Memorandum

Greenhouse Gas Inventories

To: City of Portland, City of South Portland, and Linnean Solutions
From: Integral Group and Daybreak Climate Consulting
Date: July 2020
Re: Community Inventories of 2017 Greenhouse Gas Emissions for the Cities of Portland and South Portland

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1 Introduction

As part of the scope for developing the One Climate Future plan, the consultant team was tasked with developing baseline community greenhouse gas (GHG) inventories for Portland and South Portland, Maine. City operations inventories were not within the scope of the project, so city operational emissions are not broken out in this memorandum.

The last citywide GHG Inventory for Portland was conducted in 2010, and used a different protocol, differed in methodology in numerous areas, and included many scope 3 emissions sources. Therefore, the 2010 inventory results cannot be directly compared to this new 2017 inventory; the differences are discussed in section 4.3. The City of Portland decided that 2017 would be the new baseline for GHG emissions. South Portland has never done a community-wide GHG inventory before. The 2017 inventory represents the first baseline for GHG emissions for South Portland.

Both Inventories follow the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)[1] for compliance with the Global Covenant of Mayors for Climate and Energy and the Carbon Disclosure Project. The inventories were compiled and submitted using the City Inventory Reporting and Information System (CIRIS) tool from C40 Cities,[2] which is compliant with the Global Covenant of Mayors' 'Common Reporting Framework' (CRF).[3]

GHG inventories are generally divided into "scopes" 1, 2, and 3, as shown in Figure 1.

- **Scope 1:** All emissions within the city.
- **Scope 2:** Emissions occurring as a result of grid-supplied electricity consumed within city.
- **Scope 3:** Other emissions occurring outside the boundaries of the city as a result of activities taking place within the city.

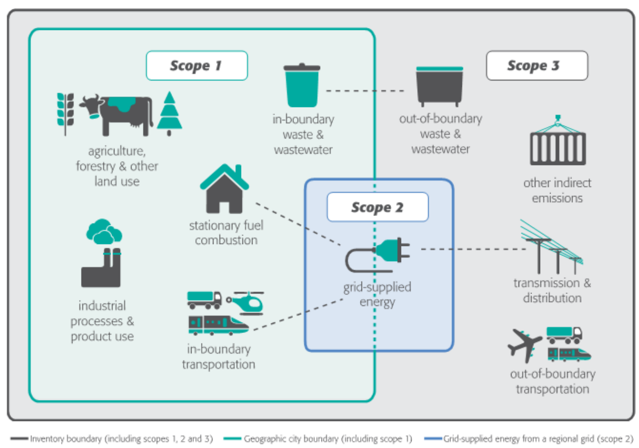

Figure 1: Inventory scopes (graphic courtesy of World Resources Institute)

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[1] GHG Protocol, Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) Washington, DC: World Resources Institute. https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[2] C40 Cities. Reporting GHG emissions inventories https://resourcecentre.c40.org/resources/reporting-ghg-emissions-inventories
[3] Global Covenant of Mayors for Climate and Energy. Global Common Reporting Framework. https://www.globalcovenantofmayors.org/our-initiatives/data4cities/common-global-reporting-framework/

2 Portland Inventory Results

2.1 Summary

The overall output of data from the CIRIS tool for Portland, Maine for 2017 is shown in Figure 2. Overall, Portland was responsible for 840,419 metric tons of carbon dioxide equivalents ($MTCO_2e$). On a per capita basis, this is 12.6 tons per resident. This compares favorably to the U.S. national average of 20.7 tons per resident, but is more emissions-intensive than many other Northeast cities. In general, this difference reflects the greater demand for heating fuel, particularly fuel oil, the greater reliance on personal cars rather than public transit, and the greater proportion of industrial energy use.

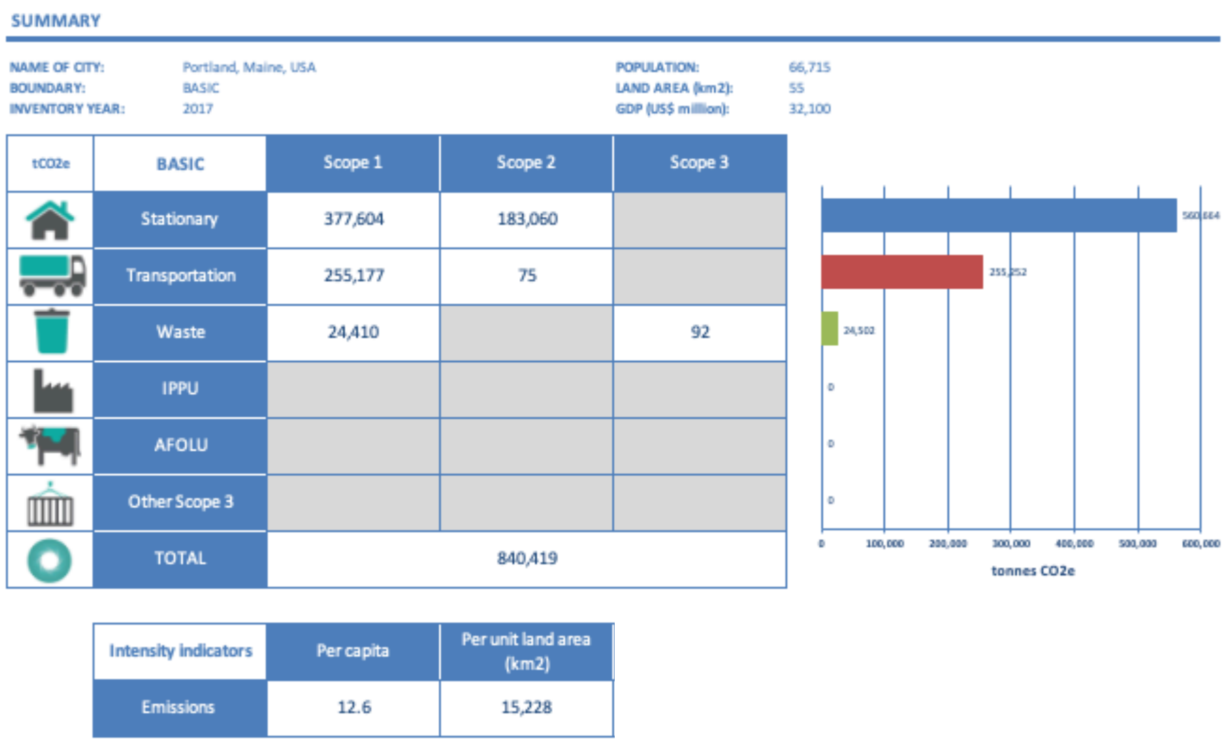


Figure 2: Portland GHG inventory summary.

Table 1: Portland emissions by scope; totals differ slightly from Figure 2 due to rounding.

Scope	CO_2 emissions ($MTCO_2e$)	CH_4 Emissions ($MTCO_2e$)	N_2O Emissions ($MTCO_2e$)	Total GHG Emissions ($MTCO_2e$)	Percent of Total Emissions
1	651,710	2,177	3,306	657,193	78%
2	181,284	819	1,033	183,136	22%
3	-	92	-	92	0%
Total	832,994	3,087	4,339	840,421	100%

Greenhouse gas emissions can be looked at by source or by sector; sources are the fuels and waste decomposition that produce greenhouse gas emissions, while sectors are different portions of the economy.

Overall, the use of electricity, natural gas, and fuel oil in buildings is the main driver of Portland's GHG footprint, with buildings being responsible for two-thirds (67%) of community-wide GHG emissions. Mobile sources within the Portland boundaries, such as cars and ships, are responsible for 30%, and the incineration of solid waste and processing of wastewater is responsible for the remaining 3%.

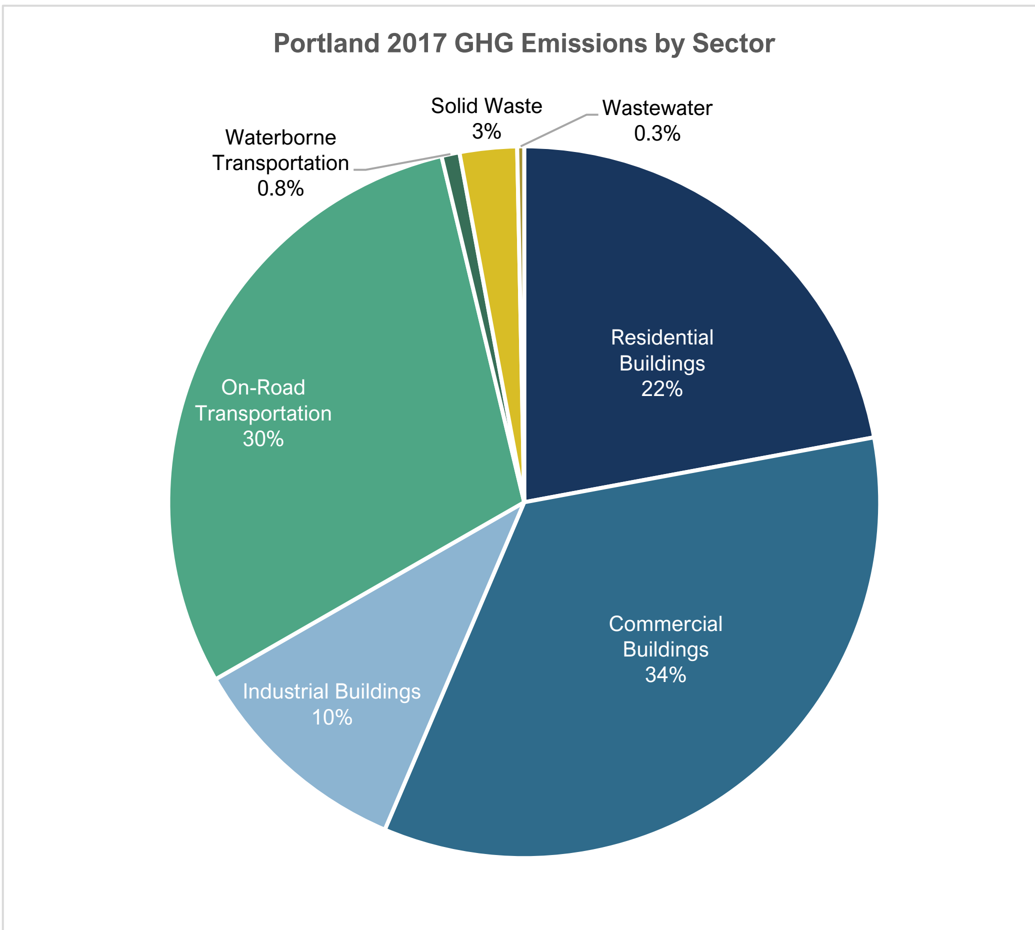


Figure 3: Portland 2017 GHG emissions by sector

Table 2: Portland 2017 energy use and GHG emissions by sector.

