectively (Figure 5). The use of electricity accounts for 55% of built environment emissions, while the use of fuel, primarily natural gas, accounts for roughly 25% (Table 21). Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 9% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 5% and 6% of the built environment total, respectively.

Table 21: Lacey built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	133,586	55%
Use of Fuel	60,329	25%
Upstream Electricity Use	22,354	9%
Upstream Fuel Use	13,461	6%
Transmission and Distribution Losses	10,967	5%
Total	240,697	100%

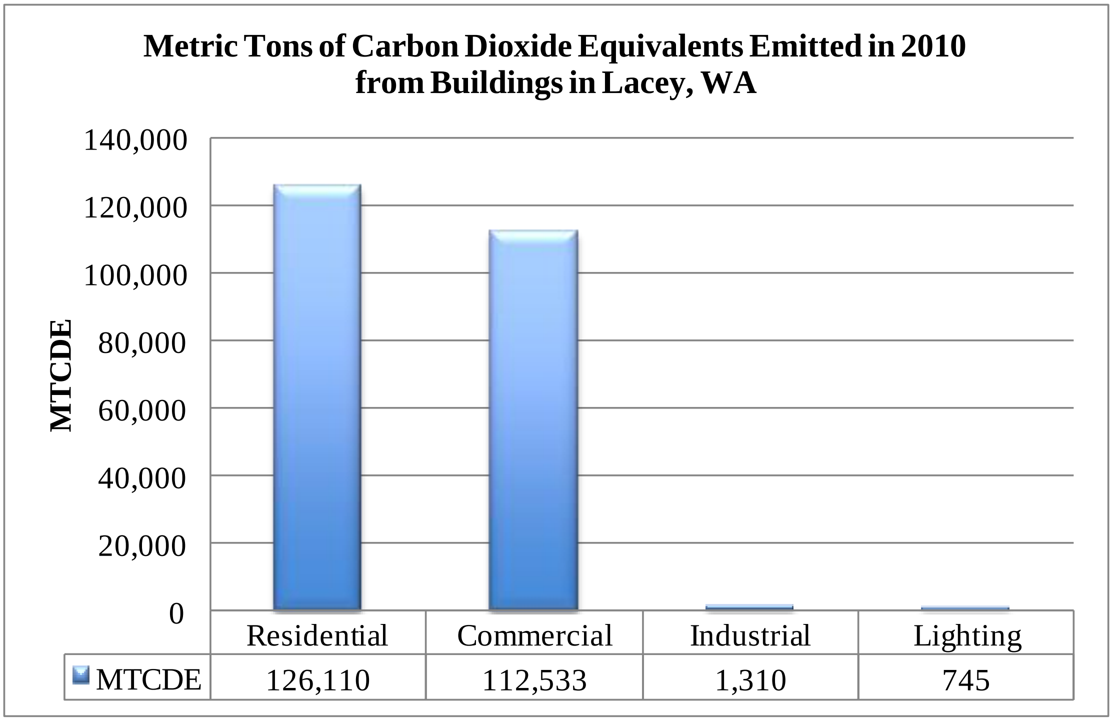

Figure 5: Lacey built environment emissions by structure type. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions accounted for approximately 35% of Lacey's total emissions in 2010, and passenger vehicles are the largest single source of on-road vehicle emissions city-wide (Table 22). Passenger vehicles account for 77% of emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions, and public transit accounts for approximately 2% of on-road transportation emissions.

Table 22: Lacey on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	105,617	77%
Heavy Duty Freight vehicles	28,391	21%
Public Transit	3,590	2%

Total	137,599	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is landfilled account for 86% of Lacey's solid waste emissions (7,870 MTCDE) (Table 23). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions, or 455 MTCDE. Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA (777 MTCDE) makeup the remaining 9% of solid waste emissions (Table 19).

Table 23: Lacey solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	MTCDE	%
Methane emissions	7,870	86%
Transportation emissions	777	9%
Process emissions	455	5%
Total	9,103	100%

Wastewater Treatment Emissions

Lacey's emissions from the onsite burning of captured methane gas (digester emissions) amounted to 4,692 MTCDE (99%), and approximately 50 MTCDE emissions (1%) were a result of methanol use in the biological treatment of waste (Table 24).

Table 24: Lacey's wastewater emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	MTCDE	%
Digester Emissions	4,692	99%

Methanol Emissions	50	1%
Total	4,742	100%

Olympia

Olympia is the capital of Washington State and the county seat of Thurston County. The population was 46,478 at the 2010 census. Situated in the northern end of Thurston County, the city borders Lacey to the east, and Tumwater to the south. The city has a total area of 19.68 square miles, of which, 17.82 sq mi is land and 1.86 sq mi is water.

In calendar year 2010, greenhouse gas emissions in Olympia from all sources and activities, totaled roughly 564,607 metric tons of carbon dioxide equivalents (MTCDEs) (Table 25). This included emissions from the built environment (365,941 MTCDE); passenger, heavy-duty, and public transit vehicles (183,487 MTCDE); the generation and disposal of solid waste (9,980 MTCDE); and the primary wastewater treatment facility in the community (5,199 MTCDE). The emissions and percentages for each of these sources are listed in Table 25 (below). Per capita emissions for Olympia were 12.15 MTCDE.

Table 25: Olympia emission source types, quantities, and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	MTCDE	%
Built Environment	365,941	65%
On-Road Vehicles	183,487	32%
Solid Waste	9,980	2%
Wastewater Treatment	5,199	1%
Total	564,607	100%
Per Capita Emissions	12.15	

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in Olympia. The commercial sector accounts for the most built environment emissions, followed by residential and industrial sectors respectively (Figure 6). Street lighting ("lighting") accounts for a very small portion of emissions within the built environment. The use of electricity accounts for 57% of built environment emissions, while the use of fuel, primarily natural gas, accounts for roughly 24% (Table 26). Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 5% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 9% and 5% of the built environment total, respectively.

Table 26: Olympia built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Use of Electricity	207,575	57%
Use of Fuel	86,906	24%
Upstream Electricity Use	34,735	9%
Upstream Fuel Use	19,683	5%
Transmission and Distribution Losses	17,042	5%
TOTAL	365,941	100%

