2014 Seattle Community Greenhouse Gas Emissions Inventory

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Note: It is difficult to compare the results of any community GHG inventory to those conducted in other places. Methods can vary between inventories and many of the differences between community inventories are due to factors that are beyond a community's control, such as differences in climate, geography, or the types of business and industries in the community rather than due to differences in energy efficiency, transportation choices, or other emission-reduction practices. For this reason, we encourage readers to use this inventory to track changes in Seattle's emissions over time rather than to make comparisons to other cities or regions.

Seattle
Office of Sustainability
& Environment

Dear Friends and Partners,

As our worldwide population grows, so do our urban populations. More people are choosing to live in cities than at any other time. While our urban growth can present challenges, it also presents tremendous opportunities. Cities like Seattle—with strong political leadership from our mayor and an engaged community that places a high value on sustainability—are in a great position to drive innovative and ambitious climate action.

Greenhouse gas (GHG) inventories are a key tool for measuring our progress against our climate goals. In Seattle, our goal is to reduce our emissions 58% by 2030 and ultimately become a carbon neutral city by 2050. This most recent inventory reports the major sources of GHG emissions in Seattle and how those emissions have changed since 1990. By tracking long- and short-term trends, we can better understand where progress has been made, how effective our initiatives have been, and where more work is needed.

I'm pleased to share that Seattle has reached "peak emissions"—our community GHG emissions have been on a downward trend since 2008. That is excellent news. It's especially impressive when you consider our population has grown significantly during that same time period.

However, the sobering reality is that while our progress is positive, we are not currently on pace to meet our 2030 climate goals. We know we must scale up the pace of our emissions reductions and we have already taken steps to make that happen.

Seattle has recently launched several initiatives in our transportation and energy sectors aimed at putting us on track towards meeting our climate goals. Those initiatives include:

- **Drive Clean Seattle**: A comprehensive strategy to transition our transportation sector, including passenger cars, trucks, transit and maritime transportation, from polluting fossil fuels to clean, carbon-neutral electricity.
- **Move Seattle**: A suite of investments in transit, pedestrian, and bicycle infrastructure and service that will continue to reduce the overall vehicle miles traveled in Seattle.
- **Building Energy Transparency:** Updated Seattle's existing energy benchmarking law to include public transparency of building energy performance to spur market demand for energy efficiency.
- **Building Tune-Ups**: Passed legislation phasing in a periodic tune-up requirement for large commercial buildings beginning in 2018. Tune-ups will optimize energy and water performance and encourage active management in Seattle's commercial buildings.
- **2015 Energy Code**: The proposed 2015 Energy Code (commercial) would increase the efficiency of new construction and substantial alternations of existing buildings, and includes a provision that would help drive use of efficient carbon neutral heat pumps instead of natural gas or inefficient electric resistance heating.

Clearly, there is much work to be done in order for us to make the deep cuts that are necessary in our emissions. But our community is up for it. The strategies above are an excellent start and with the continued support and partnership of our Seattle community, I am confident we will get there.

Jessica Finn Coven, Director
Office of Sustainability & Environment

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Introduction

The City of Seattle has been a leader in addressing climate change for many years. Seattle's Climate Action Plan[1] is the city's long-term climate protection vision that includes specific targets for future greenhouse gas (GHG) emissions and describes actions that the City can take to prepare for the likely impacts of climate change. The plan establishes the ambitious goal for Seattle to become carbon-neutral by 2050 and provides intermediate emissions targets for 2030[2].

By understanding the sources of emissions and long- and short-term trends, the City of Seattle and its residents are better able to take informed actions to reduce emissions. This GHG inventory contributes to that knowledge by reporting on the major sources and activities emitting GHGs and how those emissions have changed over time. This 2014 version of the inventory continues a series of similar inventories conducted for the years 2012, 2008, 2005, and 1990. By tracking the same categories of emissions over time, the City can see where progress has been made in reducing emissions and where more work is needed.

The emission reduction goal in Seattle's Climate Action Plan is set on an absolute basis: Seattle's emissions will decrease 58% by 2030 from a 2008 baseline and Seattle will be carbon neutral by 2050. Seattle is a rapidly-growing city that will continue to add new residents and jobs, which–absent the correct policy framework, could push Seattle's emissions higher. Therefore, it is necessary to consider emissions on a per resident basis as well in order to understand the effectiveness of the policies and programs designed to reduce emissions. This 2014 inventory shows that total emissions have decreased 6% since 2008 and per resident emissions have decreased 17%.

[1] Available online at http://www.seattle.gov/environment/climate-change/climate-action-plan

[2] Because the emissions reduction targets in the CAP are relative to Seattle's GHG emission in 2008, the City's GHG emissions in 2008 are also used as a baseline for comparison in this report.

Core Emissions Inventory

Overview

Seattle's Climate Action Plan focuses on categories of emissions over which local government policy has the greatest influence. The first of these categories is "road transportation", which includes cars and trucks, buses, and commercial freight trucks. The plan also focuses on "building energy", which is the energy used to heat and cool homes and businesses as well as the energy to power the devices and equipment (like water heaters and computers) inside those buildings. The last category that the plan addresses is waste management, which includes the GHG emissions that result from landfilling Seattle's waste. These emissions sources are those the city can most directly and significantly impact and are referred to as "core" emissions.[3] Emissions from other sources, such as industrial operations in the city or air travel to and from airports in or near Seattle, are explored further in a later section of this report, in what is characterized as an "expanded" view of emissions.

Key Findings

Seattle's 2014 GHG inventory shows some encouraging signs and also demonstrates that there is more work remaining to meet Seattle's climate goals (Table 1).[4] Changes since 2008 include:

- Total GHGs from Seattle's core emissions sources (road transportation, building energy, and waste) declined 6%, while population grew by 13% (Figure 1)
- Per resident emissions declined 17%
- Total road transportation emissions declined 2% and per resident emissions declined 12%, due to a combination of more fuel-efficient vehicles and fewer miles travelled per resident.
- Total Building energy emissions declined 13% and per resident emissions declined 23% as a result of lower building energy use, particularly for residential buildings due to energy efficiency, more multi-family living, and especially due to warmer weather that reduced heating needs. Commercial energy use has also begun to decline.

[3] The inventory methods used here are guided by ICLEI-USA's U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions. The emissions sources covered in the main body of this inventory correspond to ICLEI's "local government significant influence" framework. The "expanded view" of the inventory included as an appendix to this inventory corresponds to ICLEI's "community-wide activities" framework.

[4] The numbers are for Seattle's emissions after accounting for offsets purchased by Seattle City Light (for the small portion of fossil fuel-based electricity in their portfolio), All of the quantities reported in this inventory are reported in metric tons. These emissions have been calculated using the methodology described in the section "Detailed Results and Methodology by Sector." Methodological improvements and updates to data can result in slight discrepancies between the figures in this version of the inventory and those from prior years.

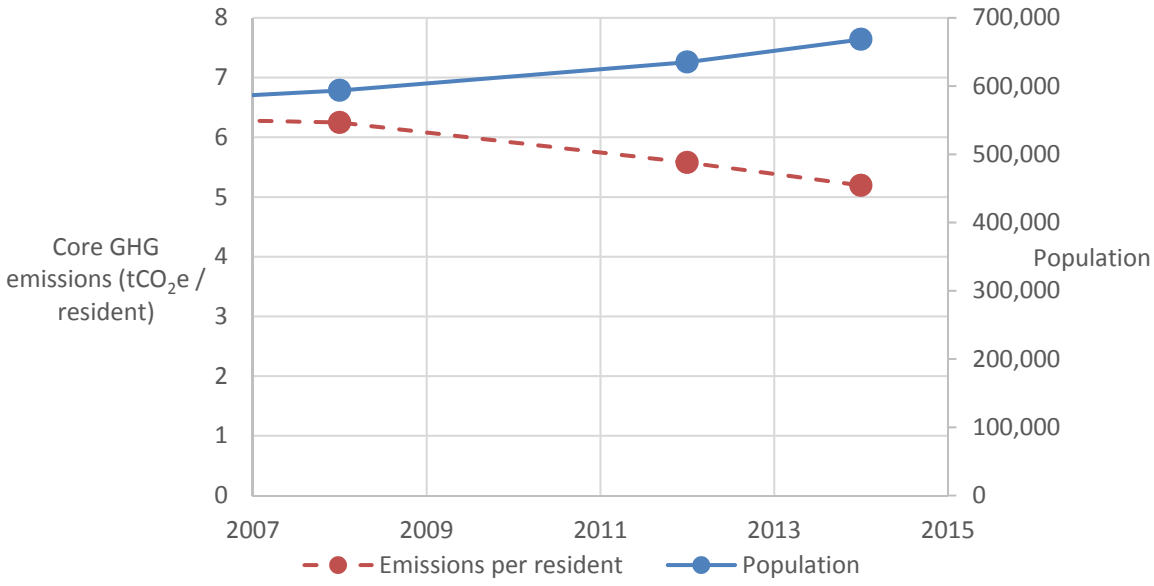
Table 1. Seattle greenhouse gas emissions by sector (metric tons CO_2e)

	2008	2012	2014	% Change Since 2008	% Change Since 2012
TRANSPORTATION	**2,339,000**	**2,306,000**	**2,283,000**	**-2%**	**-1%**
Road: Passenger	**1,777,000**	**1,746,000**	**1,720,000**	**-3%**	**-1%**
Cars & Light Duty Tru	*1,714,000*	*1,677,000*	*1,653,000*	*-4%*	*-1%*
Buses	*60,000*	*67,000*	*65,000*	*9%*	*-2%*
Vanpool	*2,000*	*2,000*	*2,000*	*-5%*	*-1%*
Road: Freight	**563,000**	**560,000**	**563,000**	**0%**	**1%**
Trucks	*563,000*	*560,000*	*563,000*	*0%*	*1%*
BUILDINGS	**1,266,000**	**1,149,000**	**1,100,000**	**0 -13%**	**-4%**
Residential	**585,000**	**522,000**	**486,000**	**-17%**	**-7%**
Electricity	*45,000*	*28,000*	*22,000*	*-51%*	*-23%*
Natural Gas	*432,000*	*420,000*	*399,000*	*-7%*	*-5%*
Oil	*109,000*	*73,000*	*65,000*	*-40%*	*-11%*
Commercial	**681,000**	**627,000**	**614,000**	**-10%**	**-2%**
Electricity	*82,000*	*53,000*	*42,000*	*-49%*	*-22%*
Natural Gas	*413,000*	*416,000*	*431,000*	*4%*	*4%*
Oil	*8,000*	*2,000*	*2,000*	*-73%*	*40%*
Steam	*177,000*	*156,000*	*138,000*	*-22%*	*-11%*
WASTE	**103,000**	**87,000**	**88,000**	**-14%**	**1%**
Waste Management	*103,000*	*87,000*	*88,000*	*-14%*	*1%*
TOTAL EMISSIONS	**3,708,000**	**3,542,000**	**3,471,000**	**-6%**	**-2%**
Per resident	**6.2**	**5.6**	**5.2**	**-17%**	**-7%**
GHG OFFSETS	**-127,000**	**-81,000**	**-64,000**		
SCL Offsets	**-127,000**	**-81,000**	**-64,000**		
TOTAL AFTER OFFSET	**3,581,000**	**3,461,000**	**3,407,000**	**-5%**	**-2%**
Per resident	**6.0**	**5.4**	**5.1**	**-16%**	**-6%**

Table 2. Seattle greenhouse gas emissions per resident by sector (metric tons CO_2e)

	2008	2012	2014	2008	2012
TRANSPORTATION	**3.9**	**3.6**	**3.4**	**-12%**	**-2%**
Road: Passenger	3.0	2.7	2.6	-14%	-6%
Road: Freight	0.9	0.9	0.8	-11%	-4%
BUILDINGS	**2.1**	**1.8**	**1.6**	**-23%**	**-9%**
Residential	1.0	0.8	0.7	-26%	-12%
Commercial	1.1	1.0	0.9	-20%	-7%
WASTE	**0.2**	**0.1**	**0.1**	**-23%**	**-3%**
Waste Management	0.2	0.1	0.1	-23%	-3%
TOTAL PER RESIDENT	**6.2**	**5.6**	**5.2**	**-17%**	**-7%**
GHG OFFSETS	**-0.2**	**-0.1**	**-0.1**		
SCL Offsets	-0.2	-0.1	-0.1		
TOTAL AFTER OFFSETS	**6.0**	**5.4**	**5.1**	**-16%**	**-6%**

Figure 1. Greenhouse gas emissions per resident have declined as population has increased



The relative contribution of the transportation, buildings, and waste sectors in 2014 is shown in**Error! Not a valid bookmark self-reference.**. Road transportation made up two thirds, 66%, of Seattle's emissions in 2014. Most of these (50% of total) were from passenger vehicles (cars, trucks, SUVs, and buses), with the remaining from freight trucks. Energy used to heat, cool, and power buildings accounted for about one third of emissions, with that total split fairly evenly between residential and commercial buildings. Waste management contributed 2% to total emissions. The relative contribution of these emissions categories has remained fairly constant since 1990, though the share attributed to buildings has declined from about 40% in 1990 and 2008 to about 33% in 2014 as building emissions have declined faster than those from transport.