Sector	Energy Use (MMBTU)	% of Energy Use	GHG Emissions ($MTCO_2e$)	% of GHG Emissions
Buildings	8,357,063	70%	560,666	66.7%
Residential Buildings	2,704,261	23%	185,573	22.1%
Commercial Buildings	4,363,247	37%	288,470	34.3%
Industrial Buildings	1,289,555	11%	86,623	10.3%
Transportation	3,564,381	30%	255,252	30.4%
On-Road Transportation	3,510,068	29%	248,375	29.6%
Waterborne Transportation	54,313	0%	6,877	0.8%
Waste	-		24,502	2.9%
Solid Waste	-	0%	21,853	2.6%
Wastewater	-	0%	2,649	0.3%
Portland Total	11,921,444	100%	840,419	100%

Table 3: Portland 2017 CO_2, CH_4, and N_2O emissions by sector; total differs slightly from Figure 2 due to rounding.

Sector	CO_2 Emissions ($MTCO_2e$)	CH_4 Emissions ($MTCO_2e$)	N_2O Emissions ($MTCO_2e$)	Total GHG Emissions ($MTCO_2e$)
Buildings	557,968	1,141	1,557	560,666
Transportation	254,324	297	631	255,252
Waste	20,702	1,650	2,151	24,503
Portland Total	832,994	3,088	4,339	840,421

Within buildings, electricity, natural gas, and fuel oil are roughly equivalent sources of GHGs, with fuel oil being responsible for slightly greater amount of emissions due to its high carbon intensity. Most emissions from transportation come from gasoline.

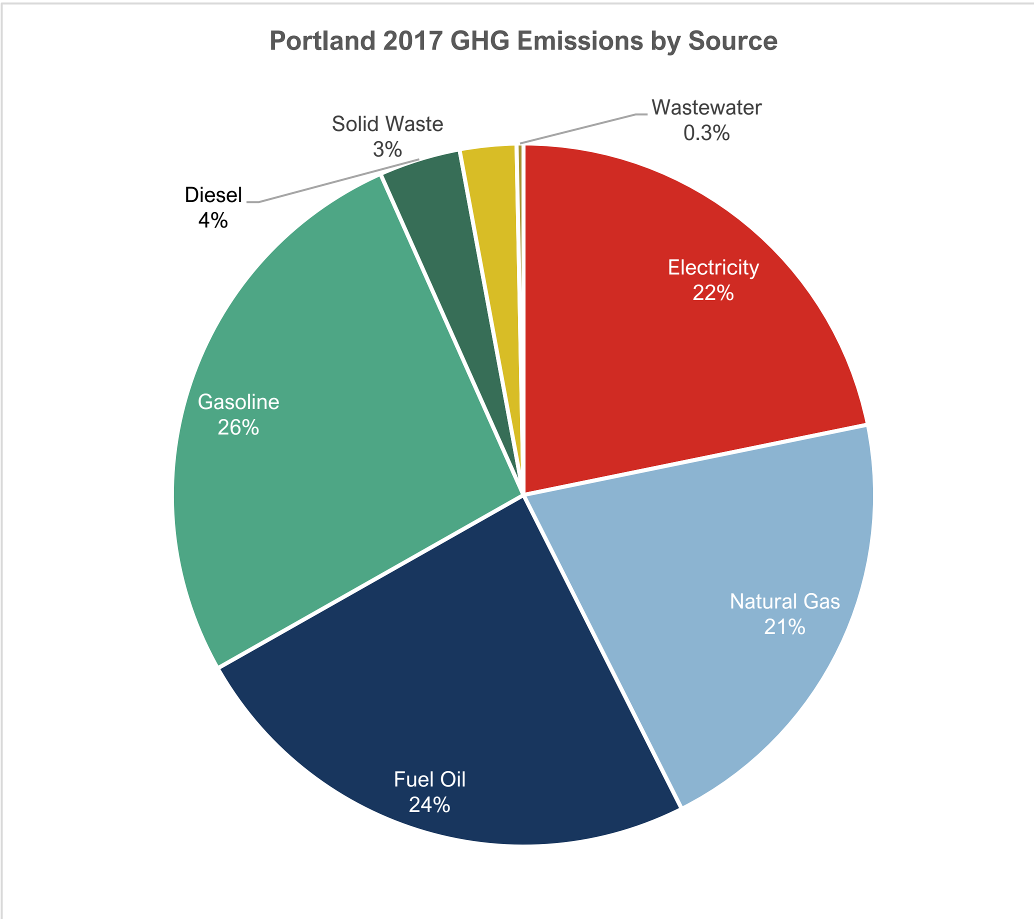


Figure 4: Portland 2017 GHG emissions by source

Table 4: Portland 2017 energy use and GHG emissions by source.

Fuel	Site Energy Consumption (MMBTU)	% of Total Site Energy	GHG Emissions ($MTCO_2e$)	% of Total GHG Emissions
Electricity	2,338,183	20%	183,136	21.8%
Natural Gas	3,287,840	28%	174,632	20.8%
Fuel Oil	2,743,837	23%	203,602	24.2%
Gasoline	3,164,909	27%	223,009	26.5%
Diesel	386,675	3%	31,540	3.8%
Solid Waste	-	0%	21,853	2.6%
Wastewater	-	0%	2,649	0.3%
Total	11,921,444	100%	840,419	100%

Table 5: Portland 2017 CO_2, CH_4, and N_2O emissions by fuel type.

Fuel	CO_2 Emissions ($MTCO_2e$)	CH_4 Emissions ($MTCO_2e$)	N_2O Emissions ($MTCO_2e$)	Total GHG Emissions ($MTCO_2e$)
Diesel	31,382	30	128	31,540
Electricity	181,284	819	1,033	183,136
Fuel Oil	202,934	231	437	203,602
Gasoline	222,240	266	503	223,009
Natural Gas	174,452	92	87	174,632
Solid Waste	20,702	563	589	21,853
Wastewater	-	1,087	1,562	2,649
Total	832,994	3,087	4,339	840,419

2.2 Buildings

Approximately 67% of Portland's GHG emissions footprint is attributable to energy use in buildings. Building GHG data was computed from actual citywide electricity and natural gas consumption information. Fuel oil use was modeled using the methodology described in Section 4.5; all fuel oil was assumed to be No. 2 fuel oil, though in practice other grades of fuel oil may also be in use.

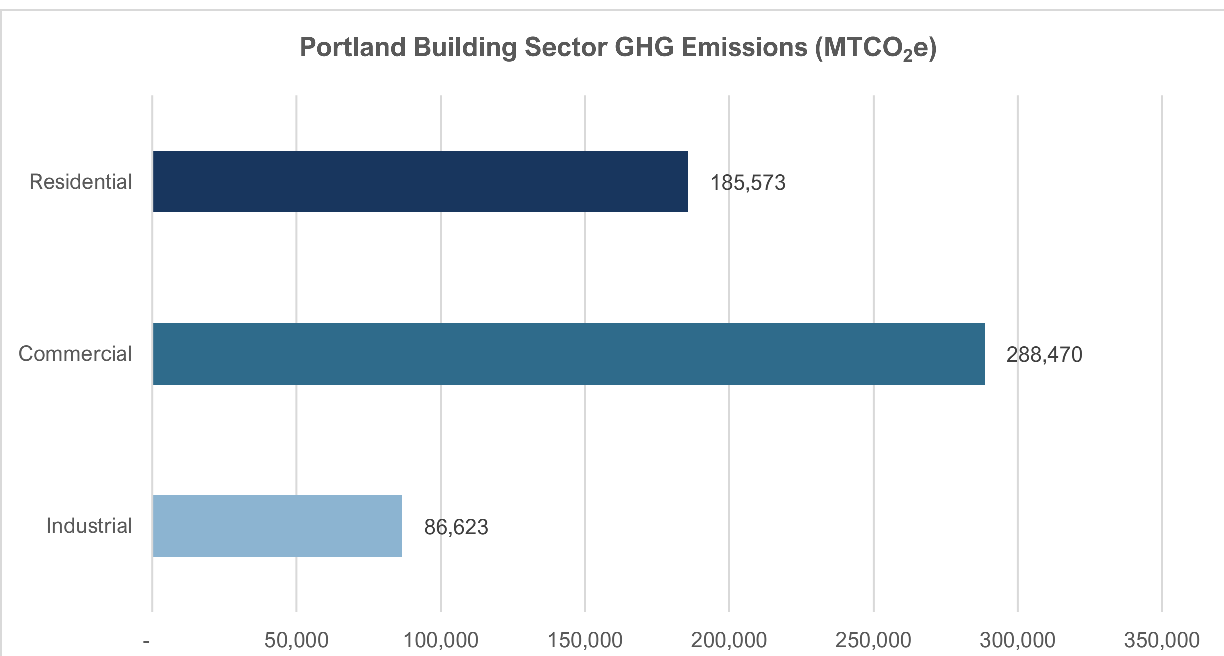


Figure 5: Portland 2017 building sector GHG emissions, $MTCO_2e$.

