2016 Seattle Community Greenhouse Gas Emissions Inventory

A snapshot of the City of Seattle's community-wide GHG emissions across the transportation, buildings, waste, and industrial sectors.

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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.

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Dear Friends and Partners,

The challenge of climate change has never been more pressing. The most recent report from the world's leading climate scientists, the International Panel on Climate Change, forecasts devastating and irreversible impacts to the planet if the world does not drastically reduce pollution by 2030.

Climate change is a global challenge and carbon pollution knows no boundaries. The United States is the largest historic emitter of greenhouse gases, requiring us to take meaningful action. While our federal government has failed on climate, cities and states are prioritizing the health of our communities by moving forward with bold and progressive climate actions. In Seattle, we have the resources necessary to do our part to reduce carbon pollution, including a spirit of innovation and a long-standing commitment to protect our environment.

We conduct GHG emissions inventories to better understand the scope and scale of our local emissions, the impact of our actions, opportunities for progress, and the challenges ahead. The 2016 inventory includes both good news and a call to action. Since our baseline year of 2008, we have reduced our emissions 5% while our population has grown 18%, resulting in a per-person emissions decrease of 20%. Seattle's annual per-person emission rate of 4.3 metric tons of CO_2e points to us being one of the most climate friendly cities in the nation.

At the same time, our overall emissions reductions are not on pace to meet our climate goals. We need to achieve a 58% reduction by 2030 to keep us on track to our ultimate goal of carbon neutrality by 2050. In order to achieve our goal of Seattle becoming a carbon neutral city, we need to increase the pace of our emissions reductions by sevenfold.

Our greatest asset in meeting this challenge is our locally produced clean and carbon-neutral electricity. Drive Clean Seattle is positioning Seattle to lead the way to accelerate the transition to an electric transportation system. Our building energy code leads the nation, and our incentives and programs to support building efficiency and reduce emissions are models for other cities.

However, we must build on this leadership and think bigger and act faster. Mayor Durkan's Climate Action Strategy is the right next step. By advancing vehicle electrification, exploring congestion pricing, and improving building performance for both energy and emissions reductions, we can lead the way while making our air and water cleaner, our homes safer, and Seattle more livable. Delivering on these strategies requires the whole community to rally together to protect our planet, our city and our children. I know Seattleites are up for the challenge and I look forward to working together to meet the promise of our clean energy future.

Jessica Finn Coven, Director
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INTRODUCTION

Seattle's Climate Action Plan (CAP)[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]. In early 2018, Mayor Durkan established an agenda of bold climate actions to further the goals of Seattle's 2013 CAP. The Mayor's Strategy includes transformative actions to accelerate the pace of reductions in the transportation and buildings sectors.

By understanding the sources and magnitude 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 inventory of 2016 emissions continues a series of similar inventories conducted every two to three years since 2005. 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 City's emissions reduction goals are 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. Therefore, it is useful to consider emissions on a per resident basis as well in order to understand trends and the effectiveness of the policies and programs designed to reduce emissions.

This 2016 inventory shows that total emissions have decreased 5% since 2008 and per-resident emissions have decreased 20%. Our carbon-neutral electricity also represents our greatest opportunity to reduce emissions at scale. By shifting from dirty fossil fuels - "natural" gas, fuel oil, gasoline, and diesel - to City Light's clean electricity, we can create a carbon neutral city with cleaner air and water and increase local control over our energy sources.

Mayor Durkan's Climate Action Strategy is designed to foster the efficient use of energy, shift use of fossil fuels to clean electricity, electrify our transportation system, reduce the need to use cars to get around, and spur innovative approaches to these challenges. Highlights from the Mayor's Strategy include:

Reducing Transportation Emissions

- Developing a strategy to address congestion and emissions through pricing and expanding transit in underserved communities
- Piloting a permit program for installing electric vehicle charging on public streets
- Installing public and residential EV charging infrastructure
- Ensuring new parking is built with electric vehicle infrastructure

[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.

- Accelerating adoption of electric vehicles by ride share providers
- Phasing out fossil fuels in the City's vehicle fleet

Reducing Building Emissions

- Offering utility incentives for actual performance rather than projected savings
- Developing minimum performance standards for existing buildings
- Incentivizing the switch from oil heat to clean electricity
- Advancing energy codes requiring new buildings to be highly efficient
- Incentivizing the highest performing developments with additional height and floor area
- Phasing out fossil fuels in the City's building portfolio

These strategies are focused on reducing our largest sources of emissions – building and transportation energy use. Inventory data has informed the strategies and provides useful data to help monitor our progress over time. The 2016 inventory results highlight the magnitude of reductions still needed to meet our goals. The strategies listed above are critical to accelerating the pace and scale of reductions to put the city on the path to achieve a 58% emissions reduction by 2030 and net zero carbon by 2050.

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. The inventory methods used here are guided by ICLEI-USA's U.S. Community Protocol for Accounting and Reporting Greenhouse Gas Emissions and the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories. 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.

Seattle's Clean Electric Grid

About 90% of the electricity that Seattle City Light (SCL) provides to consumers in Seattle comes from low-carbon hydroelectric dams. SCL purchases carbon offsets equal to the greenhouse gas emissions resulting from all other aspects of SCL's operations, including those created by fossil fuels included in the mix of power the utility buys, employees' travel, and the trucks and other equipment used in its operations. Because of variation in hydroelectricity production, the need to purchase power, and hence the amount of carbon offsets that SCL purchases varies annually. These offsets are included as emissions reductions at the bottom of Table 1 and Table 2.

Key Findings

The 2016 GHG Inventory reveals some encouraging trends. Per-person emissions continued to decline as Seattleites drove fewer miles in cleaner cars, used less energy to heat and power our buildings, and diverted more waste, particularly food scraps, from landfills. Total emissions declined 5% since 2008, which is notable as our population grew 18% in that same period. While a 5% decline during a period of rapid growth is impressive, this rate of reduction is not adequate to meet our mid-term targets and our 2050 goal of carbon neutrality. Looking at the trends identified in the inventory is important to understanding the opportunities and challenges in meeting our goals.

Changes in core emissions since 2008 include:

- **Total emissions** declined 5%, as our population grew 18% and employment grew 16%. Per-person emissions declined 20%.
- **Road transportation emissions** have remained relatively flat, with a 1% decrease. Per-person emissions declined 17%.
    - Between 2014 and 2016 passenger and commercial vehicle emissions increased slightly (1%), offsetting earlier reductions from 2008-2014 (2%).
    - Between 2014 and 2016 passenger and commercial vehicle miles increased a combined 5%, continuing an upward trend from 2012 after seeing steady reductions from 2008 - 2012.

- **Building emissions** declined 13%. Per-person emissions declined 27%.
    - Between 2014 and 2016, building emissions increased slightly. During this time:
        - City Light purchased more fossil fuel power on the market. While City Light purchases offsets for these emissions, the Protocols guiding this inventory require emissions reductions from offsets to be reported separate from total emissions.
        - Emissions from steam increased as the downtown district energy system replaced the portion of fuel previously provided by biomass with additional fossil gas.
- **Waste emissions** declined 19%, while per-person emissions declined 32%.
    - Between 2014 and 2016 waste emissions declined 6%, as more food scraps were composted.

Table 1: Seattle's core greenhouse gas emissions by sector (metric tons CO_2e)

	2008	2012	2014	2016	% change since 2008	% change since 2014
TRANSPORTATION	**2,005,000**	**1,962,000**	**1,969,000**	**1,990,000**	**-1%**	**1%**
Road: Passenger	**1,715,000**	**1,677,000**	**1,679,000**	**1,691,000**	**-1%**	**1%**
Cars & Light Duty Trucks	*1,655,000*	*1,610,000*	*1,614,000*	*1,626,000*	*-2%*	*1%*
Buses	*60,000*	*67,000*	*65,000*	*65,000*	*9%*	*0%*
Road: Trucks	**289,000**	**285,000**	**290,000**	**298,000**	**3%**	**3%**
Medium & Heavy	*289,000*	*285,000*	*290,000*	*298,000*	*3%*	*3%*
BUILDINGS	**1,274,000**	**1,153,000**	**1,102,000**	**1,109,000**	**-13%**	**1%**
Residential	**589,000**	**524,000**	**488,000**	**481,000**	**-18%**	**-1%**
Electricity	*49,000*	*31,000*	*23,000*	*36,000*	*-27%*	*54%*
Natural Gas	*432,000*	*420,000*	*399,000*	*383,000*	*-11%*	*-4%*
Oil	*109,000*	*73,000*	*65,000*	*63,000*	*-42%*	*-4%*
Commercial	**685,000**	**629,000**	**615,000**	**629,000**	**-8%**	**2%**
Electricity	*87,000*	*55,000*	*43,000*	*67,000*	*-23%*	*56%*
Natural Gas	*413,000*	*416,000*	*431,000*	*409,000*	*-1%*	*-5%*
Oil	*8,000*	*2,000*	*2,000*	*1,000*	*-91%*	*-69%*
Steam	*177,000*	*156,000*	*138,000*	*152,000*	*-22%*	*-11%*
WASTE	**103,000**	**87,000**	**88,000**	**83,000**	**-19%**	**-6%**
Waste Management	*103,000*	*87,000*	*88,000*	*83,000*	*-20%*	*-6%*
TOTAL EMISSIONS	**3,382,000**	**3,202,000**	**3,160,000**	**3,182,000**	**-5%**	**1%**
Per resident	**5.7**	**5.0**	**4.7**	**4.5**	**-21%**	**-4%**
GHG OFFSETS	**-136,000**	**-86,000**	**-66,000**	**-103,000**		
SCL Offsets	**-136,000**	**-86,000**	**-66,000**	**-103,000**		
TOTAL AFTER OFFSETS	**3,246,000**	**3,116,000**	**3,094,000**	**3,079,000**	**-5%**	**0%**
Per resident	**5.5**	**4.9**	**4.6**	**4.4**	**-20%**	**-6%**