Figure 2. 2014 Seattle greenhouse gas emissions by sector

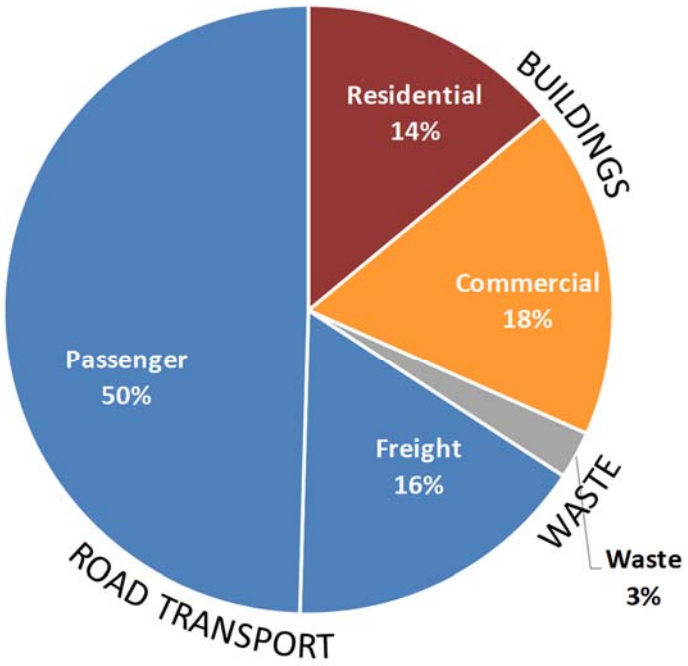
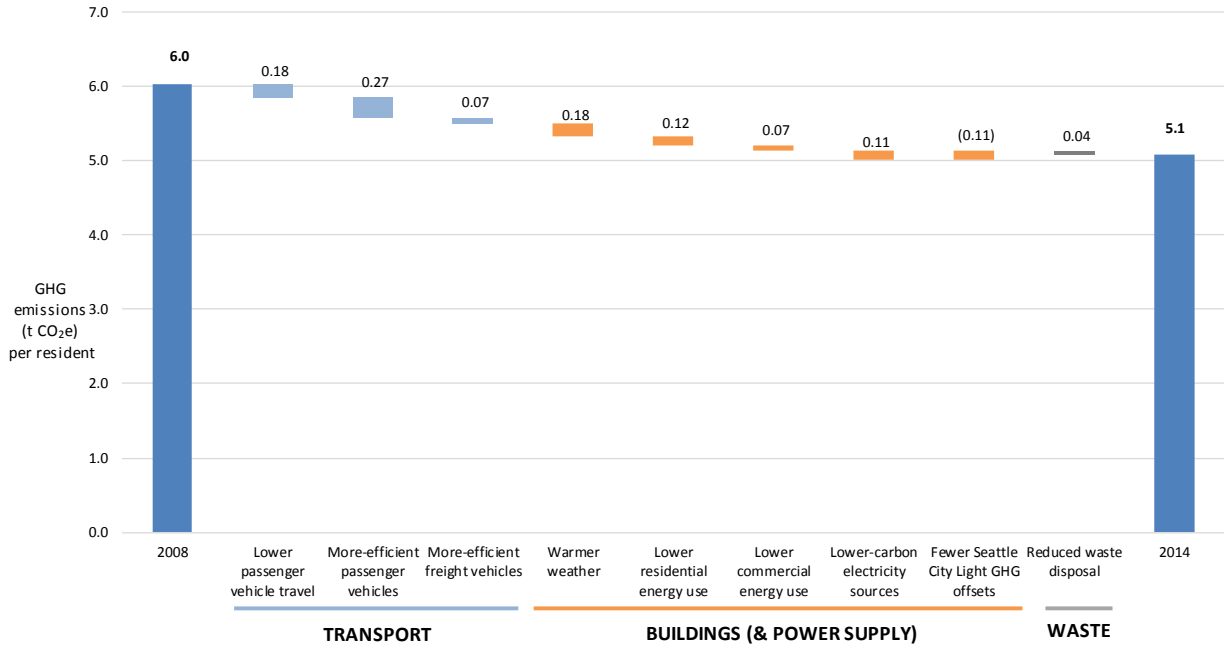


Figure 3 provides a summary of the changes in emissions per resident between 2008 and 2014. The smaller bars between 2008 and 2014 represent changes (mostly decreases[5]) in emissions that occurred between these years. More efficient passenger vehicles, lower passenger vehicle travel, and warmer

[5] Seattle City Light (SCL) secures carbon offsets equal to the greenhouse gas emissions resulting from all aspects of SCL's operations, including those created by the generation of electricity the utility buys, employees' travel, and the trucks and other equipment used in its operations. Since the utility's GHG emissions declined between 2008, so too did its purchase of offsets. The two effects have equal and opposite signs in Figure 3.

weather (reducing heating demand in buildings) represented the largest decreases in emissions per resident between 2008 and 2014.

Figure 3. Multiple factors explain the change in emissions per resident between 2008 and 2014



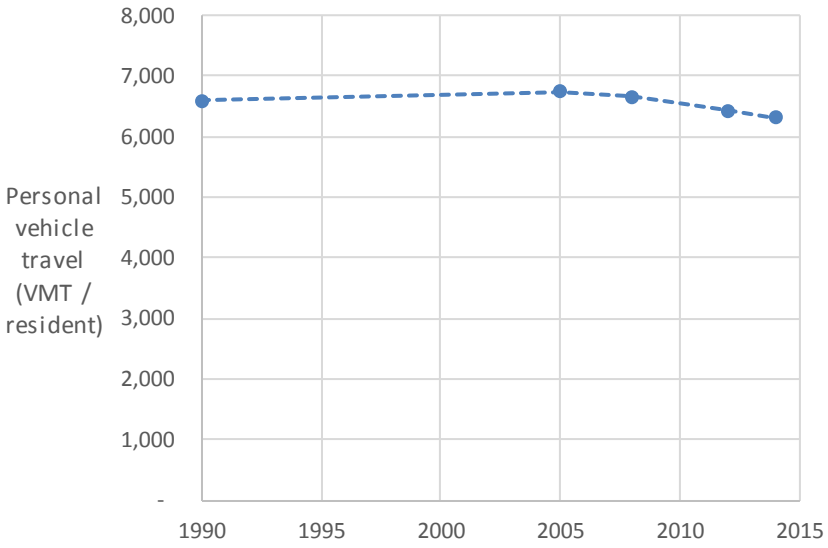
Road Transport

Road transportation has been the largest category of emissions since Seattle started tracking emissions in 1990. Total emissions in this sector increased up through 2008; however, they have been decreasing since 2008. Advances in vehicle technology have increased the average fuel economy for cars in Seattle from about 21 miles per gallon of fuel in 2008 to about 23 miles per gallon in 2014. Likewise, the average fuel economy of passenger trucks (including SUVs) in Seattle has increased from about 17 to about 19 miles per gallon between 2008 and 2014. Vehicle travel per resident has declined since 2008, after peaking in 2005 (Figure 4). The combination of more fuel-efficient vehicles and fewer miles traveled per resident have led both to decreased *absolute* emissions from road transportation (down 2% since 2008) and decreased emissions *per resident* (down 12% during this period).

Passenger transportation emissions declined an average of 0.5% per year since 2008. To achieve the 2030 goal of reducing passenger transportation emissions 82%, Seattle would need to reduce emissions from passenger vehicles by an average of 7.5% each year from 2008 onwards, indicating that the rate of reduction will need to increase above 7.5% per year if Seattle is to achieve its goal.

In order to accelerate reduction in the transportation sector the City launched the Drive Clean Seattle initiative, as comprehensive strategy to transition our transportation sector from polluting fossil fuels to clean, carbon-neutral electricity. The strategy includes actions to spur this shift for passenger cars, trucks, transit and maritime transportation.

Figure 4. Seattle's passenger vehicle travel per resident over time
(origin-destination-pair basis)



Building Energy

Energy used by buildings and the equipment inside them is the other major source of Seattle's GHG emissions. Emissions related to building energy use have declined consistently between 1990 and 2014. Building energy use can create GHG emissions both directly, through the burning of fossil fuels such as oil or natural gas to generate heat, and indirectly, through the GHG emissions that result from generating the electricity used in buildings.

Between 2008 and 2014, building-related emissions declined as a result of lower building energy use, particularly for residential buildings (Figure 5), due to energy efficiency, more multi-family living, and especially due to warmer weather that reduced heating needs. Commercial energy use has also begun to decline (Figure 6).

Figure 5. Residential energy use per resident, Seattle
(excluding yard equipment)

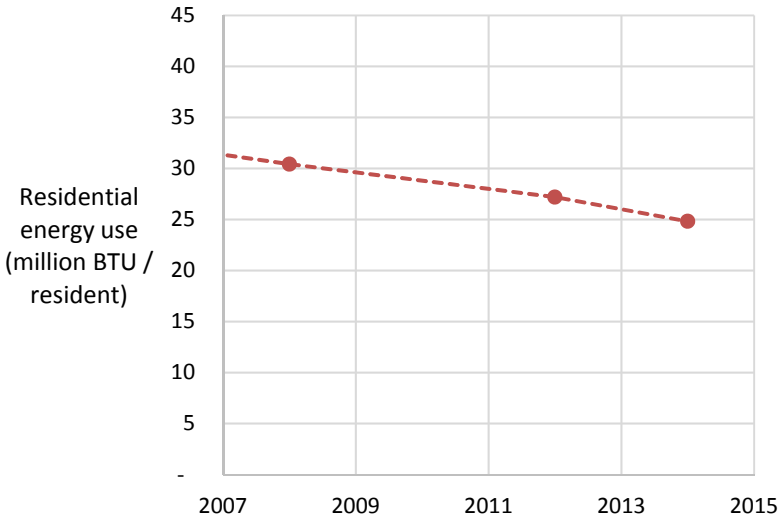
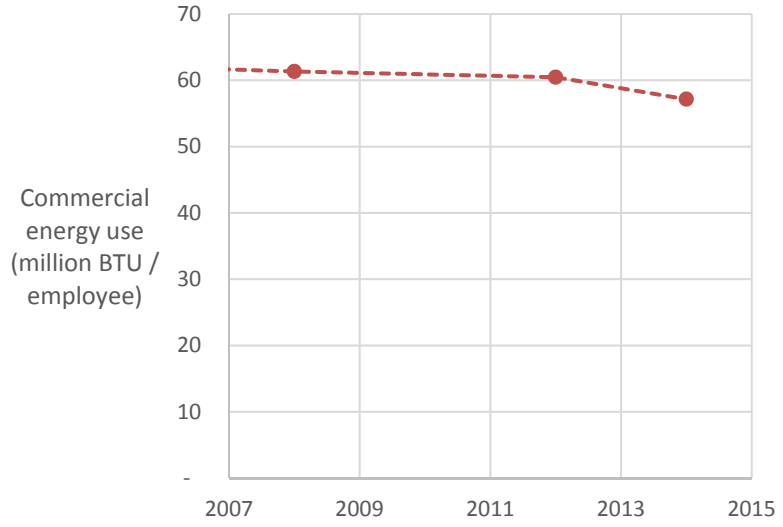


Figure 6. Commercial energy use per employee, Seattle
(excluding commercial equipment)



Seattle's 2030 goal is to reduce building energy emissions 39% from 2008 levels. On average, this implies a reduction of 2.2% per year. Between 2008 and 2014, building emissions proceeded on this pace (averaging a 2.3% reduction annually), though this slowed to an average decline of 2.1% per year between 2012 and 2014.

In order to keep building energy emissions on pace to meet the Seattle's climate goals, the City recently passed legislation (March 2016) that sets minimum expectations around efficient operations and includes public transparency of building energy performance to spur market demand for energy efficiency.

About 90% of the electricity that Seattle City Light provides to consumers in Seattle comes from low-carbon hydroelectric dams. Seattle City Light (SCL) purchases carbon offsets equal to the greenhouse gas emissions resulting from all other aspects of SCL's operations, including those created by fossil power the utility buys, employees' travel, and the trucks and other equipment used in its operations. These offsets are included as emissions reductions at the bottom of Table 1 and **Error! Reference source not found.**.

Waste

Emissions from waste management remain a relatively small component of Seattle's GHG emissions. These emissions declined 14% between 2008 and 2014, primarily as a result of continued reductions in the annual amount of waste landfilled.

Expanded View of Seattle's GHG Emissions

In addition to the core emissions sources discussed in the previous section, there are other activities in Seattle (and by Seattle residents) that generate GHG emissions. For example, air travel by Seattle residents generates GHG emissions, as does Seattle industry use of fossil fuels. Although city policy may be less able to affect these emissions directly, they are still associated with the activities of Seattle's residents and businesses.

The following GHG emissions sources are included in this "expanded" view of Seattle GHG inventory in addition to those discussed in the previous section:

- Other transportation sources, including marine traffic (e.g., ferries), freight and passenger rail, and air traffic (e.g., at Seattle-Tacoma International Airport and King County International Airport, also known as Boeing Field);
- Industrial operations, including manufacturing (e.g., of cement, steel, and glass); other GHGs (besides CO_2) from industrial process, such as methane (CH_4) from natural gas infrastructure
- Other waste-related sources, including capped (and no longer active) landfills within city limits and wastewater processing

Seattle's total GHG emissions in this expanded view are shown in **Error! Reference source not found.**. Seattle's total emissions, after offsets, declined by 7% between 2008 and 2014. During that same time period per resident emissions declined 18% as population grew.

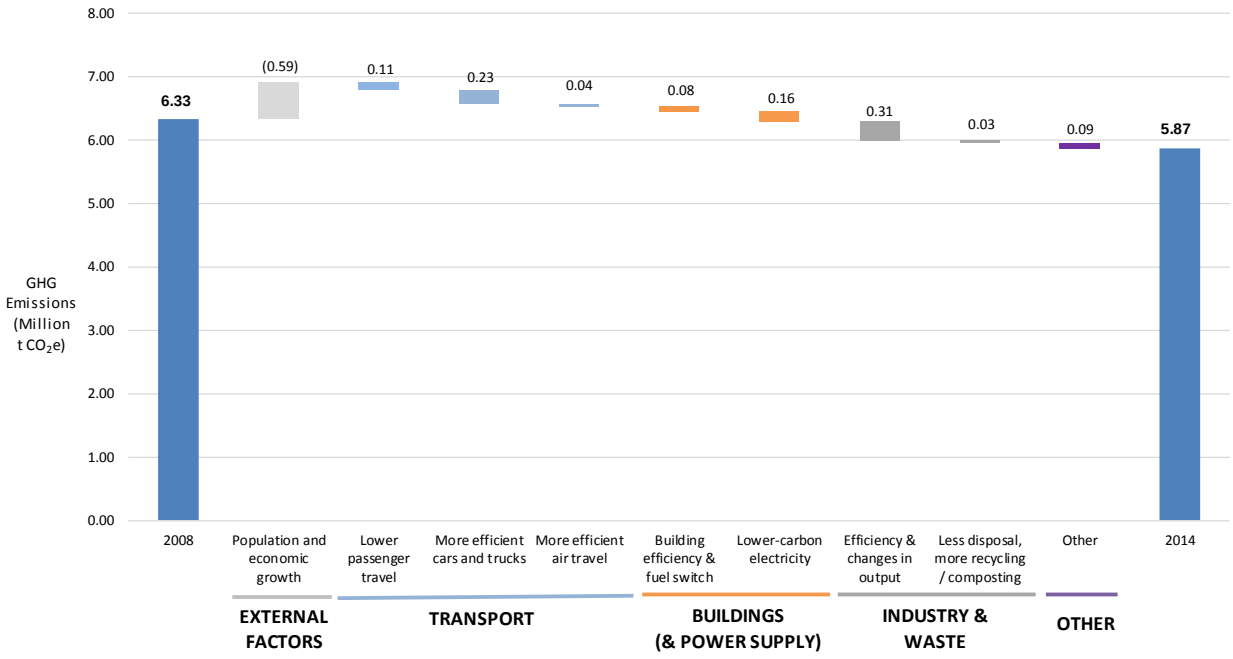
While total emissions remaining virtually flat, emissions have increased in some sectors and decreased in others. Emissions from marine and rail decreased by 23% between 2008 and 2014, primarily as a result of lower emissions from boats docked in port using shore power (also known as "hoteling") and less freight traffic handled at the Port of Seattle. Emissions from air travel increased somewhat (8%) between 2008 and 2014 as a result of increased air traffic at SeaTac Airport. Emissions from industrial processes declined by 24% between 2008 and 2014. Part of this reduction is due to decreased emissions from cement manufacture within the City, which declined by 30% between 2008 and 2014, mostly due to decreased production. However, these emissions have historically been highly variable and are sensitive to broader economic conditions outside of Seattle. Emissions from industrial energy use declined by 18% during this same period, largely as a result of decreased natural gas usage. Emissions of methane, a powerful greenhouse gas and the primary component of natural gas, from Puget Sound Energy's natural gas distribution network declined steadily from 1990 to 2014 as PSE continues to replace older, more leak-prone pipes and service lines.

