Our Contributions to Climate Change
GHG Emissions

THE GREENHOUSE GASES WE ARE ADDING TO THE ATMOSPHERE TODAY WILL CONTINUE TO DRIVE CHANGES TO OUR CLIMATE DECADES FROM NOW.

GREENHOUSE GASES
Greenhouse gases in the atmosphere trap heat radiating from the earth back into space. This trapped heat increases global temperatures, driving climate change.

BURNING FOSSIL FUELS
Burning fossil fuels adds large quantities of greenhouse gases into the atmosphere. Gasoline, diesel, heating oils, and natural gas are fossil fuels we use daily that produce greenhouse gas emissions.

CLIMATE CHANGE IMPACTS
Rising sea levels, higher temperatures, and more extreme storms are some of the many effects of climate change that can severely impact our ecosystems, economies, and health.

Portland and South Portland's greenhouse gas emissions

In 2017, Portland and South Portland collectively emitted 1,192,665 $MTCO_2e$. This threshold will serve as our baseline for measuring emissions reductions moving forward.

EMISSIONS BY SECTOR

34% COMMERCIAL BUILDINGS

22% RESIDENTIAL BUILDINGS

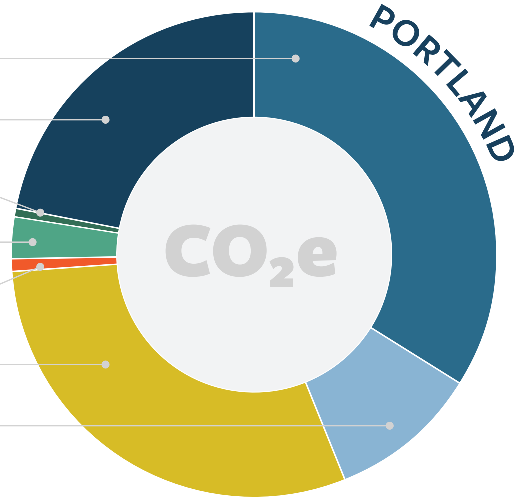
0.3% WASTEWATER

3% SOLID WASTE

0.8% WATERBORNE TRANSPORTATION

30% ON-ROAD TRANSPORTATION

10% INDUSTRIAL BUILDINGS



840,419 $MTCO_2e$

OF GREENHOUSE GASES EMITTED IN 2017

Portland's greenhouse gas emissions

In 2017, Portland emitted 840,419 $MTCO_2e$ of greenhouse gas emissions community-wide. The use of electricity, natural gas, and fuel oil in buildings is the main driver of Portland's greenhouse gas footprint—commercial and residential buildings emit over half (56%) of our city's greenhouse gas emissions. Another 10% of emissions comes from industry, including industrial buildings and process loads. Transportation within the city is responsible for roughly one third (31%) of Portland's emissions, with just under 1% of those emissions attributed to waterborne transportation, including Casco Bay Lines and cruise ships while in port. The remaining 3% of Portland's emissions are produced from the incineration of solid waste and processing of wastewater.

South Portland's greenhouse gas emissions

In 2017, South Portland emitted 352,246 $MTCO_2e$ of greenhouse gas emissions community-wide. As in Portland, the use of electricity, natural gas, and fuel oil in buildings is a primary driver of South Portland's greenhouse gas footprint—commercial and residential buildings emit 42% of our city's greenhouse gas emissions. In South Portland, however, a much larger proportion (24%) of emissions comes from our industrial sector, including industrial buildings and process loads. Transportation within the city is responsible for roughly one third (32%) of our emissions, and the incineration of solid waste and processing of wastewater is responsible for the remaining 3%.

What is $MTCO_2e$?

$MTCO_2e$ is an abbreviation for "metric tons of carbon dioxide equivalents." Each greenhouse gas has a different capacity to trap heat, or "global warming potential." By expressing quantities of greenhouse gases in $MTCO_2e$, we are converting one metric ton of a greenhouse gas into the equivalent number of metric tons of carbon dioxide, based on their global warming potential, in order to compare and sum the emissions from various greenhouse gases.

EMISSIONS BY SECTOR

23% COMMERCIAL BUILDINGS

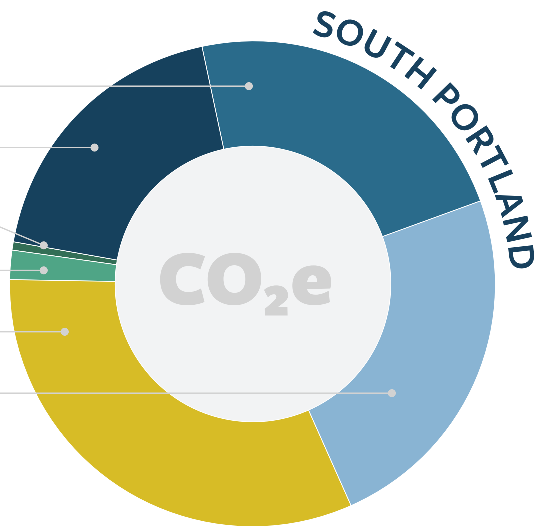
19% RESIDENTIAL BUILDINGS

0.4% WASTEWATER

3% SOLID WASTE

32% ON-ROAD TRANSPORTATION

24% INDUSTRIAL BUILDINGS



352,246 $MTCO_2e$

OF GREENHOUSE GASES EMITTED IN 2017

CASCO BAY LINES FERRIES • PHOTO BY ANNA ACKERMAN

WHAT'S INCLUDED IN THE INVENTORIES?

Greenhouse gas inventories are generally divided into three scopes:

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

The inventories follow the BASIC approach to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). BASIC includes all scope 1 and 2 emissions, as well as scope 3 out-of-boundary waste and wastewater emissions. It excludes other scope 3 emissions sources, such as emissions from natural gas leakages, electric transmissions losses, or out-of-boundary aircraft or ships. Using the BASIC methodology aligns the inventories better with the elements the cities can control.

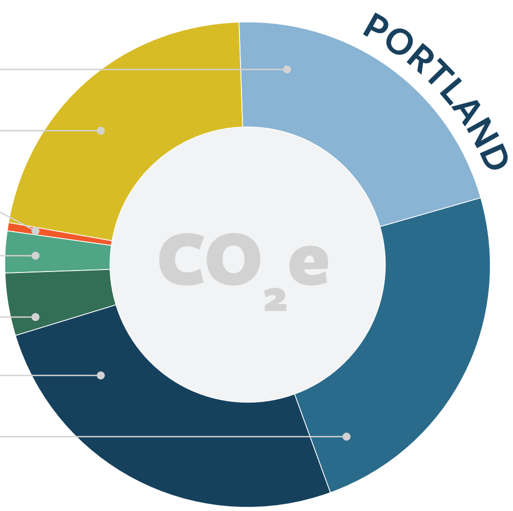
PETROLEUM TANKS IN SOUTH PORTLAND • Photo by City of South Portland

Greenhouse gas emissions by source

Another way to look at the breakdown of greenhouse gas emissions is by source. Sources are the fuels and waste decomposition processes that produce greenhouse gas emissions. In both Portland and South Portland, the total greenhouse gas emissions are split relatively evenly between electricity, natural gas, fuel oil, and gasoline. (Wastewater, solid waste and diesel fuel contribute to less than 10% of emissions in both cities.) Fuel oil, in particular, has a high carbon intensity, meaning it produces more greenhouse gases per unit of energy than other fuels.

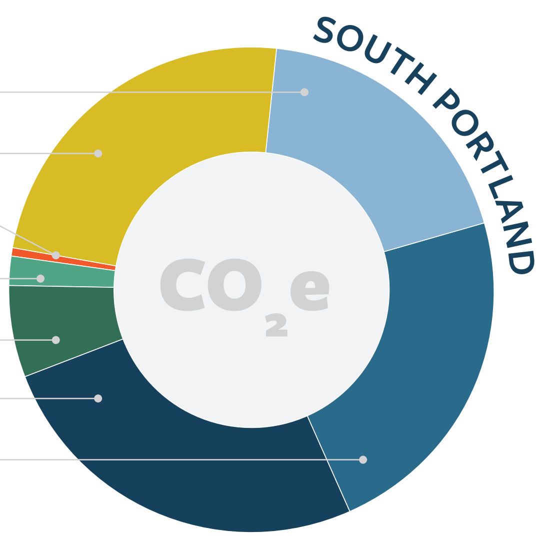
EMISSIONS BY FUEL SOURCE

- **21%** NATURAL GAS
- **22%** ELECTRICITY
- **0.3%** WASTEWATER
- **3%** SOLID WASTE
- **4%** DIESEL
- **26%** GASOLINE
- **24%** FUEL OIL



EMISSIONS BY FUEL SOURCE

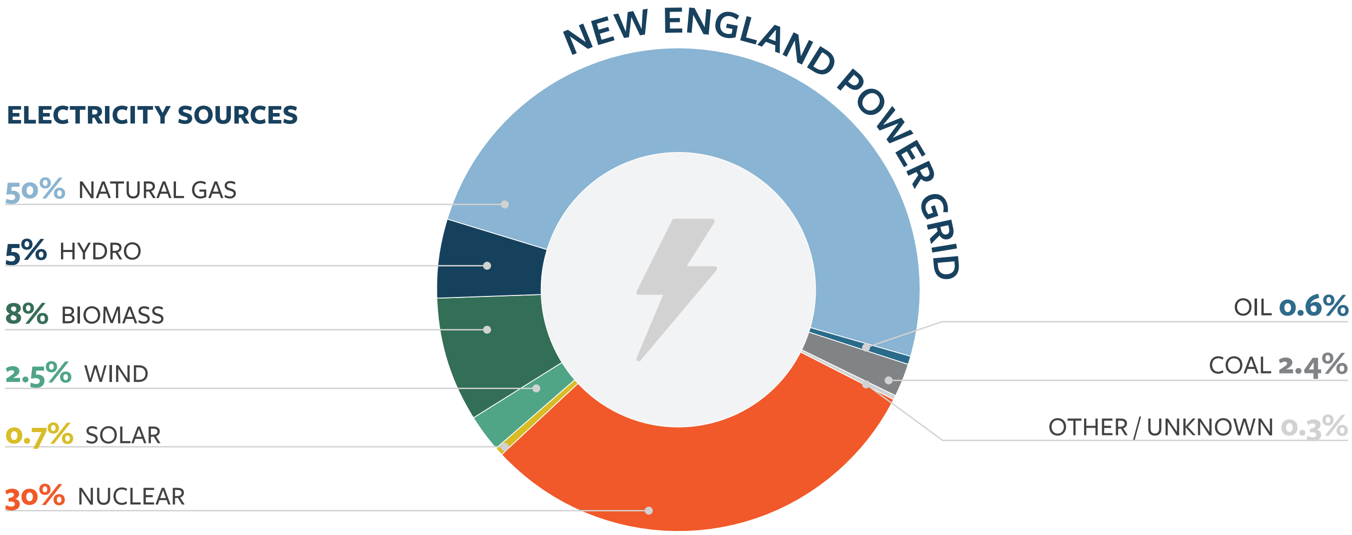
- **19%** NATURAL GAS
- **24%** ELECTRICITY
- **0.4%** WASTEWATER
- **2%** SOLID WASTE
- **6%** DIESEL
- **26%** GASOLINE
- **23%** FUEL OIL

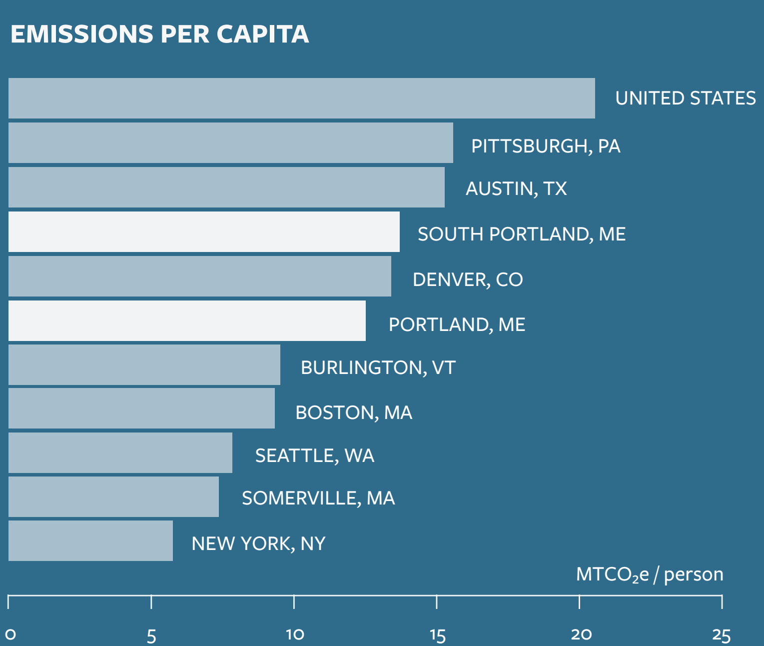


The role of electricity

Just under a quarter of all greenhouse gas emissions in both cities come from electricity, due to the mix of fuel sources that are currently used to produce electricity. As we continue to expand the amount of renewable energy on the electrical grid, such as solar and wind power, the greenhouse gas emissions from electricity (the **yellow** wedges in the "Emissions by Fuel Source" charts) will shrink. If Maine continues to hit its renewable portfolio standard targets, we will reach zero emissions from electricity by 2050.

Therefore, the primary way that we can reduce greenhouse gas emissions involves three steps: 1) Ensuring our systems run as efficiently as possible, 2) Expanding the amount of electricity that comes from renewable sources, and 3) Switching as many systems that are currently powered by fossil fuels to electricity, such as transportation and building heating and cooling. In some cases we can switch to biofuels, particularly for processes (such as industrial processes) that are difficult to run on electricity.





How do we stack up?

On a per capita basis, South Portland emits 13.8 $MTCO_2e$ per resident and Portland emits 12.6 $MTCO_2e$ per resident. These numbers are well below the U.S. national average of 20.7 $MTCO_2e$ per resident, but are more emissions-intensive than a number of other Northeast cities. In general, these differences reflect the greater use of fuel oil for heating, lower density development and less robust public transit systems, higher reliance on private vehicles, and a greater proportion of industrial energy use.

Note: Emissions per capita are shown for rough comparison; Inventory methodologies may differ.

Memorandum

Greenhouse Gas Emissions Inventories

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

Table of Contents

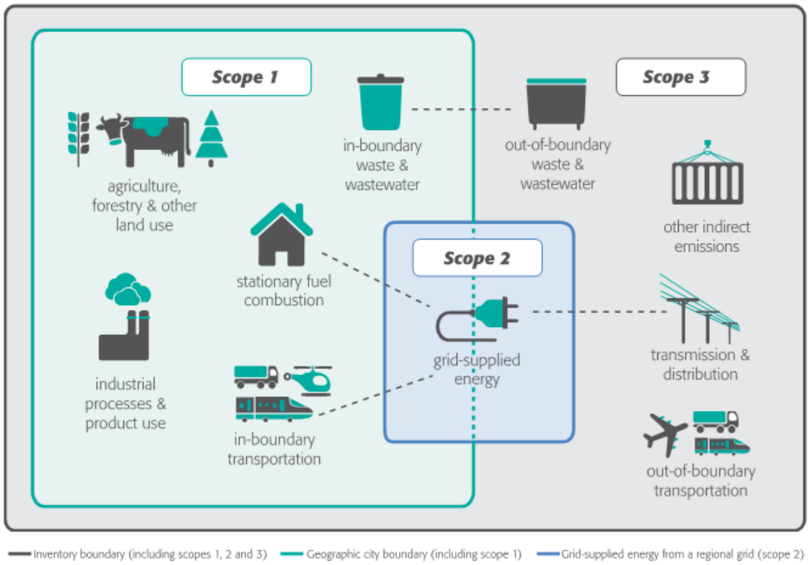
1 Introduction

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

The last community-wide GHG emissions inventory for Portland was conducted in 2010. This inventory 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 tracking GHG emissions reductions. South Portland has never completed a community-wide GHG emissions inventory before. The 2017 inventory represents the first baseline for tracking GHG emissions reductions 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 three "scopes," 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. Scopes for greenhouse gas emissions inventories; graphic courtesy of World Resources Institute.

[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

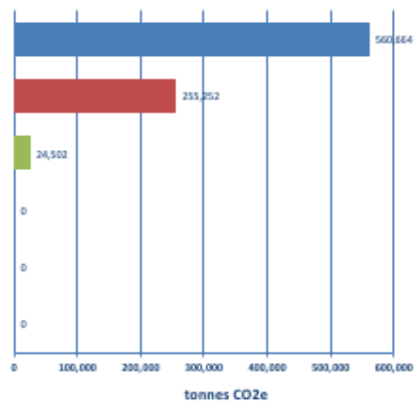
2.1 Summary

The data output 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 ($MTCO_2e$) in 2017. On a per capita basis, this is 12.6 tons per resident. This rate 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, Portland's higher emissions per capita 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.

SUMMARY

NAME OF CITY:	Portland, Maine, USA	POPULATION:	66,715
BOUNDARY:	BASIC	LAND AREA (km2):	55
INVENTORY YEAR:	2017	GDP (US$ million):	32,100

tCO2e	BASIC	Scope 1	Scope 2	Scope 3
	Stationary	377,604	183,060	
	Transportation	255,177	75	
	Waste	24,410		92
	IPPU			
	AFOLU			
	Other Scope 3			
	TOTAL	840,419		



Intensity indicators	Per capita	Per unit land area (km2)
Emissions	12.6	15,228

Figure 2. Greenhouse gas emissions summary for Portland for 2017. Visualization generated by the CIRIS tool.

Table 1. Portland greenhouse gas emissions by scope for 2017; 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.

When broken down by sector, buildings are the largest contributor to Portland's GHG footprint, with two-thirds (67%) of community-wide GHG emissions coming from energy use in buildings. Mobile sources (transportation) within Portland's boundaries are responsible for 30% of total emissions, and the incineration of solid waste and processing of wastewater are responsible for the remaining 3%.

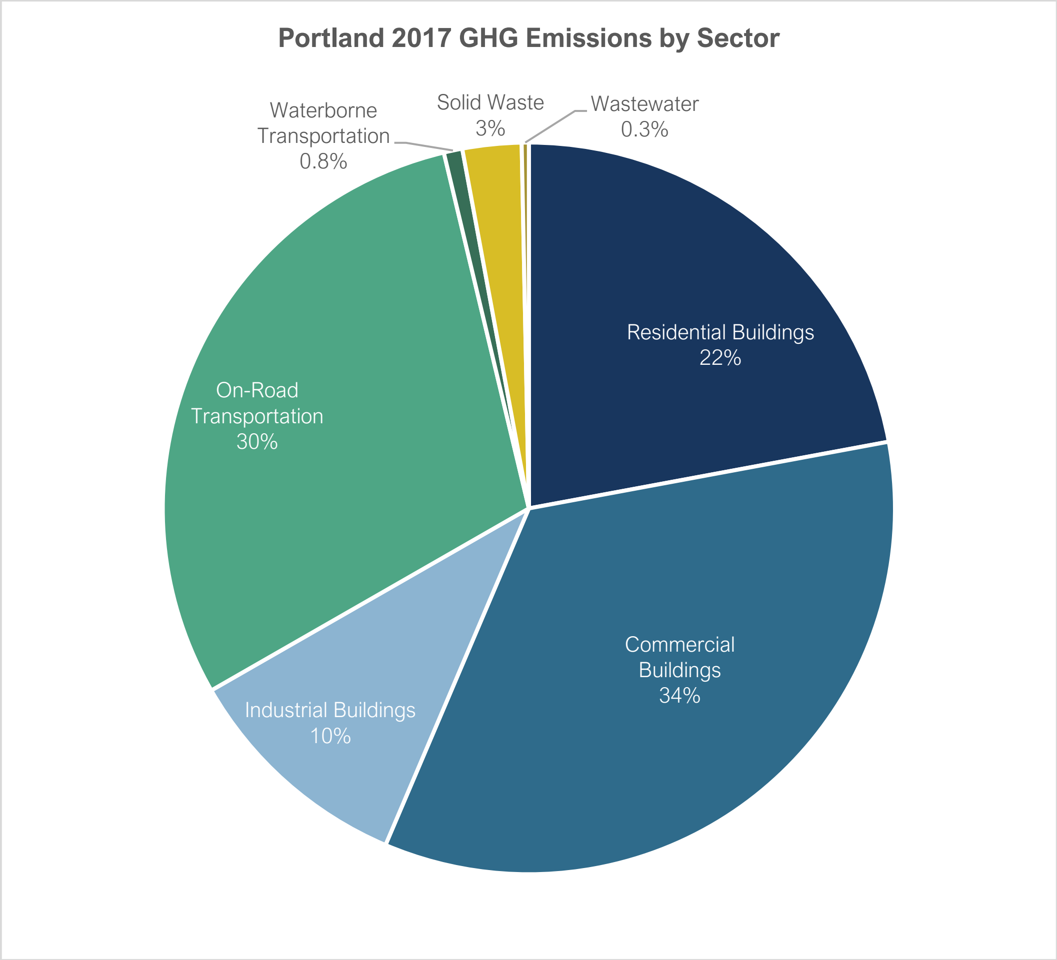


Figure 3. Portland greenhouse gas emissions by sector for 2017.