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

	2008	2012	2014	2016	% change since 2008	% change since 2014
TRANSPORTATION	**3.4**	**3.1**	**2.9**	**2.8**	**-16%**	**-4%**
Road: Passenger	2.9	2.6	2.5	2.4	-17%	-4%
Road: Trucks	0.5	0.4	0.4	0.4	-13%	-2%
BUILDINGS	**2.1**	**1.8**	**1.6**	**1.6**	**-27%**	**-4%**
Residential	1.0	0.8	0.7	0.7	-31%	-6%
Commercial	1.2	1.0	0.9	0.9	-23%	-3%
WASTE	**0.2**	**0.1**	**0.1**	**0.1**	**-32%**	**-11%**
Waste Management	0.2	0.1	0.1	0.1	-32%	-11%
TOTAL PER RESIDENT	**5.7**	**5.0**	**4.7**	**4.5**	**-21%**	**-4%**
GHG OFFSETS	**-0.2**	**-0.1**	**-0.1**	**-0.1**		
SCL Offsets	-0.2	-0.1	-0.1	-0.1		
TOTAL AFTER OFFSETS	**5.5**	**4.9**	**4.6**	**4.4**	**-20%**	**-6%**

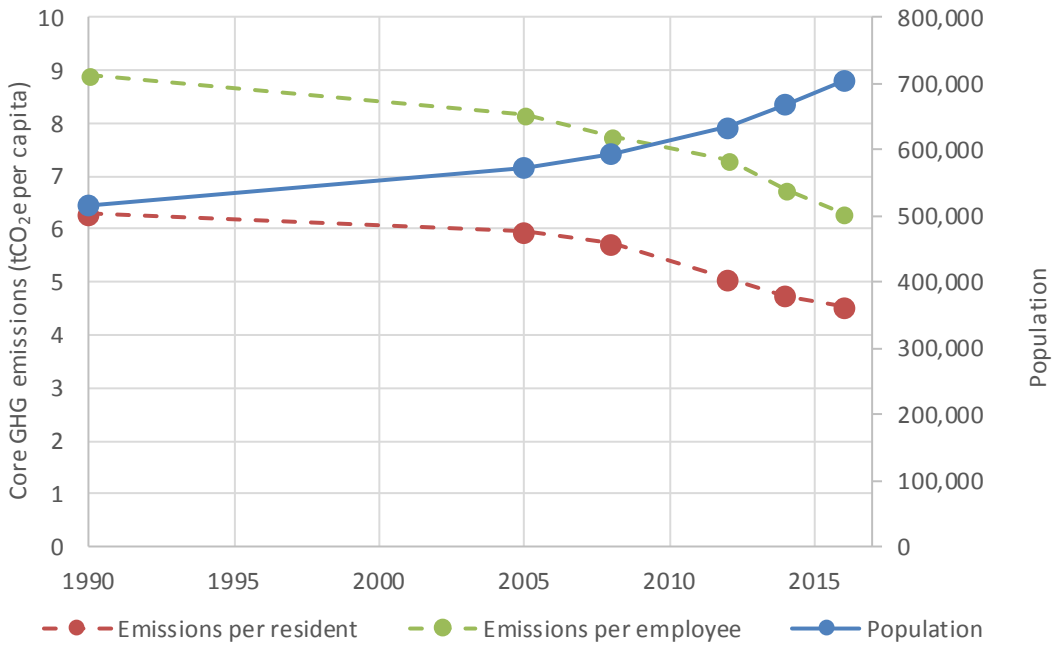


Figure 1: Greenhouse gas emissions per resident have declined as population has increased.

Figure 2 depicts the relative contribution of the transportation, buildings, and waste sectors to city-wide core emissions. The relative contribution of these emissions categories has remained relatively consistent since 1990, though the share attributed to buildings has declined from about 40% in 1990 and 2008 to about 35% in 2016.

Passenger vehicles include single- and high-occupancy cars, SUVs, passenger vans, motorcycles, light trucks, and buses. Commercial trucks include medium and heavy commercial trucks. Residential buildings include single- and multi-family residential units (excluding common spaces such as lobbies, hallways etc.). Commercial buildings include small, medium and large businesses, as well as the commercial spaces within multifamily buildings.

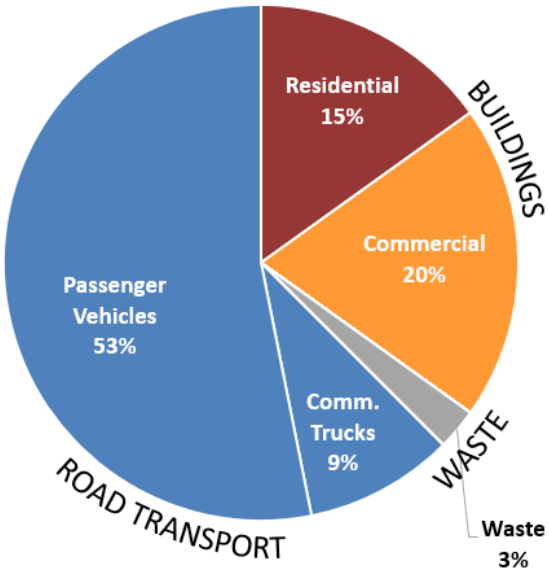


Figure 2: Seattle's 2016 core emissions by sector.

Figure 3 below includes a summary of the changes in emissions per resident between 2008 and 2016. The larger bars for 2008 and 2016 indicate the total emissions, while the smaller bars represent the specific factors within each sector, and associated emissions reductions, that occurred during this time. More efficient passenger vehicles, lower passenger vehicle travel, warmer weather (reducing heating demand in buildings), and more efficient residential energy use represented the largest decreases in emissions per resident between 2008 and 2016.

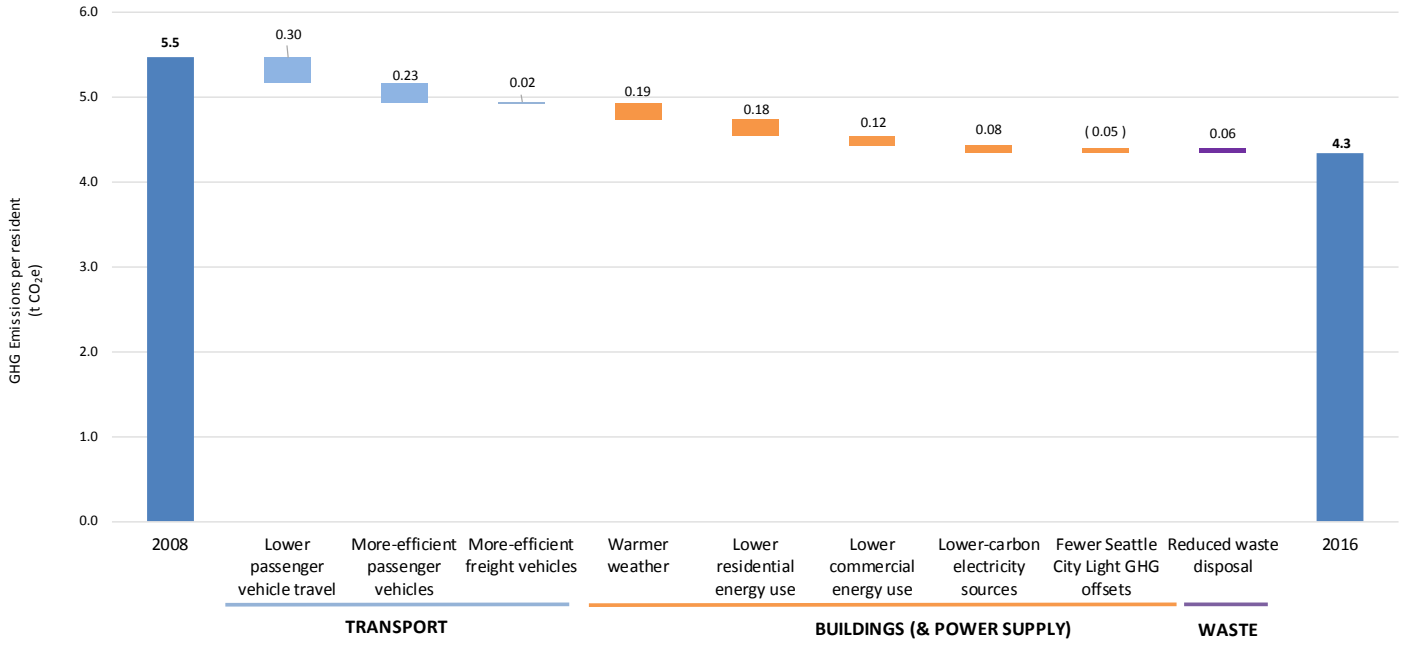


Figure 3: Factors explaining the change in emissions per resident between 2008 and 2016.

Road Transport

Road transportation has been the largest category of emissions since Seattle started tracking emissions in 1990. Total emissions in this sector increased through 2008; however, they have been decreasing since 2008 due to changes in the fuel economy of vehicles and changes in miles traveled. Advances in vehicle technology have increased the average fuel economy for cars in Seattle from about 20 miles per gallon of fuel in 2008 to about 22 miles per gallon in 2016. 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 2016. 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 1% since 2008) and decreased emissions *per resident* (down 10% during this period).

Reducing Transportation Emissions

Seattle is reducing emissions by promoting electrified public transit and making electric vehicles the easy choice when residents do need to drive:

- Developing a strategy to address congestion and emissions through pricing and expanding transit in underserved communities
- Piloting a permit program for installing electric vehicle charging on public streets
- Ensuring new parking is built with electric vehicle infrastructure
- Accelerating adoption of electric vehicles by ride share providers
- Phasing out fossil fuels in the City's vehicle fleet

Learn More

While absolute emissions have remained relatively unchanged from 2014, per-resident emissions reduced by 4% between 2014 and 2016. Seattle's Climate Action Plan (CAP) set a target of reducing passenger vehicle emissions by 82% over a 2008 baseline. In order to reach this target, Seattle requires an annual emissions reduction of roughly 7.5% in this sector from 2008 to 2030. So far, the City has managed just a 0.2% annual emissions reduction rate from 2008 to 2016. Annual passenger vehicle emissions will need to reduce by about 11.4% from 2016 onwards to meet the CAP goal.[3]

[3] Please refer to Appendix C for a sector-specific breakdown of progress towards 2030 emissions reduction goals.