Table 3. Expanded view of Seattle's community greenhouse gas emissions including additional sources (metric tons CO_2e)

	2008	2012	2014	% change since 2008	% change since 2012
TRANSPORTATION	**3,618,000**	**3,465,000**	**3,576,000**	**-1%**	**3%**
Road: Passenger	**1,777,000**	**1,746,000**	**1,720,000**	**-3%**	**-1%**
Cars & Light Duty Truck	*1,714,000*	*1,677,000*	*1,653,000*	*-4%*	*-1%*
Buses	*60,000*	*67,000*	*65,000*	*9%*	*-2%*
Vanpool	*2,000*	*2,000*	*2,000*	*-5%*	*-1%*
Road: Freight	**563,000**	**560,000**	**563,000**	**0%**	**1%**
Trucks	*563,000*	*560,000*	*563,000*	*0%*	*1%*
Marine & Rail	**290,000**	**243,000**	**222,000**	**-23%**	**-8%**
Hotelling	*74,000*	*46,000*	*38,000*	*-49%*	*-17%*
State Ferries	*35,000*	*41,000*	*40,000*	*14%*	*-2%*
Pleasure Craft	*31,000*	*31,000*	*25,000*	*-19%*	*-18%*
Other Boat Traffic	*64,000*	*64,000*	*67,000*	*4%*	*4%*
Rail - Freight	*79,000*	*53,000*	*43,000*	*-46%*	*-19%*
Rail - Passenger	*7,000*	*8,000*	*9,000*	*36%*	*13%*
Air	**989,000**	**917,000**	**1,071,000**	**8%**	**17%**
Sea-Tac Airport	*727,000*	*689,000*	*833,000*	*15%*	*21%*
King County Airport	*262,000*	*228,000*	*238,000*	*-9%*	*5%*
BUILDINGS	**1,423,000**	**1,316,000**	**1,274,000** 0	**-10%**	**-3%**
Residential	**602,000**	**540,000**	**504,000**	**-16%**	**-7%**
Electricity	*45,000*	*28,000*	*22,000*	*-51%*	*-23%*
Natural Gas	*432,000*	*420,000*	*399,000*	*-7%*	*-5%*
Oil	*109,000*	*73,000*	*65,000*	*-40%*	*-11%*
Yard Equipment	*17,000*	*18,000*	*18,000*	*3%*	*-3%*
Commercial	**820,000**	**776,000**	**770,000**	**-6%**	**-1%**
Electricity	*82,000*	*53,000*	*42,000*	*-49%*	*-22%*
Natural Gas	*413,000*	*416,000*	*431,000*	*4%*	*4%*
Oil	*8,000*	*2,000*	*2,000*	*-73%*	*40%*
Steam	*177,000*	*156,000*	*138,000*	*-22%*	*-11%*
Equipment	*140,000*	*149,000*	*156,000*	*12%*	*5%*
INDUSTRY	**1,323,000**	**852,000**	**1,001,000**	**-24%**	**18%**
Cement	**746,000**	**307,000**	**523,000**	**-30%**	**70%**
Fuel Combustion	*353,000*	*-*	*-*	*-*	*-*
Clinker Calcination	*393,000*	*-*	*-*	*-*	*-*
Other - Energy Use	**513,000**	**487,000**	**419,000**	**-18%**	**-14%**
Electricity	*17,000*	*10,000*	*8,000*	*-52%*	*-20%*
Natural Gas	*246,000*	*270,000*	*207,000*	*-16%*	*-24%*
Oil	*36,000*	*15,000*	*14,000*	*-61%*	*-8%*
Industrial Equipment	*214,000*	*191,000*	*190,000*	*-11%*	*0%*
Other - Process	**40,000**	**39,000**	**40,000**	**0%**	**2%**
Steel & Glass	*40,000*	*39,000*	*40,000*	*0%*	*2%*
Fugitive Gases	**24,000**	**19,000**	**19,000**	**-20%**	**0%**
SF6 from Switchgear	*2,000*	*1,000*	*3,000*	*50%*	*310%*
PSE Gas Distribution	*22,000*	*18,000*	*16,000*	*-26%*	*-11%*
WASTE	**105,000**	**89,000**	**91,000**	**-14%**	**2%**
Waste	**105,000**	**89,000**	**91,000**	**-14%**	**2%**
Waste Management	*103,000*	*87,000*	*88,000*	*-14%*	*1%*
Wastewater Treatment	*2,000*	*2,000*	*2,000*	*23%*	*23%*
TOTAL EMISSIONS	**6,469,000**	**5,723,000**	**5,942,000**	**-8%**	**4%**
Per resident	**10.9**	**9.0**	**9.4**	**-14%**	**4%**
GHG OFFSETS	**-144,000**	**-91,000**	**-72,000**		
SCL offsets	**-144,000**	**-91,000**	**-72,000**		
TOTAL AFTER OFFSETS	**6,325,000**	**5,631,000**	**5,870,000**	**-7%**	**4%**
Per resident	**10.7**	**8.9**	**8.8**	**-18%**	**-1%**

Some of the factors that caused changes in Seattle's total GHG emissions under this expanded view are shown in Figure 7[6]. Population and economic growth resulted in changes such as increased road transportation and air travel. These increases were counterbalanced by other factors that reduced emissions, such as reduced building energy use and switching from oil-based heat to more efficient and lower carbon heating methods. Seattle City Light's efforts to source its electricity from lower-carbon sources further reduced emissions. Industrial emissions also declined between 2008 and 2014. The net effect of the factors resulted in a small decline in GHG emissions between 2008 and 2014.

Figure 7. Multiple factors led to changes in Seattle's GHG emissions under the expanded view



[6] While Figure 3 and Figure 7 appear similar, Figure 3 tracks changes in emissions *per resident* from core emissions sources, while Figure 7 shows changes in *absolute* emissions from all sources included in this inventory.

Conclusions

Seattle's 2030 climate goals call for a combined reduction (road transportation and building energy) of emissions by 64% from 2008 levels. This inventory suggests that, indeed, Seattle has reduced these emissions since 2008 – by 6%. The reductions have resulted from lower passenger vehicle travel and more efficient cars, improvements in building energy performance, more residents living in multi-family (and less energy-intensive) dwellings, and warmer weather that led to lower heating demands in 2014 compared to 2008.[7]

Achieving Seattle's road transportation and building energy emission-reduction goals will require reductions that average 4.5% per year between 2008 and 2030.[8] Between 2008 and 2014, the actual pace has averaged 1.3% per year (Table 4). This points to the need to increase the rate of emissions reductions, especially for road transportation emissions.

Table 4. City emissions reductions compared to goals in Seattle's Climate Action Plan

	CAP target for 2030 (% emissions reduction from 2008)	Average annual % emissions reduction 2008-2030 necessary to achieve CAP goal	Actual average annual % emissions reduction 2008-2014	Actual average annual % emissions reduction 2012-2014
Passenger vehicles	82%	7.5%	0.5%	0.7%
Building energy	39%	2.3%	2.3%	2.1%
Combined vehicles + buildings	64%	4.5%	1.3%	1.3%

One trend that is particularly encouraging is the continued strong decline in transport and building emissions per resident. This decline has averaged 3% per year, demonstrating that Seattle can reduce its absolute emissions even as its population increases.

[7] A heating degree day (HDD) is a measurement of the amount of energy needed to heat a building based on outside air temperature. Colder temperatures result in more demand for building heating and thus more HDDs. During the period from 1998 to 2015, Seattle had the second-highest number of HDD in 2008 (5062 HDD) and the lowest number (3889 HDD) in 2014 (http://www.seattle.gov/light/ddays.html). The large effect of temperature on building energy use between 2008 and 2014 is due to the abnormal cold experienced in 2008 and the record warmth that occurred in 2014.

[8] There are many pathways to get to Seattle's goal – including pathways that increase in the near term but decrease faster in later years. The averages presented here are meant only to provide an indication of one possible pathway.

Detailed Results and Methodology by Sector

The following sections provide more detailed descriptions of the emissions estimates in each sector and the methodologies behind those estimates, and includes data from all inventory years.

Transportation

The transportation sector includes road (passenger travel, buses, and freight), marine (small craft, cruise ships, and freight), rail (passenger and freight), and air travel.

Core Inventory

Road Transportation

Road transportation includes the emissions from fuel use by both passenger and freight vehicles (Table 5). The Puget Sound Regional Council (PSRC) modeled and provided an estimate of vehicle miles traveled (VMT) on streets and highways. Vehicle fuel economy was estimated using results from vehicle stock models maintained by both PSRC and the Washington State Department of Ecology, and which rely on local vehicle registration data. Emissions from buses were calculated based on energy use data from the National Transportation Database (NTD). Because Sound Transit's service territory extends outside of Seattle, Sound Transit's energy use reported to NTD was scaled by bus route miles reported by the agency for routes that serve Seattle.

As many vehicle trips that start or end in Seattle do not occur entirely within the city or involve vehicles passing though the city without stopping, emissions attribution to Seattle from road transportation is not straightforward. To estimate these emissions, this inventory employs an origin-destination pair methodology which counts all emissions from trips occurring entirely in the city boundaries and one-half of emissions from trips that either begin or end in the city. No emissions from trips that both begin and end outside Seattle are included, even if they pass through the city limit. The rationale for this method is that it focuses on the trips that local government can best influence through transportation planning, programs, and incentives, while excluding trips over which the city and its partners have little influence.

Emissions from the road transportation sector have declined somewhat between 2008 and 2014. Growth in Seattle's population (up 13% since 2008) and economy has put upward pressure on vehicle emissions, resulting in more vehicles on the roads. However, vehicle emissions intensity has decreased between 2008 and 2014 (by about 11% for cars and light trucks as well as 7% for medium and heavy trucks), as has per-person personal vehicle travel (Figure 5, Table 4).

Table 5. Road transportation emissions (metric tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Car & Light Duty Truck	1,557,000	1,711,000	1,714,000	1,677,000	1,653,000
Commercial Trucks	502,000	549,000	563,000	560,000	563,000
Buses	47,000	58,000	60,000	67,000	65,000
Vans	2,000	2,000	2,000	2,000	2,000
Totals	**2,108,000**	**2,320,000**	**2,339,000**	**2,306,000**	**2,283,000**

Source Notes

This inventory employs a method that counts emissions from all trips that occur entirely within Seattle, half of trips that either begin or end in the city, and no trips that both begin and end outside the city (even if they pass through the city, e.g. on I-5), known as an origin-destination pair approach. This is an increasingly common way of counting GHG emissions in community-scale inventories, and was recommended in ICLEI's *U.S. Community Protocol*.

Road transportation emissions were predominately calculated from daily average vehicle miles traveled (VMT) modeling results provided by PSRC for cars and light trucks, vanpool, and trucks (medium and heavy duty). The table below categorizes total average weekday VMT from all vehicles traveling entirely in, starting in, or ending in Seattle in 2011 **(14-11-05)**. The shaded area depicts the VMT that are counted according to the origin-destination pair method (and totaling 12,998,661 miles): 100% of trips contained within Seattle, 50% of trips with an origin or destination in Seattle, and 0% of trips that both start and end outside Seattle.

Destination / *Origin*	Seattle	Outside Seattle
Seattle	4,633,466	8,033,767
Outside Seattle	8,696,623	

To estimate VMT for 2014 (and likewise for 2012), PSRC's modeled VMT results for 2011 **(12-11-08)** were scaled by a ratio of 2014 total VMT on state highways in urban King County to that from 2011 provided by the Washington State Department of Transportation (**14-11-10**). WSDOT uses a consistent methodology from year to year for these roads, which carry about half of total VMT in King County and which were therefore judged to be a purer signal of changes in VMT from year to year than data provided by WSDOT to the federal Highway Performance Management System (HPMS), for which WSDOT data on state highways are supplemented with sampled data for local roads but for which uncertainty is higher and methods have changed over time.

To estimate VMT for 2005, PSRC's VMT modeling results by vehicle type for 2006 **(12-11-07)** were scaled to 2005, also using WSDOT data on all VMT on state highways in urban King County (**14-11-10**), as described above. To estimate VMT for 2008, PSRC's VMT modeling results for 2008 **(12-11-12)** were used.

All VMT estimates derived from PSRC models (i.e. those for 2005, 2008, 2012, and 2014) are for average weekdays. They are scaled downward slightly to reflect the fact that average traffic on weekends – and therefore on an average day – is somewhat lower than on an average weekday. Scaling factors for 2005, 2008, 2012 and 2014 were developed by analyzing weekday and daily vehicle counts over time at two traffic stations in Seattle (one on I-5, one on I-90) from WSDOT's *Annual Traffic Report* (**12-11-09**). Factors were also developed to scale up the results to account for the fact that the models do not include VMT for trips that both begin and end within one of the many traffic analysis zones in PSRC's model. This factor was assumed to be 0.3% for all years based on communication with PSRC staff (**12-11-11**).