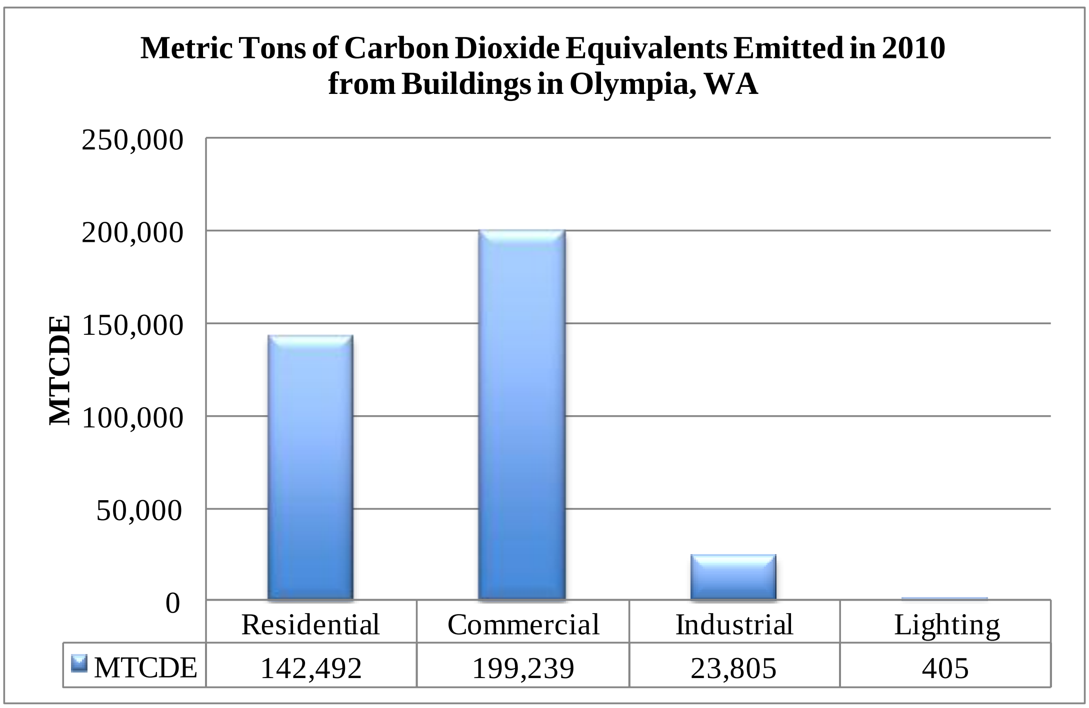

Figure 6: Olympia built environment emissions by structure type. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions accounted for approximately 32% of Olympia's total emissions in 2010 (Table 25). Emissions resulting from on-road vehicles operating within the city boundary were larger in passenger vehicles (141,511 MTCDE) than in heavy-duty freight vehicles (38,040 MTCDE). Public transit emissions were the smallest source (3,936 MTCDE). Passenger vehicles account for 71% of emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions, and public transit accounts for approximately 2% of on-road transportation emissions (Table 27).

Table 27: Olympia on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	141,511	77%
Heavy Duty vehicles	38,040	21%
Public Transit	3,936	2%
TOTAL	183,487	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is deposited in a landfill account for 86% of Olympia's solid waste emissions (8,629 MTCDE) (Table 28). Emissions associated with the decomposition of this material, and with the equipment used in processing this material, account for 5% of emissions, or 499 MTCDE. Rail and truck emissions, separate from on-road vehicle emissions, associated with transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA (852 MTCDE) make up the remaining 9% of Olympia's solid waste emissions.

Table 28: Olympia solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	8,629	86%
Transportation emissions	852	9%
Process emissions	499	5%
Total	9,980	100%

Wastewater Treatment Emissions

Onsite burning of captured methane gas (digester emissions) account for 99% of its emissions (5,145 MTCDE), and approximately 1% of emissions (54 MTCDE) were a result of methanol use in the biological treatment of waste (Table 29).

Table 29: Olympia wastewater emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Digester Emissions	5,145	99%
Methanol Emissions	54	1%
Total	5,199	100%

Rainier

Rainier is located in the southeast portion of Thurston County, about 5.5 miles southwest of Yelm along highway 507. The city has a total area of 1.73 square miles, all of it land. In terms of land cover, 18% (179 acres) of the city is urban, 27% (267 acres) is forested, and 55% (540 acres) is covered with non-forest vegetation and soils. As of 2010, there were 1,794 people, 656 households, and 484 families residing in the city

In calendar year 2010 sources and activities producing greenhouse gas emissions in Rainier emitted roughly 8,734 metric tons of carbon dioxide equivalents (MTCDEs) (Table 30), including emissions from the built environment, passenger, and heavy-duty vehicles, and the generation and disposal of solid waste. The built environment generated approximately 6,288 MTCDE (72%), on-road passenger and heavy-duty vehicles produced approximately 2,060 MTCDE (24%), and the generation and disposal of solid waste by the community emitted approximately 385 MTCDE (4%). Per capita emissions for Rainier were 4.87 MTCDE.

Table 30: Rainier emission source type quantities and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Built Environment	6,288	72%
On-Road Vehicles	2,060	24%
Solid Waste	385	4%
Total	8,734	100%
Per Capita Emissions	4.87	

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in Rainier (Table 30). The residential sector accounts for the most built environment emissions (Figure 7). The use of electricity accounts for 63% of built environment emissions, while the use of fuel, primarily natural gas, accounts for 18% (Table 31). Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 10% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 5% and 4% of the built environment total, respectively.

Table 31: Rainier built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	3,962	63%
Use of Fuel	1,110	18%
Upstream Electricity Use	663	11%
Transmission and Distribution Losses	325	5%
Upstream Fuel Use	228	4%
Total	6,288	100%

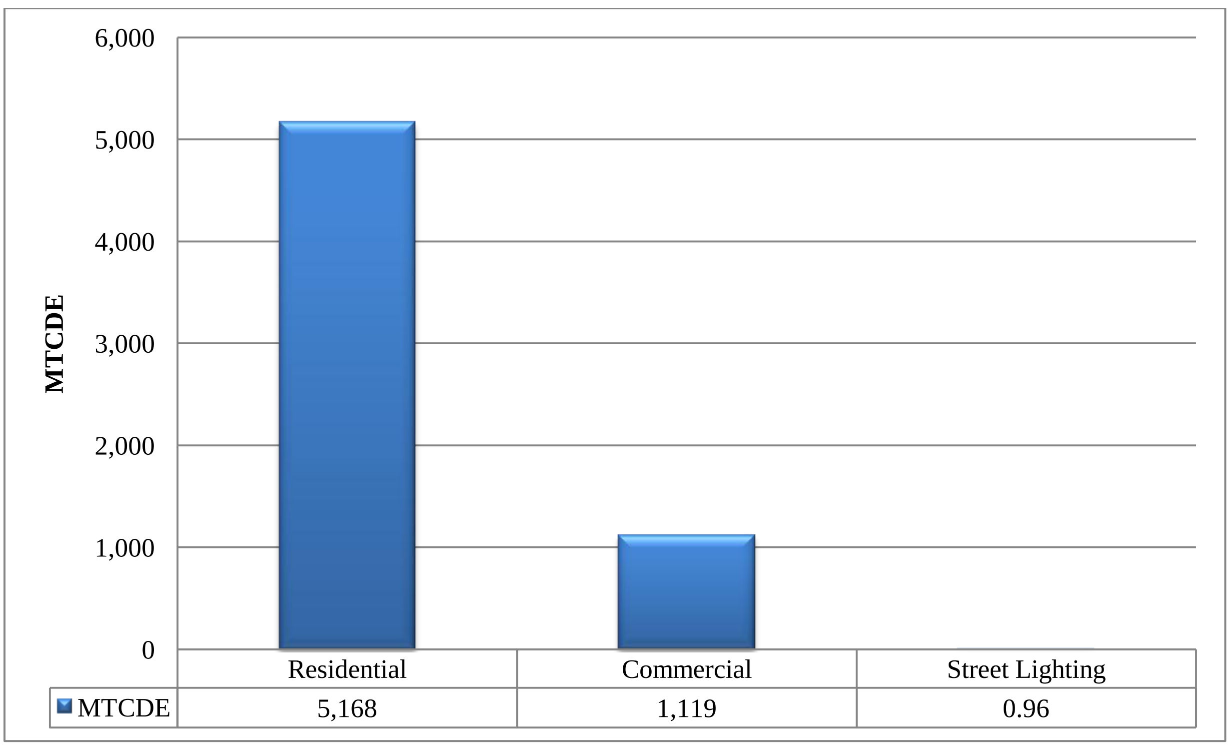

Figure 7: Rainier built environment emissions by structure type. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions accounted for approximately 24% of total emissions in Rainier in 2010, and passenger vehicles were the second largest single-source of emissions city-wide

(Table 32). Emissions resulting from on road vehicles operating within the county boundary were larger in passenger vehicles (1,624 MTCDE) than in heavy-duty freight vehicles (436 MTCDE). Passenger vehicles account for 79% of emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions.