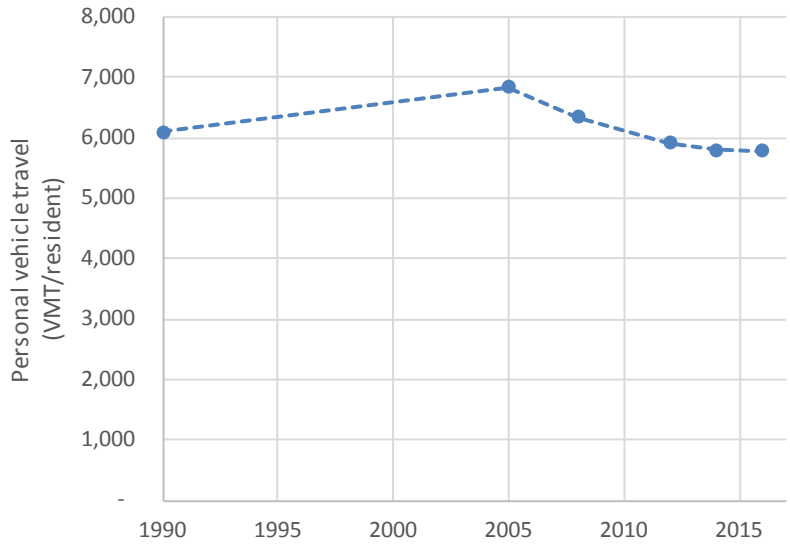


Figure 4: Seattle's passenger vehicle travel per resident over time (origin-destination-pair basis).

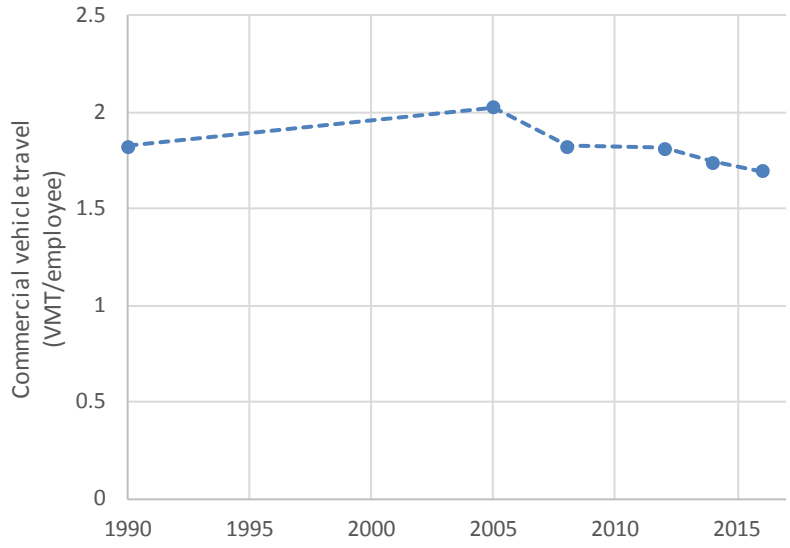


Figure 5: Seattle's commercial vehicle travel per employee over time (origin-destination-pair basis).

Building Energy

Energy used by buildings is the other major source of Seattle's GHG emissions. Building energy use can create GHG emissions both directly, through the burning of fossil fuels within a building, such as oil or natural gas to generate heat, and indirectly, through the GHG emissions that result from generating the electricity used in buildings to create steam for district energy systems.[4] Total emissions related to building energy use declined consistently between 2008 and 2014, averaging 2.3% per year, followed by a slight increase (1%) between 2014 and 2016. Between 2008 and 2016, per-capita building-related emissions declined as a result of lower building energy use, particularly for residential buildings (Figure 6), due to energy efficiency, more multi-family living, and especially due to warmer weather that reduced heating needs. Per-capital commercial energy use has also begun to decline since 2008 though at a slower rate (Figure 7).

Reducing Building Emissions

Seattle is reducing emissions by supporting the efficient use of clean energy, and encouraging innovative building strategies:

- Requiring buildings to periodically assess their energy performance and make cost-saving improvements, and providing technical and financial assistance to support owners of smaller buildings
- Incentivizing the switch from oil to clean electricity
- Advancing energy codes requiring new buildings to be highly efficient
- Incentivizing the highest performing developments with additional height and floor area
- Offering utility incentives for actual performance rather than projected savings

Learn More

Seattle's Climate Action Plan (CAP) set a target of reducing building sector emissions by 39% over a 2008 baseline. In order to reach this target, Seattle requires an annual emissions reduction of roughly 2.2% from 2008 to 2030. So far, the City has managed a 1.7% annual emissions reduction rate from 2008 to 2016. Annual emissions will need to reduce by about 2.5% from 2016 onwards to meet the CAP goal.[5]

[4]About 90% of the electricity that Seattle City Light (SCL) provides to consumers in Seattle comes from low-carbon hydroelectric dams. SCL purchases carbon offsets equal to the greenhouse gas emissions resulting from all other aspects of SCL's operations, including those created by fossil fuels included in the mix of power the utility buys, employees' travel, and the trucks and other equipment used in its operations.

[5] Please refer to Appendix C for a sector-specific breakdown of progress towards 2030 emissions reduction goals.

Figure 6: Residential energy use per resident.

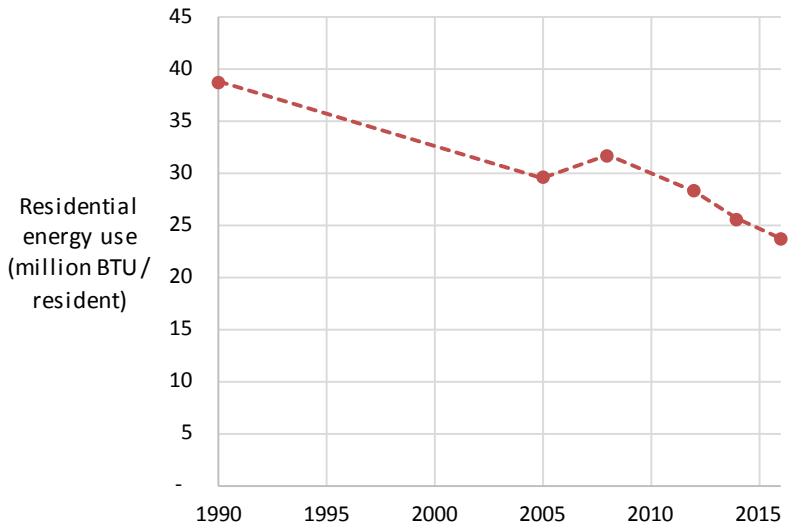
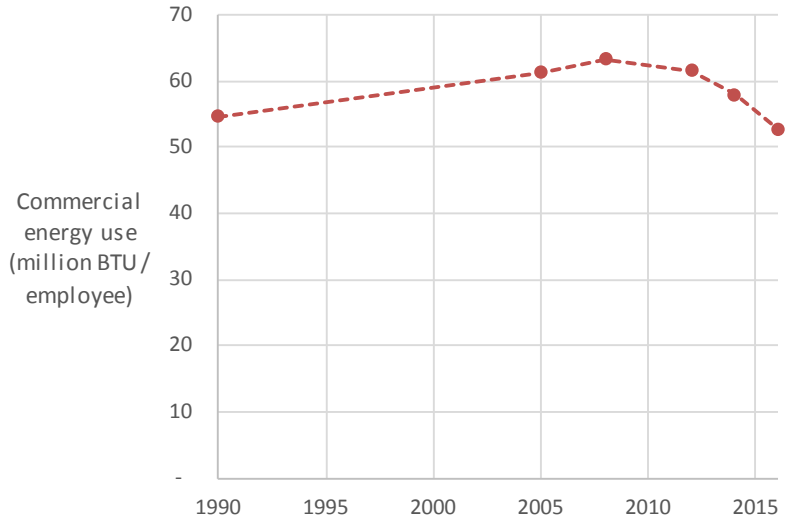


Figure 7: Commercial energy use per employee.



Waste

Emissions from waste management remain a relatively small component of Seattle's GHG emissions. These emissions declined 19% between 2008 and 2016, primarily as a result of continued reductions in the annual amount of waste landfilled. Seattle Public Utilities' (SPU's) effective waste management practices – particularly food scraps diversion – have been responsible for a 6% decrease in waste emissions from 2014 to 2016.

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 and businesses) 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;
- Wastewater treatment;
- Building equipment such as residential yard equipment, commercial landscaping equipment;
- Industrial equipment such as refrigeration units, forklifts, tractors etc.

Seattle's total GHG emissions in this expanded view are shown in Table 3. Seattle's total emissions, after offsets, declined by 4% between 2008 and 2016. During that same period, per-resident emissions declined 19% as population grew. Between 2014 and 2016, total emissions after offsets increased by 1% while per-resident emissions decreased by 4%. The following expanded categories had significant changes in emissions:

Category	**Emissions change, MT CO_2e (2008 to 2016)**	**Emissions change, MT CO_2e (2014 to 2016)**
Air Travel: increased air traffic at SeaTac Airport	+264,000 (27%)	+182,000 (17%)
Increased oil and natural gas use for industrial energy	+34,000 (3%)	+95,000 (26%)
Reduced cement production	-362,000 (49%)	-139,000 (27%)