Source Notes (continued)

Estimating VMT for 1990 using the origin-destination pair approach is more complicated, and more uncertain, because modeling results using this method are not available from either PSRC or SDOT. VMT on a purely geographic basis (all VMT that occur within the city, regardless of origin or destination) for 1990 **(05-124)** were split into vehicle types using data from 2000 **(05-123)**, the earliest available, and then adjusted upward by the estimated (vehicle-specific) ratios of origin-destination pair to purely geographic VMT in 2005, also the earliest (ratio) available.

In order to calculate emissions, annual VMT were multiplied by emissions factors derived from modeling by both PSRC and the Washington Department of Ecology. PSRC provided estimates of vehicle fuel efficiency for Seattle by vehicle class (cars, light trucks, etc.) in 2011 and 2014 created using EPA's MOVES model **(14-11-17)**. In order to generate estimates of vehicle fuel efficiency in all inventory years (1990 through 2014), we also used vehicle fuel efficiency estimates for the statewide vehicle fleet in Washington provided by the Washington State Department of Ecology from 2005 to 2014, also created using EPA's MOVES model **(14-11-18)**.

We inter- and extrapolated vehicle fuel efficiencies for each vehicle class by calculating the ratio of PSRC's Seattle-specific fuel efficiency estimate to WA Ecology's statewide fuel efficiency estimate in 2011 and 2014 **(14-11-19)**. Because the Seattle vehicle fleet is more fuel efficient than the statewide vehicle fleet (due to average vehicle age and other factors), these ratios are greater than 1 in all cases. A PSRC/WA Ecology fuel efficiency ratio was estimated in all years other than 2011 and 2014 based on a straight-line inter/extrapolation of the PSRC/WA ecology ratio in 2011 and 2014. This inter/extrapolated ratio of Seattle to state vehicle fuel efficiency was multiplied by WA Ecology's modeled vehicle fuel efficiency in 2005 through 2012 and an estimate of WA Ecology's vehicle fuel efficiency in 1990 (see below). The minimum value of the extrapolated Seattle/state vehicle fuel efficiency ratio was fixed at 1 (i.e. the linear extrapolation was terminated where the Seattle-specific estimated fuel efficiency met the statewide average), meaning that the Seattle vehicle fleet was never assumed to be less efficient than the state average.

Statewide vehicle fuel efficiency was estimated for 1990 in each vehicle class by calculating the rate of change in vehicle fuel efficiency in each respective vehicle class in WA Ecology's statewide vehicle fuel efficiency between 2005 and 2008. This rate of change was assumed to hold between 1990 and 2005, allowing 1990 vehicle fuel efficiency to be estimated based on 2005 values. The 1990 estimates obtained with this methodology were similar to those using national data as in previous versions of this inventory.

Finally, annual VMT were multiplied by energy intensities derived as above and fuel-specific (gasoline or diesel) carbon contents from the US EPA's national GHG inventory **(14-80-01)**.

Emissions from non-electric buses were calculated based on fuel usage for King County Metro and Sound Transit as reported to the National Transit Database **(14-11-13)**. Fuel use was scaled based on the percentage of Metro and Sound Transit miles of travel on routes serving the city of Seattle (approximately 12 million miles for routes serving Seattle out of 15 million total miles for all Sound Transit routes) **(14-11-14)**.

Calculation steps and data sources for Road Transportation are listed in **14-00-0_MasterSpreadsheet '*Trans-Road Traffic*'** tab.

Uncertainty exists both in the estimates of vehicle travel (VMT) and vehicle fuel efficiency, the two primary drivers of road transport GHG emissions. Sources of uncertainty for VMT include that in PSRC's underlying model and in the scaling method used to scale PSRC's 2011 model results to 2012 based on data from WSDOT. Vehicle fuel efficiencies are based on the vehicle fleet in the Puget Sound region only in the most recent inventory years (2012 and 2014), and our estimates may not accurately reflect differences between the vehicle fleet in Puget Sound and Washington as a whole before that time.

Expanded Inventory

Marine & Rail Transportation

Marine and rail transportation are not included in Seattle's core emissions, and comprised a minor share (3%) of the expanded GHG inventory for 2014. Marine transportation includes pleasure craft, Washington State Ferries, cruise ships, cargo vessels, and other commercial boat traffic, such as tug boats. Emissions that occur near shore (maneuvering) and while docked (hoteling) are included based on estimates conducted by the Puget Sound Maritime Air Forum. Freight rail transportation includes emissions, based on the Puget Sound Maritime Air Forum Air Emissions inventory, from locomotive use at the Port of Seattle (on-terminal), the movement of Port of Seattle-related cargo in the county (off-terminal), and the movement of other freight. Emissions associated with passenger rail (Amtrak and Sounder commuter rail) are also included.[9] Marine and rail transportation emissions decreased 23% from 2008, with reductions in rail freight, large ship hoteling emissions, and pleasure craft emissions contributing the largest share of the reductions. Emissions from marine and rail transportation are presented in Table 6.

Table 6. Marine and rail transportation emissions (metric tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Marine					
Hotelling	53,000	51,000	74,000	46,000	38,000
Washington State Ferries	41,000	42,000	35,000	41,000	40,000
Pleasure Craft	32,000	30,000	31,000	31,000	25,000
Other Ship & Boat Traffic	65,000	62,000	64,000	64,000	67,000
Rail					
Freight	85,000	81,000	79,000	53,000	43,000
Passenger	-	5,000	7,000	8,000	9,000
Totals	**276,000**	**271,000**	**290,000**	**243,000**	**222,000**

[9] Because Sound Transit's Link Light Rail is all electric and emissions associated with this source are estimated to be small, they are not differentiated from other electricity users.

Source Notes

Other Ship and Boat Traffic: Emissions for 2014 were based on the 2011 Puget Sound Maritime Air Emissions Inventory **(14-80-03)**, including Ocean Going Vessel (OGV) Maneuvering, and Harbor Vessels (less Ferry emissions) categories. The 2011 emissions for OGV maneuvering were scaled by 2014 port tonnage handled (in TEUs; **14-12-01**) relative to 2011 as well as the number of cruise vessels in 2014 **(14-12-01)**. Harbor vessel emissions reported for King County **(14-80-03, Table 4.11)** were scaled to 2014 city population. The reported harbor vessel emissions include emissions from ferries and recreational vehicles **(14-80-03)**, which are determined and reported separately, so are subtracted out from the harbor vessel emissions reported by the Puget Sound Maritime inventory. All other inputs and calculation steps remained the same as previously reported **(12-12-01)**.

Hoteling: Emissions for 2014 were based on the 2011 Puget Sound Maritime Air Emissions Inventory **(12-80-03, Table 2.15)**. The 2011 values were scaled to 2014 by Port tonnage handled (in TEUs; **14-12-01**) and the number of cruise calls not using shore power **(14-12-01)**. All other inputs and calculations steps remained the same as previously reported for other inventory years.

WA State Ferries: For 2014, diesel and biodiesel fuel use for all Washington State Ferries (WSF), as reported by the Washington State Department of Enterprise Services **(14-12-03)**, was multiplied by the fraction of fuel expenditures for WSF servicing each of the Seattle routes, as determined based on the WSF 2014 fiscal year route statements **(14-12-02)**. One-half of fuel use for these routes was attributed to Seattle, consistent with the origin-destination pair approach described above for other passenger transport. An emission factor (in terms of kg of CO_2 produced per gallon of fuel consumed) from the *ICLEI Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions Version 1.0* **(14-12-05)** was used to calculate emissions associated with biodiesel fuel use. This method is the same as that used for inventory year 2012 and consistent with, though not identical, to the methods for prior years.

Pleasure Craft: Marine pleasure craft emissions for 2014 were obtained directly from NONROAD modeling results for King County **(14-40-02)**. This method differs from that used in previous years in which fuel usage, rather than emissions, was taken from NONROAD modeling results. Modeled emissions from 2014 were scaled by the Seattle fraction of King County population. Marine pleasure craft emissions for 2012 and 2005 are based on NONROAD modeling results for King County for the years 2005 and 2011, obtained from the Washington State Department of Ecology **(12-40-04, 12-40-01)**. The sum of diesel and gasoline use by marine pleasure craft was scaled by the Seattle fraction of King County population. Modelled fuel use in 2011 was also scaled to 2012 population to estimate 2012 fuel use. The 2008 fuel use is scaled by population growth to 2005 emissions. Fuel use in 1990 is only available based on PSCAA NONROAD modelling results. The PSCAA NONROAD and Dept. of Ecology NONROAD modelling results for pleasure craft differ due to methodologies for attributing county-scale emissions from statewide emission. Therefore, the 1990 PSCAA NONROAD fuel use was scaled by the ratio of Dept. of Ecology modelled to PSCAA modelled fuel use in 2005 to estimate total fuel use in 1990.

Rail - Freight: Freight rail emissions reported are the sum of Port of Seattle on-terminal (line-haul and switching locomotives, reported for 2011 in Puget Sound Maritime Air Emissions Inventory **14-80-03**) and off-terminal (King County line-haul locomotive) emissions. King County off-terminal line-haul locomotive emissions were not provided for 2011, as they were for 2005 **(05-151)** and therefore were estimated by scaling the ratio of total airshed emissions for 2011 relative to 2005. Seattle is assigned 90% of the King county off-terminal emissions, consistent with previous inventory years **(05-156)**. Emissions for 2014 and 2012 were scaled relative to those reported for 2011 by the ratio of tonnage handled, in twenty-foot

Source Notes (continued)

equivalent units (TEUs) **(14-12-01)**.

Rail – Passenger: Passenger rail emissions result from the Amtrak Cascades train that stops in Seattle as it travels between Portland, Oregon and Vancouver, British Columbia. The average number of gallons of diesel fuel per mile was estimated based on national data **(14-13-01)**. National average fuel use per mile was scaled by the number of riders on the Cascade route, as reported by Amtrak. Consistent with the origin-destination pair methodology employed for vehicle trips, only half of the emissions associated with trips that begin or end in Seattle are attributed to the city's emissions totals. Emissions from Sound Transit Sounder light rail service were estimated based on light rail fuel usage reported by Sound Transit **(14-13-11)**. Because the Sounder rail services areas outside of Seattle and because the city is a major destination for commuters that use the service, half of the emissions associated with Sounder fuel use were assigned to Seattle. This is consistent with the origin-destination pair methodology employed to estimate other types of transport emissions in this inventory.

Calculation steps and data sources for Road Transportation are listed in **14-00-0_MasterSpreadsheet '*Trans-Marine Traffic*' and '*Trans-Rail*'** tabs.

Uncertainty. Uncertainty in emissions data for Washington State Ferries is relatively low, as they are based on fuel usage statistics. By contrast, uncertainties for other sources are relatively high as they are based on model output that in some cases (e.g., for pleasure craft) scale national data to Seattle.

Air Transportation

Emissions from air transportation in the expanded view of the GHG inventory include a share of emissions associated with passenger travel at Seattle-Tacoma International Airport, as well as all fuel distributed at King County International Airport (KCIA, also known as Boeing Field), mostly for freight.

Emissions attributed to Seattle from Sea-Tac airport are the estimated share of all the emissions resulting from trips in and out of Sea-Tac associated with residential and business activities in Seattle. Seattle's share of Sea-Tac Airport airline emissions, 18% in 2014, is determined by the relative share of Seattle's population (representing personal travel) and employment (representing business travel) in the region, based on Census Bureau and Washington Employment Security Department sources. Emissions from air transport are shown in Table 7.

Table 7. Air transportation emissions (metric tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Sea-Tac International Airport	756,000	700,000	727,000	689,000	833,000
King County International Airport	184,000	219,000	262,000	228,000	238,000
Totals	**940,000**	**919,000**	**989,000**	**917,000**	**1,071,000**

Source Notes

Sea-Tac International Airport: The Port of Seattle provided data for total jet fuel distributed to aircraft at Sea-Tac Airport **(14-14-06)**. The fraction of emissions attributable to Seattle was estimated with a composite of population and employment in the city compared to the greater Puget Sound region, from which Sea-Tac draws the majority of its passengers **(14-14-01)**. This methodology is consistent with that used in in 2012 and replaces the previous approach used prior to 2012, which assigned the Seattle resident fraction of Sea-Tac passengers based solely on a 2001 Passenger Survey **(08-14-10)**.

King County International Airport: King County International Airport (KCIA) provided data for jet fuel and aviation gas distributions in 2014 **(14-14-08)**. All resulting emissions are attributed to Seattle, to account for roughly half of emissions associated with air travel to and from KCIA (since presumably fuel associated with inbound flights would be approximately equal to fuel associated with outbound flights, assuming similar origins and destinations). This approach is consistent with the origin-destination pair approach taken for road travel to and from Seattle. The KCIA emissions do not include fuel for aircraft operated by Boeing, which are fueled at a separate facility and for which fuel use data is not available for all inventory years.

Calculation steps and data sources are listed in **14-00-0_MasterSpreadsheet '*Trans- Air Traffic*'.**

Uncertainty. Uncertainty in emissions from air travel via Sea-Tac attributed to Seattle is relatively high, because even as fuel usage at the airport is well known, the method for attributing emissions to Seattle assumes that passenger travel for household and business travel is identical (per resident and employee, respectively) across the region, despite demographic differences (e.g., in income, or in type of employment). By contrast, uncertainty in emissions at King County international airport is relatively low, as it is based directly on fuel usage data.

Buildings

Seattle's core emissions include GHGs associated with the energy consumed by Seattle's residential and commercial buildings for lighting, appliances, heat, and hot water. The expanded view also includes emissions associated with landscaping, yard, and other equipment used at buildings.

Including all sources, emissions in this sector declined 165,000 tCO_2e, or 12%, between 2008 and 2014. Lower residential building emissions account for most of the decline in total building emissions between 2008 and 2014.

Core Inventory

Residential Building Energy

The vast majority of residential building emissions are associated with energy used for home heating, appliances, and hot water. Emissions from residential building energy are shown in Table 8. Emissions

from residential building energy were lower in both major categories (direct fuel use and electricity) in 2014 relative to 2008. This can largely be attributed to less heating demand due to warmer temperatures, lower energy use, and lower-carbon electricity sources. Use of electricity, natural gas, and petroleum per resident have all declined between 2008 and 2014.