Table 32: Rainier on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	1,624	79%
Heavy Duty Freight vehicles	436	21%
Total	2,060	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is landfilled account for 86% of Rainier's solid waste emissions (Table 33). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions. Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA makeup the remaining 9% of solid waste emissions.

Table 33: Rainier solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	333	86%
Transportation emissions	33	9%
Process emissions	19	5%
Total	385	100%

Tenino

Tenino is located in the south central portion of Thurston County, about 14 miles south of Olympia along Old Highway 99. In 2010, there were 1,695 people, 691 households, and 440 families residing in Tenino. The city has a total area of 1.44 square miles, all of it land.

In calendar year 2010 sources and activities producing greenhouse gas emissions in Tenino, WA emitted roughly 12,852 metric tons of carbon dioxide equivalents (MTCDEs) (Table 34), including emissions from the built environment, passenger, and heavy-duty vehicles, and the generation and disposal of solid waste. The built environment generated approximately 8,143 MTCDE (63%), on-road passenger and heavy-duty vehicles produced approximately 4,345 MTCDE (34%), and the generation and disposal of solid waste by the community emitted approximately 364 MTCDE (3%). Per capita emissions for Tenino were 7.58 MTCDE.

Table 34: Tenino emission source types quantities, and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	MTCDE	%
Built Environment	8,143	63%
On-Road Vehicles	4,345	34%
Solid Waste	364	3%
Total	12,852	100%
Per Capita Emissions	7.58	

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in Tenino (Table 35). The residential sector accounts for the most built environment emissions (Figure 8). The use of electricity accounts for 79% of built environment emissions, while the use of fuel, primarily natural gas, accounts for 2%. Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 13% of built environment emissions. Emissions from electricity transmission and distribution losses account for 6% of the built environment total.

Table 35: Tenino built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	6,404	79%
Upstream Electricity Use	1,072	13%
Transmission and Distribution Losses	526	6%
Use of Fuel	142	2%
Total	8,143	100%

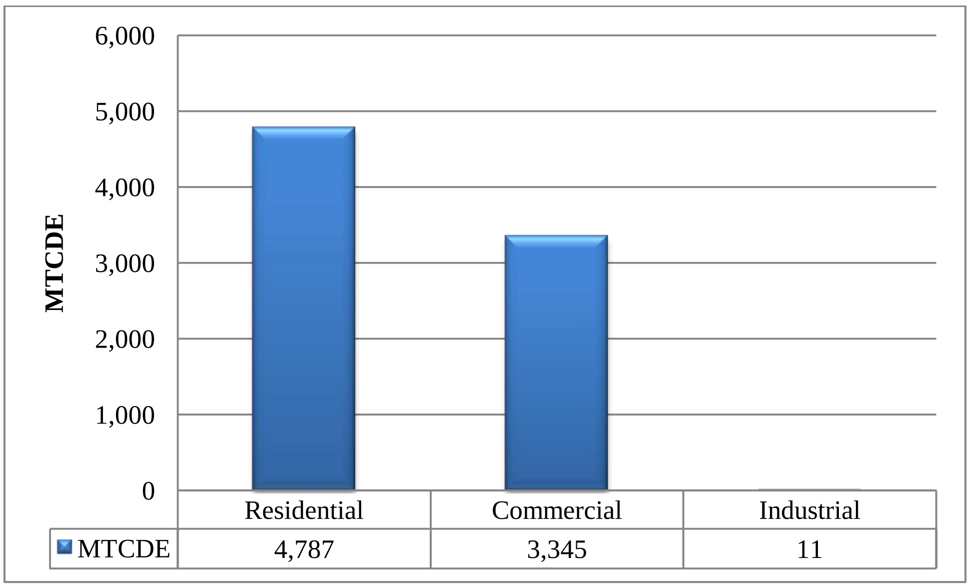

Figure 8: Tenino built environment emissions by structure type. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions account for approximately 34% of total emissions in Tenino in 2010, and passenger vehicles are the second largest single-source of emissions city-wide (Table 36). Emissions resulting from on road vehicles operating within the city boundary were larger in passenger vehicles (3,424 MTCDE) than in heavy-duty freight vehicles (921 MTCDE). Passenger vehicles account for 79% of Tenino emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions.

Table 36: Tenino on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	3,424	79%
Heavy Duty Freight vehicles	921	21%
Total	2,060	100%

Solid Waste Emissions

Methane emissions from Tenino's community-generated waste that is landfilled account for 86% of its solid waste emissions (Table 37). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions. Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA makeup the remaining 9% of solid waste emissions.

Table 37: Tenino solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	315	86%
Process emissions	18	5%
Transportation emissions	31	9%
Total	364	100%

Tumwater

Tumwater shares its northern border with Olympia, and is in the northern portion of Thurston County. The population was 17,371 at the 2010 census. The city has a total area of 14.49 square miles, of which, 14.32 square miles is land and 0.17 square miles is water.

In calendar year 2010 sources and activities producing greenhouse gas emissions in Tumwater emitted roughly 288,540 metric tons of carbon dioxide equivalents (MTCDEs) (Table 38), including emissions from the built environment, passenger, heavy-duty, and public transit vehicles, the generation and disposal of solid waste, and the primary wastewater treatment facility in the community. The built environment generated approximately 177,016 MTCDE (61%), on-road passenger and freight vehicles produced approximately 105,851 MTCDE (36%), the generation and disposal of solid waste by the community emitted approximately 3,730 MTCDE (1%), and emissions related to the primary wastewater treatment facility within the county serving Tumwater total approximately 1,943 MTCDE (1%).

Table 38: Tumwater emission source type quantities, and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Built Environment	177,016	61%
On-Road Vehicles	105,851	37%
Solid Waste	3,730	1%
Wastewater Treatment	1,943	1%
Total	288,540	100%
Per Capita Emissions	16.61	

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in Tumwater (Table 39). The commercial sector accounts for the most built environment emissions (Figure 9). The use of electricity accounts for 61% of built environment emissions, while the use of fuel, primarily natural gas, accounts for roughly 19%. Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 10% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 5% and 4% of the built environment total, respectively.

Table 39: Tumwater built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	107,915	61%
Use of Fuel	34,376	19%
Upstream Electricity Use	18,058	10%
Transmission and Distribution Losses	8,860	5%
Upstream Fuel Use	7,807	4%
Total	177,016	100%