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

	2008	2012	2014	2016	% change since 2008	% change since 2014
TRANSPORTATION	**3,220,000**	**3,098,000**	**3,251,000**	**3,455,000**	**7%**	**6%**
Road: Passenger	**1,715,000**	**1,677,000**	**1,679,000**	**1,691,000**	**-1%**	**1%**
Cars & Light Duty Trucks	*1,655,000*	*1,610,000*	*1,614,000*	*1,626,000*	*-2%*	*1%*
Buses	*60,000*	*67,000*	*65,000*	*65,000*	*9%*	*0%*
Road: Trucks	**289,000**	**285,000**	**290,000**	**298,000**	**3%**	**3%**
Medium & Heavy	*289,000*	*285,000*	*290,000*	*298,000*	*3%*	*3%*
Marine & Rail	**227,000**	**219,000**	**211,000**	**212,000**	**-7%**	**0%**
Hotelling	*53,000*	*43,000*	*37,000*	*36,000*	*-33%*	*-3%*
State Ferries	*35,000*	*41,000*	*40,000*	*44,000*	*25%*	*10%*
Pleasure Craft	*31,000*	*31,000*	*25,000*	*26,000*	*-18%*	*2%*
Other Boat Traffic	*59,000*	*61,000*	*76,000*	*74,000*	*26%*	*-2%*
Rail - Freight	*41,000*	*34,000*	*24,000*	*23,000*	*-44%*	*-3%*
Rail - Passenger	*7,000*	*8,000*	*9,000*	*9,000*	*32%*	*-3%*
Air	**989,000**	**917,000**	**1,071,000**	**1,253,000**	**27%**	**17%**
Sea-Tac Airport	*727,000*	*689,000*	*833,000*	*1,019,000*	*40%*	*22%*
King County Airport	*262,000*	*228,000*	*238,000*	*234,000*	*-11%*	*-2%*
BUILDINGS	**1,432,000**	**1,320,000**	**1,278,000**	**1,301,000**	**-9%**	**2%**
Residential	**607,000**	**542,000**	**505,000**	**499,000**	**-18%**	**-1%**
Electricity	*49,000*	*31,000*	*23,000*	*36,000*	*-27%*	*54%*
Natural Gas	*432,000*	*420,000*	*399,000*	*383,000*	*-11%*	*-4%*
Oil	*109,000*	*73,000*	*65,000*	*63,000*	*-42%*	*-4%*
Yard Equipment	*17,000*	*18,000*	*18,000*	*18,000*	*5%*	*2%*
Commercial	**825,000**	**778,000**	**772,000**	**802,000**	**-3%**	**4%**
Electricity	*87,000*	*55,000*	*43,000*	*67,000*	*-23%*	*56%*
Natural Gas	*413,000*	*416,000*	*431,000*	*409,000*	*-1%*	*-5%*
Oil	*8,000*	*2,000*	*2,000*	*1,000*	*-91%*	*-69%*
Steam	*177,000*	*156,000*	*138,000*	*152,000*	*-22%*	*-11%*
Equipment	*140,000*	*149,000*	*158,000*	*173,000*	*24%*	*10%*
INDUSTRY	**1,357,000**	**913,000**	**1,105,000**	**1,023,000**	**-25%**	**-7%**
Cement	**746,000**	**307,000**	**523,000**	**384,000**	**-49%**	**-27%**
Fuel Combustion	*353,000*	-	-	-	-	-
Clinker Calcination	*393,000*	-	-	-	-	-
Other - Energy Use	**511,000**	**486,000**	**419,000**	**547,000**	**7%**	**31%**
Electricity	*15,000*	*10,000*	*8,000*	*11,000*	*-29%*	*41%*
Natural Gas	*246,000*	*270,000*	*207,000*	*296,000*	*20%*	*43%*
Oil	*36,000*	*15,000*	*14,000*	*19,000*	*-47%*	*36%*
Industrial Equipment	*214,000*	*191,000*	*190,000*	*221,000*	*3%*	*16%*
Other - Process	**77,000**	**101,000**	**144,000**	**73,000**	**-5%**	**-49%**
Steel & Glass	*77,000*	*101,000*	*144,000*	*73,000*	*-5%*	*-49%*
Fugitive Gases	**24,000**	**19,000**	**19,000**	**19,000**	**-18%**	**2%**
SF6 from Switchgear	*2,000*	*1,000*	*3,000*	*3,000*	*49%*	*-1%*
PSE Gas Distribution	*22,000*	*18,000*	*16,000*	*17,000*	*-24%*	*3%*
WASTE	**105,000**	**89,000**	**91,000**	**85,000**	**-19%**	**-6%**
Waste	**105,000**	**89,000**	**91,000**	**85,000**	**-19%**	**-6%**
Waste Management	*103,000*	*87,000*	*88,000*	*83,000*	*-20%*	*-6%*
Wastewater Treatment	*2,000*	*2,000*	*2,000*	*2,000*	*29%*	*4%*
TOTAL EMISSIONS	**6,114,000**	**5,421,000**	**5,724,000**	**5,865,000**	**-4%**	**2%**
Per resident	**10.3**	**8.5**	**8.6**	**8.3**	**-19%**	**-3%**
GHG OFFSETS	**-151,000**	**-96,000**	**-74,000**	**-114,000**		
SCL offsets	**-151,000**	**-96,000**	**-74,000**	**-114,000**		
TOTAL AFTER OFFSETS	**5,964,000**	**5,325,000**	**5,651,000**	**5,751,000**	**-4%**	**2%**
Per resident	**10.0**	**8.4**	**8.5**	**8.2**	**-19%**	**-3%**

Some of the factors that caused changes in Seattle's total GHG emissions under this expanded view are shown in Figure 8.[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 since 2008 to source its electricity from lower-carbon sources further reduced emissions. Industrial emissions also declined between 2008 and 2016. The net effect of the factors resulted in a small decline in GHG emissions between 2008 and 2016.

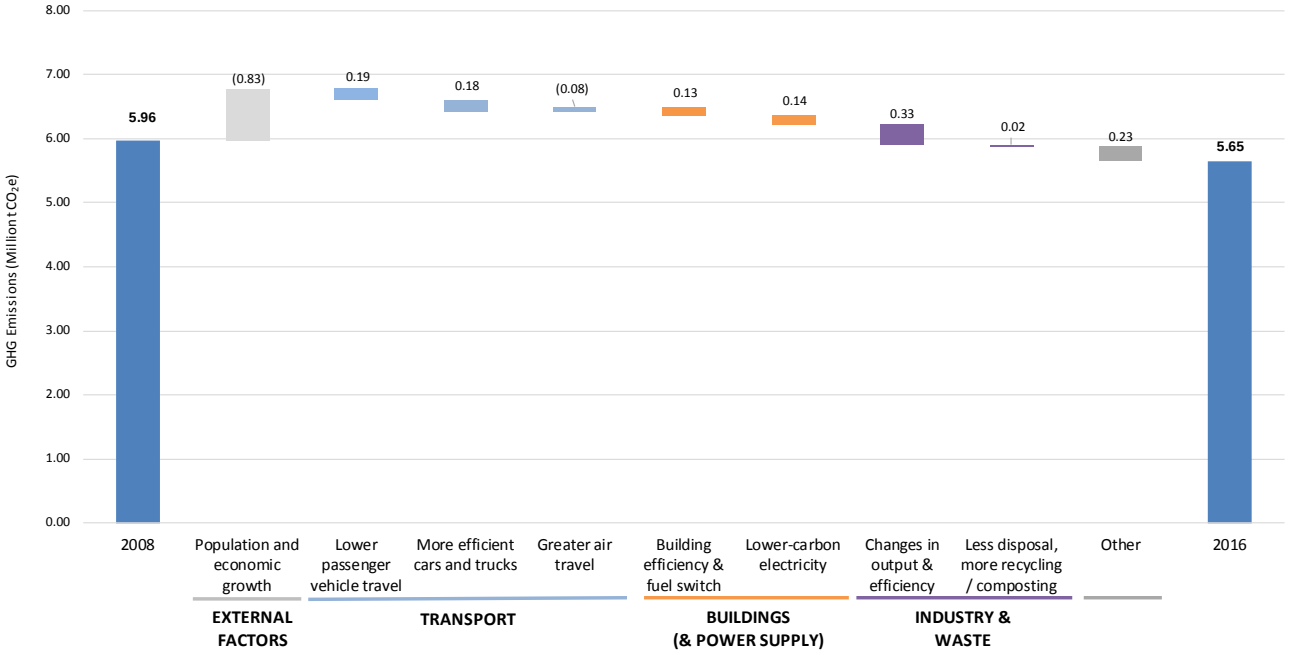


Figure 8: Multiple factors led to changes in Seattle's GHG emissions under the expanded view.

[6] While Figure 3 and Figure 8 appear similar, Figure 3 tracks changes in emissions *per resident* from core emissions sources, while Figure 8 shows changes in *absolute* emissions from all sources included in this inventory.

CONCLUSIONS

Seattle's 2030 climate goals call for a reduction of core emissions by 58% from 2008 levels. Additionally, Seattle has committed to reducing net emissions (including offsets) to zero by 2050.[7] 2016's emissions figures – around 6% lower than 2008 emissions – means that in the past eight years, Seattle has achieved an average annual emissions reduction rate of 0.8%.[8]

Seattle's overall reduction in emissions from the 2008 baseline year to 2016 can primarily be attributed to reduced passenger vehicle travel and more efficient cars, improvements in building energy performance, and warmer weather that led to lower heating demands in 2016 compared to 2008. That emissions are declining despite significant increases in population and job growth is noteworthy. However, the rate of absolute emissions reductions needs to increase if the City is to stay on track with its carbon reduction goals.

[7] Please refer to Appendix C for a sector-specific breakdown of progress towards 2030 emissions reduction goals.

[8] There are many pathways to get to Seattle's goal – including pathways that accelerate near-term emissions as a means to create greater cumulative emissions reductions between now and 2030. The average figure presented here are meant only to provide an indication of one possible pathway.

Detailed Results & Methodology by Sector

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

Transportation

The expanded 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 in core emissions includes the emissions from fuel use by both passenger and freight vehicles (Table 4). The Puget Sound Regional Council (PSRC) modeled and provided an estimate of vehicle miles traveled (VMT) on streets and highways[9]. Vehicle fuel economy was estimated using results from vehicle stock models maintained by PSRC. 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 seen a minor reduction between 2008 and 2016. Despite a 19% increase in population from 2008 to 2016, vehicle emissions intensity has decreased over the same period (by around 10% for passenger cars), as has per-person personal vehicle travel (9%). Seattle's Climate Action Plan sets a target of an 82% reduction in passenger vehicle emissions over 2008 levels by 2030. Details on progress towards this goal is included in Appendix C.

Table 4: Road transportation core emissions (metric tons CO_2e).

	Emissions, $MgCO_2e$					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Cars & light passenger trucks	1,395,761	1,718,595	1,655,286	1,610,218	1,613,548	1,625,891
Buses	46,623	57,720	59,980	66,912	65,346	65,500
Commercial trucks	242,083	301,043	289,319	284,994	290,237	298,465
Totals	1,684,466	2,077,358	2,004,586	1,962,123	1,969,131	1,989,855

[9] PSRC's model was revised for 2016, resulting in the need to "back-cast" data for prior years in the inventory model. This update is explained further in the Source Notes section.

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 (single-occupancy vehicles and carpools) and trucks (medium and heavy duty). To estimate VMT for 2016, PSRC's modeled VMT results for 2014 ***(16-11-05)*** *were scaled by a ratio of 2014 total VMT on state highways in urban King County to that from 2016 provided by the Washington State Department of Transportation (****16-11-09****). 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.*

PSRC's modeled VMT results for 2014 used a different methodology from earlier years. Given this updated methodology, results from 2014 were used as the "revised base year." Previously calculated VMT for 1990, 2005, 2008, 2012 were indexed to this new base year.