Table 8. Residential building energy emissions[10]

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Electricity	133,000	68,000	45,000	28,000	22,000
Direct Fuel Use					
Natural Gas	259,000	371,000	432,000	420,000	399,000
Oil	294,000	113,000	109,000	73,000	65,000
Totals	**686,000**	**552,000**	**586,000**	**521,000**	**486,000**

Table 9. Residential building primary energy use in million Btu[11]

	Primary Energy Consumption, Million Btu				
	1990	**2005**	**2008**	**2012**	**2014**
Electricity	33,406,000	31,484,000	25,315,000	25,041,000	24,499,000
Direct Fuel Use					
Natural Gas	4,903,000	7,004,000	8,148,000	7,928,000	7,539,000
Oil	3,976,000	1,533,000	1,471,000	990,000	879,000
Totals	42,285,000	40,021,000	34,934,000	33,959,000	32,917,000

Table 10. Residential building energy use in physical units

		Energy Consumption, Physical Units				
		1990	**2005**	**2008**	**2012**	**2014**
Electricity	MWh	3,261,000	3,074,000	2,471,000	2,445,000	2,392,000
Direct Fuel Use						
Natural Gas	Therm	49,033,000	70,044,000	81,484,000	79,279,000	75,395,000
Oil	Gal	28,747,000	11,087,000	10,635,000	7,161,000	6,355,000

[10] The distinctions between residential, commercial, and industrial sectors represented in this table and the following tables relating to building energy use and emissions can be complex. For example, energy used in common spaces in multifamily residences is counted as commercial, energy used to generate steam is listed as commercial energy use though some multifamily residences receive steam heat, and some industrial energy users may be considered commercial

[11] For electricity, primary energy refers to the total energy consumed at the source where the electricity is generated. Because of inefficiencies and energy losses in the generation process, the amount of electrical energy delivered to consumers is, on average, only 33% of the total primary energy consumed at the generation facility. We follow the convention of the U.S. Department of Energy (see, e.g., the definition of "Primary Energy Consumption" in the U.S. Energy Information Administration's Annual Energy Outlook, http://www.eia.gov/totalenergy/data/annual), in which the efficiency of renewable energy sources, including hydroelectric generation, is taken to be the same as the average efficiency of fossil-fuel steam electric plants (33%). Thus, the primary energy reported in Table 9 and Table 12 is three times the end-use energy consumption reported in Table 8 and Table 10, respectively.

Household energy use per resident decreased 18% between 2008 and 2014 and 36% since 1990. Factors that help explain the decline in Seattle's residential energy use per resident include warmer weather resulting in reduced heating demand, smaller average household floor area,[12] increased energy efficiency of lighting, appliances, and heating, and the switch from oil heat to natural gas.[13]

Source Notes
When needed, fuel-specific emissions factors (gCO_2/L) from the US EPA's national GHG inventory (**14-80-01**) were used.

Electricity: Seattle City Light (SCL) provided residential building electricity consumption within Seattle for 2014 **(14-60-03)** and a provisional utility emission factor (tCO_2/MWh) **(14-60-04)**. The provisional SCL emission rate was multiplied by residential electricity consumption to obtain total emissions.

Direct Fuel Use (Natural Gas): Puget Sound Energy (PSE) provided 2014 natural gas use by Seattle residences **(14-20-02)**.

Direct Fuel Use: (Heating Oil): Seattle residential oil use was estimated from 2014 Washington State distillate fuel oil and kerosene sales by end-use, which is reported by the U.S. Energy Information Administration **(14-40-03)** and scaled to Seattle by the ratio of Seattle homes with oil heat to Washington State homes with oil heat as reported for 2014 by the U.S. Census Bureau American Fact Finder database **(14-20-01)**. Seattle's heating oil usage was also scaled by the ratio of heating degree days in Seattle to the population-weighted statewide average number of heating degree days **(14-12-08)**. This scaling is necessary because heating demand in Seattle is somewhat less than the statewide average, which includes areas with colder winter temperatures.

Calculation steps and data sources for electricity, natural gas and petroleum (heating) are listed in **14-00-0_MasterSpreadsheet '*Electricity*', and '*Res- Heat & Hot Water*'** tabs, respectively.

Uncertainty. Uncertainty in electricity and natural gas is quite low, since it is based directly on utility data. Uncertainty in oil use, on the other hand, is relatively high, since this is scaled from statewide data. In all categories, uncertainty is high in the categorization of energy use between different classes of users, such as commercial, residential, and industrial. This split is based on utility rate class, which involves some mixing of sources between categories.

[12] Though no data on actual floor area were identified, based on data from the Census Bureau's American Community Survey, since 2008, nearly all of the net additions to households in Seattle have been (generally smaller) households in buildings with more than two units, compared to less than half (44%) of the existing housing stock.

[13] According to the U.S. Department of Energy, older oil furnaces have an efficiency of 56% to 70%, whereas newer natural gas furnaces have efficiencies of 90% or more. An estimated 32,000 households have converted from oil heat since 1990, with 3,700 of those households having switched since 2008. Census data?

Commercial Building Energy

Commercial building emissions result from generating or using the energy consumed by businesses, office buildings, and institutional facilities (such as government buildings and schools). As with residential buildings, the majority of these emissions are associated with lighting, space heating, and hot water. Many downtown Seattle buildings are heated by steam generated by Enwave and the emissions associated with steam heat are reported on a separate line.

Table 11. Commercial building energy emissions

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Electricity	169,000	102,000	82,000	53,000	42,000
Direct Fuel Use					
Natural Gas	281,000	363,000	413,000	416,000	431,000
Oil	57,000	17,000	8,000	2,000	2,000
Steam Plants					
Natural Gas	137,000	160,000	176,000	156,000	138,000
Oil	7,000	-	1,000	-	-
Totals	**651,000**	**642,000**	**680,000**	**627,000**	**613,000**

Table 12. Commercial building primary energy use in million Btu[14]

	Primary Energy Consumption, Million Btu				
	1990	**2005**	**2008**	**2012**	**2014**
Electricity	33,698,000	47,650,000	46,658,000	47,114,000	47,155,000
Direct Fuel Use					
Natural Gas	5,309,000	6,846,000	7,802,000	7,846,000	8,137,000
Oil	759,000	-	7,000	1,000	-
Steam Plants					
Natural Gas	2,589,000	3,021,000	3,324,000	2,949,000	2,613,000
Oil	98,000	-	7,000	1,000	-
Biomass	-	-	-	142,000	356,000
Totals	42,453,000	57,517,000	57,798,000	58,053,000	58,261,000

Table 13. Commercial building energy use in physical units

		Energy Consumption, Physical Units				
		1990	**2005**	**2008**	**2012**	**2014**
Electricity	MWh	3,290,000	4,652,000	4,555,000	4,599,000	4,603,000
Direct Fuel Use						
Natural Gas	Therm	53,090,000	68,458,000	78,017,000	78,459,000	81,372,000
Oil	Gal	5,487,000	1,662,000	814,000	157,000	220,000
Steam Plants						
Natural Gas	Therm	25,888,000	30,205,000	33,243,000	29,490,000	26,125,000
Oil	Gal	706,000	-	54,000	10,000	-
Biomass	Ton	-	-	-	9,000	21,000

[14] Energy associated with co-firing biomass at steam plants is reported here for informational purposes, but emissions are counted here as zero following the primary practice used in the EPA's national inventory.

Source Notes

Electricity: Seattle City Light (SCL) provided commercial building electricity consumption within Seattle for 2012 **(14-60-03)** and a provisional utility emission factor (tCO_2/MWh) **(14-60-04)**. The provisional SCL emission rate was multiplied by commercial electricity consumption to obtain CO_2 emissions.

Direct Fuel Use (Natural Gas): Puget Sound Energy (PSE) provided 2014 natural gas use by Seattle commercial customers **(14-20-02).** Natural gas use at steam plants and for commercial equipment use as CNG are assumed to be included in PSE's reported commercial sector natural gas totals, but are subtracted from the total reported by PSE and given separately for the purposes of this inventory.

Direct Fuel Use (Petroleum): Seattle commercial building oil use was estimated using 2014 Washington State Distillate Fuel Oil and Kerosene sales by end-use, which is reported by the U.S. Energy Information Administration **(14-40-03),** prorated by the ratio of Seattle to Washington State commercial employment **(14-70-11)**.

Steam: PSCAA provided natural gas and back up oil use from the Seattle Steam and the University of Washington steam plants **(14-40-05)**.

Calculation steps and data sources for electricity, natural gas (commercial equipment) and petroleum (commercial equipment), natural gas (heat and other), petroleum (heat and other), and steam are listed in **14-00-0_MasterSpreadsheet *'Electricity'*, *'Commercial- equip'*,** and ***'Commercial- Heat & Hot Water'***, respectively.

Uncertainty. Uncertainties for commercial building emissions estimates are similar to residential buildings: low uncertainty for natural gas and electricity; high uncertainty for oil use. Emissions associated with steam plants are relatively certain, since they are based directly on fuel use data.

Expanded Inventory

Residential and Commercial Building Equipment

The expanded view of Seattle's building emissions also includes emissions from small equipment associated with commercial and residential buildings, including landscaping equipment.

Table 14. Residential and commercial building equipment emissions (metric tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Residential Yard Equipment					
Diesel	<100	<100	<100	<100	<100
Gasoline	20,000	17,000	17,000	18,000	18,000
LPG	<10	<10	<10	<10	<10
Commercial Equipment					
Diesel	29,000	37,000	39,000	46,000	49,000
Gasoline	91,000	90,000	95,000	96,000	100,000
LPG	3,000	4,000	4,000	5,000	5,000
CNG	2,000	2,000	2,000	2,000	2,000
Totals	**145,000**	**150,000**	**157,000**	**167,000**	**174,000**

Source Notes

Residential Yard Equipment (Petroleum): King County yard equipment emissions in 2014 were estimated by the Washington Department of Ecology using EPA's NONROAD model, and relevant model output was provided **(14-40-01)**. Emissions by petroleum type were tabulated **(14-40-02),** prorated for Seattle by the ratio of Seattle to King County population. This methodology differs from that used in prior years. In 2012 and prior years, data on fuel use was estimated from NONROAD modeling output rather than direct emissions. Did we recalculate prior years using the new model?

Commercial Equipment (Natural Gas and Petroleum): Emissions from equipment powered by compressed natural gas (CNG) and petroleum fuel in King County in 2014 were estimated by the Washington Department of Ecology using EPA's NONROAD model and relevant model output was provided **(14-40-01)**. Emissions were tabulated by fuel type and sector **(14-40-02)**, then scaled to Seattle by the ratio of Seattle to King County commercial employment **(14-70-11)**. Emissions from CNG-powered equipment in years prior to 2014 have been corrected. CNG fuel use in NONROAD modeling output was assumed to be in units of cubic feet but is instead in units of gallons. Emissions from CNG-powered equipment are approximately 87% lower than reported in previous versions of this inventory.

Uncertainty. Uncertainty is high for residential and commercial equipment, since it is based on a national

Waste

The waste sector includes emissions associated with the disposal of municipal solid waste (included as part of core emissions) and wastewater treatment (included in the expanded view). Emissions associated with solid waste have declined 13% since 2008 and 32% since 1990 due to reduced waste generation and increased composting and recycling.

Core Inventory

Waste Management

The GHG methane can be generated when municipal solid waste (MSW) decomposes. However, because Seattle's waste is processed and landfilled outside of the City, these emissions do not occur within the City boundaries. Solid waste management is directly influenced by City policy and programs, however (via Seattle Public Utilities), and so this inventory uses a "waste commitment" methodology to estimate emissions associated with solid waste generated in the City. Our emissions estimate for solid waste includes the total quantity of methane expected to be released to the atmosphere from the landfill decomposition of all the solid waste disposed of in the inventory year. Although all methane "commitment" (i.e. future emissions) is attributed to the year in which the waste was disposed, the decay process takes many years, so these methane emissions will likely occur mostly in future years.

Collecting and processing solid waste also generate emissions in other ways: fuel combustion associated with equipment used to transport waste to landfill, process waste at the landfill, and maintain the landfill. Seattle's waste commitment emissions have decreased since 2008, mainly due to reduced disposal of organic material like food scraps, which generate methane and store relatively little of their carbon under landfill conditions.

Previous inventories counted waste sector emissions by estimating the emissions from waste in place in closed in-city landfills. These emissions are still tabulated in the section *Other Perspectives on Seattle's Emissions* later in this document.

Expanded Inventory

Wastewater Treatment

King County operates a wastewater treatment plant, West Point, within the Seattle city limits. Wastewater treatment emits methane and nitrous oxide, both greenhouse gases.[15]

Table 15: Waste sector emissions (Metric Tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Waste management	133,000	118,000	103,000	87,000	88,000
Wastewater Treatment	2,000	2,000	2,000	2,000	2,000
Totals	**134,000**	**120,000**	**105,000**	**89,000**	**90,000**

[15] Due to rounding, changes in emissions associated with wastewater treatment are not displayed in this table.

Source Notes

Waste management: Quantities of solid waste hauled and landfilled in each inventory year were calculated based on quantities of waste collection reported in Seattle Public Utilities waste composition studies (**14-50-10**) and compiled in **14-50-07**. Emissions factors for landfilling and carbon sequestration by category of solid waste were taken from EPA's WARM model (**14-50-09**) and emissions were calculated in **14-50-08**. Emissions associated with transporting waste to landfill facilities were based on EPA's default assumption of emissions associated with 20 miles of travel plus additional emissions associated with 234 miles of travel by class-1 freight rail to landfill facilities in Arlington, WA (average distance of 254 miles from Seattle).

Wastewater Treatment: Wastewater treatment emissions for 2013 were provided by the King County Wastewater Treatment Division **(14-50-01)**. These include both stationary CH_4 emissions and process N_2O emissions. Emissions from the wastewater treatment service area with a population of 1.614 million and were scaled based on Seattle population in 2014.

Calculation steps and data sources for waste management and wastewater treatment are listed in **14-00-0_MasterSpreadsheet 'Waste- Management'** and **'Waste- Wastewater'**, respectively.

Uncertainty. Uncertainty in waste management emissions include estimates of methane release based on waste composition and methane release collection efficiencies over time (including for the future, which would affect methane emissions from waste generated in 2012). There is some uncertainty in both of these values, although the impact on total Seattle emissions is likely to be relatively small due to the small overall contribution of this source. Wastewater treatment uncertainty includes methane capture rate, which is likely uncertain, although applied to a very small level of emissions.