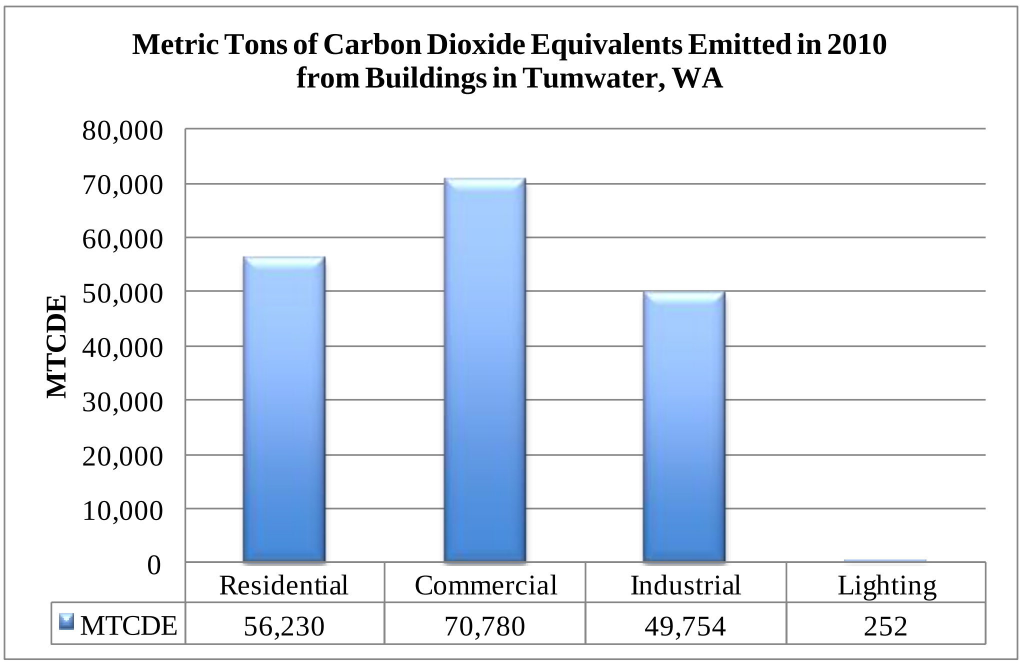

Figure 9: Tumwater built environment emissions by structure type. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions accounted for approximately 36% of Tumwater's total emissions in 2010, and passenger vehicles are the largest single source of emissions city-wide (Table 40).

Passenger vehicles account for 78% of Tumwater's emissions from on-road transport, while heavy-duty freight vehicles account for 21%, and public transit accounts for approximately 1%.

Table 40: Tumwater on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	MTCDE	%
Passenger vehicles	82,266	78%
Heavy Duty Freight vehicles	22,114	21%
Public Transit	1,471	1%
Total	105,851	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is landfilled account for 86% of Tumwater's solid waste emissions (Table 41). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions. Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA (319 MTCDE) make up the remaining 9% of solid waste emissions.

Table 41: Tumwater solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	MTCDE	%
Methane emissions	3,225	86%
Transportation emissions	319	9%
Process emissions	187	5%
Total	3,731	100%

Wastewater Treatment Emissions

Emissions from the operation of the primary wastewater treatment facility within the county (Lacey, Olympia, Tumwater, Thurston (LOTT)) Clean Water Alliance Budd Inlet Treatment Plant) were comprised of process emissions, emissions from burning methane gas from the onsite digesters, and emissions resulting from the use of methanol to biologically treat waste. Wastewater treatment related process emissions account for 62% of Tumwater's share of emissions at the primary wastewater treatment plant, 37% of emissions were from the onsite burning of captured methane gas, and approximately 1% of emissions were a result of methanol use in the biological treatment of waste (Table 42).

Table 42: Tumwater wastewater treatment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Digester Emissions	1,923	99%
Methanol Emissions	20	1%
Total	9,143	100%

Yelm

Yelm is in the eastern part of Thurston County, and is located about 20 miles southeast of Olympia. The city has a total area of 5.69 square miles, of which 5.68 square miles is land and 0.01 square miles is water. In 2010, there were 6,848 people, 2,299 households, and 1,712 families residing in the city.

In calendar year 2010 sources and activities producing greenhouse gas emissions in Yelm emitted roughly 46,679 metric tons of carbon dioxide equivalents (MTCDEs) (Table 43), including emissions from the built environment, passenger and heavy-duty vehicles, and the generation and disposal of solid waste. The built environment generated approximately 38,020 MTCDE (77%), on-road passenger and heavy-duty vehicles produced approximately 10,189 MTCDE (21%), and the generation and disposal of solid waste by the community emitted approximately 1,470 MTCDE (3%). Per capita emissions are estimated at approximately 7.25 MTCDE.

Table 43: Yelm emission source types quantities, and percentage of total emissions. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source Type	**MTCDE**	**%**
Built Environment	38,020	77%
On-Road Vehicles	10,189	21%
Solid Waste	1,470	3%
Total	49,679	100%
Per Capita Emissions	7.25	

Built Environment Emissions

Emissions resulting from the use of fuel and electricity in the built environment account for the largest portion of emissions in Yelm (Table 44). The residential sector accounts for the most built environment emissions, followed by the commercial and then industrial sectors respectively (Figure 10). The use of electricity accounts for 53% of built environment emissions (Table 44), while the use of fuel, primarily natural gas, accounts for roughly 28%, Upstream emissions involved in the generation of the electricity consumed by the community account for approximately 9% of built environment emissions. Emissions from electricity transmission and distribution losses and upstream emissions associated with the production and distribution of natural gas account for 4% and 6% of the built environment total, respectively.

Table 44: Yelm built environment emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emissions Source	**MTCDE**	**%**
Use of Electricity	20,030	53%
Use of Fuel	10,613	28%
Upstream Electricity Use	3,352	9%
Upstream Fuel Use	2,381	6%
Transmission and Distribution Losses	1,644	4%
Total	38,020	100%

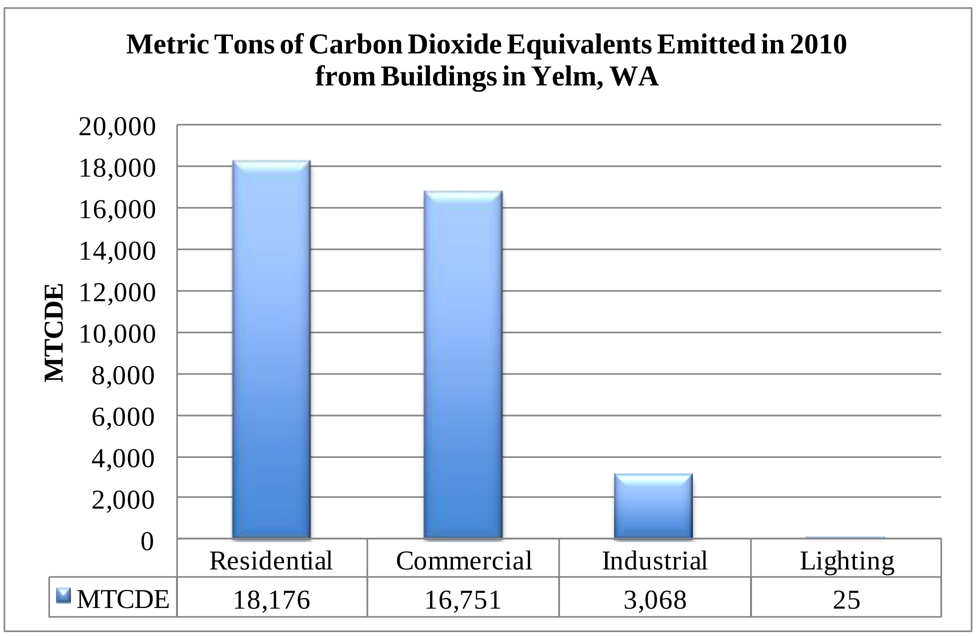

Figure 10: Yelm built environment emissions by structure type. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

On-road Vehicle Emissions

On-road vehicle emissions accounted for approximately 20% of Yelm's total emissions in 2010, and passenger vehicles were one of the largest single sources of emissions city-wide (Table 45). Emissions resulting from on road vehicles operating within the county boundary were larger in passenger vehicles (8,030 MTCDE) than in heavy-duty freight vehicles (2,159 MTCDE).

Passenger vehicles account for 79% of Yelm's emissions from on-road transport, while heavy-duty freight vehicles account for 21% of on-road transportation emissions.