In order to calculate emissions, annual VMT were multiplied by emissions factors derived from modeling by PSRC for King County. PSRC provided estimates of vehicle fuel efficiency for Seattle by vehicle class (cars, light trucks, etc.) for 2005 through 2016. For each vehicle category in PSRC's VMT model results (i.e. passenger vehicles, commercial trucks), a composite fuel economy figure was calculated using a weighted average based on the VMT of the vehicle classes in that category. 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 ***(16-80-01)****. The methodology for fuel economy calculation is a simplified version of the approach taken in prior years. Previously calculated fuel economy figures have consequently been updated in the inventory.*

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 ***(16-11-13)****. 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)* ***(16-11-14)****.*

Calculation steps and data sources for Road Transportation are listed in ***16-00-0_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 2014 model results to 2016 and prior years based on data from WSDOT.*

Expanded Inventory

Marine & Rail Transportation

Marine and rail transportation are not included in Seattle's core emissions, and comprised a minor share (3.7%) of the expanded GHG inventory for 2016. 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.[10] Marine and rail transportation emissions decreased 7% 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 5.

Table 5: Marine & rail transportation emissions (metric tons CO_2e).

	Emissions, $MgCO_2e$					
Marine	**1990**	**2005**	**2008**	**2012**	**2014**	**2016**
Pleasure craft, diesel	4,938	5,329	5,517	6,297	5,875	5,990
Pleasure craft, gasoline	27,183	24,885	25,764	24,356	19,367	19,746
Washington State ferries	40,734	42,142	35,324	41,293	40,280	44,267
Other ship & boat traffic	59,297	56,534	59,045	61,476	75,680	74,241
Hotelling	57,542	54,861	53,293	43,346	36,812	35,631
Totals	189,693	183,751	178,944	176,768	178,015	179,875

	Emissions, $MgCO_2e$					
Rail	**1990**	**2005**	**2008**	**2012**	**2014**	**2016**
Freight	44,588	42,510	41,296	33,961	23,862	23,097
Passenger	460	5,464	6,918	8,361	9,438	9,130
Totals	45,049	47,975	48,214	42,323	33,300	32,227

SOURCE NOTES

***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 **(16-13-01)**. National average fuel use per mile was scaled by the number of riders on the Cascade route, as reported by Amtrak **(16-13-02)**. 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 **(16-11-13)**. 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.*

***Rail - Freight:** Freight rail emissions were taken directly from the 2016 Puget Sound Maritime Air Emissions Inventory **(16-80-03)** estimates of locomotive related emissions associated with the Port of Seattle (Table 9.56) and the Northwest Seaport Alliance North Harbor (Table 9.49), both in Seattle. These include emissions arising from locomotive activity moving into or out of the ports, emissions while idling at the ports, and emissions from the trains as they travel in the greater Puget Sound region while traveling to or from the ports.*

Emissions for prior years were recalculated to use this same definition and were scaled to each inventory reporting year (e.g. 2014) from the closest year in which a Puget Sound Maritime Emissions Inventory was conducted (e.g., 2016) using the tonnage of cargo handled at the Seattle ports as reported in the Maritime Air Emissions inventories.

[10] 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

Pleasure Craft: *Marine pleasure craft emissions for 2016 were obtained directly from NONROAD modeling results for King County* ***(14-40-02).*** *Modeled emissions from 2016 were scaled by the Seattle fraction of King County population. The NONROAD model has not been updated for 2016, so data used for 2016 before scaling with population is identical to what was used in 2014.*

Other Ship and Boat Traffic: *Emissions for 2016 for all ships and boats other than the Washington State Ferries and recreational boats (see descriptions above) were based on the 2016 Puget Sound Maritime Air Emissions Inventory* ***(16-80-03).*** *These other types of vessels include large container ships, bulk cargo ships, and tankers as well as cruise ships, which collectively are called "Ocean Going Vessels", or OGVs. The emissions associated with these OGVs that are included in Seattle's inventory are for energy use when the ships are secured at berth at each port, termed "hoteling", as well as energy used during maneuvering of the vessels while entering and leaving port. All estimates for OGV hoteling and maneuvering emissions are taken from the Maritime Air Emissions Inventory, and were calculated as the sum of those from Northwest Seaport Alliance's North Harbor (Table 9.46) and Port of Seattle (Table 9.56) in the primary source* ***(16-80-03).*** *Other types of boats considered include tugboats, towboats, fishing vessels, and any other government or commercial vessel besides the ferries and recreational boats considered above, collectively called "harbor craft." Estimates for these emissions were adapted from those reported for King County* ***(16-80-03,*** *Table 4.5), all of which were assumed to be attributable to Seattle, since the two ports included in the Maritime Air Emissions Inventory – Port of Seattle and the Northwest Seaport Alliance North Harbor – are both in Seattle. The estimate from Table 4.5 was reduced by that source's estimate for recreational vessels (from Table 9.56), and then this Seattle inventory's estimate for ferries (as described above) was further deducted to leave just an estimate for harbor vessels other than ferries and recreational boats.*

Calculation steps and data sources for Marine & Rail transportation are listed in ***16-00-0_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.

Reducing Emissions at SeaTac

The Port of Seattle is advancing multiple strategies to reduce airport emissions, including:

- Partnering with 13 airlines to plan access to sustainable aviation fuel to meet the goal that every flight fueled at SeaTac Airport will be fueled with sustainable aviation fuel by 2028
- Providing pre-conditioned air to planes at gates so they don't have to run auxiliary engines
- Installing charging stations for electric ground support equipment
- Established environmental performance standards for taxis and TNCs serving the airport

Learn More

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 2016, 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 6.

Table 6: Air transportation emissions (metric tons CO_2e).

	Emissions, $MgCO_2e$					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
King County International Airport	183,986	219,030	261,931	227,878	238,175	234,152
Sea-Tac International Airport	756,287	700,234	726,641	689,228	832,637	1,018,939
Totals	940,273	919,264	988,573	917,107	1,070,812	1,253,091

SOURCE NOTES

Sea-Tac International Airport: *The Port of Seattle provided data for total jet fuel distributed to aircraft at Sea-Tac Airport (**16-14-06**). The fraction of emissions attributable to Seattle was estimated through a comparison of population in the city compared to the greater Puget Sound region, from which Sea-Tac draws the majority of its passengers. This methodology has been simplified from 2014 but has shown to yield similarly consistent results.*

King County International Airport: *King County International Airport (KCIA) provided data for jet fuel and aviation gas distributions in 2016 **(16-14-08)**. 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 **16-00-0_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 space heating and cooling, hot water, cooking, lighting, appliances, computers and other plug loads. The expanded view also includes emissions associated with other equipment used at buildings such as lawnmowers, generators, pressure washers etc.

Including all sources, expanded emissions in this sector declined about 10% between 2008 and 2016. Lower residential building emissions account for most of the decline. Seattle's Climate Action Plan sets a target of a 39% reduction in building emissions over 2008 levels by 2030. Details on progress towards this goal is included in Appendix C.

Core Inventory

Residential Building Energy

The vast majority of residential building emissions are associated with energy used for home heating, hot water, and appliances. 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 2016 relative to 2008. This can largely be attributed to less heating demand due to warmer temperatures, more efficient residential energy use, and lower-carbon electricity sources. Use of electricity, natural gas, and petroleum per resident have all declined between 2008 and 2016.

Table 7: Residential building emissions from site energy in metric tons of CO_2e.

	Emissions, MgCO2e					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Electricity	133,000	74,401	48,716	30,803	23,170	35,746
Direct Fuel Use						
Natural Gas	258,698	371,112	431,728	420,045	399,463	382,575
Oil	293,845	113,325	108,706	73,198	64,955	62,588
Totals	685,543	558,838	589,150	524,046	487,588	480,909

Table 8: Residential building site energy use in million Btu.

	Site Energy Consumption, Million Btu					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Electricity	11,135,416	8,430,934	9,221,131	9,048,915	8,687,007	8,646,577
Direct Fuel Use						
Natural Gas	4,903,337	7,004,371	8,148,439	7,927,928	7,539,466	7,220,722
Oil	3,975,985	1,533,389	1,470,889	990,432	878,904	846,874
Totals	20,014,738	16,968,694	18,840,460	17,967,275	17,105,377	16,714,172

Table 9: Residential building energy use in physical units by fuel type.

		Site Energy Consumption, Physical Units					
		1990	**2005**	**2008**	**2012**	**2014**	**2016**
Electricity	MWh	3,261,285	2,469,210	2,700,639	2,650,201	2,544,207	2,532,366
Direct Fuel Use							
Natural Gas	Therm	49,033,372	70,043,708	81,484,393	79,279,276	75,394,662	72,207,218
Oil	Gal	28,747,007	11,086,649	10,634,765	7,160,984	6,354,618	6,123,031

Household energy use per resident decreased 25% between 2008 and 2016 and 39% 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,[11] increased energy efficiency of lighting, appliances, and heating, and the ongoing conversions from oil heat to natural gas or electricity.[12]

[11] Though no data on actual floor area were identified, based on data from the Census Bureau's American Community Survey, since 2008, more than 90% of the net additions to households in Seattle have been (generally smaller) households in buildings with more than two units; for comparison, about half of the previously existing housing stock is units in buildings with more than two units.

[12] According to the U.S. Department of Energy, oil furnaces from 1970 or earlier have an efficiency of 56% to 70%, whereas gas furnaces from 2008 or newer have efficiencies of 90% or more. Electric resistance heat has a coefficient of power (COP) of 1, and heat pumps have COP values between 2 and 4. Based on permitting data, over 37,000 Seattle households have converted from oil heat to either gas or electric since 1996, with more than 12,000 of those households having switched since 2008.

RESIDENTIAL BUILDING SOURCE NOTES

*Fuel-specific emissions factors (gCO_2/liter) from the US EPA's national GHG inventory (**16-80-01**) were used for natural gas and oil.*

***Electricity:** Due to a change in billing systems, Seattle City Light (SCL) provided residential building electricity consumption within Seattle for 2016 as well as updated consumption info for years 2005 - 2014 **(16-60-03).** The new information constituted a change in data for prior years, and the inventory model was updated accordingly. Utility emission factors (tCO_2/MWh) remained the same for 2008 (or 1990?)-2014, and a new factor was provided for 2016 **(16-60-04)**. The SCL emission rate was multiplied by residential electricity consumption to obtain total emissions.*

***Direct Fuel Use (Natural Gas):** Puget Sound Energy (PSE) provided 2016 natural gas use by Seattle residences **(16-20-02)**.*

***Direct Fuel Use: (Heating Oil):** Seattle residential oil use was estimated from 2016 Washington State distillate fuel oil and kerosene sales by end-use, which is reported by the U.S. Energy Information Administration **(16-40-03)** and scaled to Seattle by the ratio of Seattle homes with oil heat to Washington State homes with oil heat as reported for 2016 by the U.S. Census Bureau American Fact Finder database **(16-20-01)**. 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 **(16-20-04, 16-20-08)**. 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 **16-00-0_MasterSpreadsheet 'SCL 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.*

Commercial Building Energy

Commercial building emissions result from the energy consumed by businesses (such as offices, hospitals, restaurants and retail), and institutional facilities (such as government buildings and schools). Many downtown Seattle buildings are heated by gas-fired steam generated by Enwave. In addition, many institutional facilities (such as the University of Washington and Seattle Center) operate their own gas-fired district steam systems. The emissions associated with steam heat are reported on a separate line.