Greenhouse Gas Offsets

The majority of Seattle City Light's electricity is generated from hydro and wind power, but there are some emissions associated with the power City Light purchases that are generated from other sources. Since 2005, City Light has invested in carbon reduction projects to offset the emissions associated with its electricity production. We include offsets associated with electricity use in the core and expanded views of the GHG inventory.

Seattle City Light purchases offsets using the Climate Action Reserve and other third-party organizations that have established protocols for qualifying and verifying offsets. The projects that City Light has purchased offsets from include agricultural and landfill methane capture projects, biodiesel supply projects, and shore power for cruise ships at the Port of Seattle.

Table 16. Greenhouse gas offsets counted in this inventory (Metric Tons CO_2e)[16]

	Offsets, Metric Tons CO_2e			
	2005	**2008**	**2012**	**2014**
Residential	74,000	44,000	28,000	22,000
Commercial	113,000	82,000	53,000	42,000
Industrial	29,000	17,000	10,000	8,000
Totals	**216,000**	**143,000**	**91,000**	**72,000**

Industry

The industrial sector includes emissions from industrial operations, such as manufacturing cement, steel, and glass, as well as fugitive emissions, or leaks, of non-CO_2 GHGs from industrial equipment. Industrial emissions also include those associated with generating the electricity that industrial operations consume. Industrial emissions are not included in Seattle's main inventory emissions but are part of the expanded inventory.

Expanded Inventory

Cement

Emissions associated with cement production are presented in Table 17. These include emissions from fuel combustion (natural gas, oil, coal, and tire-derived fuels) and the release of carbon dioxide from the calcination process involved in clinker production. Emissions from cement production in Seattle have historically been produced by two large plants. Both cement plants were active in 2005 and 2008, but only one was active in 1990, 2012, and 2014. The emissions associated with cement production within the city boundary are heavily influenced by market forces, such as competition from other cement producers and economic conditions determining demand for cement, that are beyond the control of policy decisions made at the city-level.

Table 17. Greenhouse gas emissions associated with cement production (Metric Tons CO_2e)[17]

	1990	**2005**	**2008**	**2012**	**2014**
Fuel combustion	211,000	377,000	353,000	-	-
Clinker calcination	206,000	484,000	393,000	-	-
Totals	**417,000**	**861,000**	**746,000**	**307,000**	**523,000**

[16] Greenhouse gas offsets counted here are equivalent to all the emissions associated with electricity generation consumed in Seattle. The total quantity of offsets purchased by Seattle City Light may be greater than this amount, since City Light's service territory is slightly bigger than Seattle city limits.

[17] Since 2012, cement production emissions from relevant facilities are taken from the EPA's Greenhouse Gas Emissions from Large Facilities. This source does not report separate fuel combustion and clinker calcination emissions, only aggregate emissions, which are reported in the "Totals" row of the table.

Source Notes

Cement: Emissions associated with cement production in 2014 are taken from the EPA 2012 Ash Grove Greenhouse Gas Emissions from Large Facilities report **(14-40-06)**. This report does not separate emissions associated with fuel combustion from emissions associated with clinker calcination. Calculation steps and data sources for cement, steel and glass, and fugitive gases are listed in **14-00-0_MasterSpreadsheet 'Ind-Cement'**.

Uncertainty. Uncertainty in cement emissions is relatively low, as these estimates are based on actual data on fuel usage and clinker production (1990 through 2008) and on data reported directly to the US EPA by the facility (2012).

Other Industry – Energy Use

Industrial operations are dominated by emissions from energy used to fuel manufacturing equipment and other industrial equipment, rather than space heating and hot water as in the residential and commercial sectors. Industrial operations also include fuel use and GHG emissions from construction equipment, material handling, and other non-road machinery. Emissions from industrial energy use (other than for cement production) are shown in Table 18.

Table 18. Industrial energy use emissions, other than for cement (metric tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Electricity	62,000	26,000	17,000	10,000	8,000
Direct Fuel Use					
Natural gas	266,000	257,000	246,000	270,000	207,000
Oil	49,000	11,000	36,000	15,000	14,000
Coal	211,000	339,000	335,000	-	-
Tire-derived Fuel	-	26,000	17,000	-	-
Industrial Equipment					
Diesel	114,000	131,000	172,000	158,000	157,000
Gasoline	6,000	4,000	6,000	4,000	3,000
LPG	20,000	25,000	33,000	27,000	28,000
CNG	1,000	2,000	2,000	2,000	2,000
Totals	**729,000**	**821,000**	**864,000**	**486,000**	**419,000**

Source Notes

Electricity: Seattle City Light (SCL) provided Industrial electricity consumption within Seattle for 2014 **(14-60-03)** and the provisional utility emission factor (tCO_2/MWh) **(14-60-04)**. The SCL provisional emission rate was multiplied by Industrial electricity consumption to obtain CO_2 emissions.

Direct Fuel Use (Natural Gas): Puget Sound Energy (PSE) provided 2014 natural gas use by Seattle Industrial customers **(14-20-02)**, from which natural gas used for industrial equipment (see below), which was assumed to be included in PSE's estimates for the industrial sector, was subtracted out (as in commercial sector).

Direct Fuel Use (Petroleum): Seattle commercial building oil use was estimated using 2014 Washington State Distillate Fuel Oil and Kerosene sales by end-use, which is reported by the U.S. Energy Information Administration **(14-40-03)**. Fuel sales were scaled by the ratio of Seattle to Washington State Industrial employment **(14-70-11)**.

Industrial Equipment (Natural Gas and Petroleum): King County industrial emissions in 2014 from equipment powered by compressed natural gas (CNG) and petroleum was estimated by the Washington Department of Ecology using EPA's NONROAD model and relevant model output was provided **(14-40-01)**. Emissions by fuel type and sector was tabulated **(14-40-02)**, then prorated for Seattle only by the ratio of Seattle to King County industrial employment **(14-70-11)**. As with commercial equipment, emissions from CNG-powered industrial equipment in years prior to 2014 have been corrected. CNG fuel use in NONROAD modeling output was assumed to be in units of cubic feet but is instead in units of gallons. Emissions from CNG-powered equipment are approximately 87% lower than reported in previous versions of this inventory.

Calculation steps and data sources for electricity, natural gas (industrial equipment) and petroleum (industrial equipment), and natural gas (heat and other), petroleum (heat and other), coal, and tire are listed in **14-00-0_MasterSpreadsheet 'Electricity', 'Ind- Small Equipment**, and **'Ind- Operations',** respectively.

Uncertainty. Uncertainties for industrial energy use are similar to those for building energy use, i.e. higher for direct oil use (scaled from statewide data according to industrial employment) and industrial equipment fuel use (model-based), and relatively certain natural gas and electricity emissions based on utility sales data.

Table 19. Industrial process and fugitive gas emissions (metric tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Process Emissions					
Steel and glass	20,000	37,000	40,000	39,000	40,000
Fugitive Gases					
PSE Natural Gas Leakage (CH4)	21,000	25,000	22,000	18,000	16,000
Switchgear insulation (SF6)	10,000	5,000	2,000	1,000	3,000
Totals	**51,000**	**67,000**	**64,000**	**58,000**	**59,000**

Source Notes

Steel: Steel emissions are from Seattle's predominant manufacturer, Nucor (an electric arc furnace that produces crude steel). PSCAA provided production data from Nucor steel production **(14-40-05)**. To calculate emissions, the production data was multiplied by the nominal IPCC emission factor associated with electric arc furnaces, 1.25 $kgCO_2$/Mg steel. Nucor uses entirely recycled stock so there are no emissions associated with carbon lost from pig iron as there would be in a basic oxygen furnace **(05-127).**

Glass: Glass operations emissions are from manufacturing at Seattle's Ardagh Glass (formerly Saint-Gobain Containers). PSCAA provided production data from this facility **(14-40-05)**. To calculate emissions, tons of glass pulled were multiplied by the default emission factor for glass manufacturing **(KC08-40-2)** and adjusted by the ratio of recycled cullet used by Saint-Gobain **(KC08-40-3).** Emissions from glass operations were calculated based on tons of glass pulled as reported in the 2008 King County Inventory and previous Seattle inventory source documents **(05-098)**.

Fugitive SF_6 emissions: Seattle City Light (SCL) provided provisional fugitive SF_6 emissions for 2012 **(14-60-05)**, which were converted to CO_2-equivalent emission based on the 100-year global warming potential of SF_6 (22,800) from the IPCC Fourth Assessment Report.

Fugitive methane emissions: Mileage of natural gas pipe and counts of natural gas service lines by material were obtained from utility filings with the Pipeline and Hazardous Materials Safety Administration (PHMSA, **14-40-11**). These data were multiplied by emissions factors from EPA's U.S. Greenhouse Gas Inventory (**14-80-02; Table A-139 "Data and CH4 emissions for the Natural Gas Distribution Stage"**) for methane emissions from these components. Methane emissions from metering and regulating (M&R) stations was taken from PSE's 2014 greenhouse gas inventory (**14-40-12**). Emissions from M&R stations were a small portion of total methane emissions from PSE's infrastructure in 2014 (only 0.5%) and this relative contribution of M&R stations to total methane emissions from PSE's natural gas infrastructure is assumed to apply to prior inventory years as well. PSE's total natural gas sales for years 1994 to 2014 were obtained from filings with the U.S. Securities and Exchange Commission (form 10-K, **14-40-13a to 14-40-13g**).

Calculation steps and data sources for cement, steel and glass, and fugitive gases are listed in **14-00-0_MasterSpreadsheet 'Ind- Process'** and **'Ind- Fug. Gases'**, respectively.

Uncertainty. Uncertainty is relatively high for all categories of process and fugitive emissions.

Appendices

Appendix A: Other Perspectives on Seattle's Emissions

This report includes a core and an expanded view of the City's emissions accounting. Other perspectives are also possible, however. Most communities in the U.S., Seattle included, consume more goods and materials than they produce. Accounting for the GHG emissions associated with these goods and materials has been the subject of considerable debate, including among those who design protocols for community-scale emissions. These other perspectives do not always fit neatly into GHG inventories. Even the approaches used here are hybrids of "production-based" approaches (which are more inclusive of emissions associated with producing goods and materials in a community) and "consumption-based" approaches (which are more inclusive of emissions associated with consuming goods and materials in a community, regardless of where the emissions are released).

For example, one way to consider emissions associated with goods and materials is to count all the emissions associated with the goods and materials (and services) consumed in Seattle, regardless of where they were made. For example, the production of a t-shirt or appliance involves energy inputs at various places all around the world. Estimating emissions associated with goods and services is a complicated endeavor that involves economic modeling and a number of assumptions. In 2011, Seattle collaborated with King County to undertake an extensive study that estimated all of these "consumption-based" emissions. That study found that the average Seattle resident's consumption was associated with 25 tCO_2e in 2008: more than 5 tCO_2e per resident were associated with goods and about 4 t CO_2e per resident were associated with food. For more information on emissions associated with consumption, see *Getting to Zero: A Pathway to a Carbon Neutral Seattle* and *Greenhouse Gas Emissions in King County*.[18]

Waste disposal

Disposing of Materials

The majority of Seattle's refuse, also called municipal solid waste (MSW), consists of organic matter. When organic waste is buried in a landfill, a portion decays releasing methane and carbon dioxide, but the remaining portion of the waste remains buried in the landfill indefinitely. The carbon that is not released to the atmosphere as methane or CO_2 remains in place in the landfill and represents net carbon storage, since the carbon in the waste was originally extracted from the atmosphere by means such as a food plant, garden vegetation, or a tree harvested for forest products. Table 20 lists the estimated carbon storage from waste disposed in landfills.

Similar to the methane commitment described above, the values in Table 20 are calculated for the waste disposed in the listed calendar year, but represent the storage enduring after that waste's decay is complete, many years in the future.

[18] Available online: http://www.seattle.gov/environment/documents/CN_Seattle_Report_May_2011.pdf

Table 20. Carbon storage associated with landfilling of Seattle's municipal solid waste (Metric Tons CO_2)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Carbon storage	(230,000)	(132,000)	(110,000)	(88,000)	(85,000)

Source Notes

MSW storage: Quantities of solid waste hauled and landfilled in each inventory year were calculated based on quantities of waste collection reported in Seattle Public Utilities waste composition studies (**14-50-10**) and compiled in **14-50-07**. Emissions factors for landfilling and carbon sequestration by category of solid waste were taken from EPA's WARM model (**14-50-09**) and emissions were calculated in **14-50-08**.

Closed Landfills

Landfills continue to emit methane long after they have been closed, although emissions levels drop significantly over time. There are several closed landfills in Seattle, and past community inventories included estimates of their methane emissions. For this inventory, waste commitment emissions are highlighted instead of emissions from closed landfills. This waste commitment approach was chosen because it records emissions commitment associated with waste generation, which reflects the global warming impact of current policy choices. In contrast, the geographic emissions of closed landfills during the same year that arise from waste generated in years not covered by the inventory have little to do with current policy. Although no longer included in the main community inventory, emissions from closed landfills in the City are still tracked and are shown in Table 21.

Table 21. Landfill emissions within Seattle (Metric Tons CO_2e)

	Emissions, Metric Tons CO_2e				
	1990	**2005**	**2008**	**2012**	**2014**
Interbay	31,000	17,000	15,000	6,000	7,000
Genesee	36,000	17,000	15,000	6,000	7,000
Montlake	-	18,000	15,000	12,000	9,000
Judkins Park	6,000	3,000	3,000	1,000	1,000
South Park	14,000	6,000	6,000	2,000	1,000
West Seattle	7,000	3,000	3,000	-	-
Totals	94,000	65,000	56,000	27,000	25,000

Source Notes

Landfills: Emissions from Interbay, Genessee, Judkins Park, and South Park landfills were estimated using Interbay monitoring data from the portion of the landfill that is under vacuum (7.2% of the landfill surface area). Min-Soon-Yim of Seattle Public Utilities provided the 2014 Interbay monitoring data **(14-50-04)**. Methane emissions from landfills in all years have been adjusted based on the 100-year global warming potential of CH_4 (25) from the IPCC Fourth Assessment Report. In previous versions of this inventory, methane emissions from landfills were adjusted using the 100-year global warming potential of CH_4 from the IPCC Third Assessment Report, which is 21.