Table 45: Yelm on-road vehicle emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Passenger vehicles	8,030	79%
Heavy Duty Freight vehicles	2,159	21%
Total	10,189	100%

Solid Waste Emissions

Methane emissions from the community-generated waste that is landfilled account for 86% of Yelm's solid waste emissions (Table 46). Emissions associated with the landfilling process (i.e., decomposition) and equipment account for 5% of emissions. Rail and truck emissions, separate from on-road vehicle emissions, from transporting waste from the Thurston County Waste and Recovery Center to the Roosevelt Regional Landfill in Roosevelt, WA makeup the remaining 9% of solid waste emissions.

Table 46: Yelm solid waste emission source quantities and percentages. Values are in Metric Tons of Carbon Dioxide Equivalents (MTCDE).

Emission Source	**MTCDE**	**%**
Methane emissions	1,271	86%
Transportation emissions	126	9%
Process emissions	74	5%
Total	1,471	100%

Implications

In this section, implications of this study for setting goals, designing strategies and programs, and monitoring results are discussed.

Because economic, social and political dynamics of the communities within Thurston County are highly interdependent, TCAT recommends that goals, strategies and programs be defined collaboratively among the county, city councils, and related agencies which serve the region. Other agencies and organizations with specific contributions to setting goals, strategies and programs include Thurston Regional Planning Council, school districts and other educational institutions, LOTT, Puget Sound Energy, and the Port of Olympia.

Setting Goals

When considering GHG reduction goals for Thurston County, it is helpful first to consider how Thurston County's current emissions compare with those of Northwest states and communities, and with emissions nation-wide. Secondly, Thurston County goals should take into account Washington State's legally-established GHG reduction goals, codified in RCW 70.235.020, and with goals set for other Northwest communities. Finally, we should consider the assessments of the Intergovernmental Panel on Climate Change (IPCC) and other international scientific bodies for GHG reduction targets.

Northwest GHG Emissions and Goals

Because each city and local jurisdiction has different population and area it includes, comparison among jurisdictions must take this into account. The easiest way of comparing GHGs among jurisdictions is on a per person basis. Table 47 compares Thurston County per person GHG emissions for 2010 with those of Washington State as a whole, other western states (Oregon and California), the U.S., King County, Washington, and Eugene, Oregon.

Table 47. Per Person GHG emission comparisons

Jurisdiction	Per Person GHG (MTCDE)	Data source
Thurston County	11.0	This study.
Washington	14.1	Washington Department of Ecology, Washington State Greenhouse Gas Emissions Inventory, 1990-2010.
Oregon	10	US-EPA CO2 Emissions from Fossil Fuel Combustion.
California	10	US-EPA CO2 Emissions from Fossil Fuel Combustion.
United States	22	US-EPA CO2 Emissions from Fossil Fuel Combustion.
Eugene, OR	8.6	City of Eugene Community Greenhouse Gas Emissions Inventory (2007)
King County, WA	8.6	Erickson, P. & Chandler, C. (2012). Greenhouse gas tracking framework for King County: 2010 update.

Since the GHG emission figures for Washington, Oregon, California, and the Unites States do not include sources other than fossil fuel combustion (for example, solid waste), slight adjustments may be necessary to bring them into line with the calculations included in this study.

We recommend that, as part of the goal setting and climate action planning process, GHG emission data on additional communities comparable to the communities in Thurston County should be further investigated.

Other communities within the Pacific Northwest have set GHG reduction goals. As listed in the ICLEI USA Annual Report for 2010, Table 48 presents a sample of GHG reduction goals for Northwest cities and counties.

Table 48: GHG Emission Reduction Goals for Northwest Cities

City	First GHG reduction target	Second GHG reduction target	Third GHG reduction target
Blaine County, ID	25% below 2007 levels by 2025	50% below 2007 levels by 2045	
Eugene, OR	50% reduction by 2030		
Portland, OR	10% below 1990 levels by 2010	40% below 1990 levels by 2030	80% below 1990 levels by 2050
Bellevue, WA	7% below 1990 levels by 2012		
Bellingham, WA	7% below 2000 levels by 2012	28% below 2000 levels by 2020	
Kirkland, WA	10% below 2005 levels by 2012	20% below 2005 levels by 2020	80% below 2005 levels by 2050
Olympia, WA	50% below 2005 levels by 2020	70% below 2005 levels by 2035	80% below 2005 levels by 2050
Seattle, WA	7% below 1990 levels by 2012	30% below 1990 levels by 2024	80% below 1990 levels by 2050
Skagit County, WA	10% below 2000 levels by 2015	20% below 2000 levels by 2020	80% below 2000 levels by 2050
Snohomish County, WA	20% below 2000 levels by 2020		
Spokane, WA	30% below 2005 levels by 2030		
Tacoma, WA	15% below 1990 levels by 2012	40% below 1990 levels by 2020	80% below 1990 levels by 2050
Whatcom County, WA	7% below 1990 levels by 2012		

Washington State Goals

The Washington Legislature has established GHG emission reduction goals for the state as a whole. Codified in RCW 70.235.020, those goals are:

- By 2020, reduce overall emissions of greenhouse gases in the state to 1990 levels;
- By 2035, reduce overall emissions of greenhouse gases in the state to twenty-five percent below 1990 levels;
- By 2050, the state will do its part to reach global climate stabilization levels by reducing overall emissions to fifty percent below 1990 levels, or seventy percent below the state's expected emissions that year.

Per person emissions can also be useful in understanding the implications of various targets for emission reductions. For example, Table 49 uses the RCW targets identified above, along with population projections for Thurston County provided by TRPC, to estimate per person emissions and emission reductions required to meet those targets. Washington State GHG emissions are taken from the Department of Ecology's Washington State Greenhouse Gas Emissions Inventory, 1990-2010.

If these estimates are correct, there has already been a significant reduction in per person GHG emissions (5.43 MTCDE) between 1990 and 2010. By comparison, the reductions required per person to meet 2020 and 2035 targets are modest (2.04 and 3.60 respectively).

We recommend that these estimates and the assumptions they are based on be further examined and refined as part of the goal setting process.

Table 49: Washington and Thurston County emissions for Washington RCW targets

	1990	**2010**	**2020**	**2035**
Statewide population	4,866,692	6,724,540	7,414,437	8,494,122
Statewide GHG MTCDE	88,400,000	96,100,000	88,400,000	66,300,000
Statewide average GHG tons / person	18.16	14.29	11.92	7.81
Thurston Co Population	161,238	252,264	295,900	370,600
Thurston Co Average GHG MTCDE / person	15.76	10.95	8.59	5.14
Thurston Co GHG MTCDE	2,540,511	2,761,800	2,540,511	1,905,383
Per person emissions differences from prev period:		-4.81	-2.36	-3.44

Data sources and calculations for Table 49 are as follows:

- Washington State GHG emissions figure is taken from Department of Ecology, Washington State Greenhouse Gas Emissions Inventory, 1990-2010, December 2012.
- Washington state population figure for 1990 is taken from US Census Bureau, Population Change and Distribution, April 2001. State population for 2010 is taken from US Census Bureau, 2010 Demographic Profile. State population projections for 2020 and 2035 are taken from the Washington Office of Financial Management, November 2012 Population Forecast, http://www.ofm.wa.gov/pop/stfc/stfc2012/stfc_2012.pdf
- Thurston County GHG emissions for 1990 were estimated by multiplying statewide emissions by the ratio of 2010 Thurston County emissions to 2010 statewide emissions. That is, Thurston County's portion of statewide GHG emissions was assumed to the same in 1990 and in 2010.
- Thurston County population figures were provided by the Thurston Regional Planning Council.