Table 6: Site and source energy use by building sector.

Sector and Energy Use	Site Energy (MMBTU)	Source Energy (MMBTU)
Residential	2,704,261	3,710,728
Electricity	528,863	1,480,816
Fuel Oil	1,356,398	1,369,962
Natural Gas	819,000	859,950
Commercial	4,363,247	7,159,128
Electricity	1,493,645	4,182,206
Fuel Oil	904,002	913,042
Natural Gas	1,965,600	2,063,880
Industrial	1,289,555	1,885,453
Electricity	314,718	881,210
Fuel Oil	483,438	488,272
Natural Gas	491,400	515,970
All Portland Buildings	8,357,063	12,755,309

2.3 Transportation

Transportation GHG emissions for Portland were estimated for all on-road and waterborne transportation occurring within the city boundaries. Data was provided by the State Department of Transportation for total vehicle miles traveled (VMT) within city boundaries, and the types and model years of vehicles registered in Portland; on-road GHG emissions were estimated from this data as described in Section 4.6.1. Gasoline and diesel fuel economies were weighted based on the makeup of vehicle types registered in Portland, as show in Figure 6.

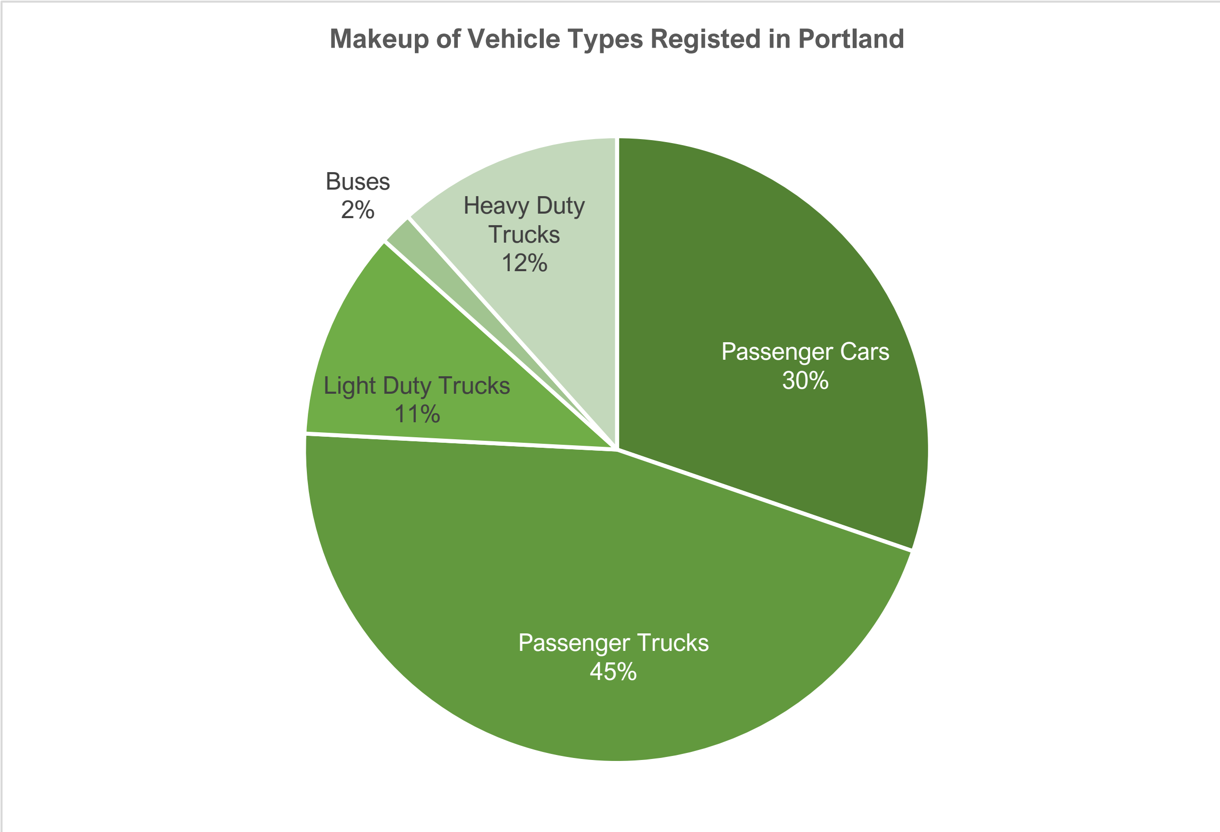


Figure 6: Registered vehicles in Portland.

Most GHGs result from the combustion of gasoline in passenger cars and light trucks. Data was not available for passenger or freight trains passing through Portland.

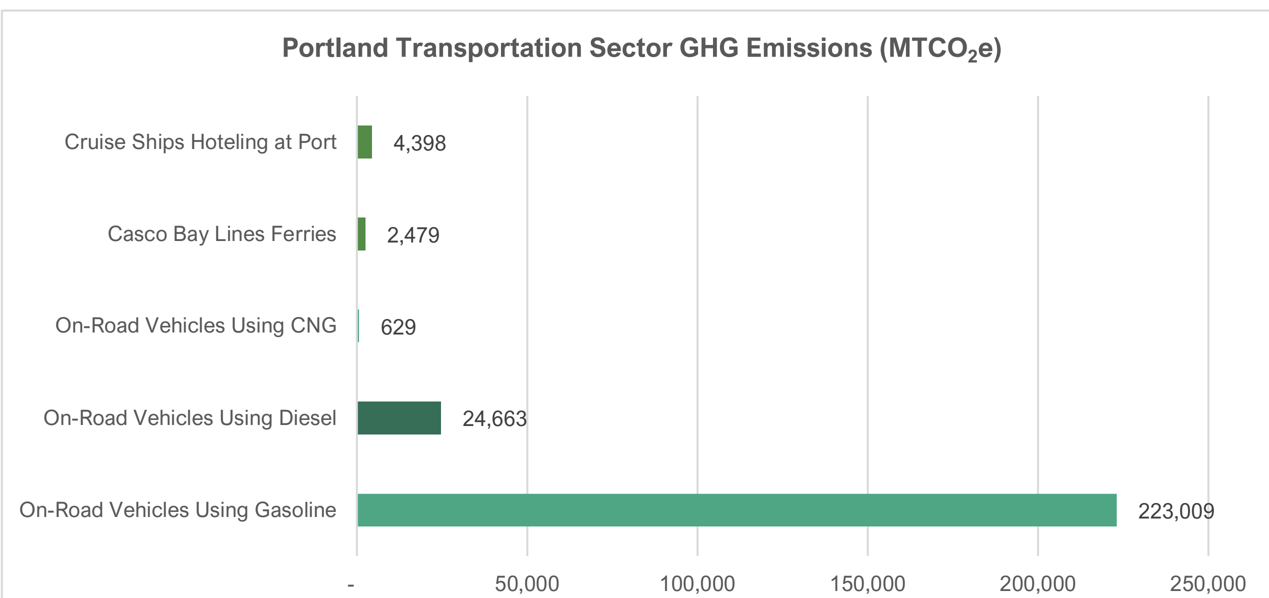


Figure 7: Portland 2017 transportation emissions, $MTCO_2e$.

2.4 Waste

Almost all non-recyclable waste that is collected in Portland goes to the ecomaine waste-to-energy incinerator and is burned. A small food waste pilot sends some food waste to an anaerobic digester outside of town. While ecomaine's facility is within Portland and processes waste for the region, its emissions were prorated for the waste generated by Portland residents and businesses. This avoids double-counting emissions associated with waste generated in other cities in southern Maine, but combusted in Portland. If all emissions from the ecomaine incinerator were counted in Portland's inventory, the emissions from the waste sector would increase by 174%. No emissions are attributed to landfills, because the incinerator ash that goes to landfills is inert and does not produce further emissions. Wastewater emissions listed here are estimated process emissions from the breakdown of wastewater. The energy used for processing wastewater is captured in industrial energy use.

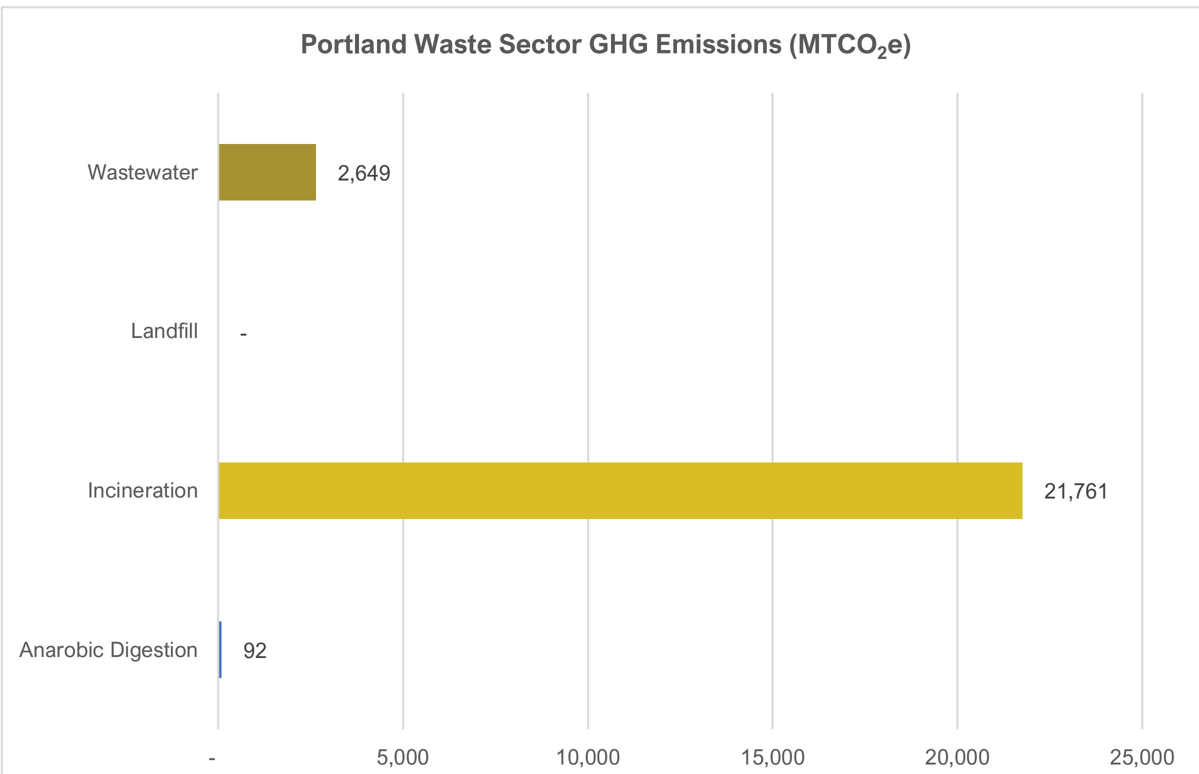


Figure 8: Portland 2017 waste sector emissions, $MTCO_2e$.