Table 2. Portland energy use and greenhouse gas emissions by sector for 2017.

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	-	0%	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's carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions by sector for 2017; 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

When broken down by source, gasoline, fuel oil, electricity, and natural gas are the four largest sources of GHG emissions in Portland in 2017. 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, with a much smaller percentage of emissions coming from diesel fuel.

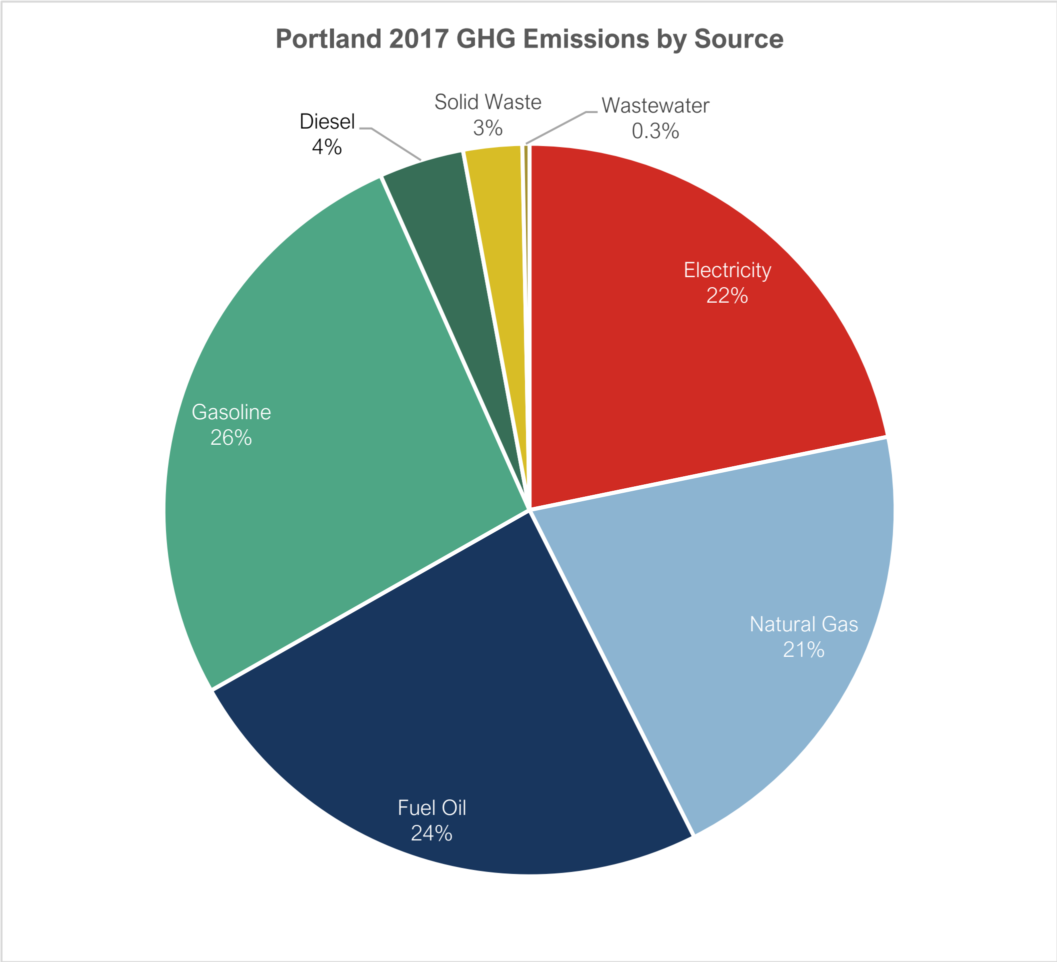


Figure 4. Portland greenhouse gas emissions by source for 2017.

Table 4. Portland energy use and greenhouse gas emissions by source for 2017.

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's carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions by source for 2017.

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 emissions totals were computed from actual citywide electricity and natural gas consumption data. 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.

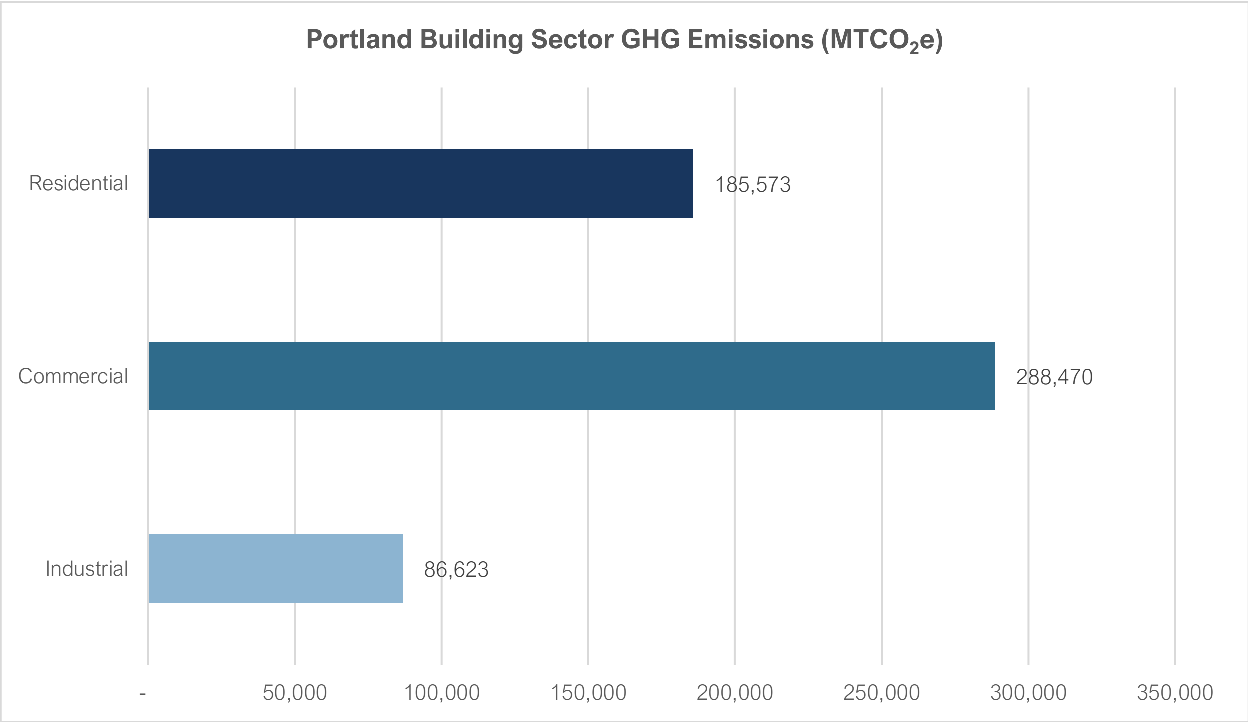


Figure 5. Portland building sector greenhouse gas emissions ($MTCO_2e$) for 2017.

Table 6. Portland site and source energy use by building sub-sector for 2017.

Sub-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 city boundaries. Data was provided by the Maine Department of Transportation (MaineDOT) 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.

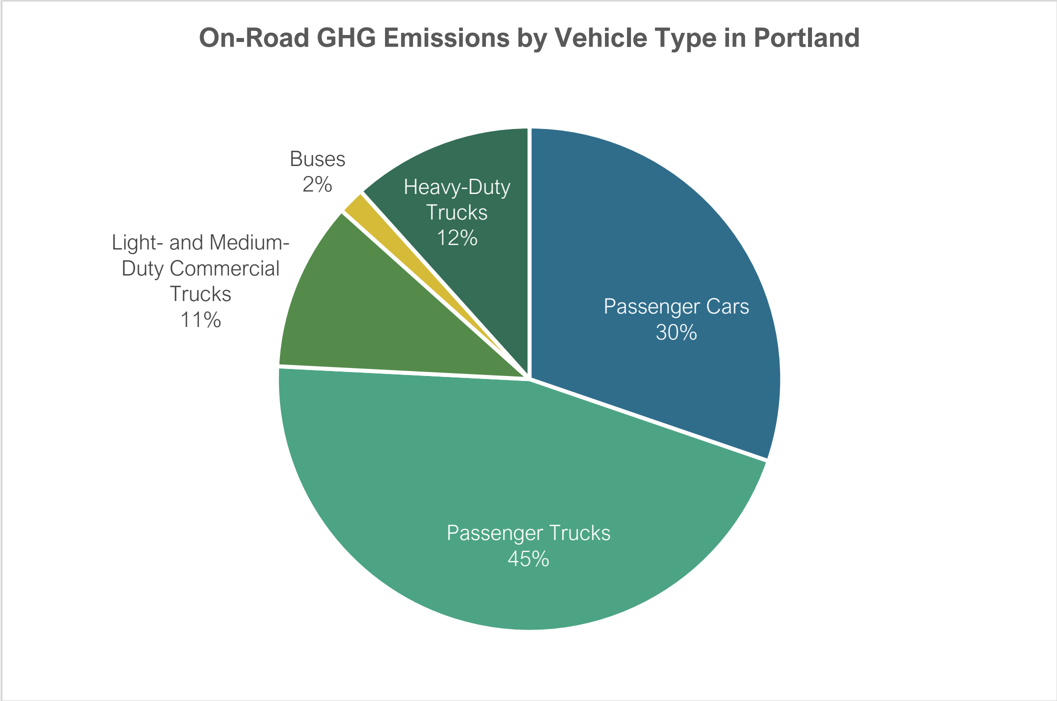


Figure 6. Percent of on-road greenhouse gas emissions by vehicle type in Portland.

Most GHG emissions in 2017 resulted from the combustion of gasoline in passenger trucks and cars. Data was not available for passenger or freight trains passing through Portland.

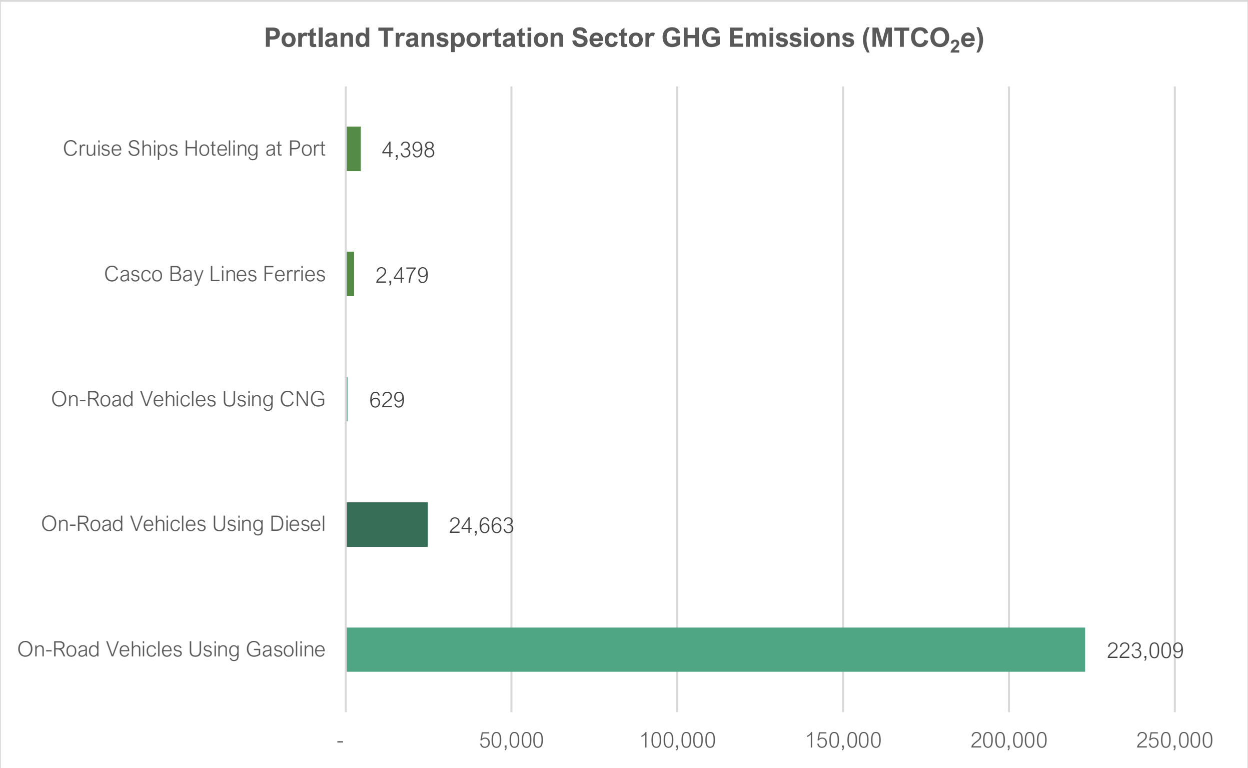


Figure 7. Portland transportation sector greenhouse gas emissions ($MTCO_2e$) for 2017.

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 is sent 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.

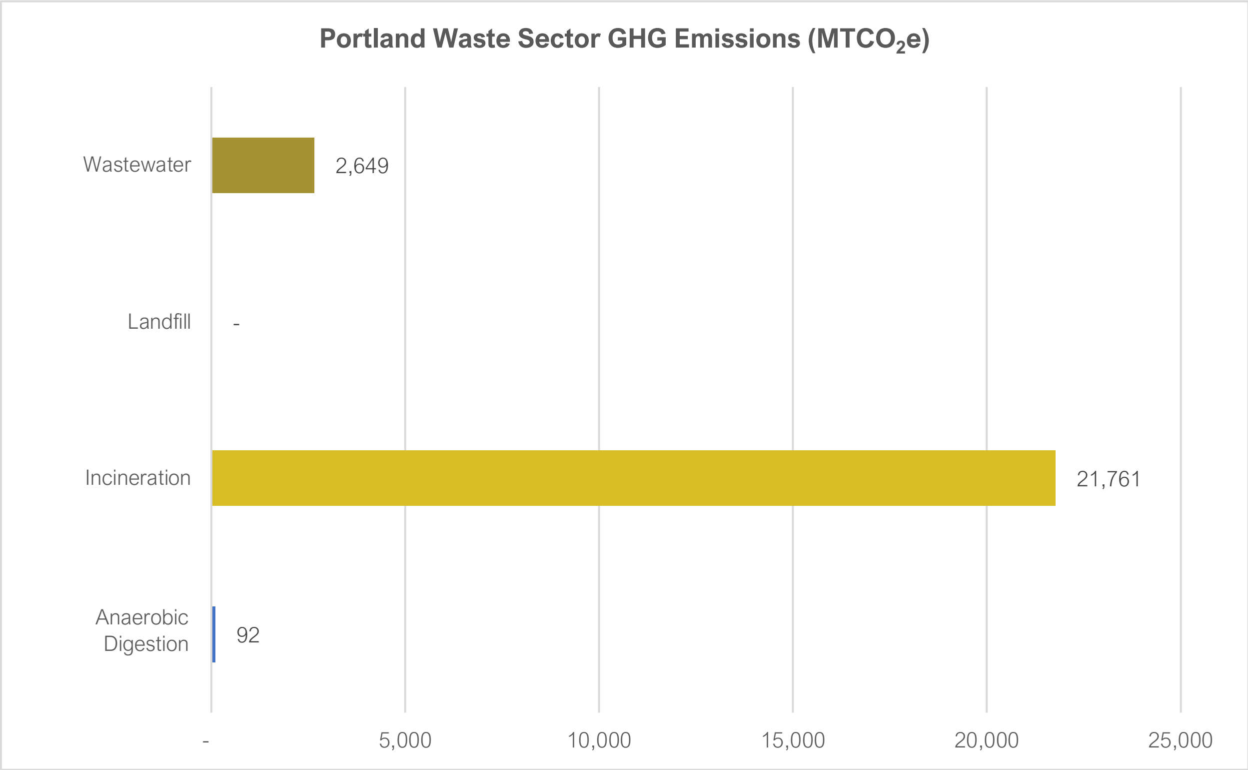


Figure 8. Portland waste sector emissions ($MTCO_2e$) for 2017.

3 South Portland Inventory Results

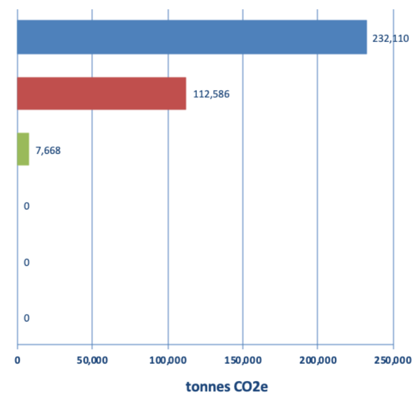
3.1 Summary

The data output 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) in 2017. On a per capita basis, this is 13.8 tons per resident. This rate 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 tons per resident. 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
BOUNDARY: BASIC
INVENTORY YEAR: 2017
POPULATION: 25,577
LAND AREA (km2): 31
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. Greenhouse gas emissions summary for South Portland for 2017. Visualization generated by the CIRIS tool.

Table 7. South Portland greenhouse gas emissions by scope for 2017.

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 areas of the economy.

When broken down by sector, buildings are the largest contributor to South Portland's GHG footprint, with two-thirds (66%) of community-wide GHG emissions coming from energy use in buildings. Mobile sources (transportation) within South Portland boundaries are responsible for 32% of greenhouse gas emissions, and the incineration of solid waste and processing of wastewater are responsible for the remaining 2%.

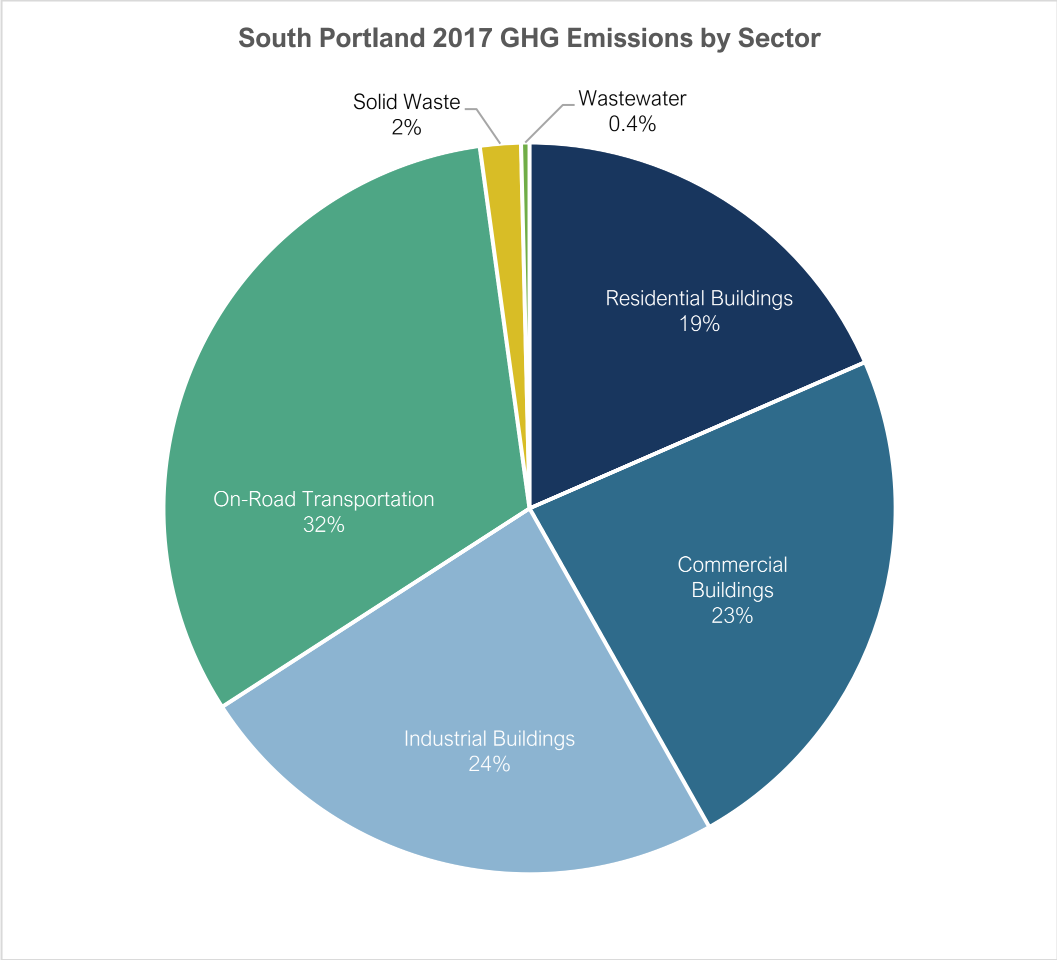


Figure 10. South Portland greenhouse gas emissions by sector for 2017.

Table 8. South Portland energy use and greenhouse gas emissions by sector for 2017.

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	100%	352,364	100%

Table 9. South Portland carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions by sector for 2017.

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

When broken down by source, gasoline, fuel oil, electricity, and natural gas are the four largest sources of GHG emissions in South Portland in 2017. Within buildings, electricity, natural gas, and fuel oil are roughly equivalent sources of GHG emissions, 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, with a much smaller percentage of emissions coming from diesel fuel.