IPCC Assessment

The Intergovernmental Panel on Climate Change (IPCC) is the primary scientific body established internationally to monitor changes in greenhouse gas accumulations, emissions, and their effects on global climate. The IPCC has assessed the level at which greenhouse gases should be stabilized in the atmosphere to prevent a crisis to human civilization, and the global reductions required in GHG emissions in order to achieve that level. Their assessments should also be considered in setting GHG reduction goals for Thurston County.

The IPCC assessments were summarized in a 2008 study by Dr. Joseph Romm, former Acting Assistant Secretary of the U.S. Department of Energy, author and climate expert. (See "The United States Needs a Tougher Greenhouse Gas Emissions Reduction Target for 2020," Center for American Progress.) IPCC assessments suggest GHG reduction targets for developed countries of 25% to 40% below 1990 levels by 2020, and 80% to 95% below 1990 levels by 2050. Table 50 applies the low end of the range for these targets, to Washington State and Thurston County GHG emissions. Since OFM and TRPC population projections do not include figures for 2050, average per person emissions and differences from the previous period could not be calculated for that year.

Table 50: Washington and Thurston County emissions for IPCC Targets

	1990	**2010**	**2020**	**2050**
Statewide population	4,866,692	6,724,540	7,414,437	??
Statewide GHG MTCDE	88,400,000	96,100,000	66,300,000	17,680,000
Statewide average GHG tons / person	18.16	14.29	8.94	??
Thurston Co Population	161,238	252,264	295,900	??
Thurston Co GHG MTCDE	2,540,511	2,761,800	1,905,383	508,102
Thurston Co Average GHG MTCDE / person	15.76	10.95	6.44	??
Per person emissions differences from prev period		-4.81	-4.51	
Per person percentage reductions		-31%	-41%	

Designing Strategies and Programs

Strategies for reducing Thurston County's GHG emissions can be defined based on an analysis of the numbers contained in this inventory. Since the largest emissions are associated with energy usage in the built environment (both residential and commercial) and transportation, it follows that strategies and programs should focus first on those segments.

We recommend placing these emission numbers in context of other trends and dynamics within Thurston County communities. This can be done by posing and researching follow up questions about the county's GHG emissions. Some sample questions are listed in Table 51.

Table 51: Sample questions for exploring community context of GHG emissions

1. What is the ratio of passenger car VMT attributable to commute and non-commute trips?
2. What drives the difference in per-capita GHG emissions between rural (south county) and urban (north county) communities?
3. What economic incentives and disincentives have greatest influence on GHG emissions related to specific activities (e.g., transportation, built environment energy usage, solid waste disposal)?
4. What needs are residents addressing when they drive (e.g., shopping, entertainment, socializing, working)? How might some of these needs be met in other ways, to reduce emissions?
5. What industries and companies are responsible for the majority of heavy duty freight traffic in Thurston County? What efficiencies or transportation alternatives might be explored to help them reduce their emissions while meeting their transportation needs?

To take one example, Question 2 in Table 51 asks, "What drives the difference in per-capita GHG emissions between rural (south county) and urban (north county) communities?" Another number that varies by city size is the amount of emissions due to commercial building energy usage. This might suggest that a useful strategy for reducing emissions in north county communities is reducing energy usage in commercial buildings. This theory deserve further exploration, both statistically and by talking with knowledgeable commercial property owners, to determine whether this strategy is likely to produce hoped for results.

We suggest that strategies and programs be defined for each of the major segments and activities that produce the most significant GHG emissions. These segments include:

- Residential built environment
- Commercial built environment

- Passenger vehicle transportation
- Public transportation (for example., service provided by Intercity Transit)
- Commercial transportation
- Wastewater
- Solid waste
- Energy generation and delivery (for example, solar, smart grid)

In addition, in order to ensure broad public engagement in implementing strategies in the above areas, as well as solid and consistent financial support, strategies and programs will be needed in the following areas:

- Public engagement
- Program finance

Following this approach to defining strategies, we recommend that a working group for each segment be commissioned to help define strategies, and to lead and coordinate GHG reduction projects and activities for that segment. Following this approach, it will be critical that there be significant coordination among these working groups. Therefore, we recommend formation of a steering committee composed of representatives of local jurisdictions and stakeholder groups to achieve this coordination. In addition, we recommend staffing the coordination effort adequately, to help track the progress in each segment, handle logistics and meeting management, and to ensure those working on strategies and programs receive needed support and guidance.

Monitoring Results

The effectiveness of adopted strategies and programs must be checked frequently against actual GHG emissions. This will allow Thurston County leaders and residences to know whether their efforts to reduce emissions are actually making a difference, and to adopt new strategies if they are not. The time frames in which results must be achieved are relatively short; 2013 to 2020, for example, is only seven years. If there were a delay of five years between reports, there would not be sufficient time to make adjustments and reach the selected target.

For this reason, we recommend that a community-based GHG inventory be prepared for Thurston County annually. As these inventories are completed, refinements and improvements to the methodology will likely be identified. As improvements in methodology and analysis are adopted, it will be important to document these changes and to adjust results for previous inventories, as needed, to ensure comparable numbers from one year to the next.

We recommend assigning local jurisdiction staff (including county, city and TRPC staff) to complete specific tasks in this annual effort. In addition, we recommend defining and funding new staff time to coordinate this annual GHG inventory, either within one of the local government organizations or in a separate organization.

Recommended Next Steps

Based on activities described in the previous section, we recommend the following steps be taken over the next six months:

1. Present this report to Thurston Regional Planning Commission, the Sustainable Thurston Task Force, and individual city councils and tribal councils. Request necessary funding to define strategies, and coordinate actions among jurisdictions.
2. Define climate action targets and recommended strategies which include all communities within the county boundaries. This should be completed by the end of calendar year 2013, and cover:
   - GHG reduction goals and targets;
   - strategies, programs and projects for reaching the targets;
   - mechanisms for broad participation (including but not limited to work groups and a steering committee);
   - assignment of individual targets, strategies and projects to owners (e.g., chairs of work groups);
   - public engagement
   - staffing; and
   - funding.
3. Establish work groups and other mechanisms for completing strategies and projects defined above.
4. Complete the GHG Inventory for 2011.

Appendices

Glossary

A comprehensive glossary of climate change terms can be found on the US Environmental Protection Agency's web site, at the following address:

http://www.epa.gov/climatechange/glossary.html

Emission Calculation Details

Emission sources and activities associated with the built environment include the consumption of electricity, electricity transmission and distribution losses, onsite combustion of fuel, and upstream emissions from electricity and fuel usage. For each jurisdiction, aggregate values for the consumption of electricity in residential, commercial, industrial, and street lighting units were used to calculate emissions associated with the generation of the electrical energy consumed (Figure 11) as well as transmission and distribution losses (Figure 12) and upstream emissions resulting from the use of electricity (Figure 13). Aggregate values for the consumption of fuel in residential, commercial, and industrial units were used to calculate associated emissions (Figure 14) and upstream emissions resulting from the use of fuel (Figure 15).

Equation BE.2.2 Calculating Electricity GHG Emissions Using Separate CO_2, N_2O, and CH_4 Emission Factors

Annual CO_2e emissions (metric tons/year) =

$$\frac{electricity}{2204.6} \times \begin{pmatrix} CO_2 \ emission \ factor \\ +21 \times CH_4 \ emission \ factor \\ +310 \times N_2O \ emission \ factor \end{pmatrix}$$

Where:

- electricity is the community's annual electricity use in MWh from Step 1,
- the CO_2 emission factor is the individual CO_2 emission factor from Step 2 (lb/MWh),
- the CH_4 emission factor is from Step 2 (lb/MWh),
- the N_2O emission factor is from Step 2 (lb/MWh),
- Use the CH_4 global warming potential[11] (GWP) to convert from pounds of CH_4 to CO_2e
- Use the N_2O global warming potential[12] (GWP) to convert from pounds of N_2O to CO_2e, and
- 2204.6 is the conversion factor to convert from pounds to metric tons.