Table 10: Commercial building emissions from site energy (metric tons CO_2e).

	Emissions, MgCO2e					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Electricity	169,089	113,258	86,781	55,130	42,915	67,034
Direct Fuel Use						
Natural Gas	281,285	362,711	413,356	415,698	431,115	408,861
Oil	56,859	17,126	8,319	1,609	2,250	708
Steam Plants						
Natural Gas	137,162	160,035	176,131	156,247	138,418	152,079
Oil	15,581	-	552	105	-	63
Biomass						
Totals	659,976	653,131	685,139	628,790	614,699	628,745

Table 11: Commercial building primary (source) energy use in million Btu[13].

Site Energy Consumption, Million Btu						
	1990	2005	2008	2012	2014	2016
Electricity	11,232,799	15,469,646	16,426,275	16,195,285	16,089,950	16,214,579
Direct Fuel Use						
Natural Gas	5,308,977	6,845,815	7,801,678	7,845,896	8,136,868	7,713,440
Oil	758,866	229,842	112,569	21,775	30,451	9,577
Steam Plants						
Natural Gas	2,588,800	3,020,503	3,324,300	2,949,000	2,612,500	2,870,349
Oil	97,619	-	7,469	1,425	-	853
Biomass				141,781	355,921	-
Totals	19,987,060	25,565,806	27,672,290	27,155,161	27,225,690	26,808,798

Table 12: Commercial building energy use in physical units.

Site Energy Consumption, Physical Units							
		1990	2005	2008	2012	2014	2016
Electricity	MWh	3,289,806	4,530,673	4,810,845	4,743,194	4,712,344	4,748,845
Direct Fuel Use							
Natural Gas	Therm	53,089,770	68,458,151	78,016,778	78,458,956	81,368,683	77,168,557
Oil	Gal	5,486,720	1,661,796	813,893	157,437	220,166	69,243
Steam Plants							
Natural Gas	Therm	25,888,000	30,205,025	33,243,000	29,490,000	26,125,000	28,703,494
Oil	Gal	705,798	-	54,000	10,300	-	6,166
Biomass	Ton	-	-	-	8,541	21,441	-

COMMERCIAL BUILDING SOURCE NOTES

Electricity: *Due to a change in billing systems, Seattle City Light (SCL) provided commercial building electricity consumption within Seattle for 2016 as well as updated consumption info for years 2005 - 2014* ***(16-60-03).*** *The new information constituted a change in data for prior years, and the model was updated accordingly. Utility emission factors (tCO_2/MWh) remained the same for 2008 to 2014, and a new factor was provided for 2016* ***(16-60-04)****. The SCL emission rate was multiplied by commercial electricity consumption to obtain total emissions.*

Direct Fuel Use (Natural Gas): *Puget Sound Energy (PSE) provided 2016 natural gas use by Seattle businesses* ***(16-20-02)****. Natural gas use at steam plants and for commercial equipment use as compressed natural gas (CNG) are 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* ***(16-40-03)****, prorated by the ratio of Seattle to Washington State commercial employment* ***(14-70-11).***

Steam: *Emissions from natural gas and oil use for steam production was sourced from EPA's Large Emitters database for Enwave* ***(16-40).***

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 ***16-00-0_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 somewhat uncertain since they rely on self-reported data in EPA's Large Emitters database.*

[13] 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.

Expanded Inventory

Residential & Commercial Building Equipment

The expanded view of Seattle's building emissions also includes emissions from small equipment associated with commercial and residential buildings. This includes yard equipment, commercial landscaping equipment, and other mobile equipment included in EPA's NONROAD model.

Table 13: Residential and commercial building equipment emissions (metric tons of CO_2e).

			Emissions, $MgCO_2e$			
Residential	**1990**	**2005**	**2008**	**2012**	**2014**	**2016**
Diesel	55	60	62	69	75	76
Gasoline	19,608	16,667	17,302	18,344	17,764	18,112
LPG	4	3	4	3	4	4
Totals	19,666	16,731	17,368	18,416	17,842	18,192
			Emissions, $MgCO_2e$			
Commercial	**1990**	**2005**	**2008**	**2012**	**2014**	**2016**
Diesel	28,726	37,396	39,179	45,917	49,182	54,052
Gasoline	89,788	89,971	94,748	96,283	100,804	110,786
LPG	2,707	3,946	4,134	4,700	5,408	5,943
CNG	11,802	1,823	1,910	2,147	2,182	2,398
totals	133,023	133,137	139,972	149,047	157,576	173,179

SOURCE NOTES

Residential Yard Equipment (Petroleum): *King County yard equipment emissions in 2016 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* ***(16-70-11).*** *The NONROAD model has not been updated for 2016, so data used for 2016 before scaling with population is identical to what was used in 2014.*

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* ***(16-40-01)****. Emissions were tabulated by fuel type and sector* ***(16-40-02)****, then scaled to Seattle by the ratio of Seattle to King County commercial employment* ***(16-70-11).*** *The NONROAD model has not been updated for 2016, so data used for 2016 before scaling with employment is identical to what was used in 2014.*

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

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 19% since 2008 and 6% since 2014 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.

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.

Table 14: Waste sector emissions (metric tons of CO_2e).

	Emissions, $MgCO_2e$					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Wastewater treatment	1,641	1,822	1,887	1,895	2,327	2,427
Transfer & long haul	18,637	19,490	17,450	13,967	13,683	13,628
Landfill emissions commitment	113,957	98,309	85,906	73,385	74,764	69,259
Totals	134,235	119,622	105,243	89,247	90,775	85,314

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 (**16-50-10**) and compiled in **16-50-07**. 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 **16-50-08**. 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 2016 were provided by the King County Wastewater Treatment Division **(16-50-01)**. These include both stationary CH_4 emissions and process N_2O emissions.*

*Calculation steps and data sources for waste management and wastewater treatment are listed in **16-00-0_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.*

SOURCE NOTES

Steel & Glass: *Emissions for both Steel and Glass are self-reported in EPA's Large Emitters Database for 2010 to 2016 (**16-40**). This data source represents an update in the methodology used to report steel and glass emissions in prior inventories. Steel emissions are from Seattle's predominant manufacturer, Nucor (an electric arc furnace that produces crude steel). Glass operations emissions are from manufacturing at Seattle's Ardagh Glass (formerly Saint-Gobain Containers).*

Fugitive SF_6 (sulfur hexafluoride) emissions: *Seattle City Light (SCL) provided provisional fugitive SF_6 emissions for 2016 **(16-60-05)**, 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: *Fugitive methane emissions were taken from PSE's 2016 Greenhouse Gas Inventory **(16-40-11)**. This data source represents a change in methodology from previous years, and moves from a resource-intensive process to a simpler and more readily available estimate from PSE.*

*Calculation steps and data sources for cement, steel and glass, and fugitive gases are listed in **16-00-0_MasterSpreadsheet 'Ind- Process'** and **'Ind- Fug. Gases'**, respectively.*

Uncertainty: *Uncertainty is relatively high for all categories of process and fugitive emissions, particularly that of steel production. There is significant variability in reported process emissions between years, much of which can be attributed to the emissions testing methodology. Nucor manufactures several different grades of steel with unique chemistries – each of which affects refining levels – in varying quantities throughout any given year. Since process emissions testing occurs over a three-day period per year, the chemistry of the scrap being tested is not consistent year to year and is likely not representative of the annual aggregate chemistry of Nucor's steel output. Additionally, Nucor's total output has changed depending on market conditions, affecting total emissions reported.*

Industry

The industrial sector includes emissions from industrial operations, such as manufacturing cement, steel, and glass. Industrial emissions also include those associated with burning fossil fuel on-site, from emissions associated with the electricity[14] that industrial operations consume, as well as fugitive emissions, or leaks, of non-CO_2 GHGs from industrial equipment. Industrial emissions are not included in Seattle's core inventory emissions but are part of the expanded inventory.

Expanded Inventory

Cement

Emissions associated with cement production are presented in the table below. 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

[14] About 90% of the electricity that Seattle City Light (SCL) provides to consumers in Seattle comes from low-carbon hydroelectric dams. SCL purchases carbon offsets equal to the greenhouse gas emissions resulting from all other aspects of SCL's operations, including those created by fossil fuels included in the mix of power the utility buys, employees' travel, and the trucks and other equipment used in its operations.

economic conditions determining demand for cement, that are beyond the control of policy decisions made at the city-level.

Table 15: Greenhouse gas emissions associated with cement production (metric tons of CO_2e). [15]

	Emissions, $MgCO_2e$					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Cement manufacture	206,120	483,622	394,644	306,918	522,982	383,836

SOURCE NOTES

***Cement**: Emissions associated with cement production in 2016 are taken from the EPA 2014 Ash Grove Greenhouse Gas Emissions from Large Facilities report **(16-40)**. 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 **16-00-0_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 (2010 through 2016).*

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 building sectors. Industrial operations also include fuel use and GHG emissions from construction equipment (such as forklifts, loading equipment and excavators), material handling, and other non-road machinery. Emissions from industrial energy use (other than for cement production) are shown in the table below.

Table 16: Industrial energy use emissions, other than for cement (metric tons of CO_2e).