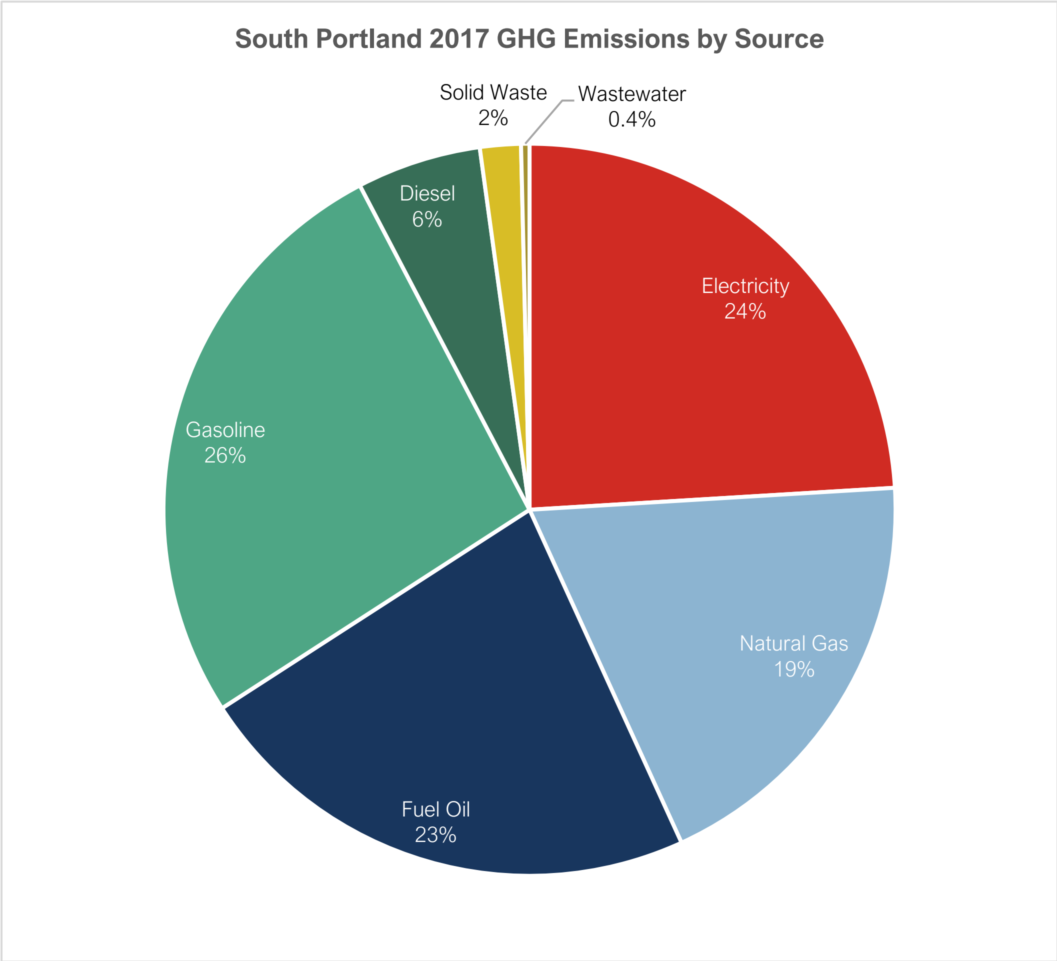


Figure 11. South Portland greenhouse gas emissions by source for 2017.

Table 10. South Portland energy use and greenhouse gas emissions by source for 2017.

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 carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions by source for 2017.

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 emissions totals were computed from actual citywide electricity and natural gas consumption data. 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. In South Portland, industrial buildings are the largest source of building sector GHG emissions.

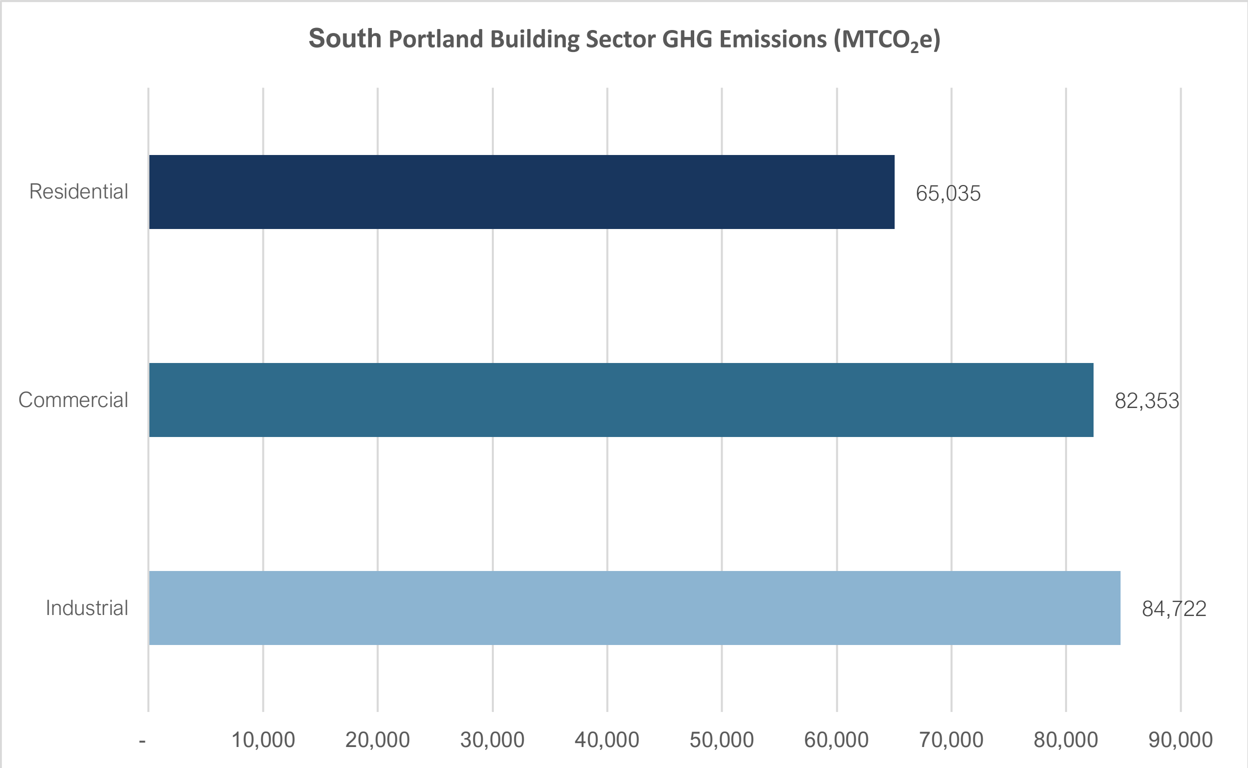


Figure 12. South Portland building sector greenhouse gas emissions ($MTCO_2e$) for 2017.

Table 12. South Portland site and source energy use by building sub-sector for 2017.

Sub-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 GHG emissions 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, as shown in Figure 13, and the associated fuel economies of those vehicle types. Data was not available for any ships docking in South Portland, nor for passenger or freight trains passing through South Portland.

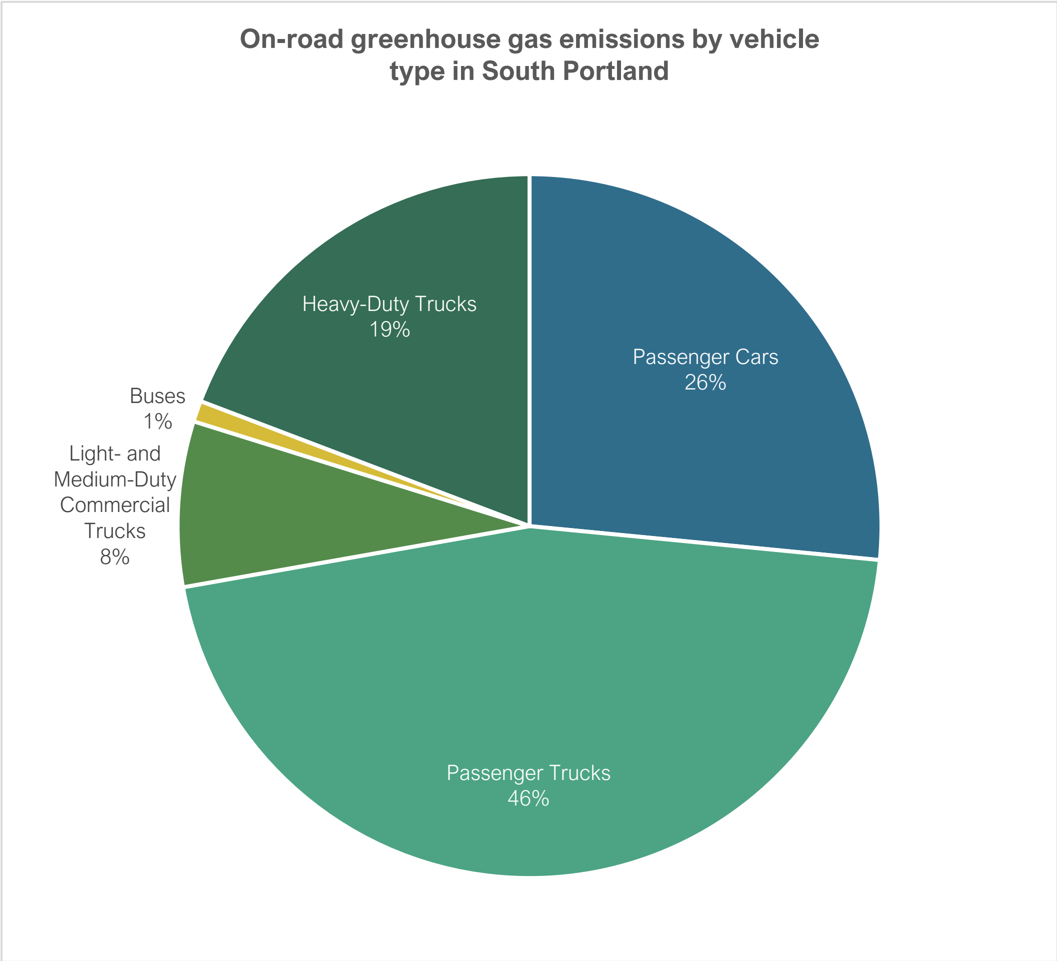


Figure 13. Percent of on-road greenhouse gas emissions by vehicle type in South Portland.

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.

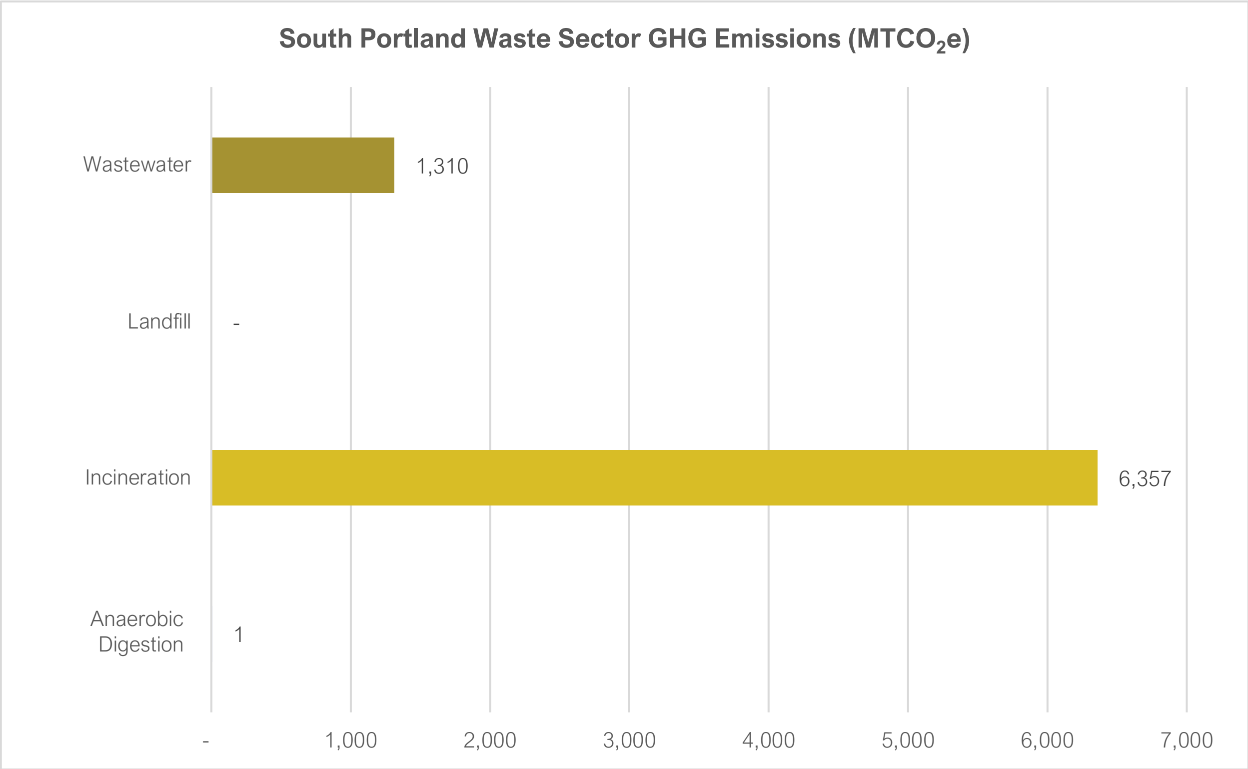


Figure 14. South Portland waste sector emissions ($MTCO_2e$) for 2017.

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] The previous 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, which makes statewide data less representative. For this project's baseline inventory, actual natural gas data was acquired for 2017. Fuel oil use was then estimated per building type based on the actual natural gas data, U.S. Department of Energy (DOE) data on heating energy

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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

intensity, tax data on heating fuel type, and an analysis by another consultant team, 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 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 in 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. 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.

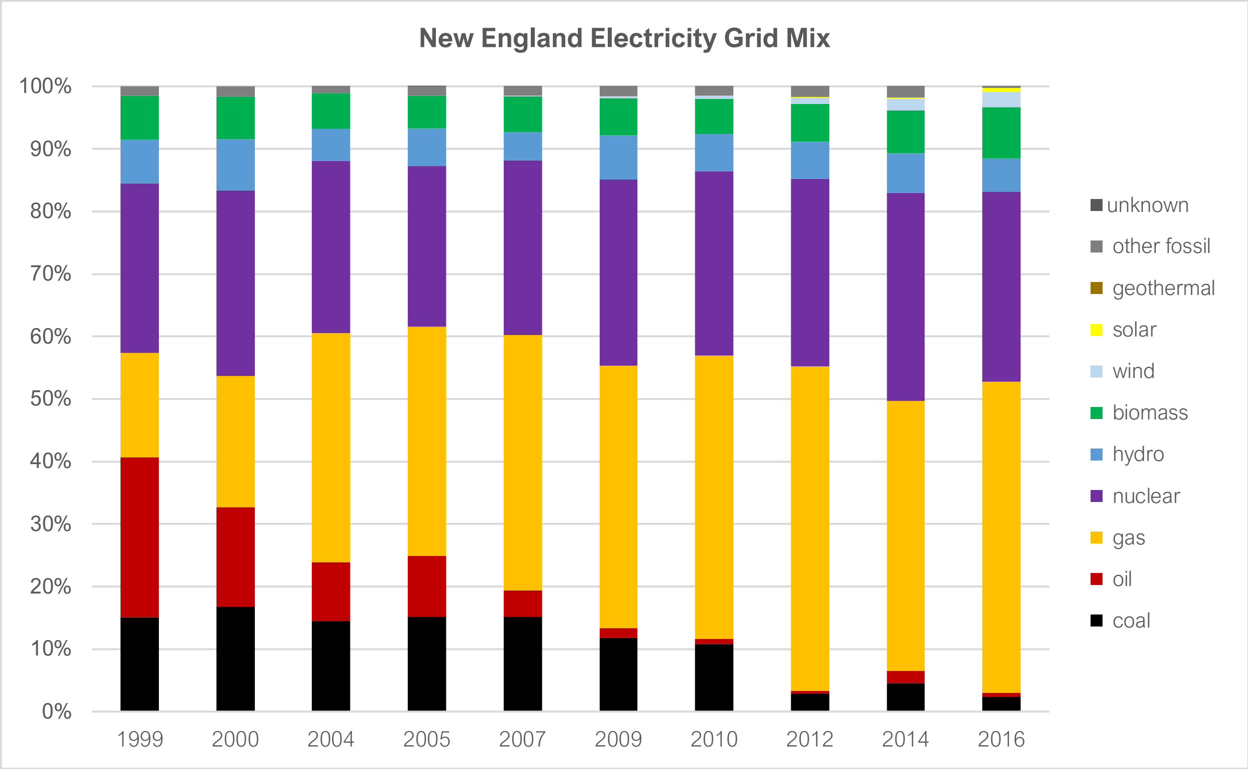

Figure 15. New England's electricity resource mix, 1999-2016.

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 this 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 2017 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. Fugitive emissions of SF_6 were not researched. Emissions of the three measured GHGs were converted to metric tons of carbon dioxide equivalents ($MTCO_2e$) 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, 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. 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 EUIs. (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 areas and energy use intensities (EUIs) by building type.

Sector	Portland Floor Area	South Portland Floor Area	Site EUI (kBtu/ft²)	Electric EUI (kBtu/ft²)	Natural Gas EUI (kBtu/ft²)	Fuel Oil EUI (kBtu/ft²)
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. Stationary energy use by sector (MMBTU) for 2017.

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 nor 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 from vehicles were calculated 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 data, 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 vehicle miles traveled (VMT), fuel use, and GHG emissions by vehicle type.

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- and Medium-Duty Commercial 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 vehicle miles traveled (VMT), fuel use, and GHG emissions by vehicle type.

Vehicle Type	Fuel Type	Vehicles	VMT	MPG (Weighted)	Fuel Use (MMBTU)	GHG ($MTCO_2e$)
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
Commercial 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

* Light- and Medium-Duty Commercial Trucks

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, two studies of docked ship emissions were reviewed, one from Los Angeles (Port of Los Angeles) and one from 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 an auxiliary boiler. For each ship, the auxiliary engines were assessed based on the passenger

[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

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 GHG 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. MSW is an abbreviation for municipal solid waste.

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.

Memorandum

Community Energy and Emissions Modeling Technical Methodology

To: City of Portland, City of South Portland, and Linnean Solutions
From: Integral Group and Daybreak Climate Consulting
Date: August 2020
Re: Methodology for One Climate Future Community Energy and Emissions Modeling, 2017-2050

Table of Contents

1 Model Overview

One Climate Future sets a goal of reducing Portland and South Portland's community-wide greenhouse gas (GHG) emissions 80% by 2050, with an interim goal of 35% by 2030. To analyze options to achieve that goal, subconsultants Integral Group and Daybreak Climate Consulting developed an Excel-based GHG emissions model to inform and model policy actions for all quantified sources of GHG emissions in Portland and South Portland.

The model is built on, and aligned with, the 2017 GHG inventories conducted by Integral Group and Daybreak Climate Consulting that were completed for the Cities of Portland and South Portland in 2019-2020. Those inventories follow the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC).[1] Wherever possible, modeling of future emissions has been aligned with standards in the GHG inventories to allow the cities to more easily track progress over time. Because the One Climate Future plan is for both cities, the results of the two inventories were combined and input into a single model, and baseline and projected numbers will appear larger than would be expected for either city on its own. The inventories show that both the scale and distribution of emissions between different fuels and sectors are extremely similar in both cities, with a few small exceptions: the industrial sector is larger in South Portland, and Portland has more non-road transportation infrastructure (e.g., Harbor, Jetport). Overall, combining the

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

two inventories into a single baseline and model simplifies planning while still yielding results applicable to each city.

The consultant team used the model to estimate future energy consumption and GHG emissions under a business-as-usual (BAU) scenario, and to quantify the potential impact various actions could have on different sectors. Actions are compared against a “no action” BAU scenario, which assumes growth in economic activity and population, but does not include energy efficiency or renewable energy policies at the city, state, or federal levels. The model is intended to inform the Cities on how they can achieve the One Climate Future 2050 climate target; it is not meant to quantify all actions or assign savings to specific actions. The team quantified specific programs and policies where actions are more directly quantifiable, such as new construction codes. In other cases, where actions are more difficult to tie to specific savings, the team focused on determining the scale of action required to achieve the climate and energy targets, looking either at feasible levels of market transformation, or achieving specific sectoral targets. All data in the model is annualized, and the model does not account for hourly or seasonal variation in energy use or emissions.

The model is not intended to be a predictive tool and does not account for costs or externalities other than GHG emissions. The intent of the One Climate Future plan is to provide the cities with a roadmap for how the two cities can achieve their GHG reduction targets. The plan provides this roadmap through a package of policy and program recommendations, with additional information and recommendations regarding the design and implementation of such actions based on available research and experience in other leading jurisdictions. The specific design and implementation of many of these actions will take further analysis, including understanding the potential cost-effectiveness and relative feasibility of program and policy approaches and designs. The model shows one way of achieving One Climate Future goals; other paths may also be feasible.