3 South Portland Inventory Results

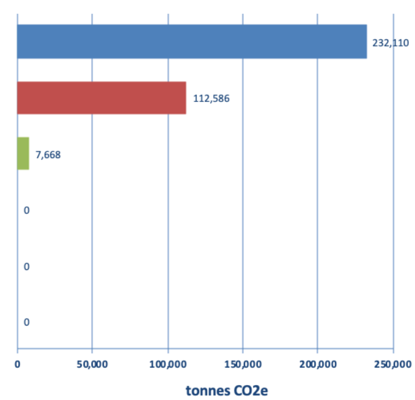
3.1 Summary

The overall output of data from the CIRIS tool for South Portland, Maine for 2017 is shown in Figure 9. Overall, South Portland was responsible for 352,264 metric tons of carbon dioxide equivalents (MTCO_2e). On a per capita basis, this is 13.8 tons per resident. This compares favorably to the U.S. national average of 20.7 tons per resident, but is more emissions-intensive than other Northeast cities, and also higher than Portland's emissions per capita at 12.6. In general, this difference from other cities is due to the greater demand for heating fuel, particularly fuel oil, the greater reliance on personal cars rather than public transit, and the greater proportion of industrial energy use. The higher per capita emissions in South Portland relative to Portland is primarily due to the larger industrial sector in South Portland, which is a significant source of emissions.

SUMMARY

NAME OF CITY:	South Portland, USA	**POPULATION:**	25,577
BOUNDARY:	BASIC	**LAND AREA (km2):**	31
INVENTORY YEAR:	2017	**GDP (US$ million):**	32,100

tCO2e	BASIC	Scope 1	Scope 2	Scope 3
	Stationary	147,407	84,703	
	Transportation	112,569	17	
	Waste	1,310		6,358
	IPPU			
	AFOLU			
	Other Scope 3			
	TOTAL	352,364		



Intensity indicators	Per capita	Per unit land area (km2)
Emissions	13.8	11,348

Figure 9: South Portland GHG inventory summary.

Table 7: South Portland GHG emissions by scope.

Scope	CO_2 Emissions (MTCO_2e)	CH_4 Emissions (MTCO_2e)	N_2O Emissions (MTCO_2e)	Total GHG Emissions (MTCO_2e)	% of Total Emissions
1	259,260	970	1,056	261,286	74%
2	83,864	379	478	84,720	24%
3	6,047	139	172	6,358	2%
South Portland Total	349,171	1,487	1,706	352,364	100%

Greenhouse gas emissions can be looked at by source or by sector; sources are the fuels and waste decomposition that produce greenhouse gas emissions, while sectors are different portions of the economy.

Overall, the use of electricity, natural gas, and fuel oil in buildings is the main driver of South Portland's GHG footprint, with buildings being responsible for two-thirds (66%) of community-wide GHG emissions. Mobile sources (transportation) within the South Portland boundaries are responsible for 32%, and the incineration of solid waste and processing of wastewater is responsible for the remaining 2%.

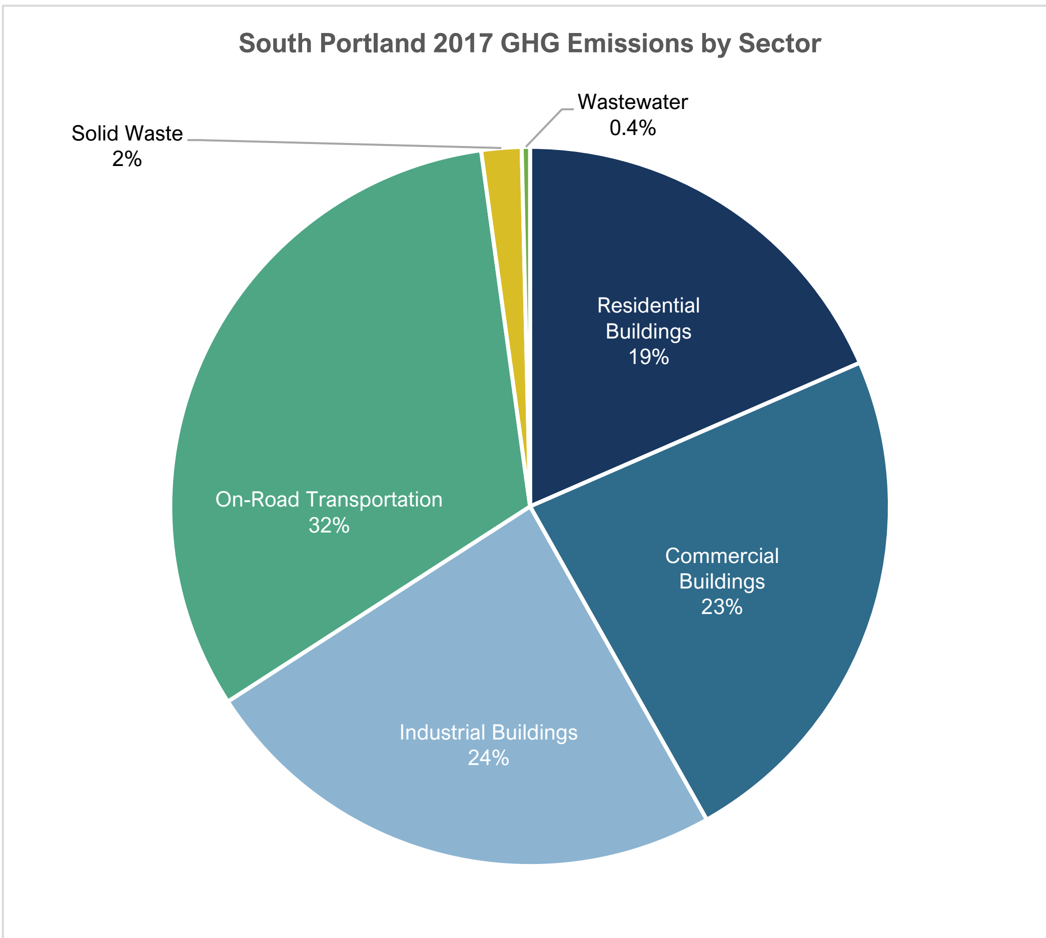


Figure 10: South Portland 2017 GHG emissions by sector.

Table 8: South Portland 2017 energy use and GHG emissions by sector.

Sector	Energy Use (MMBTU)	% of Energy Use	GHG Emissions (MTCO2e)	% of GHG Emissions
Buildings	954,308	68%	232,110	65.9%
Residential Buildings	1,214,552	19%	65,035	18.5%
Commercial Buildings	1,259,998	24%	82,353	23.4%
Industrial Buildings	1,583,930	25%	84,722	24.0%
Transportation	1,583,930	32%	112,586	32.0%
On-Road Transportation	3,428,859	32%	112,586	32.0%
Waste	-	0%	7,668	2.2%
Solid Waste	-	0%	6,358	1.8%
Wastewater	-	0%	1,310	0.4%
South Portland Total	3,428,859		352,364	

Table 9: South Portland 2017 CO_2, CH_4, and N_2O emissions by sector.

Sector	CO_2 Emissions ($MTCO_2e$)	CH_4 Emissions ($MTCO_2e$)	N_2O Emissions ($MTCO_2e$)	Total GHG Emissions ($MTCO_2e$)
Buildings	230,922	505	683	232,110
Transportation	112,201	133	252	112,586
Waste	6,047	850	771	7,668
South Portland Total	349,171	1,487	1,706	352,364

Within buildings, electricity, natural gas, and fuel oil are roughly equivalent sources of GHGs, with fuel oil being responsible for a slightly greater amount of emissions due to its high carbon intensity. Most emissions from transportation come from gasoline.