	Emissions, MgCO2e					
	1990	**2005**	**2008**	**2012**	**2014**	**2016**
Electricity	61,574	21,566	15,390	9,709	7,768	10,934
Direct Fuel Use						
Natural Gas	172,649	257,253	246,110	270,125	206,604	296,330
Oil	5,705	11,491	36,135	15,347	14,075	19,156
Coal	208,952	n.d.	n.d.	n.d.	n.d.	n.d.
Industrial Equipment						
Tire-derived fuel	-	n.d.	n.d.	n.d.	n.d.	n.d.
Diesel	28,726	37,396	39,179	45,917	49,182	54,052
Gasoline	89,788	89,971	94,748	96,283	100,804	110,786
LPG	2,707	3,946	4,134	4,700	5,408	5,943
CNG	11,802	1,823	1,910	2,147	2,182	2,398
Totals	581,902	423,447	437,607	444,228	386,023	499,600

Greenhouse Gas Offsets

The majority of Seattle City Light's electricity is generated from hydro and wind power, and is therefore counted in this inventory as carbon neutral. However, there are emissions associated with the power City

[15] Since 2012, cement production emissions from relevant facilities are taken from the EPA's Greenhouse Gas Emissions from Large Facilities. [seems like this would be included in the source notes, vs. a footnote]

Light purchases on the spot market that are generated from other sources. Since 2005, City Light has invested in carbon reduction projects to offset the emissions associated with both these purchases and with emissions from its internal operations. 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 17: Greenhouse gas offsets counted in this expanded inventory (metric tons of CO_2e). [16]

	Offsets, Metric Tons CO2e				
	2005	**2008**	**2012**	**2014**	**2016**
Residential	61,726	48,716	30,803	23,170	35,746
Commercial	113,258	86,781	55,130	42,915	67,034
Industrial	22,068	15,390	9,709	7,768	10,934
Totals	197,052	150,887	95,642	73,853	113,714

[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.

APPENDICES

Appendix A: Description of Changes to Methodology

This inventory includes some methodological changes compared to the 2014 inventory. These changes are summarized in Table 18. Emissions estimates from all prior inventory years (1990, 2005, 2008, 2012 and 2014) 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 18: Description of methodology changes from previous inventory.

Sector	Subsector	Particular Source	2014 Method	2016 Method	Reason for Change
Transportation					
	Road	VMT - all road except buses	Used modeled VMT data from PSRC.	PSRC updated their VMT model; updated VMT data was used for 2014 and scaled to all other years based on a more limited set of VMT estimates available from WSDOT.	Change in data source model.
		Fuel economy - all road except buses	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.	Used only local vehicle fuel efficiency data from PSRC as well as prior years (back to 2005, with 1990 assumed similar to 2005). Adjusted vehicle categories to match those used in PSRC's new VMT model.	Uses more readily available data.
	Air	Seattle's share of SeaTac emissions	Percentage of SeaTac travel attributable to Seattle was derived using a combination of a SeaTac customer survey and the ratio of Seattle's population and employment to those in the broader region that SeaTac serves.	Used only ratio of Seattle's population to those in the broader region.	The survey data is not reliable. New formula for ratio matches trends from prior years.
Buildings					
	Residential, Commercial, Industrial	Electricity	Used reported consumption figures from Seattle City Light.	Used reported consumption figures from SCL from new billing system for all years spanning 2005 - 2016.	Change in data source.
Industry					
	Process emissions	Process emissions from Steel and Glass production	Emissions were calculated using estimated production figures and applying default emissions factors.	Process emissions figures reported to EPA's Large Emitter Database were used.	Uses more readily available data.

Appendix B: 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 16.xlsx>, lists names, descriptions, and sources of all other files in the inventory.

Source files – These files are numbered 16-00-00 to 16-80-00. The files are organized by category in the following format:

16-00 Inventory

16-10 Transportation

16-20 Buildings

16-40 Industry

16-50 Waste

16-60 Electricity

16-70 Demographics

16-80 Reference

Calculation files – File 16-00-0 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: <16_00_0_Master_Spreadsheet.xlsx>.

Every datum in the calculation files is traceable to one of the source files through the 16-XX-XX number provided in the "call no." column of most of the calculation files. In addition, some source files from prior inventory work in Seattle are referenced. These source files are in the format 14-XX-XX (*2014 Seattle Community Greenhouse Gas Inventory*), 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).

Appendix C: Sector-Specific Progress towards 2030 Climate Goals

Seattle's Climate Action Plan (CAP) calls for the following emissions reduction targets by 2030 over a 2008 baseline:

- Passenger vehicles: 82%
- Building energy: 39%
- Combined target for passenger vehicles and building energy: 64%
- Total core emissions (including commercial vehicles and waste): 58%

The table below provides a snapshot of progress towards each of these goals. There are many pathways to get to these goals – including pathways that accelerate near-term emissions as a means to create greater cumulative emissions reductions between now and 2030. The average figures presented here are meant only to provide an indication of one possible pathway.

	CAP target for 2030 (% emissions reduction from 2008)	Average annual % emissions reduction 2008-2030 necessary to achieve CAP goal	Actual average annual % emissions reduction 2008-2016	Actual average annual % emissions reduction 2014-2016
Passenger vehicles	82%	7.5%	0.2%	-0.4%
Building energy	39%	2.2%	1.7%	-0.3%
Combined vehicles + buildings	64%	4.5%	0.8%	-0.4%
Total Core Emissions	58%	3.9%	0.8%	-0.4%

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 the table below.

Table 19: Population by geographic region and employment type.

	1990	2005	2008	2012	2014	2016
Seattle						
Residents	516,259	573,336	593,588	635,063	668,342	704,352
Commercial Employees	363,932	417,057	436,943	441,043	469,907	508,264
Industrial Employees	58,147	45,879	55,106	41,356	43,966	48,563
King County						
Residents	1,517,208	1,795,268	1,875,020	2,008,526	2,079,967	2,149,970
Commercial Employees	-	948,453	1,005,634	1,009,746	1,072,508	1,141,693
Industrial Employees	-	165,424	181,195	150,982	162,837	171,013
Washington						
Residents	4,903,043	6,257,304	6,562,231	6,897,292	7,063,166	7,280,934
Commercial Employees	-	2,243,114	2,383,847	2,384,842	2,501,439	2,642,116
Industrial Employees	-	432,773	473,002	407,180	435,569	460,967

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* ***16-70-03*** *(Seattle),* ***16-70-01*** *(King County), and* ***16-70-17*** *(Washington State).*

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* ***16-70-105)****. Covered Employment for Seattle for 2016 comes from the Seattle Department of Planning and Development (DPD) (****16-70-16)****. All employment data are tabulated in workbook* ***16-70-11****. 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 D: Detailed Tracking Metrics

The table below presents detailed metrics that may be useful for tracking trends in underlying drivers that affect Seattle's core emissions.

Table 20: Detailed emissions tracking metrics.

							% change since:			
Emissions Source	**1990**	**2005**	**2008**	**2012**	**2014**	**2016**	**1990**	**2008**	**2012**	**2014**
Population	516,259	573,336	593,588	635,063	668,342	704,352	36%	19%	11%	5%
Employment	363,932	417,057	436,943	441,043	469,907	508,264	40%	16%	15%	8%
Transportation: Road										
Emissions (Million MT CO2e)	1.7	2.1	2.0	2.0	2.0	2.0	18%	-1%	1%	1%
Emissions per person (MT CO_2e/resident)	3.3	3.6	3.4	3.1	2.9	2.8	-13%	-16%	-9%	-4%
Passenger emissions per person (MT CO_2e/resident)	2.8	3.1	2.9	2.6	2.5	2.4	-14%	-17%	-9%	-4%
Freight emissions per person (MT CO2e/resident)	0.5	0.5	0.5	0.4	0.4	0.4	-10%	-13%	-6%	-2%
Passenger VMT (billion miles)	3.2	3.9	3.8	3.8	3.9	4.1	29%	7%	8%	5%
Freight Truck VMT (billion miles)	0.24	0.30	0.29	0.29	0.30	0.31	30%	8%	9%	5%
Passenger VMT/person (thousand miles/resident)	6.1	6.9	6.4	6.0	5.8	5.8	-6%	-9%	-3%	0%
Freight Truck VMT/person (thousand miles/resident)	0.47	0.53	0.49	0.46	0.45	0.45	-5%	-9%	-2%	0%
VMT (billions miles)	3.4	4.3	4.1	4.1	4.2	4.4	29%	8%	8%	5%
VMT per resident (thousand miles/resident)	6.6	7.4	6.9	6.4	6.3	6.2	-6%	-9%	-3%	0%
Emissions per mile (kgCO2e/VMT)	0.49	0.49	0.49	0.48	0.47	0.45	-8%	-8%	-6%	-4%
Passenger emissions per mile (kgCO2e/VMT)	0.45	0.45	0.45	0.44	0.43	0.41	-9%	-8%	-6%	-4%
Freight truck emissions per mile (kgCO2e/VMT)	1.0	1.0	1.0	1.0	1.0	0.9	-5%	-5%	-4%	-2%
Buildings: Residential & Commercial										
Emissions (Million MT CO2e)	1.3	1.2	1.3	1.2	1.1	1.1	-17%	-13%	-4%	1%
Residential Emissions (Million MT CO2e)	0.69	0.55	0.59	0.52	0.49	0.48	-30%	-18%	-8%	-1%
Commercial Emissions (Million MT CO2e)	0.65	0.65	0.69	0.63	0.61	0.63	-4%	-8%	0%	2%
Emissions per resident (MT CO_2e/resident)	2.6	2.1	2.1	1.8	1.6	1.6	-39%	-27%	-13%	-4%
Residential emissions per resident (MT CO_2e/resident)	1.3	1.0	1.0	0.8	0.7	0.7	-49%	-31%	-17%	-6%
Commercial emissions per resident (MT CO_2e/resident)	1.3	1.1	1.2	1.0	0.9	0.9	-29%	-23%	-10%	-3%
Commercial emissions per employee (MT CO_2e/employee)	1.8	1.6	1.6	1.4	1.3	1.24	-31%	-21%	-13%	-5%
Residential Energy use (trillion BTU)	20.0	17.0	18.8	18.0	17.1	16.7	-16%	-11%	-7%	-2%
Natural gas (trillion BTU)	4.9	7.0	8.1	7.9	7.5	7.2	47%	-11%	-9%	-4%
Heating oil (trillion BTU)	4.0	1.5	1.5	1.0	0.9	0.8	-79%	-42%	-14%	-4%
Electricity (trillion BTU)	11.1	8.4	9.2	9.0	8.7	8.6	-22%	-6%	-4%	0%
Commercial energy use (trillion BTU)	19.9	25.5	27.7	27.2	27.2	26.8	35%	-3%	-1%	-2%
Natural gas (trillion BTU)	5.3	6.8	7.8	7.8	8.1	7.7	45%	-1%	-2%	-5%
Heating oil (trillion BTU)	0.7	0.2	0.1	0.0	0.0	0.0	-99%	-91%	-56%	-69%
Steam (trillion BTU)	2.7	3.0	3.3	3.1	3.0	2.9	7%	-14%	-7%	-3%
Electricity (trillion BTU)	11.2	15.5	16.4	16.2	16.1	16.2	44%	-1%	0%	1%
Total energy use (residential + commercial) (trillion BTU)	39.9	42.5	46.5	45.1	44.3	43.5	9%	-6%	-4%	-2%
Residential energy per resident (million BTU/resident)	38.8	29.6	31.7	28.3	25.6	23.7	-39%	-25%	-16%	-7%
Commercial energy per employee (million BTU/employee)	54.6	61.3	63.3	61.6	57.9	52.75	-3%	-17%	-14%	-9%
Heating degree days (HDD)	4,840	4,489	5,062	4,738	3,889	3,828	-21%	-24%	-19%	-2%
Cooling degree days (CDD)	250	164	195	181	372	291	16%	49%	61%	-22%
Emissions per GJ (kg CO_2e/million BTU)	33.5	28.2	27.4	25.5	24.9	25.5	-24%	-7%	0%	3%
Residential GHG intensity of energy (kg CO_2e/million BTU)	34.3	32.2	31.3	29.2	28.5	28.8	-16%	-8%	-1%	1%
Commercial GHG intensity of energy (kg CO_2e/million BTU)	32.8	25.6	24.8	23.2	22.6	23.4	-28%	-5%	1%	4%
Waste Management										
Emissions (Million MT CO_2e)	0.13	0.12	0.10	0.09	0.09	0.08	-37%	-20%	-5%	-6%
Emissions per resident (MT CO_2e/resident)	0.26	0.21	0.17	0.14	0.13	0.12	-54%	-32%	-14%	-11%
Residential waste (tons)	140,528	134,557	127,219	111,420	112,211	103,732	-26%	-18%	-7%	-8%
Residential waste per resident (tons/resident)	0.27	0.23	0.21	0.18	0.17	0.15	-46%	-31%	-16%	-12%
Nonresidential waste (tons)	317,317	306,345	267,685	204,563	197,305	204,554	-36%	-24%	0%	4%
Nonresidential waste per resident (tons/employee)	0.87	0.73	0.61	0.46	0.42	0.40	-54%	-34%	-13%	-4%
Emissions per ton disposed (MT CO_2e/ton)	0.94	0.88	0.81	0.78	0.79	0.80	-15%	-2%	2%	1%
Total										
Emissions (Million MT CO_2e)	**3.2**	**3.4**	**3.4**	**3.2**	**3.2**	**3.2**	**1%**	**-6%**	**-1%**	**1%**
Emissions per resident (MT CO_2e/resident)	**6.1**	**5.9**	**5.7**	**5.0**	**4.7**	**4.5**	**-26%**	**-21%**	**-10%**	**-4%**