This memorandum is divided into four major sectors: Energy Supply, Buildings and Industry, Transportation, and Waste. For each sector, the baseline and BAU assumptions are discussed first, and then the policy scenario assumptions. The titles of the policy scenario sections correspond to the titles in the wedge charts depicting GHG savings by policy. Table 1 shows how actions are aggregated into plan sections, and which actions in the plan relate to each wedge in the wedge chart.

Table 1. The correlation between One Climate Future plan sections, sub-sections, policy wedge shown in the wedge chart, and plan actions. BE refers to Buildings and Energy, TLU refers to Transportation and Land Use, and WR refers to Waste Reduction.

Plan Section	Plan Sub-section	Wedge	Plan Actions	Methodology Memo Section
BE	**BE 1:** Municipal Buildings and Energy	Municipal Renewable Energy	BE 1.1	2.2.3
		Municipal Building Efficiency	BE 1.2, 1.3	3.2.4
	BE 2: New Construction Energy Efficiency & Decarbonization	New Construction Policies	BE 2.1, 2.3	3.2.1
	BE 3: Existing Buildings Energy Efficiency & Decarbonization	Existing Building Efficiency	BE 3.1, 3.2, 3.3	3.2.2
		Existing Building Decarbonization	BE 3.4, 3.5, 5.4, 5.6	3.2.3
	BE 4: Industrial Energy Efficiency & Decarbonization	Industrial Decarbonization	BE 4.1, 4.2	3.2.5
	BE 5: Clean and Renewable Energy	Renewable Portfolio Standard	BE 5.1	2.2.1
		Local Solar	BE 2.2, 3.5, 3.6, 5.1	2.2.2
TLU	**TLU 1:** Mode Shift & Land Use	Mode Shift and Land Use Policies	TLU 1 (all)	4.2.1
	TLU 2 & 3: Vehicle Electrification and Infrastructure	Bus Electrification	TLU 2.3	4.2.2
		Fuel Economy Standards	N/A	4.2.3
		Electric Vehicle Adoption	TLU 2.1, 2.2, 2.4, 2.5	4.2.4
		Ferry and Ship Electrification	TLU 3.3, 3.4	4.2.5
WR	**WR 1 & 2:** Waste Reduction	Solid Waste Reduction	WR 1 (all)	5.2.1
		Wastewater Efficiency	WR 2.3	5.2.2

2 Energy Supply and Emissions Intensities

The assessment models greenhouse gas emissions from all sectors from now through 2050, accounting for all energy use, energy sources, and emissions factors. The business-as-usual scenario assumes that the 2017 baseline emissions factors all stay constant. Further, the BAU discounts the existing impact of renewable energy in order to capture the full effect of renewable energy in the policy wedge. The model then assesses the greenhouse gas emissions avoided between now and 2050, considering the implementation of a set of state and local policies for renewable electricity supply.

2.1 Baseline GHG Emissions Intensities

GHG intensity factors were applied to energy use by fuel type to calculate total GHG emissions. In the model, the GHG intensity of electricity accounted for losses from generation, but not from transmission and distribution (T&D), because T&D losses are not included in the GHG inventories under the GPC BASIC protocol. The model used the Northeast Power Coordinating Council (NPCC) New England sub-region factor from EPA's eGRID database of regional GHG intensities for 2016; this region is aligned with ISO New England. However, in order to fully capture the impact of the renewable portfolio standard (RPS), the BAU GHG intensity of electricity was calculated by removing renewables from the BAU grid mix.

We kept the GHG intensity ($tCO_2e/kBTU$) of all energy types constant in the BAU scenario. This was done to capture and communicate the impact of state policy for renewable energy and carbon pricing, most notably the RPS. The BAU model does not assume additional declines due to the federal regulation or electricity generation plant closures and replacements. To avoid overly optimistic assumptions about declining electricity emissions, these external forces were assumed not to decrease the electricity emissions factor. This means deeper emissions reductions from changes in electricity supply are very likely to occur than is modeled for the BAU scenario.

Table 2. Electricity GHG intensity for the business-as-usual scenario.

	Baseline from eGRID (tCO2/kBTU)	Baseline without Renewable Energy (tCO2/kBTU)	Trajectory
Electricity GHG emissions factor	7.75E-05	9.04E-05	Declines due to renewable energy policies
Carbon dioxide factor	7.75E-05	9.04E-05	
Methane factor	3.35E-07	3.91E-07	
Nitrous oxide factor	4.23E-07	4.93E-07	

The emissions factors for natural gas, fuel oil, gasoline, and diesel are a function of their carbon content and are constant over time. For simplicity, all fuel oil use is assumed to be No. 2 fuel oil, and all diesel use is assumed to be standard diesel. In reality, there is likely some marginal use of No. 1, 4, 5, & 6 fuel oils; however, the data collected for the inventory and the model does not allow the disaggregation of fuel oils, and the marginal differences in GHG emissions would not have a significant effect on the modeling. (The differences in criteria pollutants among fuel oils is more significant, but non-GHG air pollutants are not within the scope of the modeling.) Marine diesel does have a slightly different composition and GHG factor than the diesel fuel used in land vehicles; this difference is accounted for in the inventory, but it is minor and in the interest of simplicity was not included in the modeling.

Our analysis did not include fugitive emissions from the transmission and distribution of natural gas, because these losses are not included in the GHG inventories, in alignment with the GPC BASIC protocol.

Table 3. Fossil fuel GHG intensities.

	Emissions Factor (tCO2e/kBTU)	Trajectory
Natural Gas GHG Emissions Factor	5.31E-05	Constant over time in all scenarios
Fuel Oil No. 2 GHG Emissions Factor	7.44E-05	
Gasoline GHG Emissions Factor	7.22E-05	
Diesel GHG Emissions Factor	7.41E-05	

2.2 Avoided Energy Supply Sector Emissions Due to Policies

2.2.1 Renewable Portfolio Standard

Renewable electricity currently supplies 16% of electricity in the ISO-NE region. Maine's new renewable portfolio standard (RPS) calls for 80% of electricity supply to come from renewable sources by 2030, and 100% of the electricity supply to come from renewable power by 2050.

To fully show the impact of the recently updated RPS, the BAU assumes that 16% of electricity comes from renewable sources from now until 2050. The policy scenario then increases the renewable portion of electricity, beginning at 16% in 2017 (to align with the inventory), and rising to 80% by 2030 and 100% by 2050.

These GHG emissions savings show up in the Renewable Portfolio Standard wedge. As the actions in section BE 5 of the One Climate Future plan most directly relate to the RPS and the build out of statewide renewable energy, these savings are counted towards section BE 5.

Table 4. Electricity GHG intensity projections under the Maine renewable portfolio standard, 2017-2050.

Year	% Renewable	GHG Intensity (tCO2e/kBTU)
2017	16%	7.832E-05
2018	21%	7.373E-05
2019	26%	6.914E-05
2020	31%	6.455E-05
2021	36%	5.996E-05
2022	41%	5.537E-05
2023	46%	5.078E-05
2024	50%	4.619E-05
2025	55%	4.160E-05
2026	60%	3.701E-05
2027	65%	3.242E-05
2028	70%	2.783E-05

2029	75%	2.324E-05
2030	80%	1.865E-05
2031	81%	1.771E-05
2032	82%	1.678E-05
2033	83%	1.585E-05
2034	84%	1.492E-05
2035	85%	1.398E-05
2036	86%	1.305E-05
2037	87%	1.212E-05
2038	88%	1.119E-05
2039	89%	1.025E-05
2040	90%	9.321E-06
2041	91%	8.389E-06
2042	92%	7.457E-06
2043	93%	6.525E-06
2044	94%	5.593E-06
2045	95%	4.661E-06
2046	96%	3.728E-06
2047	97%	2.796E-06
2048	98%	1.864E-06
2049	99%	9.321E-07
2050	100%	0.000E+00

2.2.2 Local Solar

Locally generated solar power counts towards the state RPS, and most-to-all of the Solar Renewable Energy Credits (SRECs) generated from locally produced solar are expected to be sold to entities that have to comply with the state RPS mandates. Therefore, local solar generation in the model does not increase overall renewable power in the model, but merely reassigns energy from the RPS wedge to the local solar wedge.

Local solar is assumed to supply a negligible (effectively 0%) amount of power today and to increase linearly over time until 2050.

Analysis done by GridSolar estimates the full capacity for local solar generation within Portland and South Portland in 2050, as documented in Table 5, with solar PV installed to the fullest technical and economic extent.

Table 5. Maximum local solar photovoltaic (PV) capacity in Portland and South Portland. (Analysis by GridSolar.)

City	Number of PV Panels	Annual Generation (MWh)	Capacity[2] (MW)
Portland	698,895	401,699	252
South Portland	343,703	197,793	123
Both	1,042,598	599,492	375

Solar built out to this capacity would provide 29% of all electricity needed in both cities, even with electrification of buildings. In reality, not all building owners will install solar, for a variety of reasons, even if it is both technologically and economically feasible. (For example, shading, structural integrity of roof space, owner desires, property turnover, planned demolition, the ratio of solar potential to on-site electricity use, among other factors all influence that decision.) Rather, the GridSolar estimate for full capacity verifies that a significant supply of solar can be locally sourced.

Based on our work in other jurisdictions and experience with what can be considered a reasonable expectation, for the modeling we assumed that 14.5% of all electricity would be met by local solar, or half as much as included in GridSolar's analysis.

Avoided GHG emissions from renewable energy generated from solar PV systems within the Cities shows up in the Local Solar wedge. The One Climate Future actions that will most increase local solar are those that will expand solar installs on existing buildings included in plan section BE 3. However, as local solar will count towards the state RPS, the amount of renewable energy needed for Portland and South Portland that the RPS needs to supply from outside the Cities decreases as more local solar is installed. Thus, the savings from the RPS and from local solar cannot be looked at independently. Therefore, the savings from local solar are grouped with the other RPS savings under BE 5.

2.2.3 Municipal Renewable Energy

The model assumes that both Portland and South Portland procure 75% of their electricity supply from renewable sources starting in 2022, and 100% by 2032. The two municipal governments make up 1.9% of electricity consumption, so this initially decreases citywide electricity emissions by almost 2%; this relative impact declines over time, however, as municipal buildings undergo energy efficiency retrofits.

The savings from municipal renewable energy procurement show up in the Municipal Renewable Energy wedge and are counted with the other municipal buildings and energy actions in BE 1.

3 Buildings and Industry

The assessment models greenhouse gas emissions for buildings and industry from now through 2050, accounting for all energy use by buildings as well as industrial process loads. The business-as-usual scenario assumes energy use intensities stay constant, while accounting for projected growth in the cities. The model

[2] In line with GridSolar's assumptions of 360 watts/panel.

then assesses the greenhouse gas emissions avoided between now and 2050 if we were to implement a set of policy scenarios that focus on buildings and industry energy efficiency and decarbonization.

3.1 Baseline and Business-as-Usual Building Assumptions

3.1.1 Building Floor Area and Growth Rate

To address the growth in buildings, the consultant team used a stock turnover model based on tax parcel data provided by both cities. Buildings were aggregated into 12 broad categories based on their use classifications in the parcel data and the classifications available from the U.S Department of Energy, as shown in Table 6.

Portland, and to a lesser extent, South Portland, are experiencing a period of rapid growth in population and buildings. The population of Portland and South Portland is expected to grow by 1.5% per year. The model accounts for this growth through a change in floor area growth by sector. Because no official city estimates for floor area growth by sector were available, average annual growth rate (AAGR) assumptions were made based on Integral Group experience with similar sized cities on similar growth trajectories. These construction rates should not be seen as indicative of any official estimate by either city government or as endorsements of any given policy goal.

Table 6. Total building floor areas by building classification for Portland and South Portland and average annual growth rate (AAGR) assumptions.

Sector/Subsector	Gross Floor Area (ft^2)	AAGR (%)
Residential	54,141,052	
Single Family	28,441,359	0.45%
2-4-unit Multi-family	10,261,092	0.62%
5+ unit Multi-family	15,438,601	0.80%
Institutional and Government	7,971,690	
Education and Institutional	4,438,537	0.20%
Government - City	1,364,081	0.05%
Government - Other	2,169,072	0.05%
Commercial	43,428,233	
Office	9,984,137	0.43%
Healthcare	3,482,279	0.17%
Warehouse and Storage	6,948,374	0.17%
Other Commercial, including hotels	23,013,443	0.17%
Industrial	3,951,460	N/A[3]
Parking	770,661	0%
Total	105,540,975	

[3] Forward projections for industrial loads in Southern Maine were not available, and industrial energy use is largely uncorrelated with floor area. Therefore, no industrial floor area growth rates were developed.

3.1.2 Energy Use Intensity of Residential and Commercial Buildings

Electricity consumption data for Portland and South Portland for 2017 and 2018 was provided by Central Maine Power (CMP), broken out between commercial, residential, and industrial sectors, including total consumption and number of accounts. Natural gas consumption data for Portland and South Portland was provided by Unitil for 2017 and 2018, broken down into residential and commercial, including both total consumption and number of units. While the GHG inventories were completed for calendar year 2017, the consultant team noted significant differences in industrial energy use between the 2017 and 2018 data and opted to use 2018 electricity and natural gas data to inform the energy use intensity assumptions for the modeling. Other than the consumption of fuel oil in city-owned buildings, fuel oil consumption data was not available. While using fuel oil for heating is very common in Maine, there is an ongoing process of converting buildings to natural gas in Portland and South Portland. Therefore, state gas consumption numbers could not be considered as a reliable reference, proportionally, for either city.

As part of conducting the GHG inventory, Integral developed estimates for electricity, natural gas, and fuel oil consumption for each building category. These values could then be divided by floor area to calculate the EUI, or the total amount of energy a building uses per year divided by total building area (e.g. $kBTU/ft^2/yr.$). To allocate a specific energy consumption to the various building categories, a set of preliminary energy use intensities were developed based on EIA's nationwide building energy surveys—the Commercial Building Energy Consumption Survey (CBECS) for 2012 and the Residential Energy Consumption Survey (RECS) from 2015.[4,5]

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 ASHRAE Climate Zone 6A. Estimated EUIs for each type were multiplied by the floor area and compared to the total consumption for that building type. EUIs were adjusted by maintaining the same energy consumption ratio seen with the preliminary EUIs and shifting the EUI to match total energy consumption; only minor adjustments were needed.

Natural gas use and fuel oil use in residential buildings were estimated using energy models from the Residential Prototype Building Models from the U.S. Department of Energy and Pacific Northwest National Laboratory (LBNL) for the state of Maine.[6] 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 consultant team 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. In the case of natural gas, these values were then adjusted to true up the totals with the citywide natural gas consumption data; only minor adjustments were needed. 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.

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[4] U.S Department of Energy. 2012 CBECS Survey Data https://www.eia.gov/consumption/commercial/data/2012/index.php?view=consumption

[5] U.S Department of Energy 2015 RECS Survey Data https://www.eia.gov/consumption/residential/data/2015/

[6] U.S Department of Energy. Residential Prototype Building Models. https://www.energycodes.gov/development/residential/iecc_models

All analysis was done using site EUIs, that is, the energy use as consumed at the building. Source energy, which accounts for losses in generation and transmission was not included. This aligns with the data sources above, which all use site EUI, and the GPC BASIC GHG Inventory standards, which apply GHG intensities to site energy use. Electricity generation losses are captured in the GHG intensities applied to electricity. Per the BASIC inventory standards, transmission and distribution losses are not included. The final energy use and EUI assumptions for the OCF modeling are documented in Table 7.

Table 7. Energy use and energy use intensity (EUI) assumptions.

Building Type	Total Site EUI (kBTU/ft^2)	Electric EUI (kBTU/ft^2)	Natural Gas EUI (kBTU/ft^2)	Fuel Oil EUI (kBTU/ft^2)	Total Energy Use (MMBTU)	Total Electricity Use (MMBTU)	Total Natural Gas Use (MMBTU)	Total Fuel Oil Use (MMBTU)
Residential					3,762,504	828,044	1,163,524	1,770,936
Single Family	64.6	12.5	10.0	42.1	1,837,317	355,519	284,906	1,196,892
Apt 2-4	77.0	17.4	30.1	29.4	789,908	178,455	309,309	302,144
Multi-family	73.5	19.0	36.9	17.6	1,135,279	294,070	569,308	271,900
Institutional/ Government					854,628	284,672	383,525	195,409
Education/ Institutional	107.3	30.4	53.0	23.4	476,443	134,968	235,242	103,862
Government - City	73.9	41.1	42.0	0.4	100,821	56,053	57,249	514
Government - Other	127.9	43.2	42.0	42.0	277,364	93,651	91,034	91,034
Commercial					4,827,479	1,711,446	2,088,353	934,735
Office	115.0	43.2	46.1	23.4	1,148,515	431,070	460,527	233,629
Other Commercial	115.4	43.5	46.1	23.4	2,654,821	1,000,980	1,061,516	538,515
Healthcare	127.1	55.5	70.6	-	442,639	193,431	245,810	0
Warehouse and Storage	83.7	12.4	46.1	23.4	581,504	85,965	320,500	162,592
Parking	20	20	0	0	15,412	15,412	0	0
Total					9,444,611	2,824,162	3,635,402	2,901,080

3.1.3 Industrial Energy Use

Both cities have substantial industrial sectors. The CMP electricity data broke out industrial use; 2018 industrial use was notably higher than in 2017, and so was used as a basis for the modeling. However, Unitil does not have a separate rate classification 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 loads were estimated using a combination of the MCG data on gas and oil service, and the ratio of industrial to commercial use found in the electricity consumption data.

The major drivers of energy use in industrial buildings are industrial process loads, which are uncorrelated with floor area. For private industry, process load data was not available, and the available data on industrial job growth projections and its relation to energy use was too inconclusive for the purposes of long-term planning. For these reasons, industrial energy use was held flat for the BAU scenario and does not rise with floor area. The following BAU assumptions were made for industrial energy use across the two cities.

Table 8. Private industrial energy use in Portland and South Portland for the baseline and business-as-usual (BAU) scenario.

Sector	EUI (kBTU/ft^2)	Total Energy Use (MMBTU)	Total Electricity Use (MMBTU)	Total Natural Gas Use (MMBTU)	Total Fuel Oil Use (MMBTU)
Private Industry	696	2,813,087	859,729	993,746	959,613

3.2 Avoided Buildings Sector Emissions Due to Policies

3.2.1 New Construction Policies

The model uses modeled building codes to affect the energy performance of new and rehabilitated buildings. Two sets of building codes are applied: one targeting single-family and small (2-4-unit) multifamily buildings, and another targeting commercial and large (5-unit or larger) multifamily buildings.

When a new energy code is adopted, buildings in the process of permitting and construction can be completed under the prior code, which creates a lag between code adoption and code impact. For residential buildings, the impact of new codes is modeled as occurring two years after code adoption; for commercial and large multifamily buildings, the impact of new codes is modeled as occurring three years after code adoption (e.g., a code adopted in 2021 impacts energy use of new buildings in 2024). These delays are drawn from Integral Group field experience. Each code adoption impacts building energy performance by reducing the EUI of the building type. PNNL models were used to compare the modeled EUIs under the new codes to the existing average EUIs of buildings, as listed above. Due to a low baseline efficiency of buildings, this results in the appearance of much deeper savings than the codes actually will be requiring.

Table 9. Energy code assumptions.

Adoption Year	Code	Residential	Commercial
Current/2020	IECC 2015	• 30% reduction in EUI	• 35-65% reduction in EUI, depending on building type
2023	Next Stretch Code	• 45% reduction in EUI • 100% reduction in fuel oil use	• 45-75% reduction in EUI, depending on building type • 100% reduction in fuel oil use
2030	Net Zero Stretch Code	• 65% reduction in electricity use intensity • 100% reduction in natural gas and fuel oil use	• 65-85% reduction in electricity use intensity • 100% reduction in natural gas and fuel oil use

The high-performance stretch code update for commercial and large multifamily buildings is assumed to reduce the EUI of new buildings to approximately halfway between the EUI required under the 2018 code update and the net-zero stretch code for 2030. Buildings constructed under net-zero codes are assumed to have EUIs that would allow the building to be supplied with on-site energy. However, the specific EUI and fuel source requirements will vary by building type and size, as well as other characteristics, and the EUIs used in the model should not be seen as a “net-zero level EUI” for purposes beyond this broad modeling exercise.

The model assumes code compliance of 75% for the first two years of each code, 80% for the year after that, and 85% thereafter. Based on the structure of the model, an 85% code compliance rate means achieving 100% of the code’s energy and GHG reduction potential from 85% of the affected building square footage, and no energy or GHG reductions from the remaining 15%. In reality, the 15% non-compliant buildings would very likely still achieve some energy use and GHG reductions from partial code compliance. This means the GHG reductions attributed to new construction may be underestimated.

The savings from new construction show up in the New Construction Policies wedge and are associated with BE 2.

3.2.2 Existing Building Efficiency

For existing buildings, the model includes several overlapping programs. These programs in the model represent the impact of a suite of actions recommended in the plan and are not a one-for-one match to any specific BE action. Three policies were modeled for energy efficiency in existing buildings—benchmarking, energy efficiency retrofits, and gut-rehab renovations. Each policy is also applied to municipal buildings at differing levels, as discussed in Section 2.2.4.