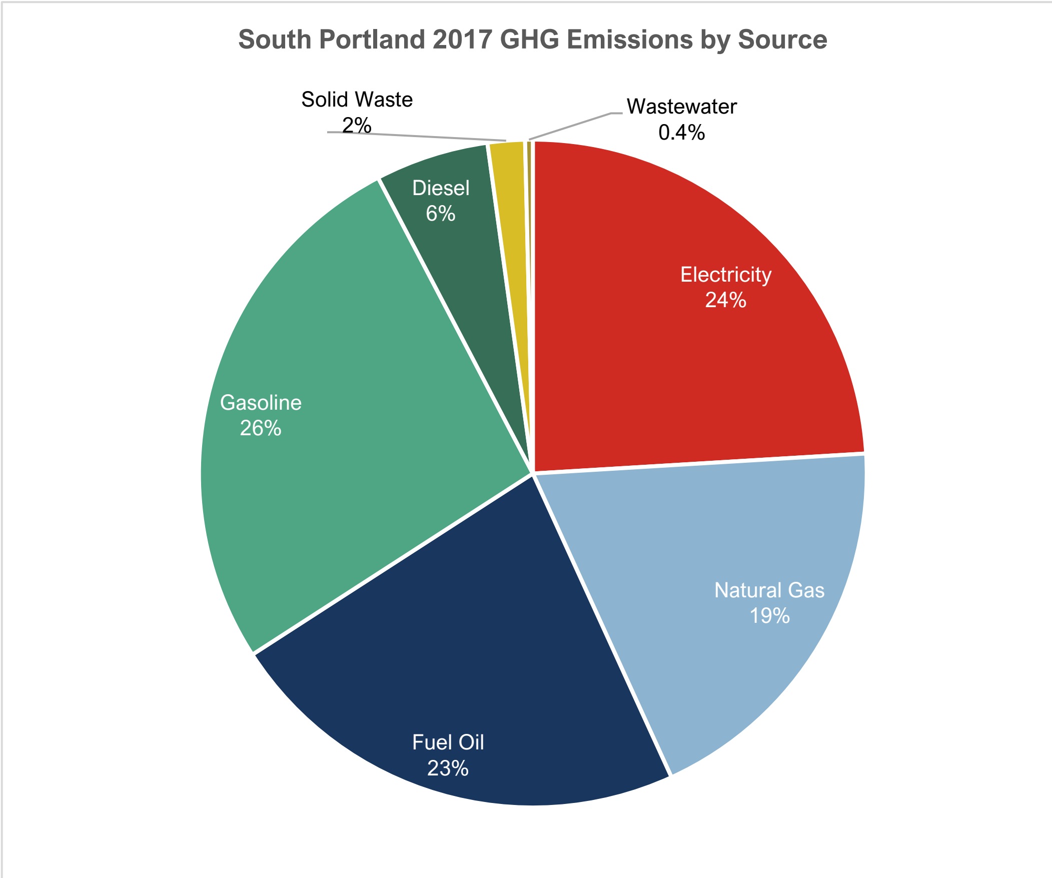


Figure 11: South Portland 2017 GHG emissions by source.

Table 10: South Portland 2017 energy use and GHG emissions by source.

Fuel	Site Energy Consumption (MMBTU)	% of Total Energy	GHG Emissions ($MTCO_2e$)	% of Total Emissions
Electricity	1,081,664	22%	84,720	24.0%
Natural Gas	1,269,800	25%	67,445	19.1%
Fuel Oil	1,077,614	21%	79,962	22.7%
Gasoline	1,322,672	26%	93,199	26.4%
Diesel	261,039	5%	19,370	5.5%
Solid Waste	-	0%	6,358	1.8%
Wastewater	-	0%	1,310	0.4%
Total	5,012,789	100%	352,364	100%

Table 11: South Portland 2017 CO_2, CH_4, and N_2O emissions by fuel type.

Fuel	CO_2 Emissions ($MTCO_2e$)	CH_4 Emissions ($MTCO_2e$)	N_2O Emissions ($MTCO_2e$)	Total GHG Emissions ($MTCO_2e$)
Diesel	19,306	22	42	19,370
Electricity	83,864	379	478	84,720
Fuel Oil	79,700	91	171	79,962
Gasoline	92,878	111	210	93,199
Natural Gas	67,376	36	34	67,445
Solid Waste	6,047	139	172	6,358
Wastewater	-	711	599	1,310
Total	349,171	1,487	1,706	352,364

3.2 Buildings

Roughly 66% of South Portland's GHG emissions footprint is attributable to energy use in buildings. Building GHG data was computed from actual citywide electricity and natural gas consumption information. Fuel oil use was modeled using the methodology described in section 4.5; all fuel oil was assumed to be No. 2 fuel oil, though in practice other grades of fuel oil may also be in use.

While in Portland, commercial buildings are the main source of building sector GHG emissions, in South Portland, the industrial sector is the largest.

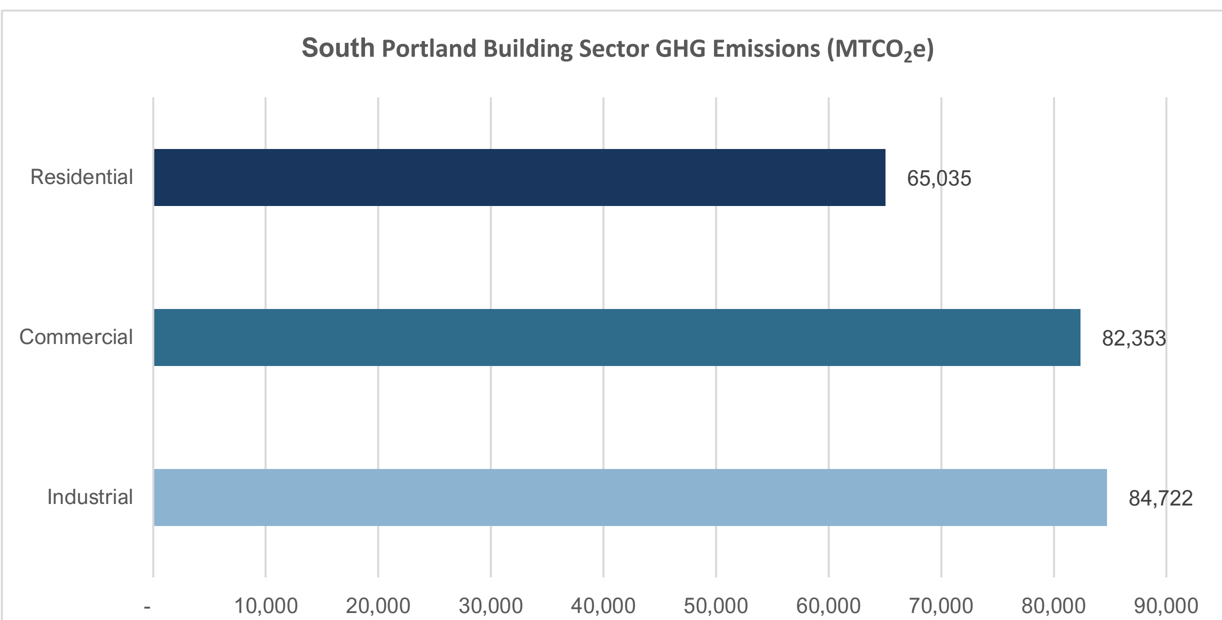


Figure 12: South Portland 2017 building sector GHG emissions, $MTCO_2e$.

Table 12: Site and source energy use by building sector.

Sector and Energy Use	Site Energy (MMBTU)	Source Energy (MMBTU)
Residential	954,308	1,375,052
Electricity	222,627	623,356
Fuel Oil	414,232	418,374
Natural Gas	317,450	333,323
Commercial	1,214,552	2,232,339
Electricity	551,170	1,543,276
Fuel Oil	187,207	189,079
Natural Gas	476,175	499,984
Industrial	1,259,998	1,842,335
Electricity	307,648	861,414
Fuel Oil	476,175	480,937
Natural Gas	476,175	499,984
South Portland Total	3,428,859	5,449,726

3.3 Transportation

All transportation GHGs included in the South Portland inventory were from on-road sources within the city boundaries, using the methodology described in section 4.6.1. Vehicle miles traveled were apportioned based on the registered vehicles in South Portland. Data was not available for any ships docking in South Portland, nor for passenger or freight trains passing through South Portland.

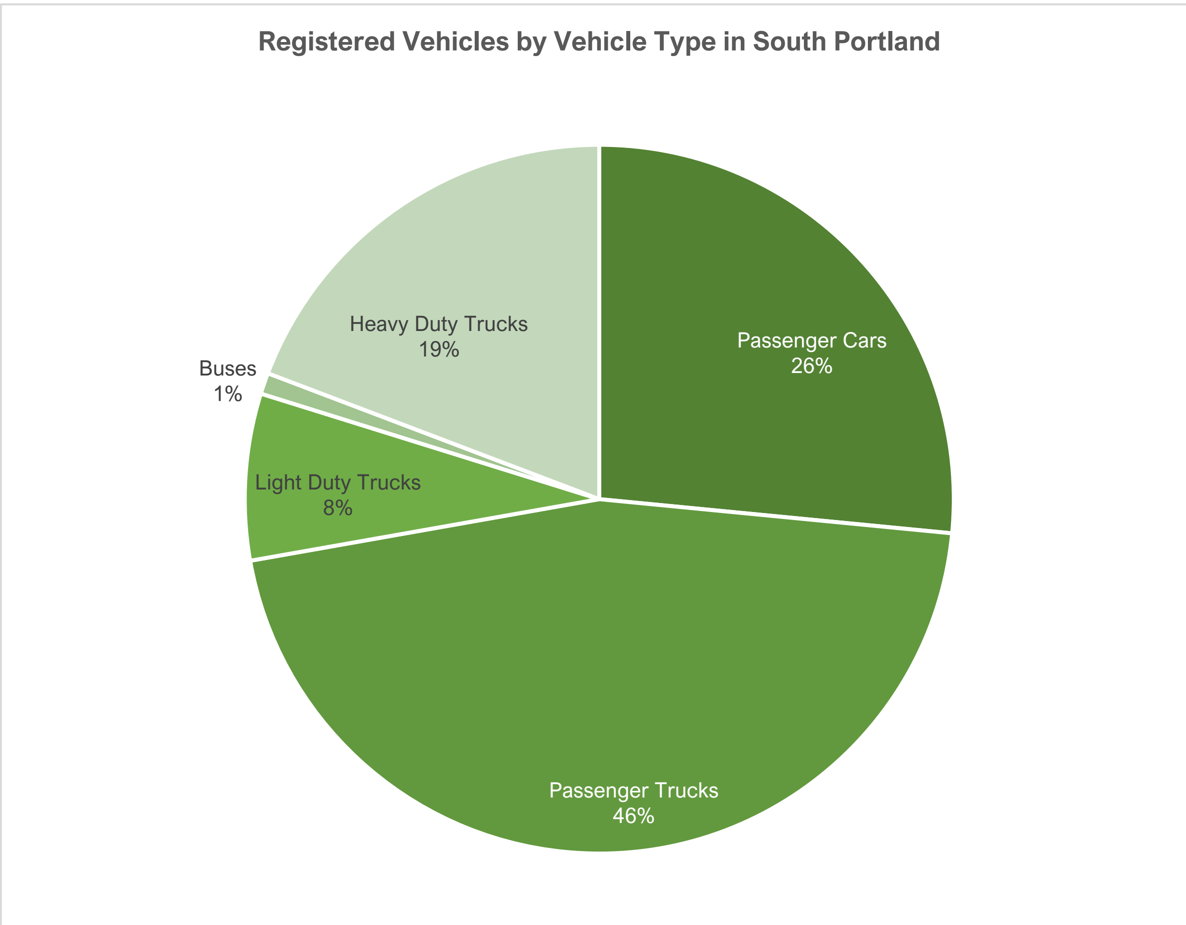


Figure 13: South Portland registered vehicles by vehicle type.