Emissions from the Montlake landfill for 2008 were calculated using the landfill volume, mass, and the methane kinetics equation from the 2005 University of Washington greenhouse gas inventory **(05-158)**. The calculation steps are the same as for the previous inventory **(08-50-5)**.

No emissions data for the West Seattle landfill were calculated in 2012 or 2014.

Uncertainty. Uncertainty in emissions estimates from closed landfills includes the extent of landfill gas capture. A higher than estimated landfill gas capture rate would mean lower landfill emissions. An additional uncertainty is the rate at which uncaptured methane is oxidized to CO_2.

Appendix B. Description of changes to methodology

This inventory includes some methodological changes compared to the 2012 inventory. These changes are summarized in Emissions estimates from all prior inventory years (1990, 2005, 2008 and 2012) presented in this version of the City's GHG inventory have been calculated using these updated methods. As such, emissions estimates for prior inventory years may differ somewhat from those reported in previous versions of this inventory.

Table 22. Emissions estimates from all prior inventory years (1990, 2005, 2008 and 2012) presented in this version of the City's GHG inventory have been calculated using these updated methods. As such, emissions estimates for prior inventory years may differ somewhat from those reported in previous versions of this inventory.

Table 22. Summary of substantial methodological changes from previous inventory calculations.

Sector	Subsector	Particular Source	2012 Method	2014 Method	Reason for Change
Transportation					
	Road	All road except buses	Used national average fuel efficiency information from U.S. DOT	Used a combination of local vehicle fuel efficiency data from PSRC (2012 and 2014) extrapolated to prior years in combination with statewide fuel efficiency estimates from WA Department of Ecology.	Better reflects local vehicle fleet under influence of local policy makers, since is based on actual vehicle registration data not national averages
		King County Metro diesel buses	Based on fleet-miles traveled in-city and average fuel efficiency of fleet	Based on total fuel use reported by Metro and Sound Transit to the National Transportation Database	Relies on publically-available data, does not require special data request; less time-intensive to compile and consistent with past results.
	Marine & Rail	Passenger Rail	All emissions associated with Amtrak Cascades trains in Seattle assigned to City	Half of emissions associated with Amtrak Cascades trains in Seattle assigned to City	More consistent with origin-destination pair methodology used for road traffic
Buildings					
	Commercial	Oil	Based on total commercial oil usage reported by EIA for Washington	Excludes diesel included in EIA's total commercial oil usage for Washington	EIA reports diesel sales to government agencies as commercial oil use. Some of this diesel may be used for constructio7n equipment and government vehicles, which are counted elsewhere in the inventory.
Industry					
	Fugitive gases	Methane	Not included	Included	Included in national EPA inventory and ICLEI Community Protocol
	Fugitive gases	Ozone-depleting substance (ODS) substitutes	Included	Not included	Incorrectly attributes GHGs to ODS and their substitutes since existing methods count only the substitutes, not the GWP of the ODS themselves.
Waste					
	Waste management		Information provided by Jenny Bagby, Seattle Public Utilities	Emissions based on tons of waste disposed in City reports and EPA emissions factors	Uses publicly available data

Appendix C. Source documentation

The formal inventory is a dataset consisting of electronic files. These data files are divided into the following categories:

Index file – A single index file, <Community dataset index 14.xlsx>, lists names, descriptions, and sources of all other files in the inventory.

Source files – These files are numbered 14-00-00 to 14-80-00. The files are organized by category in the following format:

14-00 Inventory

14-10 Transportation

14-20 Buildings

14-40 Industry

14-50 Waste

14-60 Electricity

14-70 Demographics

14-80 Reference

Calculation files – File 14-00-0 is the master calculation file for the inventory, and includes at least the highest-level calculations for every datum reported in this document. Every table describing the inventory in this document is duplicated from: <14_00_0_Master_Spreadsheet.xlsx>.

Every datum in the calculation files is traceable to one of the source files through the 14-XX-XX number provided in the "call no." column of most of the calculation files. These sources files are listed below in Table 23. In addition, some source files from prior inventory work in Seattle are referenced. These source files are in the format 12-XX-XX (*2012 Seattle Community Greenhouse Gas Inventory*), 08-XX-XX (*2008 Seattle Community Greenhouse Gas Inventory*) or 05-XX-XX (*2005 Inventory of Seattle Greenhouse Gas Emissions: Community & Corporate*) and are maintained by the City of Seattle Office of Sustainability & Environment (OSE). Additionally, some source files reference KC08-XX-XX (*Greenhouse Gas Emissions in King County*).

Table 23. Catalog of Source Documents

Call#	Subject	Ext.	Document title
14-00-0	**Inventory**		
14-00-0	Master Spreadsheet	.xlsx	Master_Spreadsheet_X_XX_XX
14-10-0	**Transportation**		
14-11-XX	**Road**		
14-11-01	National Transport Statistics Table 4-11 for Passenger vehicles and motorcycles	.xlsx	Passenger_Motorcycle
14-11-02	National Transport Statistics Table 4-12 for light duty trucks	.xlsx	Light_Trucks
14-11-03	National Transport Statistics Table 4-13 for single-unit trucks	.xlsx	Single_Unit_Trucks
14-11-04	National Transport Statistics Table 4-14 for combo trucks	.xlsx	Combo_Trucks
14-11-05	VMT Calculations	.xlsx	VMT_calcs
14-11-10	Annual VMT for WSDOT roads	.xlsx	WSDOT_State_Highway_VMT
14-11-13	NTD transit energy usage	.xlsx	Transit_energy_use
14-11-14	Sound Transit Service Implementation Plans, 2014 and 2015	.pdf	Sound_Transit_SIP_201X
14-11-16	VMT calculations adjustment factors for intra-zonal and weekend travel	.pdf	VMT_calcs_adjustments
14-11-17	PSRC vehicle fuel efficiency	.pdf	PSRC_fuel_efficiency
14-11-18	WA Ecology vehicle fuel efficiency modeling output	.xlsx	WA_ecology_MOVES_output
14-11-19	Vehicle fuel efficiency calculations	.xlsx	Vehicle_efficiency_calcs
14-12-XX	**Marine**		
14-12-01	Port of Seattle 10-year History	.xlsx	10yearhistory
14-12-02	WSF Route Statements and Analysis, FY 2009-2014 (Gives Fuel Costs)	.pdf	WSF_RouteStatementsAndAnalysis
14-12-03	WA Department of Enterprise Services Biodiesel Use Report	.pdf	WA_DES_BiodieselUseReport
14-12-04	WA Department of Ecology 2005 NONROAD model output (multiple text files loaded into	.xlsx	NONROAD_WA_DoE_2005_Rec_Boat
14-12-05	US Community Protocol for Accounting and Reporting, Appendix D: Transportation and	.pdf	ICLEI_Appendix_D_Tansportation_and_Other_Mobile_Emission
14-12-06	Port of Seattle total tonnage and vessel calls	.pdf	PortofSeattle_tonnage_vc
14-13-XX	**Rail**		
14-13-01	Amtrak Energy Intensity per passenger revenue mile	.xls	Amtrak_EnergyIntensity
14-13-02	2014 Amtrak Cascades Annual Report	.pdf	AmtrakCascadesAnnualPerformanceReport2014
14-13-11	Sound Transit 2014 Q4 Service Delivery Report	.pdf	2014Q4_QuarterlyServiceDeliveryPerformanceReport
14-14-XX	**Air**		
14-14-01	Sea Tac Emissions Ratio Workbook	.xlsx	SeaTacRatio
14-14-05	Sea-Tac annual activity report	.xlsx	SeaTac_Activity_Report2014
14-14-06	Sea-Tac total jet fuel uplift	.pdf	StephanieMyer_JetFuelSeaTac
14-14-07	Sea-Tac passenger enplanement survey 2014	.xlsx	SeaTac_passenger_survey2014
14-14-08	King County International Airport fuel usage	.udf	KCIA_fuel_usage
14-20-0	**Buildings**		
14-20-01	Home Heating Type	.xlsx	Home_Heating_ACS
14-20-02	Natural gas consumption for residential, commercial, industrial sectors, from PSE	.pdf	PSE_nat_gas
14-20-04	Heating degree days, SeaTac airport station	.xlsx	HDD_SeaTac
14-20-05	Cooling degree days, SeaTac airport station	.xlsx	CDD_SeaTac
14-20-06	EIA residential sector energy usage	.xlsx	EIA_residential_energy
14-20-07	EIA commercial sector energy usage	.xlsx	EIA_commercial_energy
14-20-08	WA state-wide population-weighted heating degree days	.xlsx	WA_HDD
14-40-0	**Industry**		
14-40-03	Distillate Fuel and Kerosene Use	.xls	WA_DistillateFuel_Kerosene_Sales_EndUse
14-40-04	ODS Emissions - EPA Module	.xls	EPA_IP_MODULE
14-40-05	Point Source Summary	.xls	PointSourceSummary
14-40-06	Ash Grove 2014 Emissions Report to EPA	.pdf	AshGrove_EPAEmissions
14-40-07	LaFarge 2014 Emissions Report to EPA	.pdf	LaFarge_EPAEmissions
14-40-08	Cement Sustainability Initiative "Getting the Numbers Right" US carbon intensity of clinker	.xls	CSI_GNR_CementIntensity_UnitedStates
14-40-10	January 2015 Mineral Industry Surveys - Cement, USGS	.pdf	2014CementUse
14-40-11	PSE natural gas emissions workbook	.xlsx	PSE_natural_gas_emissions
14-40-12	PSE emissions inventory 2014	.pdf	PSE_emissions_inventory
14-40-13a to g	Various Puget Sound Energy SEC filings listing natural gas sales	.pdf	PSE_sales_XXXX-XXXX
14-40-14	ODS emissions estimate for 2014	.xlsx	ODS_emissions_2014
14-50-0	**Waste**		
14-50-01	Wastewater treatment emissions	.doc	WWT_2013
14-50-02	2014 Seattle MSW GHG Inventory	.xls	SPU_MSW_GHGInventory
14-50-03	2014 SPU Construction and Demolition GHG Inventory	.xls	SPU_2014_CDL_GHG Inventory
14-50-04	2014 Seattle MDW GHG Inventory	.xls	GHGInventory_Interbay_MDW
14-50-05	SPU 3rd Quarter 2015 Garbage Report for Seattle	.pdf	SPU_Nov2015_GarbageReport
14-50-06	King County wastewater system facts	.pdf	KCWTD_facts
14-50-07	Seattle solid waste disposal calculations	.xlsx	Seattle_disposal
14-50-08	Seattle solid waste emissions calculations	.xlsx	Waste_calcs
14-50-09	EPA WARM model excerpted emissions factors	.xlsx	WARM_Efs
14-50-10a	2012 Seattle solid waste report	.pdf	2012_Seattle_solid_waste_report
14-50-10b	2014 Seattle solid waste report	.pdf	2014_Seattle_solid_waste_report
14-50-10c	2012 commercial and self-haul waste composition report	.pdf	2012_commercial_and_self-haul_waste_composition_report
14-50-10d	2014 residential waste composition report	.pdf	2014_residential_waste_composition_report
14-50-10e	1990 residential and self-haul waste composition report	.pdf	1990_residential_and_self-haul_waste_composition_report
14-50-10f	1988 and 1989 Seattle waste composition report	.pdf	1988_1989_waste_report

Call#	Subject	Ext.	Document title
14-60-0	**Electricity**		
14-60-01	WA Commerce State aggregate fuel mix time series	.xlsx	WACommercerCO2electricity
14-60-02	WA Commerce Fuel Mix Disclosure Report	.pdf	2014FuelMixDisclosure
14-60-03	SCL electricity sales for Seattle	.msg	SCL_electricity_Seattle
14-60-04	SCL carbon intensity of electricity	.pdf	SCL_carbon_intensity_of_electricity
14-60-05	SCL SF6 emissions estimate	.pdf	SCL_SF6_emissions
14-70-0	**Population and Employment**		
14-70-01	Population Counties 2000-2012	.xls	Pop_Counties
14-70-03	Population	.xls	Pop_Cities
14-70-16	Seattle DPD Employment Data	.pdf	DPD_Seattle_Employment_2014
14-70-17	Annual Estimates of the US and state population	.xls	Pop_US_and_State
14-70-18	U.S. Employment estimates	.xls	US_Employment
14-70-104	2013 Annual Average of Quarterly Census Employment and Wages (QCEW)	.xls	2013QCEW
14-70-105	2014 Annual Average of Quarterly Census Employment and Wages (QCEW)	.xls	2014QCEW
14-80-0	**Reference Docs**		
14-80-01	US GHG Inventory 2015, Annex 2, Emissions from fossil fuel combustion	.pdf	US-GHG-Inventory-2015-Annex-2-Emissions-from-Fossil-Fuel-Combustion
14-80-02	US GHG Inventory 2016, Annex 3, Methodological Descriptions for Additional Source or Si	.pdf	US_GHG_Inventory_2016_Annex_3_Additional_Source_or_Sink_Categories
14-80-03	Puget Sound Maritime Air Emissions Inventory, May 2013 Update	.pdf	EI_Full_Report

Appendix D. Population information

Some of the methodologies employed in this inventory involved scaling emissions estimates from one year by population or employment from other years, or from the state to county level. The population figures used in these estimates are listed in Table 24 below.

Table 24: Population Geographic Region and Employment Type

	1990	2005	2008	2012	2014
Seattle					
Residents	516,259	573,336	593,588	635,063	668,342
Commercial Employees	363,932	417,057	436,943	441,043	469,907
Industrial Employees	58,147	45,879	55,106	41,356	43,966
King County					
Residents	1,517,208	1,795,268	1,875,020	2,008,526	2,079,967
Commercial Employees	-	948,453	1,005,634	1,009,746	1,072,508
Industrial Employees	-	165,424	181,195	150,982	162,837
Washington					
Residents	4,903,043	6,257,304	6,562,231	6,897,292	7,063,166
Commercial Employees	-	2,243,114	2,383,847	2,384,842	2,501,439
Industrial Employees	-	432,773	473,002	407,180	435,569

Source Notes

Population: Resident populations were acquired from the U.S Bureau of the Census Population Estimates Program (www.census.gov/popest/). Population estimates can be found in **14-70-03** (Seattle), **14-70-01** and **12-70-02** (King County), and **12-70-13** and **12-70-14** (Washington State). Seattle Population in 1990 was taken from the Seattle Department of Planning and Development website **(12-70-15)**.