3.2.2.1 Benchmarking

The model includes projected effects from expansions to the Cities’ mandatory benchmarking programs. Benchmarking is the act of tracking and publicly reporting the energy performance of buildings, usually using the ENERGY STAR Portfolio Manager platform. Benchmarking does not itself save energy, but it reveals low-cost and no-cost opportunities for savings.

Benchmarking is assumed to be fully implemented in both cities as of 2025. Based on a survey of results from other cities, we assumed an 80% compliance rate once the benchmarking programs are fully implemented, applied only to the percent of floor area for each building type that is over the size thresholds for the Cities' current programs (but assuming, in South Portland's case, an expansion from the current limited geography to the whole city). We estimated cumulative 10% savings per benchmarked building over 5 years, which is a composite of multiple studies that find energy savings of 7% to 14%, over periods of 3 to 5 years.[7,8]

3.2.2.2 Energy Retrofits

The retrofits assumed in the model are intended to provide a sense of the scale of action required in the existing building sector to achieve the 2050 GHG reduction target, while being realistic enough to achieve and sustain. The scale of retrofits assumed for private buildings is equivalent to achieving a 40-50% energy use reduction across 1% to 2% of the building stock each year (or, in practice, a lower average energy use reduction across a larger portion of existing buildings). The term retrofit in this regard is a bit of a misnomer; in reality, the modeled retrofits will include a variety of building interventions focused on reducing energy and/or emissions, ranging from lighting upgrades to full envelope and HVAC system replacements. For this retrofit program, energy reductions are applied across all fuel types in equal measure.

For municipal government buildings, the penetration rate is calculated to achieve retrofits of all municipally owned buildings by 2050, as discussed below. State and county government buildings are modeled as being retrofitted to the same level of energy performance, but across only 25% as much floor area. For other building types, the assumed retrofit rates are based on national and global best practices and Integral Group field experience.

Table 10. Energy retrofit assumptions by building type and timeframe.

Sector	Years	% EUI Reduction	Penetration Rate Per Year
Local Government	2021-2025	10%	1%
Local Government	2026-2030	30%	3%
Local Government	2031-2050	80%	3%
State/County Government	2021-2025	10%	0.25%
State/County Government	2026-2030	30%	1%
State/County Government	2031-2050	80%	1%
Single Family & Apt 2-4	2022-2030	40%	1.5%
Single Family & Apt 2-4	2031-2050	50%	1.5%
Multifamily	2022-2030	40%	1.5%
Multifamily	2031-2050	50%	1.5%
Commercial	2020-2030	40%	2%
Commercial	2030-2050	50%	2%

[7] Mims, N. et. al. 2017. Evaluation of U.S. Benchmarking and Transparency Programs; Attributes, Impacts, and Best Practices. Berkley, CA: Lawrence Berkley National Laboratory. Pp 60- 62 https://emp.lbl.gov/sites/default/files/lbnl_benchmarking_final_050417_0.pdf

[8] Meng, T., D. Hsu, and D. Han. 2016. "Measuring Energy Savings from Benchmarking Policies in New York City." Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2016/data/papers/9_988.pdf,

3.2.2.3 Gut-Rehabs

Additionally, the model assumes that a portion of existing buildings would go through a renovation each year, triggering the requirement to comply with the most recent building codes for the portion of the building undergoing a rehab. We assumed that the rehabs would result in the average building improving its energy performance by half as much as if the entire building was required to meet the latest code, because gut retrofits may not address all aspects of a building, such as the building envelope; these assumptions are based on Integral Group field experience.

The savings from these three policies show up in the Existing Building Efficiency wedge and are attributed to section BE 3 with the other existing building actions.

3.2.3 Existing Building Decarbonization

Given the high penetration of natural gas and fuel oil heating in Maine, Portland and South Portland will not be able to achieve an 80% reduction in GHG emissions—let along carbon neutrality—without switching most residential and commercial buildings to carbon-neutral sources of heating, such as high-efficiency cold-climate air-source heat pumps (ASHP) or ground-source heat pumps (GSHP) for heating and cooling, and converting other process loads such as domestic hot water and cooking to electricity as well. Electrifying these systems will have immediate benefits for health and safety and important ripple effects in terms of GHG reductions.

Electric heat pump systems are significantly more efficient than traditional combustion-based systems. With few exceptions, the efficiency gains from using heat pumps will lead to immediate reductions in GHG emissions. Moreover, electric systems create more dispatchable loads—loads that can be intelligently managed and timed throughout the day to reduce peak demand on the grid or to coincide with peak periods of renewable energy generation. This alignment can help make it more beneficial and cost-effective to add more renewable energy to the grid.

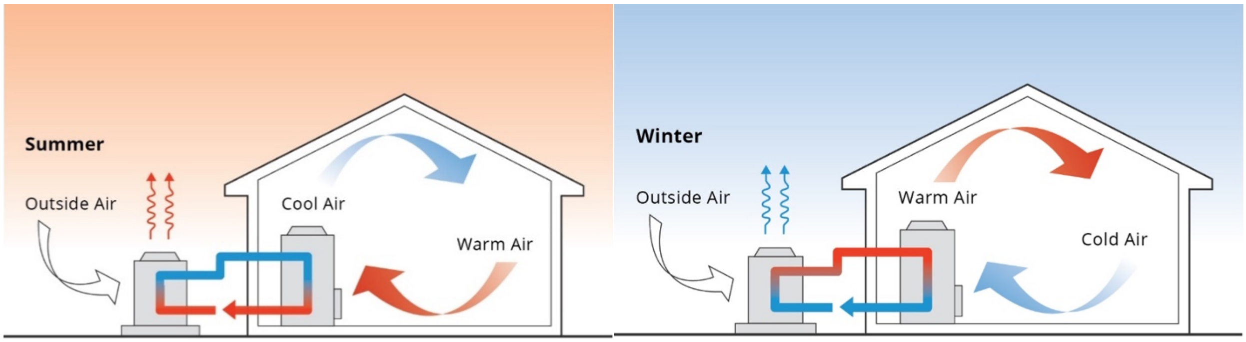

Figure 1. Heat pump operation in summer and winter.

Modern cold-climate air-source heat pumps are capable of supplying heating even when it is below freezing, albeit with decreasing efficiency. A study of the ASHP and GSHP potential in Portland and South Portland by

Meister Consultants Group found that most buildings in Portland and South Portland are good candidates for heat pump systems.

The efficiency of a heat pump is measured using a coefficient of performance (COP), which represents the amount of usable heating or cooling produced per unit of electricity consumed. Because heat pumps move heat rather than directly generate it, most have COPs ranging from 2.0 to 3.0, which is to say they are 200% to 300% efficient. While best practice heat pumps have theoretical COPs of 3.0, in the context of cold Maine winters, a COP assumption of 2.5 is more reasonable.[9] To make a further conservative assumption, we assumed that 20% of natural gas use would not be able to be replaced with heat pumps, though this may not remain true as technology continues to improve.

The model makes the following assumptions for system efficiencies (Table 11). The fuel switch factors are the amount of additional electricity required to make up for the removed fossil fuel. For example, a natural gas fuel switch factor of 0.377 for single-family homes means that for every unit of natural gas consumption reduced/removed, 0.377 units of electricity consumption will be added; a building that formerly used 5,000 kBtu of electricity and 10,000 kBtu of natural gas, after a fuel switch, uses 8,770 kBtu of electricity and 0 kBtu natural gas. These factors are a function of the relative efficiency assumptions, and also the distribution of fuel use in each building type

Table 11. Fuel switching assumptions for natural gas (NG) and fuel oil (FO).

Sector	Sub-Sector	Natural Gas / Fuel Oil Baseline Efficiency				New Electric System Efficiencies			NG Fuel Switch Factor	FO Fuel Switch Factor
		NG Space Heat	FO Space Heat	NG/FO DHW*	NG Cooking / Other	Space Heat	DHW*	Cooking / Other		
Residential	Single Family	75%	75%	63%	75%	250%	200%	75%	0.377	0.438
	Apt (2-4 units)	75%	75%	63%	75%	250%	200%	75%	0.377	0.438
	Multi-family	85%	75%	63%	75%	250%	200%	75%	0.403	0.30
Inst./Gov.	Educational Institutional	85%	75%	63%	75%	250%	200%	75%	0.410	0.360
	Gov't City	85%	75%	63%	75%	250%	200%	75%	0.437	0.346
	Gov't Other	85%	75%	63%	75%	250%	200%	75%	0.437	0.346
Commercial	Office	85%	75%	63%	75%	250%	200%	75%	0.440	0.346
	Other Commercial	85%	75%	63%	75%	250%	200%	75%	0.390	0.303
	Healthcare	85%	75%	63%	75%	250%	125%	100%	0.590	0.345
	Warehouse	85%	75%	63%	75%	250%	125%	100%	0.610	0.330

*DHW = domestic hot water

[9] Schoenbauer, B. and M. Kushler. 2016. "Field Assessment of Cold Climate Air Source Heat Pumps." Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in Buildings. https://www.aceee.org/files/proceedings/2016/data/papers/1_700.pdf

With some sectoral exceptions, the modeling assumes that 100% of all residential and commercial buildings that use natural gas or fuel oil are electrified by 2050—a rate of over 3% per year, starting in 2024. No fuel switching is assumed for healthcare and state/county government buildings; the high energy demand of healthcare facilities makes retrofits in this sector more challenging, and it is assumed that state and county buildings would not be covered by any city government retrofit programs or requirements.

The savings from these decarbonization efforts show up in the Existing Building Decarbonization wedge and are attributed to section BE 3 with other existing building actions.

3.2.4 Municipal Buildings Policies

All energy savings from municipal buildings are grouped under the Municipal Buildings Policies wedge. Together with savings from Municipal Renewable Energy, it provides the assumed savings for plan section BE 1. In the short-term, most of the savings under BE 1 come from Municipal Renewable Energy (see section 4.2.3), but building policies become the dominant source of municipal GHG savings as the municipal buildings become more energy efficient, and as the difference between the RPS and the proportion of municipal energy coming from renewable sources becomes less significant after 2030. The Municipal Buildings Policies wedge has the same subcomponents as rest of the building policy actions discussed above.

New municipal buildings are assumed to be built to the same stretch energy code as other new buildings, but to reflect the Cities leading by example, new municipal buildings are assumed to follow a net-zero-energy-ready path beginning in 2026.

At the same time, all municipal buildings are modeled as undergoing retrofits to become highly energy efficient and all-electric. For municipal buildings, the penetration rate is calculated to achieve retrofits of all municipally owned buildings by 2050, at 3% per year. The municipal buildings follow the same fuel switching efficiencies as buildings owned by other governments, per Table 11. To avoid double-counting savings between retrofits and gut-rehabs, no municipal building energy savings are assumed from gut-rehabs.

Table 12. Municipal building retrofit assumptions by timeframe.

Sector	Years	% EUI Reduction	Penetration Rate Per Year
Local Government	2021-2025	10%	1%
Local Government	2026-2030	30%	3%
Local Government	2031-2050	80%	3%

3.2.5 Industrial Decarbonization

Industrial efficiency can be highly cost-effective, and in states like Maine where there has been a limited focus on industrial savings to date, large savings are reasonable to expect. At the same time, the high energy demands of industry, particularly the need for very high temperatures in many industries, make direct electrification a challenge. Three initiatives were modeled for private industry.[10] These savings were assumed to begin in 2028, the timeline for the increase in industrial energy efficiency programs, through no longer allowing industrial energy users to opt out of supporting Efficiency Maine.

First, the model assumes that almost all (90%) of industrial space would be affected by efficiency measures. Of these, we assume 60% (54% of all industrial space, or 1.86% per year) would undertake an efficiency project that reduces their energy use by 35%, based on the median efficiency savings in industrial projects nationwide for various sectors identified in studies by the American Council for an Energy Efficiency Economy (ACEEE).[11] A study would need to be commissioned to determine if these values are achievable for the industries and industrial users located in Portland and South Portland.

Secondly, we modeled that 40% of the industrial spaces that undertake any efficiency project would undertake a combined heat and power (CHP) conversion by 2050 (36% of all facilities, or 1.24% per year), to leverage excess thermal energy and offset electric demand. A CHP conversion is estimated at reducing grid-supplied electricity use by 90% while increasing natural gas use by 54%, based on findings from the U.S. Environmental Protection Agency.[12] These are average numbers—the actual energy savings for CHP will vary greatly by facility.

Finally, we estimated that 95% of facilities that use fuel oil will convert to using natural gas or a biofuel. We estimate that 33% of facilities that use fuel oil will convert to using biofuels, such as renewable fuel oil (RFO) or biogas, 33% will electrify, and the remainder will switch to natural gas.

The savings from these three policies show up in the Industrial Decarbonization wedge and make up the savings attributed to section BE 4.

4 Transportation

The assessment models greenhouse gas emissions for all mobile transportation within the boundaries of Portland and South Portland from 2020 through 2050. For on-road transportation, the business-as-usual scenario assumes that vehicle miles traveled continues to increase at historical rates, with the current levels of vehicle fuel economy. For waterborne transportation, the business-as-usual scenario holds energy use constant. The policy scenario models GHG emissions avoided as a result of the implementation of transportation and land use policies that encourage mode shift and vehicle electrification.

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[10] Kelly, M. and E. Rodgers. 2016. Communicating the Value of Industrial Energy Efficiency Programs. Washington, DC: American Council for an Energy-Efficiency Economy. https://www.aceee.org/sites/default/files/value-industrial-ee-programs.pdf

[11] Elliot, N. 2017. Energy efficiency and industry: the national trend. Washington, DC: American Council for an Energy-Efficiency Economy. https://www.aceee.org/blog/2017/08/energy-efficiency-and-industry

[12] U.S. Environmental Protection Agency. 2015. Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems. Washington, DC: U.S. Environmental Protection Agency https://www.epa.gov/sites/production/files/2015-07/documents/fuel_and_carbon_dioxide_emissions_savings_calculation_methodology_for_combined_heat_and_power_systems.pdf

4.1 Baseline and Business-as-Usual Transportation Assumptions

4.1.1 On-Road Emissions

Baseline and business-as-usual transportation demand are based on the greenhouse gas inventories that were conducted for Portland and South Portland for this project. 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 city, regardless of whether the vehicle owners reside in either city 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 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 this, 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 were matched to the registered vehicle stock, and from this, weighted average fuel economy calculations were created for each city and each vehicle class. Table 13 and Table 14 aggregate this data across both cities.

Table 13. On-road energy use by fuel type in Portland and South Portland.

Fuel Type	Vehicles	VMT	MPG (Weighted)	Fuel Use (MMBTU)	GHG emissions ($MTCO_2e$)	GHG Intensity ($MTCO_2e$/VMT)
Diesel	2,689	27,244,599	6.4	591,848	43,917	1.61E-03
Gasoline	68,753	696,596,483	21.6	4,487,117	316,176	4.54E-04
Hybrid electric	2,110	21,378,246	31.1	95,464	6,727	3.15E-04
CNG	33	334,352	3.4	11,700	622	1.86E-03
Electric	59	597,780	37.0	344,780	92	1.54E-04

Table 14. On-road emissions by vehicle type in Portland and South Portland.

Vehicle Type	Baseline VMT	Baseline GHG emissions ($MTCO_2e$)	Portion of VMT	Portion of GHG emissions
Passenger cars	3.59E+08	1.07E+05	48.0%	29.1%
Passenger trucks	2.94E+08	1.68E+05	39.3%	45.6%
Electric passenger vehicles	5.98E+05	9.21E+01	0.1%	0.0%
Buses	1.88E+06	5.45E+03	0.3%	1.5%
Other light- & medium-duty vehicles	6.32E+07	3.61E+04	8.4%	9.8%
Heavy-duty trucks	2.68E+07	5.15E+04	3.6%	14.0%

Mode share numbers come from the Portland Comprehensive Plan (Portland's Plan 2030) and American Community Survey data on commute modes in Portland and South Portland.[13] Because these mode share numbers come from commute data, they likely inflate the use of transit, walking, and biking, relative to all travel, but better data for all passenger trips was not available.

Preliminary modeling by PACTS and AECOM for the ongoing "Transit Tomorrow" regional analysis was shared with the consultant team, and it indicates that VMT in southern Maine can be expected to increase in the business-as-usual scenario by 16% between 2020 and 2040—which works out to 0.74% per year on average. Passenger ridership on buses is increasing faster, however. Greater Portland METRO reported in 2019 that their system has seen a 45% increase in use between 2013 and 2019—which works out to 5.45% per year.[14] Limited data was available on the growth rates for walking and biking, and so a growth rate similar to the growth in overall VMT was assumed, keeping the percentage of walking/biking constant at 9%. While any shift to walking and biking from other modes is captured in the modeling as VMT reductions, the explicit growth of walking and biking under a business-as-usual scenario due to population growth, for example, is not included in the modeling as those trips have no emissions.

Table 15. Passenger mode share in Portland and South Portland under the business-as-usual (BAU) scenario.

Mode	Baseline Mode Share	BAU Average Annual Growth Rate	2050 BAU Mode Share
Passenger Vehicle	88%	0.75%	80%
Transit Buses	3%	5.45%	10%
Walking and Biking	9%	1%	10%

Heavy-duty trucks are not included in the mode share numbers. Due to insufficient data on their growth rates, the VMT, fuel consumption, and emissions, use of heavy-duty vehicles (other than transit buses) is held flat over time. While the plan contains actions that will help mitigate emissions from heavy trucks, the magnitude of impact of these actions is uncertain and was not modeled.

4.1.2 Non-Road Transport Emissions

Emissions from cruise ships were estimated using the cruise ship visit schedule for 2017 from the City of Portland, and calculated based on 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.[15] To estimate emissions from the docked cruise ships, we reviewed two studies of docked ship emissions, one from Los Angeles (Port of Los Angeles) and one from Seattle, Washington (Puget Sound Maritime Air Forum).[16,17] See section 4.6 of the GHG Inventory Methodology for the assumptions that went into this modeling. While cruise ship visits are

[13] City of Portland. Portland's Plan 2030. Retrieved from https://www.portlandmaine.gov/DocumentCenter/View/18269/Portlands-Plan-2030-with-Appendices

[14] McGuire, P. 2020. "Portland Metro got a record 2.1 million riders on the bus in 2019." Portland Press Herald. January 8, 2020. https://www.pressherald.com/2020/01/08/portland-metro-bus-ridership-hits-record-2-1-million-in-2019/

[15] https://www.portlandmaine.gov/DocumentCenter/View/27428/2017-Cruise-Schedule

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

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

increasing, the scale of the increase is difficult to forecast, and so no increase was assumed in the BAU or policy scenarios.

The Casco Bay Lines ferry system travels between the Portland peninsula and Portland's islands; these trips are included within the GHG inventory and One Climate Future modeling, as these routes are within the City of Portland. Casco Bay Lines staff estimated that their ferries consume 240,000 gallons of marine diesel fuel every year. No increase in ferry travel was assumed over time.

Table 16. Waterborne transportation energy use under the business-as-usual scenario.

Waterborne Transportation	Annual Diesel Use (units variable)	Annual Energy Consumption (kBTU)	Annual GHG Emissions ($MTCO_2e$)
Cruise Ship Auxiliary Engines	6,004,611 kWh-e	20,487,733	4,167
Cruise Ship Boilers	250,192 kWh-e	853,656	231
Casco Bay Lines Ferry	240,000 gallons	33,120,000	2,479

Emissions from passenger and freight rail and intracity aircraft were not included in either the inventory or the model due to limited data availability. As discussed in the GHG Inventories Memorandum, transboundary ship, train, and plane emissions are not included in the GPC BASIC protocol.

4.2 Avoided Transportation Sector Emissions Due to Policies

4.2.1 Mode Shift & Land Use Policies

Land use policies are crucial to reducing GHG emissions by encouraging a shift in travel modes away from driving passenger vehicles. However, modeling the effects of a variety of individual land use policies on mode shift and vehicle miles traveled (VMT) is a complex and intensive modeling process that was not within the scope of this project. Given that constraint, the consultant team modeled the VMT changes, and the correlated GHG emissions reductions, that result from reaching a set of mode share thresholds, defined as part of the modeling process.

As shown in Table 17, the selected mode share thresholds include: 60% of trips completed by passenger vehicles (down from 88% currently); 20% of trips completed by public transit (up from 3% currently), and 20% of trips completed by walking or biking (up from 9% currently).[18] These thresholds were selected through discussions with Portland and South Portland city staff, and the Climate Planning Process Committee. These targets are informed by mode-shift targets being set in other cities with a similar current level of transit ridership (including Richmond, Virginia and Oakland, CA).[19] The targets are also informed by the more aggressive mode share targets being set by cities with robust transit systems, like Boston, MA or

[18] It is important to note that the current mode share breakdown is based on commuting trips, which is used as a proxy for all trips, given the lack of better mode share data.
[19] City of Oakland. 2020. Oakland Equitable Climate Action Plan. https://cao-94612.s3.amazonaws.com/documents/Oakland-ECAP-07-24.pdf

Washington, DC, which aim to reduce trips by passenger vehicles to 25% of all trips by 2030 and 2032, respectively.[20,21]

Table 17. Mode share current breakdown, projections, and targets for Portland and South Portland.