3.4 Waste

Most waste emissions in South Portland's inventory are scope 3 emissions. Almost all non-recyclable waste that is collected in South Portland goes to the ecomaine incinerator in Portland and is burned. A small food waste pilot sends some food waste to an anaerobic digester outside of town. No emissions are attributed to landfills, because ash from the incinerator that goes to landfills is inert and does not produce further emissions. Wastewater emissions listed here are estimated process emissions from the breakdown of wastewater. The energy used for processing wastewater is captured in industrial energy use.

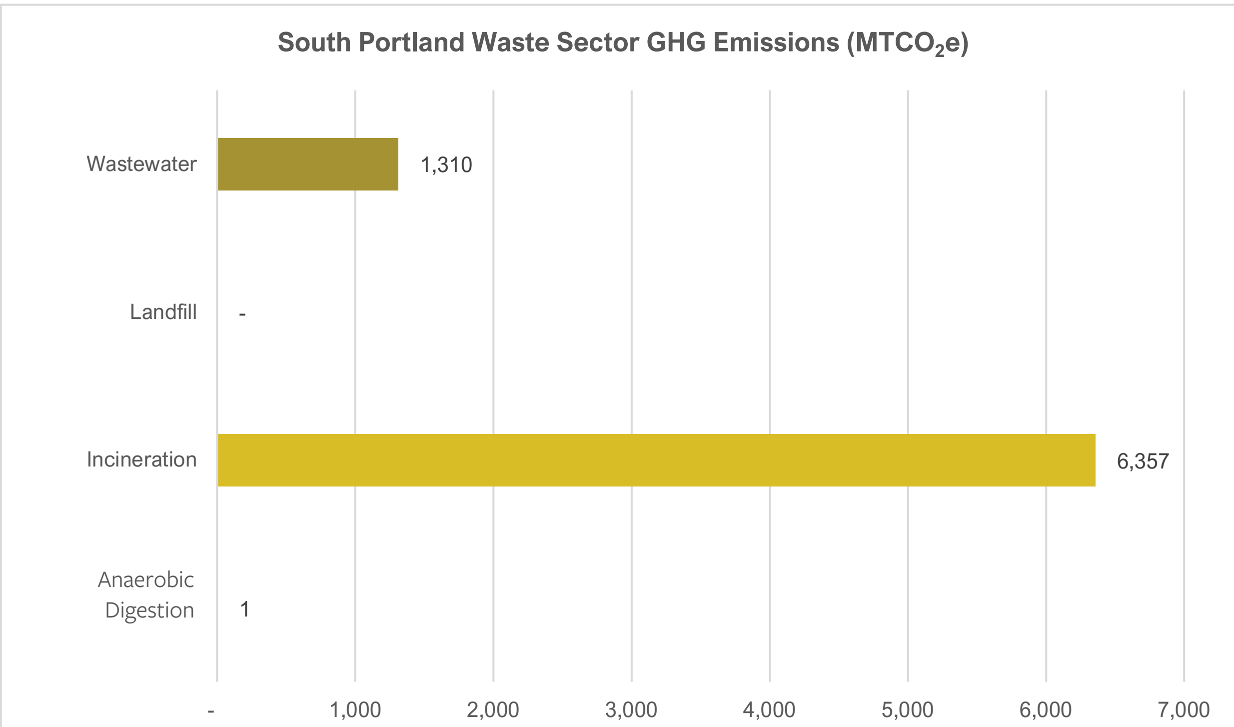


Figure 14: South Portland waste emissions, $MTCO_2e$.

4 Methodology

4.1 Uncertainty

The inventories are compiled using measured data, projections, models, and, where data is unavailable, best estimates. The inventories will be regularly revised as new and better data become available, as models are improved, and as international standards and guidance evolve. For these reasons, longer-term trends are likely to prove more reliable than absolute numbers or year-to-year changes.

4.2 Citywide Protocol

Both inventories follow the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)[4] for compliance with the Global Covenant of Mayors for Climate and Energy and the Carbon Disclosure Project. The inventories were compiled and submitted using the City Inventory Reporting and Information System (CIRIS) tool from C40 Cities,[5] which is compliant with the Global Covenant of Mayors' 'Common Reporting Framework' (CRF).[6]

It was decided by the Cities of Portland and South Portland and the consultant team to use the BASIC approach in the GPC. Compared to the GPC BASIC+ option, using the BASIC methodology aligns the inventories better with the elements the cities can control. BASIC includes all scope 1 and 2 emissions, as well as the scope 3 out-of-boundary waste and wastewater emissions. However, the BASIC methodology excludes other major scope 3 emissions sources such as emissions from leakage of natural gas, emissions from electricity that is lost in transmission, and emissions from out-of-boundary aircraft or ships.

4.3 Differences from the Portland 2010 Inventory

The use of the GPC BASIC protocol also represents a major shift from the last GHG inventory that was completed for Portland in 2010.[7] That inventory used the ICLEI protocol, which was common at the time but has been superseded by the GPC. There are several critical differences between the 2010 Portland inventory and the 2017 Portland inventory. (These notes are not applicable to South Portland, which had no prior community-wide inventory.)

4.3.1 Heating Fuels:

The 2010 inventory estimated natural gas and fuel oil consumption based on statewide data. However, there has been a rapid expansion of natural gas hookups and the use of natural gas as a heating fuel in Portland and South Portland over the past decade. Actual natural gas data was acquired for 2017. Using the actual natural gas data, U.S. Department of Energy (DOE) data on heating energy intensity, tax data on heating fuel

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[4] GHG Protocol, Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) Washington, DC: World Resources Institute. https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities

[5] C40 Cities. Reporting GHG emissions inventories https://resourcecentre.c40.org/resources/reporting-ghg-emissions-inventories

[6] Global Covenant of Mayors for Climate and Energy. Global Common Reporting Framework. https://www.globalcovenantofmayors.org/our-initiatives/data4cities/common-global-reporting-framework/

[7] City of Portland, Community Inventory of Greenhouse Gas Emissions, 2010. https://www.portlandmaine.gov/DocumentCenter/View/6278/GHG-Inventory-2010

type, and analysis by another consultant team, fuel oil use was estimated per building type, as described in detail in section 4.5.

4.3.2 Aircraft Emissions:

The 2010 inventory included GHG emissions from all outgoing flights from Portland International Jetport (PWM), prorated for the percentage of travelers who were Portland residents. The GPC BASIC protocol does not include these scope 3 emissions, so they were excluded from the 2017 inventory. The BASIC protocol does include emissions from intracity aircraft, such as helicopters that depart and land within the city limits, or recreational planes that depart and return to the city without landing elsewhere. However, no data on intracity helicopter or small plane traffic was available, and such emissions are likely trivial.

4.3.3 Marine Fuel Emissions:

The 2010 inventory attributed GHG emissions to all ships that came to Portland, attributing a portion of national data for marine fuel use to Portland based on the ratio between ships that docked in the city and ship traffic nationally. The GPC BASIC protocol does not include these scope 3 emissions, so they were excluded from the 2017 inventory. The BASIC protocol does include emissions from ships while docked, and ships traveling within the city boundaries (or not docking anywhere else). A portion of these emissions were able to be estimated:

- Cruise ships maintain power by running auxiliary engines while docked; as they are within the city, they are scope 1 emissions. Emissions from these cruise ships were estimated using the methodology described in section 4.6.2.
- The Casco Bay Lines ferry system travels between the Portland peninsula and Portland's islands; as these routes are within the city, they are scope 1 emissions. These emissions were estimated from an approximation of annual fuel use by Casco Bay Lines.
- Emissions from the fuel used by commercial lobster and fishing boats and recreational boats that depart from and return to Portland without docking elsewhere is within scope 1. However, no data on the total number of boats or their fuel use was available, and the emissions are unlikely to be very significant at a citywide scale.
- Emissions from any tankers and container ships that dock at Portland would be in scope, but no data on the numbers and size of these ships was available.

4.3.4 Train Travel:

The 2010 inventory estimated emissions from freight trains and passenger trains. No train data was available for the 2017 inventory, and so train emissions are missing from the inventory; again, such emissions are likely trivial.

4.3.5 Passenger Vehicle Emissions

Vehicle miles traveled (VMT) were calculated based on all trips within city borders in both cities. Vehicle emissions were modeled proportionally to the weighted average fuel economy of the registered vehicle stock in Portland.

4.3.6 Waste Incineration:

Ecomaine was able to provide a facility-specific emissions factor for their waste incinerator for 2017. The ecomaine incinerator has a relatively low emissions intensity, compared to national averages, likely related to its ISO compliance.

4.3.7 Electrical Emissions Factor:

The 2017 inventory uses the 2016 GHG intensity for the Northeast Power Coordinating Council (NPCC) New England sub-region factor from EPA's eGRID database of regional GHG intensities; this region is aligned with ISO New England. Due to increasing renewable energy generation, this emissions factor is lower than ones used in the past.