Figure 11: Method for estimating individual GHG emissions from the use of electricity. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation BE.4.1.1 Calculating Electricity GHG Emissions Using a CO_2e Emission Factor

Annual CO_2e emissions (metric tons/year) =

$$\frac{Community\ electricity\ use \times grid\ loss\ factor \times CO_2\ e\ emission\ factor}{2204.6}$$

Where:

- Electricity is the community's annual electricity use in MWh from Step 1,
- the CO_2e emission factor is the combined carbon dioxide *equivalents* emission factor from Step 2 in lbs/MWh,
- the grid loss factor is from Step 3, and
- 2204.6 is the conversion factor to convert from pounds to metric tons.

Figure 12: Method for estimating GHG emissions resulting from transmission and distribution losses. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation BE.5.2.A **- Upstream emissions associated with electricity used within a community.**		
Total upstream emissions= (Total Electricity Use x Regional Upstream Emissions Factor Conversion Factor) Where: Description		
Annual CO_2e	= Total annual CO_2e emitted by upstream activities ($mtCO_2e$)	User Input
Total Electricity Use	= Total annual electricity used in a community including transmission and distribution losses	User Input
EF_{region}	= Regionally appropriate upstream emissions factor from Table B.18	User Input
Conversion Factor	= Conversion from kg to metric ton (mt/kg)	10^{-3}

Figure 13: Method for estimating upstream GHG emissions associated with electricity used within a community. Retrieved from “U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions,” Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation BE.1.1.1	Calculating CO_2 Emissions From Stationary Combustion (gallons)
Fuel A CO_2 Emissions (metric tons) = Fuel Used (gallons) × Emission Factor (kg CO_2/gallon) ÷ 1,000 (kg/metric ton)	
Fuel B CO_2 Emissions (metric tons) = Fuel Used (gallons) × Emission Factor (kg CO_2/gallon) ÷ 1,000 (kg/metric ton)	
Total CO_2 Emissions (metric tons) = CO_2 from Fuel A (metric tons) + CO_2 from Fuel B (metric tons)	
Note that Equation BE.1.1.1 expresses fuel use in gallons. If fuel use is expressed in different units (such as short tons, cubic feet, MMBtu, etc.), replace "gallons" in the equation with the appropriate unit of measure. Be sure that your units of measure for fuel use are the same as those in your emission factor.	

Equation BE.1.1.2	Calculating CH_4 Emissions From Stationary Combustion (MMBtu)
Fuel/Sector A CH_4 Emissions (metric tons) = Fuel Use (MMBtu) × Emission Factor (kg CH_4/MMBtu) ÷ 1,000 (kg/metric ton)	
Fuel/Sector B CH_4 Emissions (metric tons) = Fuel Use (MMBtu) × Emission Factor (kg CH_4/MMBtu) ÷ 1,000 (kg/metric ton)	
Total CH_4 Emissions (metric tons) = CH_4 from Type A (metric tons) + CH_4 from Type B (metric tons)	

Equation BE.1.1.4	Calculating N_2O Emissions From Stationary Combustion (MMBtu)
Fuel/Sector A N_2O Emissions (metric tons) = Fuel Use (MMBtu) × Emission Factor (kg N_2O/MMBtu) ÷ 1,000 (kg/metric ton)	
Fuel/Sector B N_2O Emissions (metric tons) = Fuel Use (MMBtu) × Emission Factor (kg N_2O/MMBtu) ÷ 1,000 (kg/metric ton)	
Total N_2O Emissions (metric tons) = N_2O from Type A (metric tons)+ N_2O from Type B (metric tons)	

Figure 14: Method for estimating emissions from on-site combustion of fuels in residential, commercial, and industrial units. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

***Equation BE.5.1.1* Upstream emissions associated with stationary fuel use within a community. Note: this is for primary fuels only and also applies to primary fuels combusted outside of the community for generating electricity used by the community.**		
Annual CO_2e *emissions =Σ(Total Fuel Use$_{Fuel\ Type}$ x Conversion Factor x Upstream EF) x 10^{-3}* Where:		
Description		Value
Annual CO_2e	= Total annual CO_2e emitted by upstream activities ($mtCO_2e$)	Result
Total Fuel Use$_{Fuel\ Type}$	= Total annual fuel of each type used in a community and sector	User Input
Conversion Factor	= Conversion factor to obtain the same units of fuel used in Table B.13	User Input
Upstream EF	= Fuel specific upstream emissions factor from Table B.13	User Input
10^{-3}	= Conversion from kg to metric ton (mt/kg)	10^{-3}

Figure 15: Method for estimating upstream emissions associated with on-site fuel use in residential, commercial, and industrial units. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Emissions activities and sources associated with on-road transportation and other mobile units include the use of fuel in on-road passenger and freight vehicles, as well as the use of fuel in public transit vehicles. For each jurisdiction, on-road passenger and freight vehicle emissions were calculated by using the formula:

$$\sum\left(\frac{VMT\ \times\ \%_{vehicle\ type}}{Average\ MPG_{vehicle\ type}} \times\ Emission\ Factor_{fuel\ type}\right)$$

Emissions from public transit vehicles were obtained from InterCity Transit's 2010 greenhouse gas emissions inventory.

Emission sources and activities associated with the generation and disposal of solid waste include methane emissions from community-generated waste sent to landfills (Figure 16), process emissions associated with landfilling waste (Figure 17), and rail transportation emissions (Figure 18). In order to estimate emissions for each jurisdiction within Thurston County, each emission source was multiplied by the percentage of total Thurston County population for that jurisdiction.

Equation SW.4.1 Methane Emissions

$$CH_4\ Emissions\ = GWP_{CH4} * (1-\ CE) * (1-OX) * M * \sum_i P_i\ * EF_i$$

Where:

Term	Description	Value
CH_4 emissions	= Community generated waste emissions from waste M ($mtCO_2e$)	Result
GWP_{CH4}	= CH_4 global warming potential	
M	= Total mass of waste entering landfill (wet short ton)	User Input
P_i	= Mass fraction of waste component i	User Input
EF_i	= Emission factor for material i ($mtCH_4$/wet short ton)	Table SW.5
CE	= Default LFG Collection Efficiency	No Collection, 0 Collection, 0.75
OX	= Oxidation rate	0.10

Source: As developed by ICLEI staff and Solid Waste Technical Advisory Committee. Emissions factors from U.S. EPA Municipal Solid Waste Publication (2008) available at http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2008data.pdf

Figure 16: Method for estimating methane emissions from community-generated waste sent to landfills. Retrieved from “U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions,” Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation SW.5 Process Emissions			
$PE_{LF} = M*EFP$			
Where:			
Term	Description	Value (Diesel)	Value (CNG)
PE_{LF}	= Total landfill process emissions ($mtCO_2e$)	Result	Result
M	= Total mass of solid waste that enters the landfill in the inventory year (wet short ton)	User Input	User Input
EFP	= Emissions factor for landfill process emissions (mtCO2e/wet short ton)	0.0164	0.011
Source: U.S. EPA, Waste Reduction Model (WARM), Version 12 and Model Documentation			

Figure 17: Method for estimating process emissions from community-generated waste sent to landfills. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation SW.6 Collection and Transportation Emissions			
$CE = M*EFC$			
$TE = M*MT*EFT$			
Where:			
Term	Description	Value (Diesel)	Value (CNG)
CE	= Total collection emissions ($mtCO_2e$)	Result	Result
TE	= Total transportation emissions ($mtCO_2e$)	Result	Result
M	= Total mass of solid waste collected and transported in the inventory year (wet short ton)	User Input	User Input
MT	= Miles traveled to disposal site	User Input	User Input
EFC	= Emissions factor for collection emissions ($mtCO_2e$/ wet short ton)	0.020	0.014
EFT	= Emissions factor for transport emissions ($mtCO_2e$/ wet short ton/mile)	0.00014	0.00010

Figure 18: Method for estimating rail transportation emissions from community-generated waste sent to landfills. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Emissions sources and activities associated with domesticated animal production include methane emissions from enteric fermentation. In this inventory, only emissions from enteric fermentation are reported as the availability of data related to manure management practices in Thurston County is not readily available. Beef cows, dairy cows, swine, and sheep populations were included in methane emissions estimates resulting from enteric fermentation (Figure 19). Emissions from livestock production were allocated to unincorporated Thurston County.