Mode	Current Mode Share	BAU Annual Growth Rate	BAU 2050 Mode Share Projection	Target Mode Share	Target Annual Growth Rate	Change in Growth Rate from BAU to Target
Passenger Vehicle	88%	0.74%	80%	60%	-0.42%	-156%
Transit Buses	3%	5.45%	10%	20%	7.43%	36%
Walking and Biking	9%	1.0%	10%	20%	3.45%	255%

While these targets may seem aggressive, they are both in line with planning efforts elsewhere and a reasonable shift from the current rates of change. Doubling walking and biking trips (9% to 20%) is well within the norm for most sustainability plans. Increasing transit ridership to 20% of trips does represent a transformation of the transit system and a more difficult challenge. However, Greater Portland METRO ridership is increasing at over 5% per year, while overall passenger VMT is increasing at 0.745% per year; at those rates, bus ridership will represent approximately 10% of passenger miles traveled by 2050. To reach the target mode share, the growth rate will need to be 7.4% per year, a 36% increase in the annual ridership growth rate relative to the recent past.

In order to model the full potential of greenhouse gas emissions reductions created due to mode shift, mode shift greenhouse gas emissions savings were calculated using the energy efficiency and emissions intensity of the current vehicle stock, prior to accounting for fuel economy standards and a transition to electric vehicles.

With transit ridership increasing, the total VMT and emissions from the bus fleet will also increase, though not in direct proportion, since some existing bus routes are under-utilized today. The modeling assumes that total VMT from buses will increase by 6.4% per year, or a six-fold increase by 2050. For the purposes of looking at savings specifically from mode shift, the model assumes the bus fleet continues to be diesel buses. (The GHG reductions from bus electrification are captured in another wedge, discussed in section 4.2.2.) Thus, the total GHG emissions savings achieved through lower passenger vehicle miles traveled are reduced by 12.8%, due to higher emissions from diesel buses.

Table 18. Mode share net emissions savings by 2050 in Portland and South Portland.

Action	2050 GHG Emissions Savings ($MTCO_2e$)	Cumulative GHG Emissions Savings, 2020-2050 ($MTCO_2e$)
Reduced Passenger Vehicle Use	109,698	1,997,310
Increased Bus Use (Diesel)	-13,309	-256,831
Net Mode Shift Impact	96,388	1,742,479

[20] City of Boston. 2019.Boston Climate Action Plan https://www.boston.gov/sites/default/files/imce-uploads/2019-10/city_of_boston_2019_climate_action_plan_update_2.pdf
[21] District of Columbia. 2019. Sustainable DC 2.0. http://www.sustainabledc.org/wp-content/uploads/2019/04/sdc-2.0-Edits-V5_web.pdf

To fully capture the potential for GHG savings from mode shift, the buses need to be battery electric buses, which are modeled below. The savings from mode shift show up in the Mode Shift & Land Use Policies wedge and constitute the savings for TLU 1.

4.2.2 Bus Electrification

The transit buses of Greater Portland METRO and South Portland Bus Service (SPBS) are treated as a single fleet for modeling purposes, in line with the overall modeling approach of combining data for both cities. Based on the increases in transit ridership, we project the combined bus fleets of METRO and SPBS will need to grow by 6.4% per year, rising from 51 buses in 2019 to 350 buses by 2050. Both bus services have set a goal of having a zero-emissions bus fleet by 2040. As buses have a 15-year lifespan on average, all new bus purchases must therefore be battery-electric vehicle (BEV) buses starting in 2025. For simplicity, we modeled the bus fleet as increasing in size and electrifying linearly: starting in 2026, all public transit bus retirements (3 per year) are diesel, and all new buses (14 per year) are BEV buses, reaching a fully electric fleet by 2040. The bus fleets produce no direct emissions as of 2040, and once the Maine renewable portfolio standard reaches 100% by 2050, no operational emissions at all.

The One Climate Future plan also calls for the electrification of school buses, with all new school bus purchases being BEV buses by 2030. However, insufficient data was available to estimate the savings specifically from electrifying the school bus fleet, and so no savings for this transition are incorporated in the model. Transportation GHG savings are underestimated in this respect.

The savings from BEV transit buses show up in the Bus Electrification wedge, and with the other vehicle electrification actions, are collectively attributed to sections TLU 2 & 3 of the plan.

4.2.3 Fuel Economy Standards

Each year, 6.67% of the existing passenger vehicle stock is replaced by new vehicles.[22] New vehicles entering the stock have a higher fuel efficiency rating due to the federal Corporate Average Fuel Economy (CAFE) Standard, which results in an increase in the average fuel efficiency of the entire stock.[23] The reductions in GHG emissions and energy use driven by the CAFE Standard were included in the analysis to make its impact explicit. Because it is a federal regulation already in place, the CAFE Standard will achieve GHG reductions regardless of actions taken in the Cities of Portland and South Portland.

The Trump administration has proposed a rollback of the CAFE standards; however, Maine is one of the states that follows the California standards, which are aligned with the CAFE standards set under President Obama. The model assumes that that lawsuits to end California's higher standards fail to have an impact, and that California and other states (including Maine) continue to use higher fuel standards and that the auto industry does not market different cars in adjoining states. CAFE thresholds would continue to get stricter out

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[22] Based on the number of new vehicle sales versus the number of total registered vehicles in the United States over the past several years (https://www.statista.com/statistics/185198/age-of-us-automobiles-and-trucks-since-1990/), with approximately 70% of vehicles on the road after 15 years, and some longer (http://www-nrd.nhtsa.dot.gov/Pubs/809952.pdf); Total registered vehicles in 2015 - https://www.statista.com/statistics/183505/number-of-vehicles-in-the-united-states-since-1990/; Light vehicle retail sales: https://www.statista.com/statistics/199983/us-vehicle-sales-since-1951/

[23] CAFE Standard fuel efficiency values are based on modeling from the U.S. Energy Information Administration's Annual Energy Outlook 2015.

to 2025, and then remain constant. Savings would continue to grow as older cars are replaced. Because of the current low weighted average fuel economy of the vehicle fleet in southern Maine, the impact of the CAFE Standards is significant on its own. The blended fuel economy numbers assume that 45% of passenger vehicle VMT continues to be from light trucks, as it is today, as shown in Table 19.

Table 19. Corporate Average Fuel Economy (CAFE) assumptions by vehicle type and year.

Vehicle Type	Corporate Average Fuel Economy (kBTU/mile)						
	Baseline (2017)	2020	2021	2022	2023	2024	2025 (and thereafter)
Conventional Passenger Car	4.22	3.22	3.08	3.02	2.93	2.83	2.79
Conventional Passenger Light Truck	8.08	4.75	4.46	4.25	4.07	3.88	3.86
Blended Conventional Passenger Vehicle	6.54	4.14	3.91	3.76	3.61	3.46	3.43
Battery Electric Passenger Vehicle	1.72	1.62	1.56	1.55	1.55	1.52	1.50

The implementation of fuel economy standards is the only policy action included in the modeling that cannot be linked to any specific action in the One Climate Future plan. However, CAFE Standards play a crucial role in reducing GHG emissions. By joining the strong California standards, Maine has taken statewide action to ensure these GHG savings are realized, regardless of federal action. The savings from these standards show up in the Fuel Economy Standards wedge, and with the other vehicle electrification actions, are collectively attributed to sections TLU 2 & 3 of the plan.

4.2.4 Electric Vehicle Adoption

Electric vehicle (EV) adoption is rapidly increasing around the world, driven by technological changes, decreasing prices, and EV-supportive policies, including EV-readiness requirements and the build-out of charging infrastructure. The model includes the expansion of battery electric vehicles, powered entirely by electricity from the grid, and plug-in hybrid electric vehicles, initially powered by a battery and then by a petroleum fuel-based engine when the battery is depleted.[24] The model assumes the breakdown of battery electric vehicles (EVs) to plug-in hybrid electric vehicles (PHEVs) starts at 50/50, and steadily shifts towards EVs with a 60/40 breakdown in 2030, a 91/9 breakdown in 2040, and a 97/3 breakdown in 2050.

The model also assumes that the EV market share for new vehicles (the share of new vehicles sold that are electric vehicles) will increase over time. Due to continually accelerating market trends plus stronger local and/or state incentives, and increasing federal regulations, we make the assumption that EV adoption will exceed currently predicted global trends, with EVs being 60% of new car sales by 2040 and 100% by 2050 (a plausible scenario if the U.S. were to follow the lead of the United Kingdom, France, Norway, Sweden, India, and China in restricting the sale of gasoline- and diesel-powered cars in the 2040-2050 timeframe).

[24] The model assumes plug-in hybrid electric vehicles operate on electricity 66% of the time and gasoline 34% of the time, based on Marshall, B.M., Kelly, J.C., Lee, T.-K., Keoleian, G.A., Filipi, Z., 2013. Environmental assessment of plug-in hybrid electric vehicles using naturalistic drive cycles and vehicle travel patterns: A Michigan case study. Energy Policy 58, 358–370; Kelly, J.C., MacDonald, J.S., Keoleian, G. a., 2012. Time-dependent plug-in hybrid electric vehicle charging based on national driving patterns and demographics. Appl. Energy 94, 395–405.

This projection is in line with extrapolating forward projections from Bloomberg New Energy Finance (Figure 2).

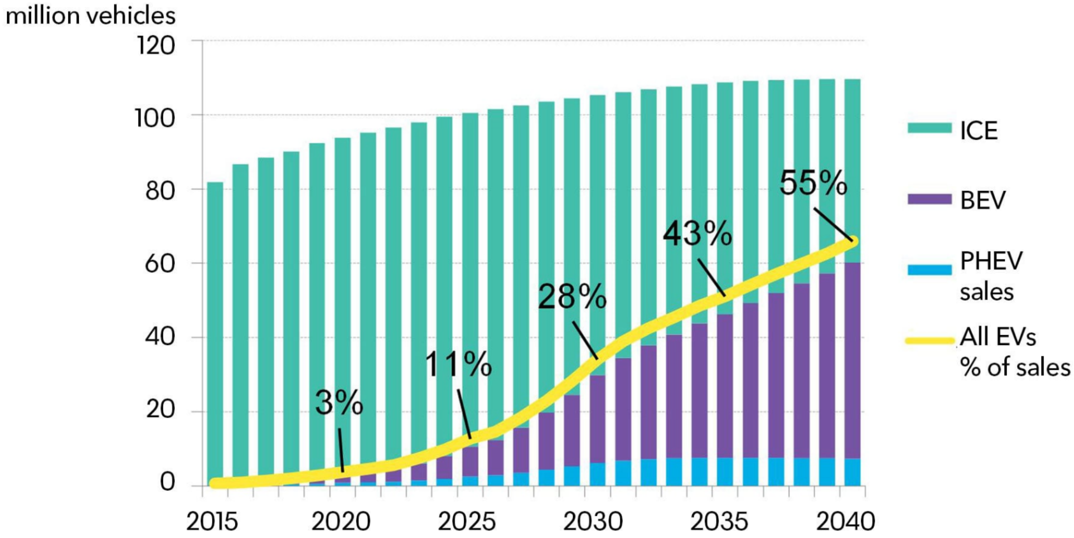

Figure 2. EV adoption projections (courtesy of Bloomberg New Energy Finance, 2019); ICE: Internal Combustion Engine, BEV: Battery Electric Vehicle, PHEV: Plug-in Hybrid Electric Vehicle, EV: Electric Vehicle

Insufficient data was available to calculate specific savings from electrifying the light-duty fleet vehicles owned and operated by both cities. However, these vehicles are included in the total vehicle counts, and so their electrification is captured within this action (albeit on a less aggressive timeline than called for in the plan, which calls for all new municipal light-duty vehicle purchases to be EVs by 2028). The savings from private and municipal passenger EV adoption show up in the Electric Vehicle Adoption wedge and are grouped with other vehicle electrification actions in TLU 2 & 3.

4.2.5 Ferry & Ship Electrification

The model assumes that all new Casco Bay Lines ferries are hybrid-electric ferries, which will be more energy-efficient, and will run on 100% electric power once sufficient shore power resources are provided. All ferry conversions are assumed to be completed by 2045. While there will be marginal short-term emissions reductions due to the efficiency of a hybrid-electric engine even without shore power hookups, these savings are not included in the model.

In line with the One Climate Future strategy for shore power, the model includes the effects of shore power hookups installed by 2040. Cruise ship auxiliary engines and boilers are assumed to be 50% efficient, while electric power is 100% efficient, so hooking up to shore power decreases not only emissions, but also energy consumption. Once the grid is 100% renewable in 2050, the electricity provided through shore power will have no associated emissions.

Table 20. Assumptions for shore power annual energy consumption and peak electrical demand.

Type of Vessel Energy Use	Annual Energy Consumption (kBTU)	Peak Electrical Demand (MW)
BAU Cruise Ship Auxiliary Engines, Diesel	20,487,733	N/A
BAU Cruise Ship Boilers, Diesel	853,656	N/A
BAU Ferry Diesel	33,120,000	N/A
Total Shore Power Demand	27,230,694	31.8
Shore Power Demand for Cruise Ships	10,670,694	27.0
Shore Power Demand for Ferries	16,560,000	4.8

The savings from shore power show up in the Ferry & Ship Electrification wedge and are grouped with other vehicle electrification actions in sections TLU 2 & 3 of the plan.

5 Waste

The model estimates greenhouse gas emissions from waste from now through 2050, looking at the direct emissions from breaking down waste and the energy used to process the waste. The business-as-usual scenario assumes increases in waste emissions based on population growth. The model then assesses the greenhouse gas emissions avoided between now and 2050, considering the implementation of policies to divert waste from incineration and to reduce the energy intensity of wastewater processing.

5.1 Baseline and Business-as-Usual Waste Assumptions

5.1.1 Solid Waste

All waste in Portland and South Portland is collected and processed by ecomaine. Waste that is not recycled or sent to an anaerobic digester 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 Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), emissions from the incineration of biogenic waste (e.g. paper, food waste, wood products) are considered carbon-neutral—whether this is appropriate is an active industry debate; however, modeling must follow current GHG inventory standards.

The BAU scenario for waste increases proportionally to population in the model. BAU diversion rates were held at current documented levels: 32.4% for residential; 12% for commercial, institutional, and industrial waste; and 0% for drop-off. A small food waste collection program is currently operating in South Portland; 77% of the waste collected through that program goes to an anaerobic digester; the remaining 23% are contaminants that are incinerated. The quantity of construction and demolition waste is unknown and not included in the GHG inventory or modeling at this time. The emissions intensity of the incineration was calculated based on data collected and shared by ecomaine, equivalent to 0.33685 $MTCO_2e$/tonne of waste. The anaerobic digester has an emissions intensity of 0.02239 $MTCO_2e$/tonne of organic waste.

Table 21. Baseline (2017) and business-as-usual (BAU) (2050) waste volumes and GHG emissions for Portland and South Portland. MSW stands for municipal solid waste.

Category/Sub-Category	Baseline (2017) Waste Volume (tonnes)	Baseline (2017) GHG Emissions ($MTCO_2e$)	BAU 2050 Waste Volume (tonnes)	BAU 2050 GHG Emissions ($MTCO_2e$)
Residential Disposed Waste Total	16,400	5,525	26,802	9,029
Residential MSW	15,402		25,170	
Residential Bulky	999		1,632	
Commercial Disposed Waste Total	65,820	22,172	107,566	36,234
Commercial MSW	54,454		88,993	
Commercial Bulky	11,365		18,574	
Food Waste	5,396	515	8,819	836
Food Waste Digested	4,143		6,771	
Food Waste Contaminates	1,253		2,031	
Waste not producing GHGs	38,461		62,855	
Inert Ash [no GHG]	21,979		35,919	
Residential Recycling [no GHG]	7,843		12,817	
Commercial Recycling [no GHG]	8,639		14,119	
Total MSW including recycling	126,077		206,026	
Total MSW producing GHGs	87,616	28,211	143,188	46,099

5.1.2 Wastewater

Table 22 reports baseline energy use from wastewater treatment for 2017. Wastewater energy use and process emissions are assumed to increase at a rate of 1.5% per year, proportional to population growth. 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 for the 2017 baseline were estimated at 3,959 $MTCO_2e$ and increase to 6,471 $MTCO_2e$ by 2050.

Table 22. Wastewater energy use baseline (2017) for Portland and South Portland.

Sector	Wastewater EUI (kBTU/gal/day)	Annual Energy Use (MMBTU)	Annual Electricity Use (MMBTU)	Annual Natural Gas Use (MMBTU)	Annual Fuel Oil Use (MMBTU)
Wastewater Treatment	1.71	29,418	20,764	8,308	346

5.2 Avoided Waste Emissions Due to Policies

5.2.1 Solid Waste Reduction

The modeling for solid waste reduction was oriented towards achieving “zero waste” by 2050. As some products cannot be recycled or composted, the model targets an 80%-90% reduction in waste, which is in line with common definitions for zero waste targets. Waste emissions are reduced in the model through several measures. Due to source reduction, total waste generated is reduced by 20% relative to the BAU case. However, due to population growth, total waste generated still grows by 81% relative to 2017. The model assumes that through a combination of recycling and composting, 90% of residential and commercial waste that is generated is diverted from incineration by 2050. Greenhouse gas emissions from waste decrease from 28,221 $MTCO_2e$ in 2017 to 4,133 $MTCO_2e$ in 2050—an 85% decrease. The savings from solid waste show up in the Solid Waste Reduction wedge and are attributed to the WR section of the plan.

5.2.2 Wastewater Efficiency

All water/wastewater actions were calculated assuming energy reductions per gallon of water/wastewater, with the quantity of water/wastewater increasing in proportion to population growth. The model assumes natural gas and fossil fuel use at the wastewater treatment plant would be met with biodigester gas, beginning implementation in 2035 and completing by 2040. We also assumed a 10% reduction in electricity consumption per gallon treated due to plant efficiency efforts. Improvements were calculated to occur over a five-year timeframe starting in 2030.

No policy interventions were assumed to reduce wastewater process emissions, as insufficient information was gathered on current process emissions to be able to recommend appropriate interventions and potential reductions.

The savings from the wastewater plants show up in the Wastewater Efficiency wedge and are attributed to the WR section of the plan.

6 Results from the Energy and Emissions Modeling

The following section summarizes the results of the model, including the effects on greenhouse gas emissions reductions as well as energy savings driven by the implementation of strategies in the One Climate Future plan.

6.1 Greenhouse Gas Results

6.1.1 GHG Emission Reductions from Policies

The modeling shows that Portland and South Portland can reduce citywide greenhouse gas emissions by over 81% by 2050, relative to 2017. Many of the assumptions in the model are conservative, and greater savings may well be possible with additional state and federal support.

Recognizing the scale of the global climate crisis and the need to take aggressive action, many actions have been front-loaded. Almost half of all the plan's actions occur in the next decade. The Cities are projected to achieve a 33% reduction in GHG emissions by 2030, and a 50% reduction by 2036, relative to 2017.

The following actions are some of the critical "front-loaded" actions. Because they are implemented early, they make up a higher percentage of the cumulative savings from 2020 to 2050 than of the annual savings for the year 2050.

- New Construction: The stretch code will require new buildings to be net-zero energy (NZE)-ready by 2030, if implemented as planned.
- Renewable Portfolio Standard: The state renewable portfolio standard will require electricity to be 80% renewable by 2030, thus achieving most of the GHG savings from electricity generation within the next ten years.
- Fuel Economy Standards: Federal fuel economy standards for cars level off after 2025, with most of the savings locked in early.
- Municipal Renewable Energy: The municipal government electricity supply will be 100% renewable by 2032.
- Municipal Building Policies: Municipal government building retrofits will be net-zero energy by 2030.
- Bus Electrification: All transit buses and school buses will be electric vehicles by 2040.

Conversely, the following key actions are phased in or ramp up over a longer period. Consequently, these actions make up a higher percentage of 2050 annual savings than 2030 or 2040 annual savings, or cumulative savings from 2020 to 2050.

- Existing Building Decarbonization: Fuel switching retrofits do not begin in earnest until 2025, because the program requires further study and will take a few years to ramp up.
- Electric Vehicle Adoption: EV adoption is limited by the rate of new vehicle purchases and the available types of electric vehicles, but is accelerating over time; the model results show most emissions savings from EV adoption coming after 2035.
- Mode Shift and Land Use Policies: Transit system expansion and land use changes require a large number of infrastructure and development projects before we begin to see the aggregated effects, primarily after 2030.
- Industrial Decarbonization: Industrial energy efficiency and decarbonization efforts are not forecast to take off until 2030, due to the need for sector-specific energy efficiency and decarbonization potential studies, regulatory changes that support greater investment in this sector, and technological innovation.

The five biggest areas of GHG emission savings in the plan modeling are as follows:

1. Renewable Portfolio Standard and Local Solar—40% of all cumulative savings.
2. Existing Building Efficiency and Existing Building Decarbonization—23% of all cumulative savings.
3. Electric Vehicle Adoption and Fuel Economy Standards—17% of all cumulative savings.
4. Mode Shift and Land Use Policies—6% of all cumulative savings.
5. Industrial Decarbonization—4% of all cumulative savings.