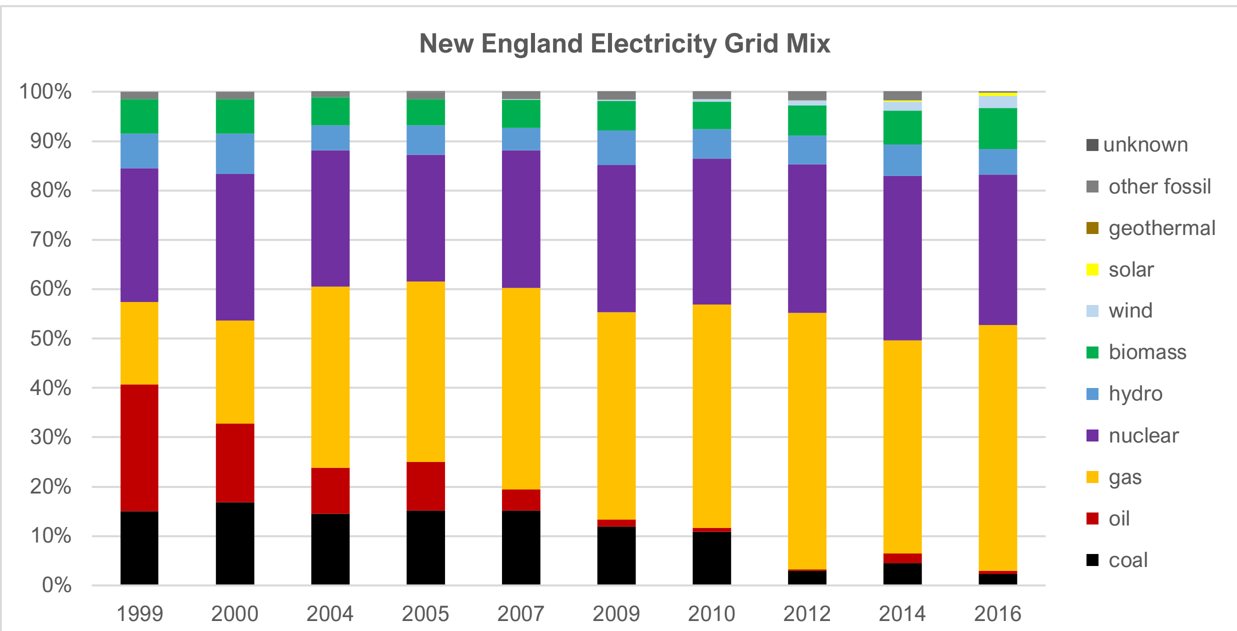

Figure 15: New England grid mix, 1999-2016.

4.3.8 Results of the differences in approach:

These changes collectively result in Portland's 2017 GHG footprint of 840,419 $MTCO_2e$ appearing to be 26% smaller than the 1,140,875 $MTCO_2e$ published for 2010. Most of the difference comes from mobile sources, which are 51% less in the new inventory, due mostly to the exclusion of transboundary aircraft and ships. It is possible that the actual GHG footprint of Portland has decreased some in the intervening time, but the two inventories cannot be directly compared.

4.4 Greenhouse Gases Included

The inventory quantified three of the six internationally recognized GHGs, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The emissions of the other three internationally recognized GHGs, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), were considered negligible to the emissions inventory under the assumption that all refrigerators and air conditioners are disposed of properly, since the disposal of any appliances that could emit those GHGs is regulated by the State of Maine. Fugitive emissions of SF_6 were not researched. Emissions of the three measured GHGs were converted to metric tons carbon dioxide equivalent ($MTCO_2e$) emissions using the Global Warming Potential (GWP) coefficients of each gas developed by the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report.

4.5 Stationary Sources

4.5.1 Data Sources

Electricity consumption data for Portland and South Portland for 2017 and 2018 was provided to the Cities via email by Central Maine Power (CMP), broken out between commercial, residential, and industrial sectors, including total consumption and number of accounts.

Across the State of Maine, fuel oil is the dominant source of space heating and domestic hot water for buildings. However, natural gas use has been rapidly expanding in Portland and South Portland over the last decade, and so the Cities and the consultant team did not consider statewide data on natural gas and fuel oil use to be representative of city-specific energy use and an early priority was placed on accessing actual natural gas data for both cites. (This effort took some time, and the difficulties encountered directly inform One Climate Future action BE 5.2.) The natural gas utility Unitil provided natural gas data for the commercial and residential sectors for calendar years 2017 and 2018 to the Cities via email in October 2019.

Other than for municipal facilities, no fuel oil data was available: fuel oil is delivered by many companies, and these companies were unwilling to share data on their sales. This situation is very common across the country. In most places, statewide fuel oil sales data can be used to estimate citywide fuel oil use, but because of the recent expansion of natural gas infrastructure in Greater Portland, this was not feasible.

To develop the One Climate Future modeling, the consultant team had to develop estimates of energy use intensity (EUI), measured in kBtu/ft2, for various building types, for electricity, natural gas, and fuel oil. This process also provided the fuel oil estimates for each city.

4.5.2 Energy Use Estimation and Assumptions

To allocate a specific energy consumption to various building categories, the consultant team first compiled building floor areas from city parcel data, and then developed a set of preliminary energy use intensities based on the U.S. Energy Information Administration's nationwide building energy surveys—the Commercial

Building Energy Consumption Survey (CBECS) for 2012 and the Residential Energy Consumption Survey (RECS) from 2015. [8,9]

Electricity EUIs for commercial buildings were developed for each building type from the 2012 CBECS data for the Northeast or New England region, depending on data availability. Electricity EUIs for residential buildings were developed from the RECS data and models for the ASHRAE Climate Zone 6A.

Natural gas use and fuel oil use in residential buildings was estimated using Residential Prototype Building Models from the U.S. Department of Energy and the Pacific Northwest National Laboratory (PNNL) for the state of Maine.[10] Natural gas and fuel oil use in commercial buildings used the 2012 CBECS for New England. These models were used to develop EUI estimates for heating loads by fuel type. The assignment of residential buildings to heating fuel types built on a prior analysis for both cities done by Meister Consultants Group (MCG), which was provided to the consultants by the Cities. Once floor area and unit counts had been determined for building and fuel type, EUI per square foot or per unit were assigned.

Estimated EUIs for each type were multiplied by the floor area, and the electricity and natural gas results compared to the total consumption numbers. There was only a small difference between the top-down and bottom-up energy use numbers; electric and gas EUIs were adjusted by maintaining the same energy consumption ratio seen with the preliminary EUIs and shifting the EUI to match total energy consumption. Since the residential and commercial building code data showed that the heating EUI of a building with the same equipment and efficiency is equivalent for natural gas and fuel oil, the adjustments to local EUIs made to the natural gas consumption were also applied to the fuel oil consumption.

Industrial sector electricity use was developed directly from the CMP data. Unlike CMP for electricity, Unitil does not have separate rate classes for industrial users; industrial gas use was grouped into the commercial data. To estimate industrial gas use, the commercial gas data was apportioned between commercial and industrial sectors based on the ratio of commercial and industrial electricity use in each city. Industrial fuel oil use was estimated based on the MCG data that identified industrial lots that use fuel oil, and assuming similar fuel oil energy use intensities. (This assumption would benefit from refinement in future inventories.)

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[8] US Energy Information Administration (EIA). 2012 Commercial Building Energy Consumption Survey (CBECS) Data. Retrieved from https://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption
[9] US Energy Information Administration (EIA). 2015 Residential Energy Consumption Survey (RECS) Data. Retrieved from https://www.eia.gov/consumption/residential/data/2015/
[10] US Department of Energy (DOE). Residential Prototype Building Model. Building Energy Codes Program. Retrieved from https://www.energycodes.gov/development/residential/iecc_models

Table 13: Floor area and energy use intensity (EUI) findings.

Sector	Portland Floor Area	South Portland Floor Area	Site EUI (kBtu/ft^2)	Electric EUI (kBtu/ft^2)	Natural Gas EUI (kBtu/ft^2)	Fuel Oil EUI (kBtu/ft^2)
Residential	40,453,915	13,687,137				
Single Family	19,020,191	9,421,168	64.6	12.5	10	42.1
Apt 2-4	8,445,101	1,815,991	77	17.4	30.1	29.4
Multi-family	12,988,623	2,449,978	73.5	19	36.9	17.6
Commercial	41,548,843	10,055,727				
Education and Institutional	2,295,620	435,211	107.3	30.4	53	23.4
Government - City	3,117,298	306,156	73.9	41.1	42	0.4
Government - Other	1,952,984	216,088	127.9	43.2	42	42
Office	7,687,843	2,243,666	115	43.2	46.1	23.4
Other Commercial	17,496,539	5,461,336	115.4	43.5	46.1	23.4
Healthcare	3,447,597	34,682	127.1	55.5	70.6	0
Warehouse and Storage	5,550,962	1,358,588	83.7	12.4	46.1	23.4
Parking	378,341	N/A	20	20	0	0
Industrial	3,195,487	755,973	696.0[11]	208	244.9	242.8
Total	85,576,586	24,498,837				

Table 14: 2017 stationary energy use by sector, in MMBTU.

City/Sector	Electricity (MMBTU)	Natural Gas (MMBTU)	Fuel Oil (MMBTU)	Total Stationary Energy (MMBTU)
Portland Stationary Energy	2,337,226	3,276,000	2,743,837	8,357,063
Commercial	1,493,645	1,965,600	904,002	4,363,247
Industrial	314,718	491,400	483,438	1,289,555
Residential	528,863	819,000	1,356,398	2,704,261
South Portland Stationary Energy	1,081,445	1,269,800	1,077,614	3,428,859
Commercial	551,170	476,175	187,207	1,214,552
Industrial	307,648	476,175	476,175	1,259,998
Residential	222,627	317,450	414,232	954,308
Total Stationary Energy	3,418,671	4,545,800	3,821,451	11,785,922

Neither Portland or South Portland have any agriculture, forestry, or mining, so emissions reported for the stationary sector are limited to those associated with building and industrial energy use.