Employees: King County and Washington State employees were obtained from Annual Averages of the Quarterly Census of Employment and Wages (QCEW) available through the Washington State Employment Security Department **(12-70-100** to **14-70-105)**. Covered Employment for Seattle for 2005, 2008, and 2012 come from the Seattle Department of Planning and Development (DPD) (**14-70-16)**. All employment data are tabulated in workbook **12-70-11**. Industrial employees are taken as the sum of manufacturing and construction covered employment and commercial employees are the remainder less agriculture, forestry, fishing, and hunting.

Appendix E. Detailed tracking metrics

The table below presents detailed metrics that may be useful for tracking trends in underlying drivers that affect Seattle's emissions tracked in the main portion of this inventory (excluding emissions only included in the expanded inventory).

Emissions Source		1990	2005	2008	2012	2014	% change since: 1990	2008	2012
Population		516,259	573,336	593,588	635,063	668,342	29%	13%	5%
Transportation: Road									
	Emissions (Million MT CO2e)	2.1	2.3	2.3	2.3	2.3	8%	-2%	-1%
	Emissions per person (MT CO_2e/resident)	4.1	4.0	3.9	3.6	3.4	-16%	-13%	-6%
	Passenger emissions per person (MT CO_2e/resident)	3.1	3.1	3.0	2.7	2.6	-17%	-14%	-6%
	Freight emissions per person (MT CO2e/resident)	1.0	1.0	0.9	0.9	0.8	-13%	-11%	-4%
	Passenger VMT (billion miles)	3.4	3.9	4.0	4.1	4.2	24%	6%	3%
	Freight Truck VMT (billion miles)	0.37	0.43	0.44	0.46	0.47	26%	7%	3%
	Passenger VMT/person (thousand miles/resident)	6.6	6.8	6.7	6.5	6.3	-5%	-6%	-2%
	Freight Truck VMT/person (thousand miles/resident)	0.72	0.74	0.74	0.72	0.71	-3%	-5%	-2%
	VMT (billions miles)	3.8	4.3	4.4	4.6	4.7	24%	6%	3%
	VMT per resident (thousand miles/resident)	7.4	7.5	7.4	7.2	7.0	-4%	-6%	-2%
	Emissions per mile (kgCO2e/VMT)	0.55	0.54	0.53	0.50	0.49	-12%	-8%	-4%
	Passenger emissions per mile (kgCO2e/VMT)	0.47	0.45	0.45	0.42	0.41	-13%	-9%	-4%
	Freight truck emissions per mile (kgCO2e/VMT)	1.3	1.3	1.3	1.2	1.2	-11%	-7%	-3%
Buildings: Residential & Commercial									
	Emissions (Million MT CO2e)	1.3	1.2	1.3	1.1	1.1	-18%	-13%	-4%
	Residential Emissions (Million MT CO2e)	0.69	0.55	0.59	0.52	0.49	-29%	-17%	-7%
	Commercial Emissions (Million MT CO2e)	0.65	0.64	0.68	0.63	0.61	-6%	-10%	-2%
	Emissions per resident (MT CO_2e/resident)	2.6	2.1	2.1	1.8	1.6	-36%	-23%	-9%
	Residential emissions per resident (MT CO_2e/resident)	1.3	1.0	1.0	0.8	0.7	-45%	-26%	-11%
	Commercial emissions per resident (MT CO_2e/resident)	1.3	1.1	1.1	1.0	0.9	-27%	-20%	-7%
	Commercial emissions per employee (MT CO_2e/employee)	1.8	1.5	1.6	1.4	1.3	-27%	-16%	-8%
	Residential Energy use (trillion BTU)	20.0	19.0	18.1	17.3	16.6	-17%	-8%	-4%
	Natural gas (trillion BTU)	4.9	7.0	8.1	7.9	7.5	54%	-7%	-5%
	Heating oil (trillion BTU)	4.0	1.5	1.5	1.0	0.9	-78%	-40%	-11%
	Electricity (trillion BTU)	11.1	10.5	8.4	8.3	8.2	-27%	-3%	-2%
	Commercial energy use (trillion BTU)	19.9	26.0	26.8	26.6	26.5	33%	-1%	0%
	Natural gas (trillion BTU)	5.3	6.9	7.8	7.9	8.2	53%	4%	4%
	Heating oil (trillion BTU)	0.7	0.2	0.1	0.0	0.0	-95%	-73%	40%
	Steam (trillion BTU)	2.7	3.0	3.3	3.0	2.6	-3%	-22%	-11%
	Electricity (trillion BTU)	11.2	15.9	15.6	15.7	15.7	40%	1%	0%
	Total energy use (residential + commercial) (trillion BTU)	39.9	45.0	44.9	43.8	43.1	8%	-4%	-2%
	Residential energy per resident (million BTU/resident)	38.8	33.2	30.4	27.2	24.8	-36%	-18%	-9%
	Commercial energy per employee (million BTU/employee)	54.7	62.3	61.4	60.2	56.5	3%	-8%	-6%
	Heating degree days (HDD)	4,840	4,489	5,062	4,738	3,889	-20%	-23%	-18%
	Cooling degree days (CDD)	250	164	195	181	372	49%	91%	106%
	Emissions per GJ (kg CO_2e/million BTU)	33.5	26.5	28.2	26.2	25.5	-24%	-10%	-3%
	Residential GHG intensity of energy (kg CO_2e/million BTU)	34.3	29.0	32.4	30.2	29.3	-14%	-10%	-3%
	Commercial GHG intensity of energy (kg CO_2e/million BTU)	32.7	24.7	25.4	23.6	23.1	-29%	-9%	-2%
Waste Management									
	Emissions (Million MT CO_2e)	0.13	0.12	0.10	0.09	0.09	-33%	-14%	1%
	Emissions per resident (MT CO_2e/resident)	0.26	0.21	0.17	0.14	0.13	-48%	-24%	-4%
	Residential waste (tons)	140,528	134,557	127,219	111,420	112,211	-20%	-12%	1%
	Residential waste per resident (tons/resident)	0.27	0.23	0.21	0.18	0.17	-38%	-22%	-4%
	Nonresidential waste (tons)	317,317	306,345	267,685	204,563	191,936	-40%	-28%	-6%
	Nonresidential waste per resident (tons/employee)	0.61	0.53	0.45	0.32	0.29	-53%	-36%	-11%
	Emissions per ton disposed (MT CO_2e/ton)	0.94	0.88	0.81	0.78	0.79	-16%	-3%	1%
Total									
	Emissions (Million MT CO_2e)	**3.6**	**3.6**	**3.7**	**3.5**	**3.5**	**-3%**	**-6%**	**-2%**
	Emissions per resident (MT CO_2e/resident)	**6.9**	**6.3**	**6.2**	**5.6**	**5.2**	**-25%**	**-17%**	**-7%**

Appendix F. Community GHG emissions summary (ICLEI-US Format)

The data in this inventory were entered into ICLEI-USA's online inventory tool, ClearPath. To obtain the data entered into that tool in a format consistent with ICLEI-USA inventory reporting protocols, contact the City of Seattle's Office of Sustainability. Data in the ICLEI-USA inventory is not exactly analogous to the expanded view of this inventory, as ICLEI-USA employs slightly different emissions factors for various fuel uses and categorizes some emissions sources differently than they are categorized in this inventory.

Appendix G. Detailed Emissions Inventory Summary 1990-2014

	1990	2005	2008	2012	2014	% change since: 1990	2008	2012
TRANSPORTATION	**3,324,000**	**3,510,000**	**3,618,000**	**3,465,000**	**3,576,000**	**8%**	**-1%**	**3%**
Road: Passenger	**1,606,000**	**1,771,000**	**1,777,000**	**1,746,000**	**1,720,000**	**7%**	**-3%**	**-1%**
Cars & Light Duty Trucks	*1,557,000*	*1,711,000*	*1,714,000*	*1,677,000*	*1,653,000*	*6%*	*-4%*	*-1%*
Buses	*47,000*	*58,000*	*60,000*	*67,000*	*65,000*	*40%*	*9%*	*-2%*
Vanpool	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*21%*	*-5%*	*-1%*
Road: Freight	**502,000**	**549,000**	**563,000**	**560,000**	**563,000**	**12%**	**0%**	**1%**
Trucks	*502,000*	*549,000*	*563,000*	*560,000*	*563,000*	*12%*	*0%*	*1%*
Marine & Rail	**276,000**	**271,000**	**290,000**	**243,000**	**222,000**	**-19%**	**-23%**	**-8%**
Hotelling	*53,000*	*51,000*	*74,000*	*46,000*	*38,000*	*-29%*	*-49%*	*-17%*
State Ferries	*41,000*	*42,000*	*35,000*	*41,000*	*40,000*	*-1%*	*14%*	*-2%*
Pleasure Craft	*32,000*	*30,000*	*31,000*	*31,000*	*25,000*	*-21%*	*-19%*	*-18%*
Other Boat Traffic	*65,000*	*62,000*	*64,000*	*64,000*	*67,000*	*3%*	*4%*	*4%*
Rail - Freight	*85,000*	*81,000*	*79,000*	*53,000*	*43,000*	*-50%*	*-46%*	*-19%*
Rail - Passenger	*< 1,000*	*5,000*	*7,000*	*8,000*	*9,000*	*> 100%*	*36%*	*13%*
Air	**940,000**	**919,000**	**989,000**	**917,000**	**1,071,000**	**14%**	**8%**	**17%**
Sea-Tac Airport	*756,000*	*700,000*	*727,000*	*689,000*	*833,000*	*10%*	*15%*	*21%*
King County Airport	*184,000*	*219,000*	*262,000*	*228,000*	*238,000*	*29%*	*-9%*	*5%*
BUILDINGS	**1,481,000**	**1,344,000**	**1,423,000**	**1,316,000**	**1,274,000**	**-14%**	**-10%**	**-3%**
Residential	**705,000**	**569,000**	**602,000**	**540,000**	**504,000**	**-29%**	**-16%**	**-7%**
Electricity	*133,000*	*68,000*	*45,000*	*28,000*	*22,000*	*-84%*	*-51%*	*-23%*
Natural Gas	*259,000*	*371,000*	*432,000*	*420,000*	*399,000*	*54%*	*-7%*	*-5%*
Oil	*294,000*	*113,000*	*109,000*	*73,000*	*65,000*	*-78%*	*-40%*	*-11%*
Yard Equipment	*20,000*	*17,000*	*17,000*	*18,000*	*18,000*	*-10%*	*3%*	*-3%*
Commercial	**776,000**	**775,000**	**820,000**	**776,000**	**770,000**	**-1%**	**-6%**	**-1%**
Electricity	*169,000*	*102,000*	*82,000*	*53,000*	*42,000*	*-75%*	*-49%*	*-22%*
Natural Gas	*281,000*	*363,000*	*413,000*	*416,000*	*431,000*	*53%*	*4%*	*4%*
Oil	*57,000*	*17,000*	*8,000*	*2,000*	*2,000*	*-96%*	*-73%*	*40%*
Steam	*144,000*	*160,000*	*177,000*	*156,000*	*138,000*	*-4%*	*-22%*	*-11%*
Equipment	*124,000*	*133,000*	*140,000*	*149,000*	*156,000*	*26%*	*12%*	*5%*
INDUSTRY	**988,000**	**1,386,000**	**1,323,000**	**852,000**	**1,001,000**	**1%**	**-24%**	**18%**
Cement	**417,000**	**861,000**	**746,000**	**307,000**	**523,000**	**25%**	**-30%**	**70%**
Fuel Combustion	*211,000*	*377,000*	*353,000*	*-*	*-*	*-*	*-*	*-*
Clinker Calcination	*206,000*	*484,000*	*393,000*	*-*	*-*	*-*	*-*	*-*
Other - Energy Use	**519,000**	**457,000**	**513,000**	**487,000**	**419,000**	**-19%**	**-18%**	**-14%**
Electricity	*62,000*	*26,000*	*17,000*	*10,000*	*8,000*	*-86%*	*-52%*	*-20%*
Natural Gas	*266,000*	*257,000*	*246,000*	*270,000*	*207,000*	*-22%*	*-16%*	*-24%*
Oil	*49,000*	*11,000*	*36,000*	*15,000*	*14,000*	*-71%*	*-61%*	*-8%*
Industrial Equipment	*142,000*	*162,000*	*214,000*	*191,000*	*190,000*	*34%*	*-11%*	*0%*
Other - Process	**20,000**	**37,000**	**40,000**	**39,000**	**40,000**	**97%**	**0%**	**2%**
Steel & Glass	*20,000*	*37,000*	*40,000*	*39,000*	*40,000*	*97%*	*0%*	*2%*
Fugitive Gases	**31,000**	**30,000**	**24,000**	**19,000**	**19,000**	**-39%**	**-20%**	**0%**
SF6 from Switchgear	*10,000*	*5,000*	*2,000*	*1,000*	*3,000*	*-72%*	*50%*	*310%*
PSE Gas Distribution	*21,000*	*25,000*	*22,000*	*18,000*	*16,000*	*-24%*	*-26%*	*-11%*
WASTE	**134,000**	**120,000**	**105,000**	**89,000**	**91,000**	**-32%**	**-14%**	**2%**
Waste	**134,000**	**120,000**	**105,000**	**89,000**	**91,000**	**-32%**	**-14%**	**2%**
Waste Management	*133,000*	*118,000*	*103,000*	*87,000*	*88,000*	*-33%*	*-14%*	*1%*
Wastewater Treatment	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*42%*	*23%*	*23%*
TOTAL EMISSIONS	**5,927,000**	**6,360,000**	**6,469,000**	**5,723,000**	**5,942,000**	**0%**	**-8%**	**4%**
Per resident	**11.5**	**11.1**	**10.9**	**9.0**	**9.4**	**-19%**	**-14%**	**4%**
GHG OFFSETS		**-196,000**	**-144,000**	**-91,000**	**-72,000**			
SCL offsets		**-196,000**	**-144,000**	**-91,000**	**-72,000**			
TOTAL AFTER OFFSETS	**5,927,000**	**6,164,000**	**6,325,000**	**5,631,000**	**5,870,000**	**-1%**	**-7%**	**4%**
Per resident	**11.5**	**10.8**	**10.7**	**8.9**	**8.8**	**-24%**	**-18%**	**-1%**