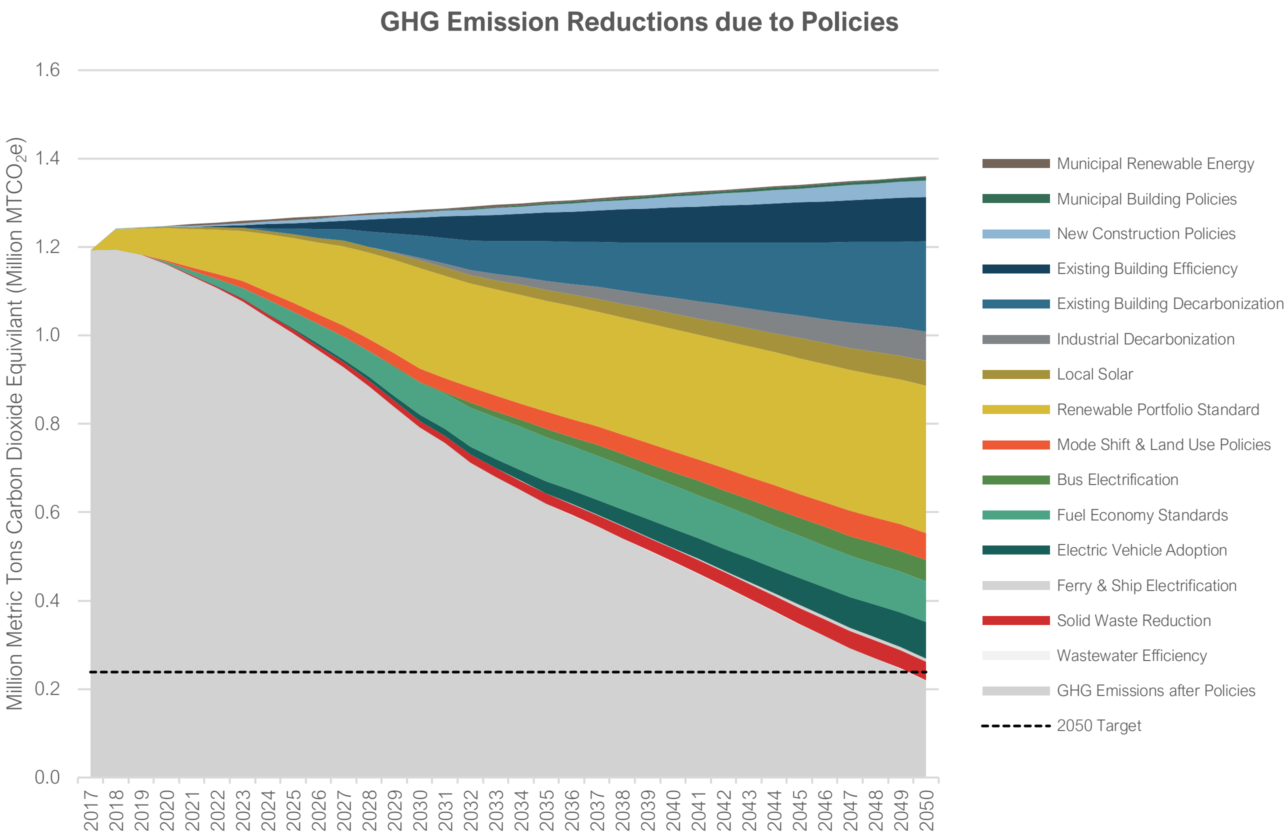

Figure 3. GHG emissions reductions from 2017 to 2050 due to policies.

Figure 4 shows what the wedge chart looks like if we were to “take out” the two wedges related mostly to state and federal action—the Maine Renewable Portfolio Standard (RPS) and the Federal Corporate Average Fuel Economy (CAFE) Standards. By doing this, we are incorporating these policies into the “business-as-usual” scenario, and assuming that we can be relatively sure that these policies will continue to exist and be implemented as planned. By contrast, by including the RPS and CAFE Standards in the wedge diagram, Figure 3 illustrates how important these components are to achieving our carbon reduction goals.

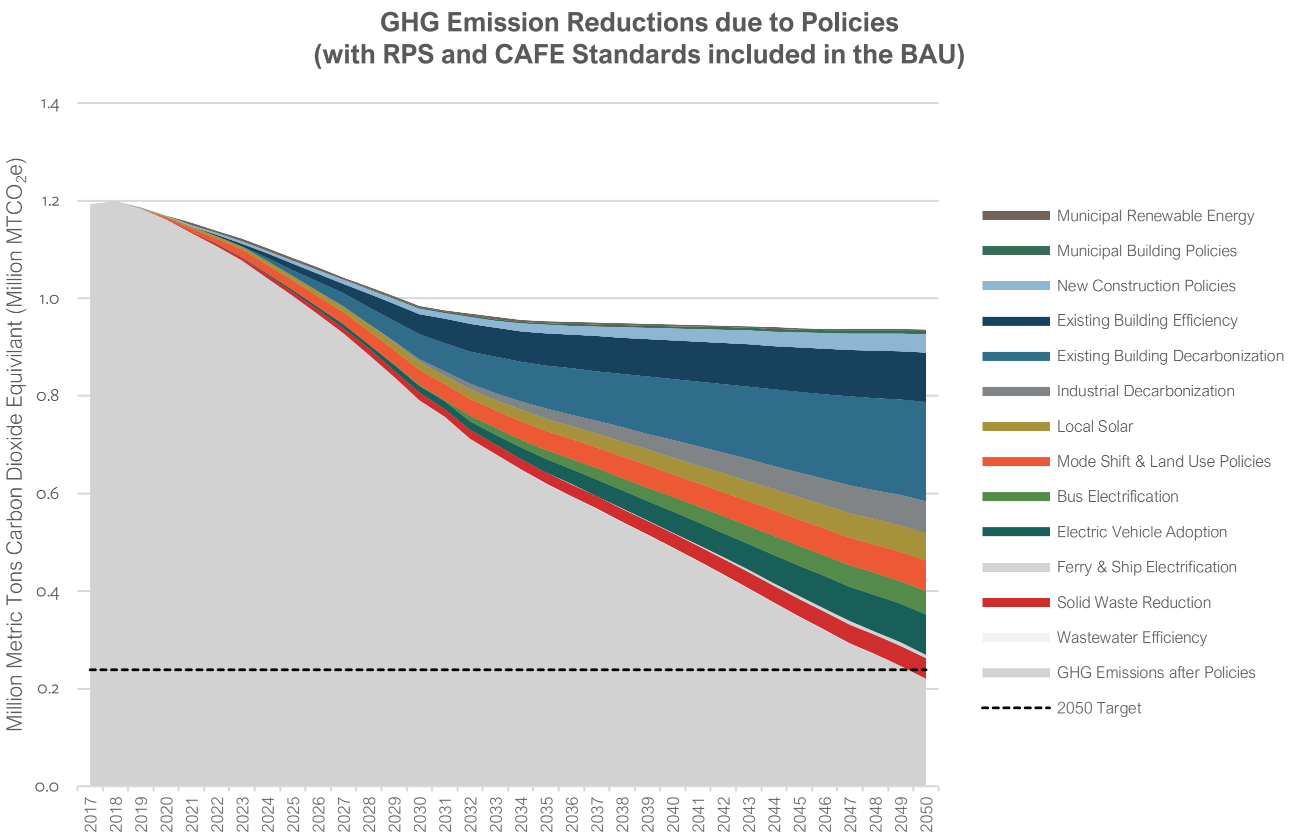

Figure 4. GHG reductions due to policies (with RPS and CAFE standards included in the BAU).

Table 23. Business-as-usual (BAU) GHG emissions trajectory for 2030, 2040, and 2050, and GHG emission reductions by policy in 2030, 2040, and 2050.

Absolute GHG Emissions and Reductions	GHG Reductions in Year 2030		GHG Reductions in Year 2040		GHG Reductions in Year 2050	
	$MTCO_2e$	% of reduction	$MTCO_2e$	% of reduction	$MTCO_2e$	% of reduction
BAU GHG Emissions	1,283,823		1,321,596		1,360,362	
Municipal Renewable Energy	3,567	0.7%	3,542	0.4%	1,930	0.2%
Municipal Building Policies	1,429	0.3%	4,299	0.5%	7,170	0.6%
New Construction Policies	11,797	2.4%	24,477	2.9%	38,116	3.3%
Existing Building Efficiency	41,122	8.4%	79,137	9.5%	100,336	8.8%
Existing Building Decarbonization	51,019	10.4%	125,181	15.0%	204,056	17.9%
Industrial Decarbonization	5,413	1.1%	35,779	4.3%	66,144	5.8%
Renewable Portfolio Standard	227,605	46.2%	276,951	33.2%	333,004	29.2%
Local Solar	16,598	3.4%	34,497	4.1%	56,474	4.9%
Mode Shift & Land Use Policies	30,744	6.2%	46,681	5.6%	61,089	5.4%
Bus Electrification	2,093	0.4%	29,837	3.6%	48,866	4.3%
Fuel Economy Standards	71,726	14.6%	98,559	11.8%	91,746	8.0%
Electric Vehicle Adoption	13,959	2.8%	42,853	5.1%	82,396	7.2%
Ferry & Ship Electrification	0	0.0%	1,578	0.2%	6,852	0.6%
Solid Waste Reduction	15,292	3.1%	29,292	3.5%	42,272	3.7%
Wastewater Efficiency	0	0.0%	917	0.1%	1,024	0.1%
GHG Emissions after Policies	791,459		488,017		218,887	
% Change from Baseline (2017)*	-33.6%		-59.1%		-81.6%	
% Change from Default BAU	-38.4%		-63.1%		-83.9%	
% Change from a BAU that includes Renewable Portfolio Standards and Fuel Economy Standards	-23.9%		-51.7%		-75.5%	

*Baseline (2017) GHG emissions = 1,192,784 $MTCO_2e$

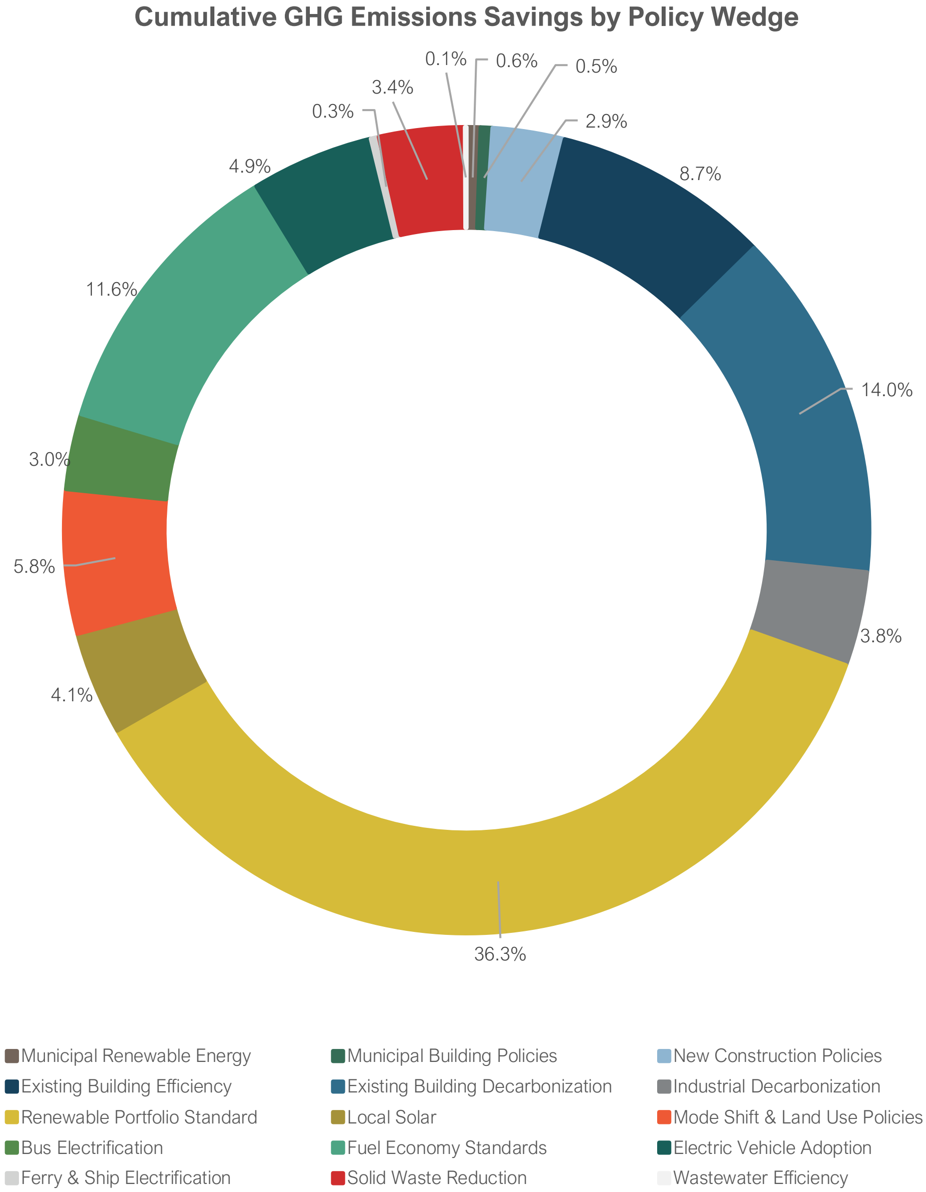

Figure 5. Proportion of cumulative GHG emissions savings from 2017 to 2050 by policy wedge.

Table 24. Cumulative GHG emission reductions by policy.

Policy	Modeled Plan Actions	Cumulative GHG Reductions, 2020-2050	
		$MTCO_2e$	% of Reductions
Municipal Renewable Energy	BE 1.1	110,421	0.6%
Municipal Building Policies	BE 1.2, 1.3	93,748	0.5%
New Construction Policies	BE 2.1, 2.3	578,672	2.9%
Existing Building Efficiency	BE 3.1, 3.2, 3.3	1,744,458	8.7%
Existing Building Decarbonization	BE 3.4, 3.5, 5.4, 5.6	2,800,102	14.0%
Industrial Decarbonization	BE 4.1, 4.2	753,726	3.8%
Renewable Portfolio Standard	BE 5.1	7,247,418	36.3%
Local Solar	BE 2.2, 3.5, 3.6, 5.1	828,246	4.1%
Mode Shift & Land Use Policies	TLU 1 (all)	1,151,719	5.8%
Bus Electrification	TLU 2.3	604,305	3.0%
Fuel Economy Standards	N/A	2,320,100	11.6%
Electric Vehicle Adoption	TLU 2.1, 2.2, 2.4, 2.5	982,046	4.9%
Ferry & Ship Electrification	TLU 3.3, 3.4	64,965	0.3%
Solid Waste Reduction	WR 1 (all)	685,655	3.4%
Wastewater Efficiency	WR 2.3	13,998	0.1%

6.1.2 GHG Emissions by Source

Greenhouse gas emissions reductions come from every major fuel source:

- Electricity: The renewable portfolio standard, local solar, and municipal energy purchase will reduce GHG emissions from electricity by 71% by 2030 and 100% by 2050.
- Natural Gas: Fuel switching and energy efficiency in buildings and industry, in addition to new energy codes, will reduce GHG emissions from natural gas by 16% by 2030 and 70% by 2050.
- Fuel Oil: Fuel switching and energy efficiency in buildings and industry, and new energy codes, will reduce GHG emissions from fuel oil by 25% by 2030 and 94% by 2050.
- Gasoline: Land use policy and mode shift, fuel efficient vehicles, and vehicle electrification will reduce unleaded gasoline use by 31% by 2030 and 74% by 2050.
- Diesel: Land use policy and mode shift, fuel efficient vehicles, electrification of buses, decarbonization of municipal vehicles, and electric shore power for ferries and docked cruise ships will reduce diesel use by 14% by 2030 and 23% by 2050.
- Solid Waste: Reduction of waste, and diversion of waste from incineration to landfills, composting, and anaerobic digestion will reduce solid waste emissions by 35% by 2030 and 89% (zero waste) by 2050.
- Wastewater: Wastewater process emissions are not affected by any plan or model actions, and so increase by 21% by 2030 and 63% by 2050.

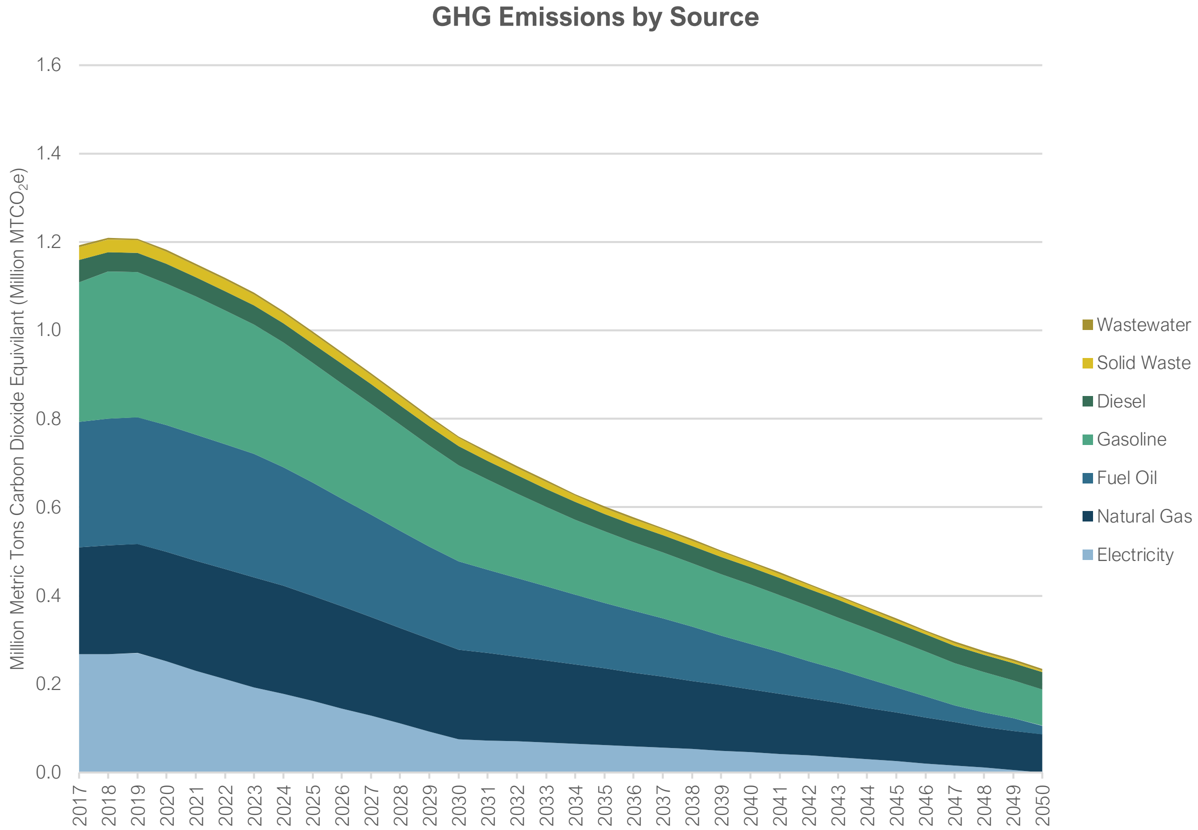

Figure 6. GHG emissions by source in Portland and South Portland from 2017 to 2050.

Table 25. GHG emissions by source in Portland and South Portland in 2017, 2030, 2040, 2050.

Fuel	Baseline (2017)	2030		2040		2050	
	$MTCO_2e$	$MTCO_2e$	% Reduction from Baseline	$MTCO_2e$	% Reduction from Baseline	$MTCO_2e$	% Reduction from Baseline
Electricity	267,856	78,803	-71%	48,021	-82%	0	-100%
Natural Gas	241,448	203,430	-16%	134,851	-44%	66,655	-72%
Fuel Oil	283,564	212,303	-25%	107,700	-62%	17,327	-94%
Gasoline	316,208	216,925	-31%	133,955	-58%	81,691	-74%
Diesel	50,910	43,783	-14%	43,783	-14%	39,385	-23%
Solid Waste	28,211	18,316	-35%	9,711	-66%	2,990	-89%
Wastewater	3,959	4,804	21%	5,576	41%	6,471	63%
Total	1,192,784	791,459	-34%	488,017	-59%	218,887	-82%

6.1.3 Aggregated GHG Emissions Reductions

To help show the relative cumulative impact of the actions, wedges are aggregated based on sections of the One Climate Future plan in Table 26. The assignments were discussed in the above narrative.

Table 26. (Repeated from Table 1.) The correlation between One Climate Future plan sections, sub-sections, policy wedge shown in the wedge chart, and plan actions. BE refers to Buildings and Energy, TLU refers to Transportation and Land Use, and WR refers to Waste Reduction.