Equation A.1
Methane Emissions due to Enteric Fermentation from Domesticated Animal Production

CH_4 Emissions =Σ (Animal Population x EF x (1/1000) x GWP)$_{animal\ type}$

Where:

		Description	Value
CH_4 Emissions	=	Methane emissions due to enteric fermentation ($MTCO_2e$)	Product of equation A.1
Animal Population	=	Average annual animal population (head)	User input (or as calculated in A.0)
EF	=	Emissions Factor (kg CH_4/head/year)	Varies by animal type, see tables A.1.1 and A.1.2
1/1000	=	Conversion of kg CH_4 to metric tons	1/1000
GWP_{CH4}	=	Global Warming Potential; conversion from metric tons of methane into metric tons of CO_2 equivalents (CO_2e)	GWP[1]

Source: US Environmental Protection Agency's *2011 Inventory of US Greenhouse Gas Emissions and Sinks* Annex 3 Section 3.9 Methodology for Estimating CH_4 Emissions from Enteric Fermentation

Figure 19: Method for estimating methane emissions from enteric fermentation. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Emission sources and activities associated with wastewater treatment at the LOTT Clean Water Alliance Budd Inlet Treatment Plant include digester operation (Figure 20, Figure 21, Figure 22), and biological (Figure 23) wastewater treatment processes. In order to estimate emissions for each of the jurisdictions served by LOTT (Lacey, Olympia, Tumwater), each emission source was multiplied by the percentage of the total population served by LOTT. The portions of unincorporated Thurston County served by LOTT were not included in the inventory for unincorporated Thurston County.

***Equation WW.1.a* Emissions from Devices Designed to Combust Digester Gas, with CH_4 Content Known**

Annual CH_4 emissions =
(Digester Gas $\times fCH_4 \times BTU_{CH4} \times 10^{-6} \times EF_{CH4} \times 365.25 \times 10^{-3}$) $\times$ GWP

Where:

Description		Value
Annual CH_4 emissions	= Total annual CH_4 emitted by incomplete combustion ($mtCO_2e$)	Result
Digester gas	= Standard cubic feet of digester gas produced per day (std ft^3/day)	User Input
fCH_4	= Fraction of CH_4 in gas	User Input
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028 (nation-wide average)
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{CH4}	= CH_4 emission factor (kg CH_4/MMBTU)	3.2×10^{-3} kg CH_4 per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{CH_4}	= Global Warming Potential; conversion from mt of CH_4 into mt of CO_2 equivalents	GWP[5]

***Equation WW.1.a* Emissions from Devices Designed to Combust Digester Gas, with CH_4 Content Known**

Source: In 40 CFR Part 98, Mandatory Reporting of Greenhouse Gases; Final Rule, Table C-2, page 79154 of the Federal Register / Vol. 75, No. 242 / Friday, December 17, 2010 / Rules and Regulations, is referenced an emission factor for digester gas combustion: 3.2×10^{-3} kg CH_4 per million BTU. See: http://edocket.access.gpo.gov/2010/pdf/2010-30286.pdf

Figure 20: Method for estimating methane emissions from devices designed to combust digester gas. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Box WW.2.a	**Example Calculation of N_2O Emissions from the Combustion of Anaerobic Digester Gas when fraction of CH_4 is known**	
A wastewater facility generates 1,000,000 ft^3 per day of digester gas containing 65% CH_4. The BTU content of the digester gas is not available. Based on this scenario the N_2O emissions from the combustion of digester biogas can be calculated as follows		
Description		Value
N_2O emissions	= Total N_2O emitted by combustion ($mtCO_2e$)	Result
Digester gas	= Measured standard cubic feet of digester gas produced per day (std ft^3/ day)	1,000,000
fCH_4	= Fraction of CH_4 in biogas	0.65
BTU_{CH4}	= Default BTU content of CH_4, higher heating value (BTU/ft^3)	1028
10^{-6}	= Conversion from BTU to 1 MMBTU	10^{-6}
EF_{N2O}	= N_2O emission factor (kg N_2O/MMBTU)	6.3 X 10^{-4} kg N_2O per MMBTU
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion from kg to mt (mt/kg)	10^{-3}
GWP_{N_2O}	= Global Warming Potential; conversion from mt of N_2O into mt of CO_2 equivalents	GWP[9]
Sample Calculation: *Annual* N_2O *emissions* = $(1{,}000{,}000 \times 0.65 \times 1028 \times 10^{-6} \times (6.3 \times 10^{-4}) \times 365.25 \times 10^{-3}) \times 310$ = *47.7* $mtCO_2e$		

Figure 21: Method for estimating nitrous oxide emissions from the combustion of digester gas. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation WW.3 **CO_2 Emissions from Digester gas Combustion**		
Annual CO_2 *emissions* = *Digester gas* * BTU_{CO2} * EF_{CO2} * 365.25 * 10^{-3}		
Where:		
Description		Value
CO_2 emissions	= Total annual biogenic CO_2 emitted by combustion of biogas ($mtCO_2e$)	Result
Digester gas	= Standard cubic feet of digester gas produced per day (std ft^3/day)	User input
BTU_{CO2}	= BTU content of biogas (MMBTU/scf)	User input or 0.000841
EF_{CO2}	= Emission factor for CO_2 (kg CO_2/ MMBTU)	52.07
365.25	= Conversion factor (day/year)	365.25
10^{-3}	= Conversion factor kg to mt	10^{-3}
Source: Table G.2 of the Local Government Operations Protocol version 1.1 May, 2010		

Figure 22: Method for estimating carbon dioxide emissions from digester gas combustion. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.

Equation WW.9 **CO2 Emission from Methanol Use**		
*Annual CO_2 emissions = Methanol Load *F *(44.01/32.04) *GWP *365.25*		
Where:		
Description		Value
Annual CO_2 emissions	= Total annual CO_2 emitted ($mtCO_2e$)	Result
Methanol load	= Amount of neat chemical used per day (mt CH_3OH/day)	User Input
F	= Factor to be applied based on WWTP's sludge treatment type: • Raw Solids Disposal 80% • Anaerobic Digestion 90% • Solids Combustion 100%	0.80, 0.90, 1.0
44.01/32.04	= Molecular weight ratio of 44.01 (for CO_2) to 32.04 (for CH_3OH)	1.37
GWP	= Global Warming Potential for CO_2	1
365.25	= Conversion factor from days to year	365.25

Figure 23: Method for estimating carbon dioxide emissions from methanol usage in the biological treatment of wastewater. Retrieved from "U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions," Developed by ICLEI Local Governments for Sustainability – USA, 2012.