[11] Industrial energy use intensities per square foot are provided for consistency, but these are not meaningful, as the primary drivers of energy use in industrial facilities are process loads largely uncorrelated with floor area.

4.6 Mobile Sources

4.6.1 Road Traffic

The GHG emissions for vehicles were based on the vehicle miles traveled (VMT) and the GHG intensities of fuel sources. As is standard for calculating VMT and tracking transportation sector emissions, VMT numbers were based on the miles traveled within the boundaries of the cities, regardless of whether the vehicle owners reside in the cities or whether the vehicles are purchased at dealers within the city limits. Because sport utility vehicles (SUVs) and pickup trucks are a common mode of transit in Maine, passenger vehicle VMT was broken out between passenger vehicles and light duty trucks.

Maine Department of Transportation (MaineDOT) data was used to calculate the total VMT on each road segment in each city, and from this, we can estimate that a total 748,773,000 vehicle miles were traveled across the two cities in the baseline year (2017).

This extremely granular data does not tell us which vehicles traveled on which roads, however. To estimate energy use and emissions, vehicle registration data was used to look at the registered vehicle stock within each city. U.S. Department of Transportation and U.S. Energy Information Administration data for the fuel economy of vehicles sold in each class and model year was matched to the registered vehicle stock, and from this, weighted average fuel economy calculations were created for each city and each vehicle class. The resulting tables are shown below.

Table 15: Portland on-road VMT and fuels.

Vehicle Type	Fuel Type	Number of Vehicles	VMT	MPG (Weighted)	Fuel Use (MMBTU)	GHG ($MTCO_2e$)
Passenger Cars	Diesel	232	2,350,594	33.3	9,810	728
	Electric	48	486,330	N/A	280,499	75
	Gasoline	23816	241,300,624	32.9	1,017,975	71,730
	Hybrid Electric	1413	14,316,333	34.1	58,328	4,110
Passenger Trucks	Diesel	108	1,094,242	17.2	8,843	656
	Gasoline	19748	200,084,176	17.2	1,616,959	113,936
	Hybrid Electric	138	1,398,198	17.2	11,299	796
Light Duty Trucks	Diesel	166	1,681,890	17.2	13,631	1,011
	Gasoline	4554	46,140,538	17.2	372,851	26,272
	Hybrid Electric	20	202,637	17.4	1,616	114
Buses	CNG	31	314,088	3.3	11,401	606
	Diesel	82	830,813	3.3	34,995	2,597
	Gasoline	38	385,011	3.3	16,217	1,143
Heavy Duty Trucks	Diesel	994	10,071,079	5.3	264,128	19,599
	Gasoline	529	5,359,759	5.3	140,567	9,905
Total	Diesel	1,582	16,028,619	6.7	331,408	24,591
	Gasoline	48,685	493,270,108	21.7	3,164,570	222,985

	Hybrid Electric	1,571	15,917,168	31.1	71,243	5,020
	CNG	33	334,352	3.4	11,700	622
	Electric	48	486,330	N/A	280,499	75

Table 16: South Portland on-road VMT and fuels.

Vehicle Type	Fuel Type	Vehicles	VMT	MPG (Weighted)	Fuel Use (MMBTU)	GHG (MTCO2e)
Passenger Cars	Diesel	80	810,550	33.3	3,386	251
	Electric	11	111,451	N/A	64,281	17
	Gasoline	9441	95,654,988	32.7	406,314	28,630
	Hybrid Electric	489	4,954,485	34.2	20,125	1,418
Passenger Trucks	Diesel	58	587,648	17.2	4,749	352
	Gasoline	8936	90,538,394	17.2	731,677	51,556
	Hybrid Electric	48	486,330	17.2	3,930	277
Light Duty Trucks	Diesel	57	577,517	17.3	4,652	345
	Gasoline	1442	14,610,157	17.2	118,069	8,319
Buses	Diesel	33	334,352	3.3	14,083	1,045
	Gasoline	2	20,264	3.3	854	60
Heavy Duty Trucks	Diesel	879	8,905,914	5.3	233,570	17,332
	Gasoline	247	2,502,572	5.3	65,633	4,625
Total	Diesel	1,107	11,215,980	6.0	260,440	19,325
	Gasoline	20,068	203,326,374	21.4	1,322,546	93,191
	Hybrid Electric	539	5,461,078	31.3	24,220	1,707
	Electric	11	111,451	N/A	64,281	17

4.6.2 Off-Road Traffic

Cruise ships maintain power by running auxiliary engines while docked. As this process occurs within the city, they are scope 1 emissions. Emissions from these cruise ships were estimated by using the Cruise Ship visit schedule for 2017 from the City of Portland to calculate the number of hours each cruise ship was docked in Portland, the size of each ship, and whether more than one ship was docked at any one time.[12]

To use this data to estimate emissions from docked cruise ships, we reviewed two studies of docked ship emissions from Los Angeles (Port of Los Angeles) and Seattle, Washington (Puget Sound Maritime Air Forum).[13,14] Cruise ships that are hoteling at dock generally run two engines—an auxiliary diesel engine and

[12] Portland Maine 2017 Cruise Schedule. Retrieved from https://www.portlandmaine.gov/DocumentCenter/View/27428/2017-Cruise-Schedule

[13] Starcrest Consulting Group. 2018. “Inventory of Air Emissions for Calendar Year 2017.” Port of Los Angeles. Retrieved from https://kentico.portoflosangeles.org/getmedia/880bc597-84bc-4ae6-94e2-59a2e6027f42/2017_Air_Emissions_Inventory

[14] Starcrest Consulting Group. 2018. “2016 Puget Sound Maritime Emissions Inventory, Revised October 2018” Puget Sound Maritime Air Forum. Retrieved from https://pugetsoundmaritimeairforum.files.wordpress.com/2018/10/final-2016-psei-report-19-oct-2018-scg.pdf

an auxiliary boiler. For each ship, the auxiliary engines were assessed based on the passenger size; variable passenger size estimates were not available for backup boilers. Only hoteling emissions were included, because only those could be guaranteed to be within the scope of the inventory—while maneuvering emissions might occur within the city borders, reliable data on the length of time the ships spend maneuvering was not available. No tanker docking information was available for South Portland, so tanker hoteling emissions were not included.

Table 17: Ship hoteling energy use assumptions.

Engine	Passenger Size Class	kW Demand		
		Transit	Maneuvering	Hoteling
Cruise Ship Auxiliary Engine	<1,500	5,733	6,800	3,267
	1,500-2,000	7,000	9,000	5,613
	2,000-2,500	11,000	11,350	6,900
	2,500-3,000	9,781	8,309	6,089
	3,000-3,500	8,313	10,116	8,313
	3,500-4,000	9,934	11,764	10,600
	4,000-4,499	12,500	14,000	12,000
	4,500-4,999	13,000	14,500	13,000
Cruise Ship Boiler	<4,000	282	361	918
Tanker Boiler	N/A	N/A	145	220

The Casco Bay Lines ferry system travels between the Portland Peninsula and Portland's islands; as these routes are within the city, they are scope 1 emissions. Casco Bay Lines staff estimated that their ferries consume 240,000 gallons of marine diesel fuel per year.

Table 18: Cruise ship and ferry energy use and emissions.

Type of Vessel Energy Use	Annual Diesel Use (units variable)	Annual Energy Consumption (kBtu)	Annual GHG Emissions ($MTCO_2e$)
Cruise Ship Auxiliary Engines, Diesel	6,004,611 kWh-e	20,487,733	4,167
Cruise Ship Boilers, Diesel	250,192 kWh-e	853,656	231
Ferry Fuel Consumption, Diesel	240,000 gallons	33,120,000	2,479

Emissions from passenger and freight rail and intracity aircraft—such as helicopters that depart and land within the city limits or recreational planes that depart and return to the city without landing elsewhere—were not included due to limited data availability. It is estimated that such emissions would be negligible.

4.7 Waste and Wastewater

4.7.1 Solid Waste

Solid waste data was provided by ecomaine. All waste in Portland and South Portland is collected and processed by ecomaine. Waste that is not recycled or taken to an anaerobic digestor is incinerated at the ecomaine incinerator in Portland. The emissions from the plant are prorated to only capture the portion attributable to Portland and South Portland waste streams (along with the relatively small amount of energy and emissions needed for ecomaine operations, which are attributed to Portland because of the plant's location). In accordance with the GPC protocol, emissions from the incineration of biogenic waste (e.g. paper, food waste, wood products) are considered carbon-neutral for the purposes of the inventory. The incinerator produces ash, which goes to landfills, but is inert and has no further GHG emissions.

Portland and South Portland have begun operating a small food waste pilot, which takes food waste to an anaerobic digester. A portion of the collected waste is contaminants and not suitable for digestion, and this portion was assumed to go to the incinerator.

The emissions intensity of incineration was provided by ecomaine, and applied to the total waste sent to the incinerator from each city. Emissions from the digested food waste were modeled using the "CIRIS Biological Treatment of Solid Waste Emissions Calculator."

Table 19: Solid waste volumes.

Category/Sub-Category	Tonnes
Residential Disposed Waste Total	16,400
Residential MSW	15,402
Residential Bulky	999
Commercial Disposed Waste Total	65,820
Commercial MSW	54,454
Commercial Bulky	11,365
Food Waste	5,396
Food Waste Digested	4,143
Food Waste Contaminates	1,253
Inert Ash [no GHGs]	21,979
Residential Recycling [no GHGs]	7,843
Commercial Recycling [no GHGs]	8,639
Total MSW including recycling	126,077
Total MSW producing GHGs	87,616

4.7.2 Wastewater

Wastewater energy use is included in the industrial energy use sector for the inventory, though the One Climate Future modeling broke it out using data from Portland and South Portland. Wastewater process emissions were modeled using data provided by the Portland Water District and the South Portland Water Resource Protection Department, and the “CIRIS Wastewater Emissions Calculator.” Wastewater process emissions were estimated at 3,959 $MTCO_2e$ annually.