Appendix E: Detailed Emissions Inventory Summary 1990 – 2016

							% change since:		
	1990	2005	2008	2012	2014	2016	1990	2008	2014
TRANSPORTATION	**2,859,000**	**3,228,000**	**3,220,000**	**3,098,000**	**3,251,000**	**3,455,000**	**21%**	**7%**	**6%**
Road: Passenger	**1,442,000**	**1,776,000**	**1,715,000**	**1,677,000**	**1,679,000**	**1,691,000**	**17%**	**-1%**	**1%**
Cars & Light Duty Trucks	*1,396,000*	*1,719,000*	*1,655,000*	*1,610,000*	*1,614,000*	*1,626,000*	*16%*	*-2%*	*1%*
Buses	*47,000*	*58,000*	*60,000*	*67,000*	*65,000*	*65,000*	*40%*	*9%*	*0%*
Road: Trucks	**242,000**	**301,000**	**289,000**	**285,000**	**290,000**	**298,000**	**23%**	**3%**	**3%**
Medium & Heavy Duty	*242,000*	*301,000*	*289,000*	*285,000*	*290,000*	*298,000*	*23%*	*3%*	*3%*
Marine & Rail	**235,000**	**232,000**	**227,000**	**219,000**	**211,000**	**212,000**	**-10%**	**-7%**	**0%**
Hotelling	*58,000*	*55,000*	*53,000*	*43,000*	*37,000*	*36,000*	*-38%*	*-33%*	*-3%*
State Ferries	*41,000*	*42,000*	*35,000*	*41,000*	*40,000*	*44,000*	*9%*	*25%*	*10%*
Pleasure Craft	*32,000*	*30,000*	*31,000*	*31,000*	*25,000*	*26,000*	*-20%*	*-18%*	*2%*
Other Boat Traffic	*59,000*	*57,000*	*59,000*	*61,000*	*76,000*	*74,000*	*25%*	*26%*	*-2%*
Rail - Freight	*45,000*	*43,000*	*41,000*	*34,000*	*24,000*	*23,000*	*-48%*	*-44%*	*-3%*
Rail - Passenger	*< 1,000*	*5,000*	*7,000*	*8,000*	*9,000*	*9,000*	*> 100%*	*32%*	*-3%*
Air	**940,000**	**919,000**	**989,000**	**917,000**	**1,071,000**	**1,253,000**	**33%**	**27%**	**17%**
Sea-Tac Airport	*756,000*	*700,000*	*727,000*	*689,000*	*833,000*	*1,019,000*	*35%*	*40%*	*22%*
King County Airport	*184,000*	*219,000*	*262,000*	*228,000*	*238,000*	*234,000*	*27%*	*-11%*	*-2%*
BUILDINGS	**1,481,000**	**1,349,000**	**1,432,000**	**1,320,000**	**1,278,000**	**1,301,000**	**-12%**	**-9%**	**2%**
Residential	**705,000**	**563,000**	**607,000**	**542,000**	**505,000**	**499,000**	**-29%**	**-18%**	**-1%**
Electricity	*133,000*	*62,000*	*49,000*	*31,000*	*23,000*	*36,000*	*-73%*	*-27%*	*54%*
Natural Gas	*259,000*	*371,000*	*432,000*	*420,000*	*399,000*	*383,000*	*48%*	*-11%*	*-4%*
Oil	*294,000*	*113,000*	*109,000*	*73,000*	*65,000*	*63,000*	*-79%*	*-42%*	*-4%*
Yard Equipment	*20,000*	*17,000*	*17,000*	*18,000*	*18,000*	*18,000*	*-8%*	*5%*	*2%*
Commercial	**776,000**	**786,000**	**825,000**	**778,000**	**772,000**	**802,000**	**3%**	**-3%**	**4%**
Electricity	*169,000*	*113,000*	*87,000*	*55,000*	*43,000*	*67,000*	*-60%*	*-23%*	*56%*
Natural Gas	*281,000*	*363,000*	*413,000*	*416,000*	*431,000*	*409,000*	*45%*	*-1%*	*-5%*
Oil	*57,000*	*17,000*	*8,000*	*2,000*	*2,000*	*1,000*	*-99%*	*-91%*	*-69%*
Steam	*144,000*	*160,000*	*177,000*	*156,000*	*138,000*	*152,000*	*-4%*	*-22%*	*10%*
Equipment	*124,000*	*133,000*	*140,000*	*149,000*	*158,000*	*173,000*	*39%*	*24%*	*10%*
INDUSTRY	**1,018,000**	**1,434,000**	**1,357,000**	**913,000**	**1,105,000**	**1,023,000**	**1%**	**-25%**	**-7%**
Cement	**417,000**	**861,000**	**746,000**	**307,000**	**523,000**	**384,000**	**-8%**	**-49%**	**-27%**
Fuel Combustion	*211,000*	*377,000*	*353,000*	-	-	-	-	-	-
Clinker Calcination	*206,000*	*484,000*	*393,000*	-	-	-	-	-	-
Other - Energy Use	**519,000**	**452,000**	**511,000**	**486,000**	**419,000**	**547,000**	**6%**	**7%**	**31%**
Electricity	*62,000*	*22,000*	*15,000*	*10,000*	*8,000*	*11,000*	*-82%*	*-29%*	*41%*
Natural Gas	*266,000*	*257,000*	*246,000*	*270,000*	*207,000*	*296,000*	*11%*	*20%*	*43%*
Oil	*49,000*	*11,000*	*36,000*	*15,000*	*14,000*	*19,000*	*-61%*	*-47%*	*36%*
Industrial Equipment	*142,000*	*162,000*	*214,000*	*191,000*	*190,000*	*221,000*	*34%*	*-11%*	*16%*
Other - Process	**50,000**	**90,000**	**77,000**	**101,000**	**144,000**	**73,000**	**45%**	**-5%**	**-49%**
Steel & Glass	*50,000*	*90,000*	*77,000*	*101,000*	*144,000*	*73,000*	*45%*	*-5%*	*-49%*
Fugitive Gases	**31,000**	**30,000**	**24,000**	**19,000**	**19,000**	**19,000**	**-38%**	**-18%**	**2%**
SF6 from Switchgear	*10,000*	*5,000*	*2,000*	*1,000*	*3,000*	*3,000*	*-72%*	*49%*	*-1%*
PSE Gas Distribution	*21,000*	*25,000*	*22,000*	*18,000*	*16,000*	*17,000*	*-22%*	*-24%*	*3%*
WASTE	**134,000**	**120,000**	**105,000**	**89,000**	**91,000**	**85,000**	**-36%**	**-19%**	**-6%**
Waste	**134,000**	**120,000**	**105,000**	**89,000**	**91,000**	**85,000**	**-36%**	**-19%**	**-6%**
Waste Management	*133,000*	*118,000*	*103,000*	*87,000*	*88,000*	*83,000*	*-37%*	*-20%*	*-6%*
Wastewater Treatment	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*2,000*	*48%*	*29%*	*4%*
TOTAL EMISSIONS	**5,493,000**	**6,131,000**	**6,114,000**	**5,421,000**	**5,724,000**	**5,865,000**	**7%**	**-4%**	**2%**
Per resident	**10.6**	**10.7**	**10.3**	**8.5**	**8.6**	**8.3**	**-22%**	**-19%**	**-3%**
GHG OFFSETS		**-197,000**	**-151,000**	**-96,000**	**-74,000**	**-114,000**			
SCL offsets		**-197,000**	**-151,000**	**-96,000**	**-74,000**	**-114,000**			
TOTAL AFTER OFFSETS	**5,493,000**	**5,935,000**	**5,964,000**	**5,325,000**	**5,651,000**	**5,751,000**	**5%**	**-4%**	**2%**
Per resident	**10.6**	**10.4**	**10.0**	**8.4**	**8.5**	**8.2**	**-23%**	**-19%**	**-3%**