Plan Section	Plan Sub-section	Wedge	Plan Actions	Methodology Memo Section
BE	**BE 1:** Municipal Buildings and Energy	Municipal Renewable Energy	BE 1.1	2.2.3
		Municipal Building Efficiency	BE 1.2, 1.3	3.2.4
	BE 2: New Construction Energy Efficiency & Decarbonization	New Construction Policies	BE 2.1, 2.3	3.2.1
	BE 3: Existing Buildings Energy Efficiency & Decarbonization	Existing Building Efficiency	BE 3.1, 3.2, 3.3	3.2.2
		Existing Building Decarbonization	BE 3.4, 3.5, 5.4, 5.6	3.2.3
	BE 4: Industrial Energy Efficiency & Decarbonization	Industrial Decarbonization	BE 4.1, 4.2	3.2.5
	BE 5: Clean and Renewable Energy	Renewable Portfolio Standard	BE 5.1	2.2.1
		Local Solar	BE 2.2, 3.5, 3.6, 5.1	2.2.2
TLU	**TLU 1:** Mode Shift & Land Use	Mode Shift and Land Use Policies	TLU 1 (all)	4.2.1
	TLU 2 & 3: Vehicle Electrification and Infrastructure	Bus Electrification	TLU 2.3	4.2.2
		Fuel Economy Standards	N/A	4.2.3
		Electric Vehicle Adoption	TLU 2.1, 2.2, 2.4, 2.5	4.2.4
		Ferry and Ship Electrification	TLU 3.3, 3.4	4.2.5
WR	**WR 1 & 2:** Waste Reduction	Solid Waste Reduction	WR 1 (all)	5.2.1
		Wastewater Efficiency	WR 2.3	5.2.2

Table 27. Cumulative GHG emission savings, and GHG reductions in years 2030 and 2050, by plan section.

Plan Section	Acronym	Cumulative GHG Reductions, 2020-2050		GHG Reductions in Year 2030		GHG Reductions in Year 2050	
		$MTCO_2e$	%	$MTCO_2e$	%	$MTCO_2e$	%
Buildings & Energy	BE	14,156,791	71%	358,550	73%	807,230	71%
Transportation & Land Use	TLU	5,123,135	26%	118,523	24%	290,948	25%
Waste Reduction	WR	699,653	4%	15,292	3%	43,297	4%
Total		19,979,579	100%	492,364	100%	1,141,475	100%

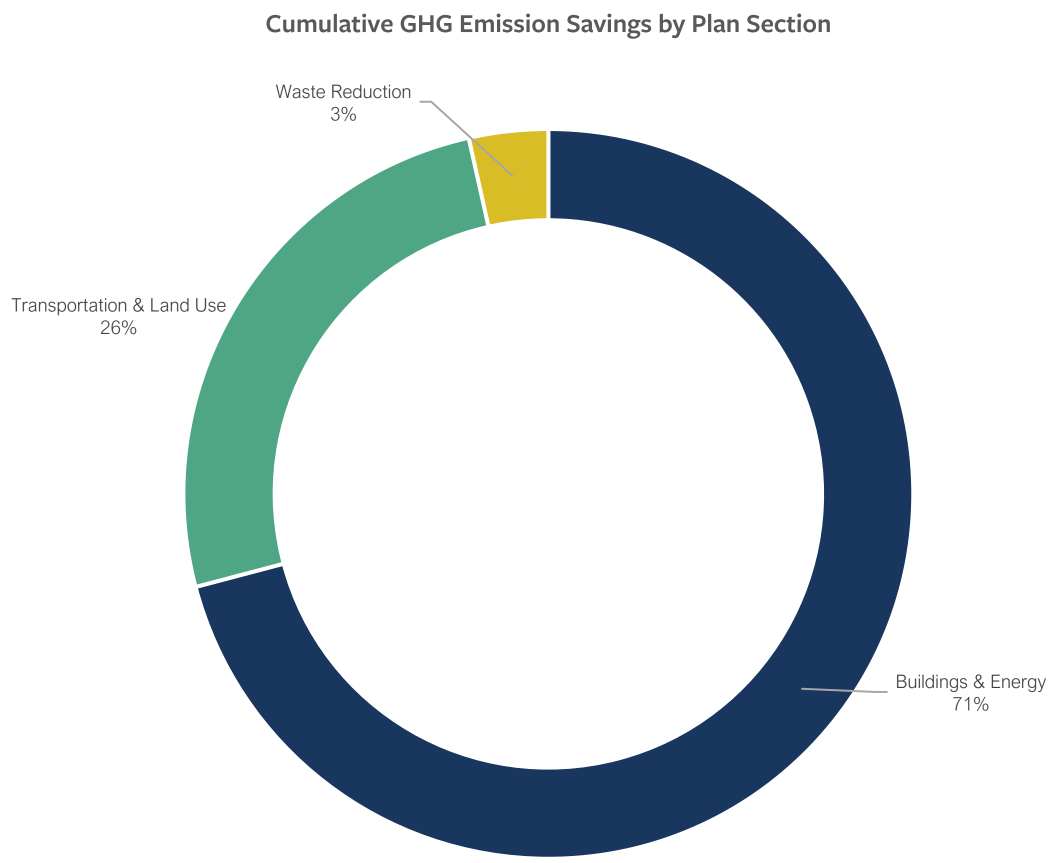

Figure 7. Cumulative GHG emission savings from 2020 to 2050 by One Climate Future plan section.

Table 28. Cumulative GHG emission savings, and GHG reductions in years 2030 and 2050, by plan sub-section.

Plan Sub-Section	Acronym	Cumulative GHG Reductions, 2020-2050		GHG Reductions in Year 2030		GHG Reductions in Year 2050	
		$MTCO_2e$	%	$MTCO_2e$	%	$MTCO_2e$	%
BE 1: Municipal Buildings and Energy	BE 1	204,169	1.0%	1,429	0.3%	7,170	0.6%
BE 2: New Construction Energy Efficiency & Decarbonization	BE 2	578,672	2.9%	11,797	2.4%	38,116	3.3%
BE 3: Existing Buildings Energy Efficiency & Decarbonization	BE 3	4,544,560	22.7%	92,141	18.9%	304,392	26.7%
BE 4: Industrial Energy Efficiency & Decarbonization	BE 4	753,726	3.8%	5,413	1.1%	66,144	5.8%
BE 5: Clean and Renewable Energy	BE 5	8,075,664	40.4%	244,203	50.0%	389,478	34.2%
TLU 1: Mode Shift & Land Use	TLU 1	1,151,719	5.8%	30,744	6.3%	61,089	5.4%
TLU 2 & 3: Vehicle Electrification and Infrastructure	TLU 2+3	3,971,416	19.9%	87,778	18.0%	229,860	20.2%
WR 1 & 2: Waste Reduction	WR 1+2	699,653	3.5%	15,292	3.1%	43,297	3.8%
Total		19,979,579	100.0%	488,798	100.0%	1,139,545	100.0%

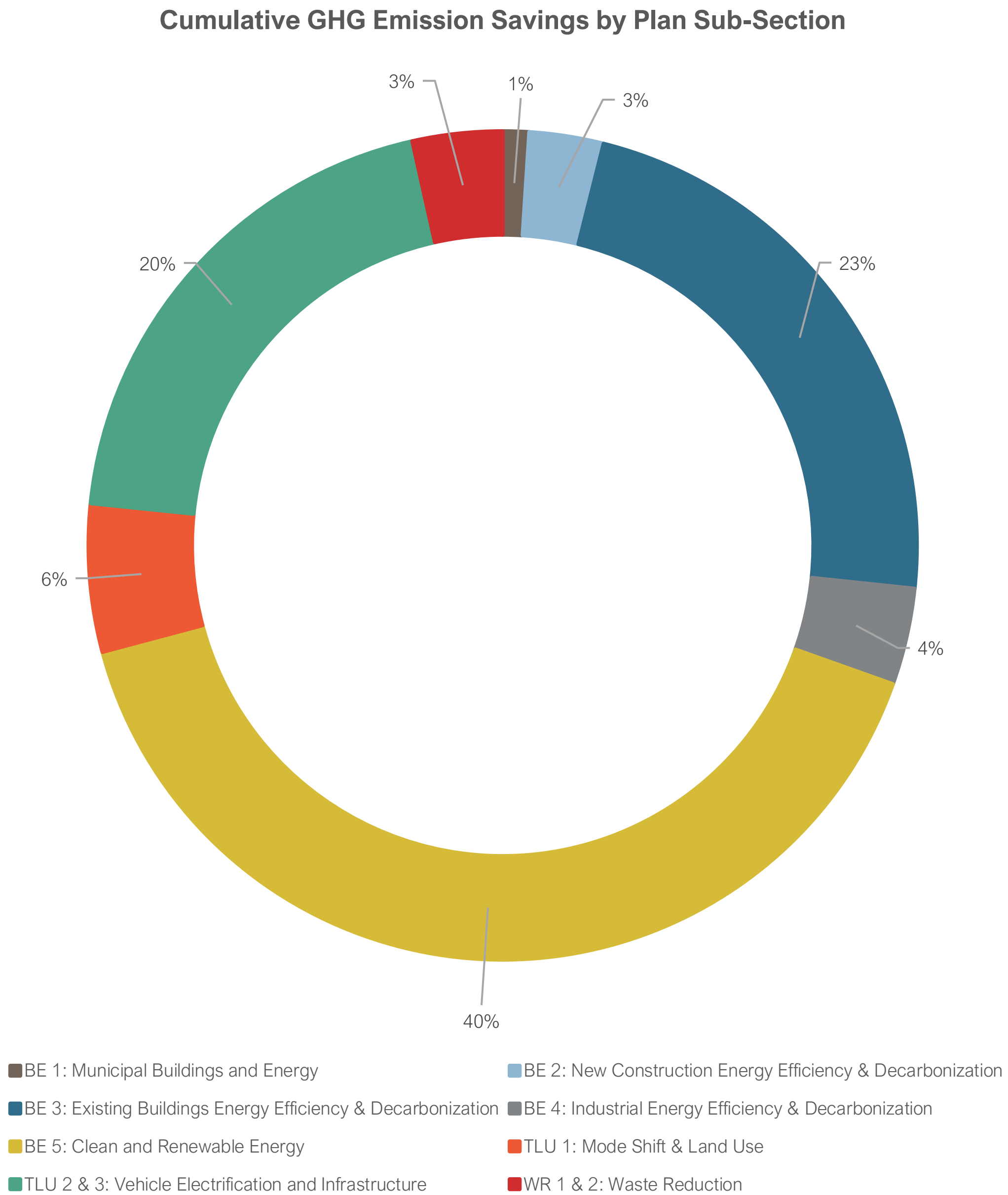

Figure 8. Cumulative GHG emission savings from 2020 to 2050 by plan sub-section.

6.2 Energy Use Results

6.2.1 Energy Use Reductions from Policies

While energy use reductions as such are not a plan goal, the prevalence of energy efficiency measures and fuel switching to efficient electric sources, results in a total site energy savings of 45%.[25] Figure 9 shows energy use reductions from the policies. Renewable energy policies are excluded. All BE 3 (Existing Buildings Energy Efficiency and Decarbonization) actions have been combined for simplicity. These site energy savings are very relevant for considering total grid load as we electrify buildings and transportation; however, hourly and seasonal electricity loads were outside the scope of this modeling exercise.

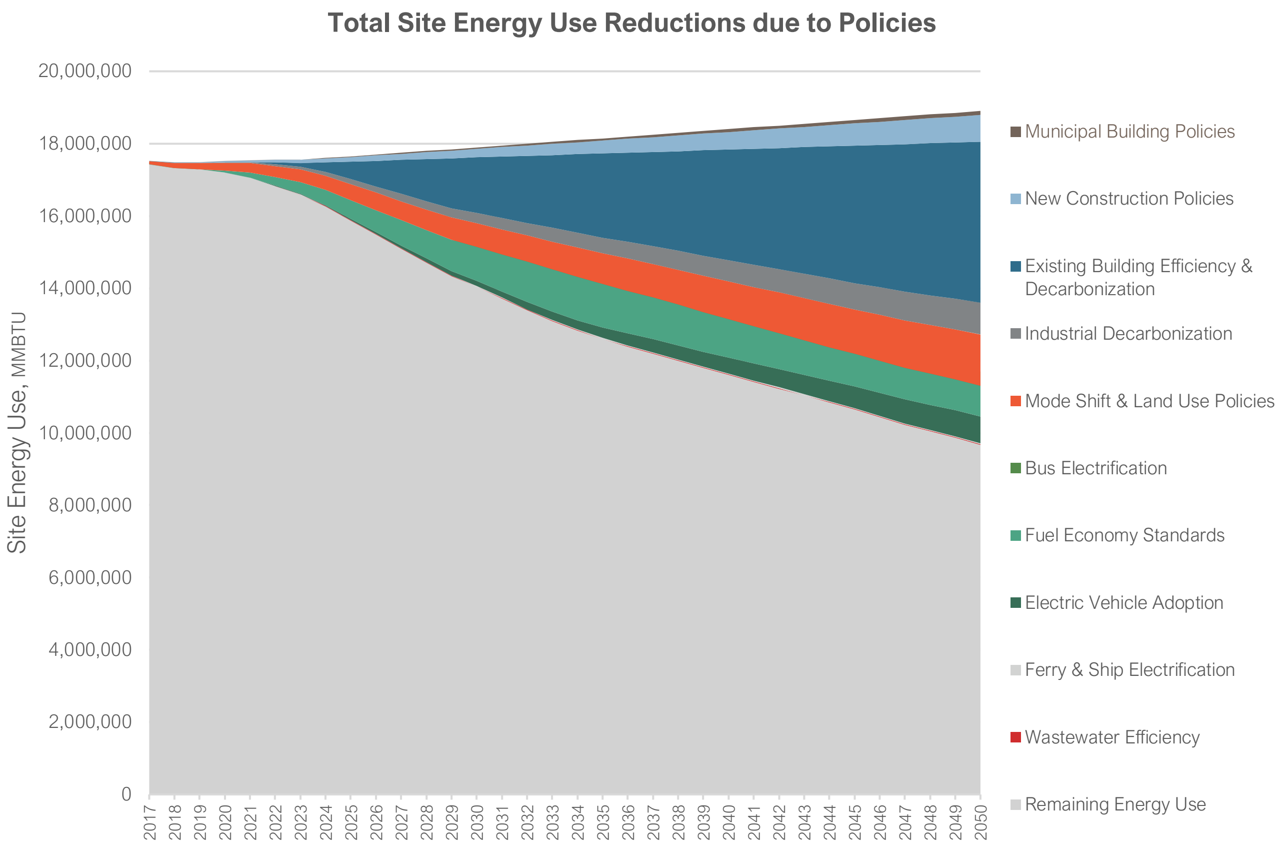

Figure 9. Total site energy use reductions in Portland and South Portland due to policies.

[25] Source energy, which accounts for losses in generation, transmission, and distribution, only decreases by 13%—at least as measured today, with an electricity source-to-site ratio of 2.8. However, most of that ratio is the result of large losses in electricity generation using fossil fuel combustion. On-site renewable energy has a source-to-site ratio of 1.0, and off-site renewable energy has an effective source-to-site ratio of 1.05 (accounting for transmission loss). Therefore, is expected that the source factor for electricity will decline dramatically as more renewable energy comes online, and the source energy savings in 2050 will be more comparable to the site energy savings.

Table 29. Business-as-usual (BAU) site energy projections for 2030, 2040, and 2050, and site energy savings by policy in 2030, 2040, and 2050.

Scenarios / Policies for Site Energy Use Reductions	MMBTU Savings in Year 2030		MMBTU Savings in Year 2040		MMBTUs in Year 2050	
	MMBTU	% of Savings	MMBTU	% of Savings	MMBTU	% of Savings
BAU GHG Emissions	17,893,117		18,399,250		18,905,211	
Municipal Building Policies	22,104	1%	75,123	1%	109,340	1%
New Construction Policies	213,679	6%	473,473	7%	747,376	8%
Existing Building Efficiency & Decarbonization	1,376,502	40%	3,024,716	46%	4,418,252	48%
Industrial Decarbonization	102,974	3%	469,804	7%	836,634	9%
Mode Shift & Land Use Policies	646,627	19%	1,044,586	16%	1,421,867	16%
Bus Electrification	-24,817	-1%	-271,497	-4%	-392,484	-4%
Fuel Economy Standards	970,174	28%	1,333,104	20%	1,240,908	14%
Electric Vehicle Adoption	141,998	4%	445,586	7%	741,345	8%
Ferry & Ship Electrification	0	0%	21,291	0%	27,231	0%
Wastewater Efficiency	519	0%	15,046	0%	17,032	0%
Remaining Energy Use	14,443,358		11,768,018		9,737,710	
% Change from Baseline (2017)*	-17.5%		-32.8%		-44.5%	
% Change from BAU	-19.3%		-36.0%		-48.5%	

*Baseline (2017) site energy use = 17,514,711 MMBTU

6.2.2 Energy Use Reductions by Source

By 2050, the energy use by fuel type also changes dramatically due to electrification, as summarized below:

- Electricity: Electricity use increases by 81% (1.81x).
- Natural Gas: Natural gas use decreases by 73%.
- Fuel Oil: Fuel oil use decreases by 94%.
- Gasoline: Unleaded gasoline use decreases by 74%.
- Diesel: Diesel fuel use for road and sea transportation decreases by 23%.

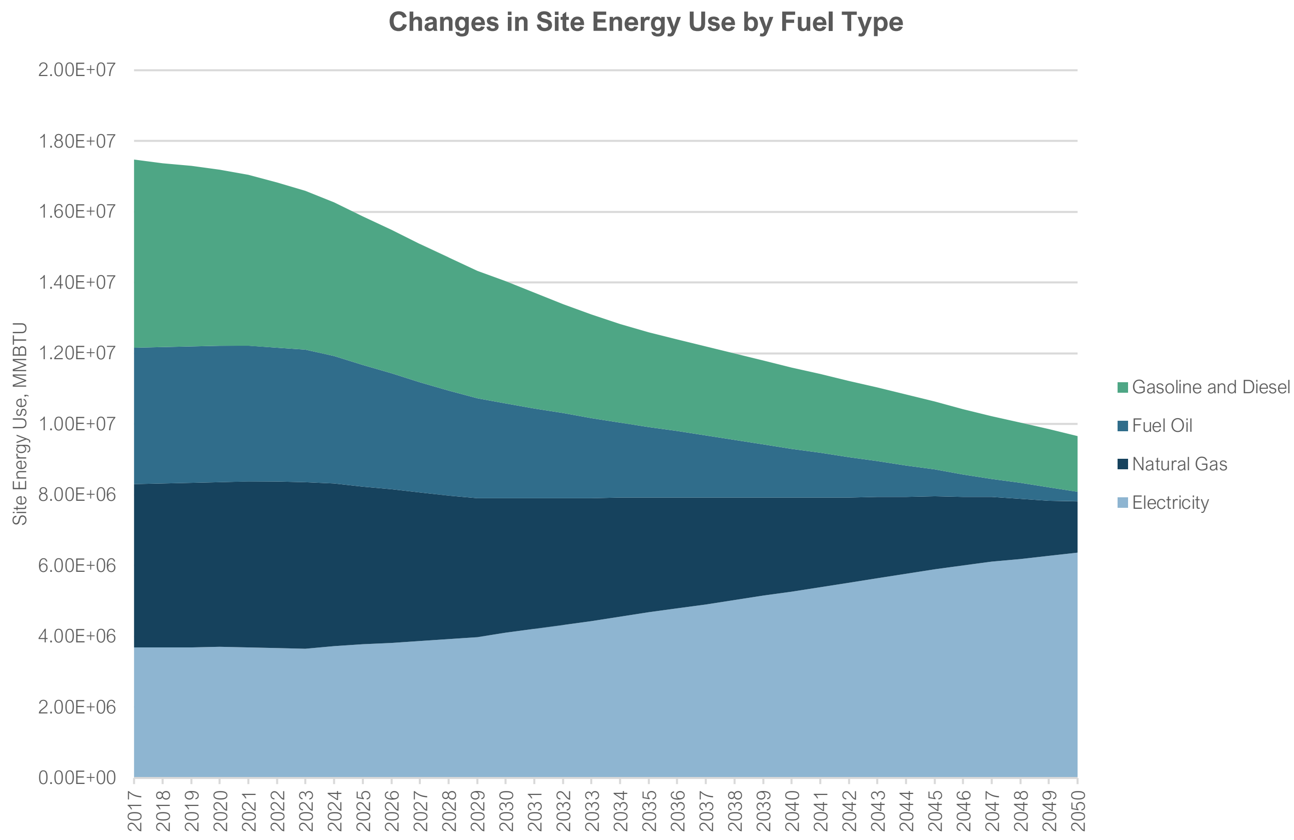

Figure 10. Changes in site energy use by fuel type in Portland and South Portland due to policies.

Table 30. Site energy use by fuel type for 2030, 2040, and 2050.

Site Energy Use	Baseline	2030		2040		2050	
	MMBTU	MMBTU	% From Baseline	MMBTU	% From Baseline	MMBTU	% From Baseline
Electricity	3,684,663	4,299,046	17%	5,477,681	49%	6,669,928	81%
Natural Gas	4,611,286	3,827,946	-17%	2,523,254	-45%	1,254,938	-73%
Fuel Oil	3,860,693	2,851,627	-26%	1,446,006	-63%	231,932	-94%
Gasoline and Diesel	5,319,825	3,464,739	-35%	2,321,077	-56%	1,580,911	-70%
Total	17,476,466	14,443,358	-17%	11,768,018	-33%	9,737,710	-44%

6.2.3 Renewable Electricity

As required by the RPS, renewable electricity increases to 80% of the total source mix by 2030 and 100% by 2050. At the same time, electricity consumption increases by 73% due to electrification of buildings and vehicles.

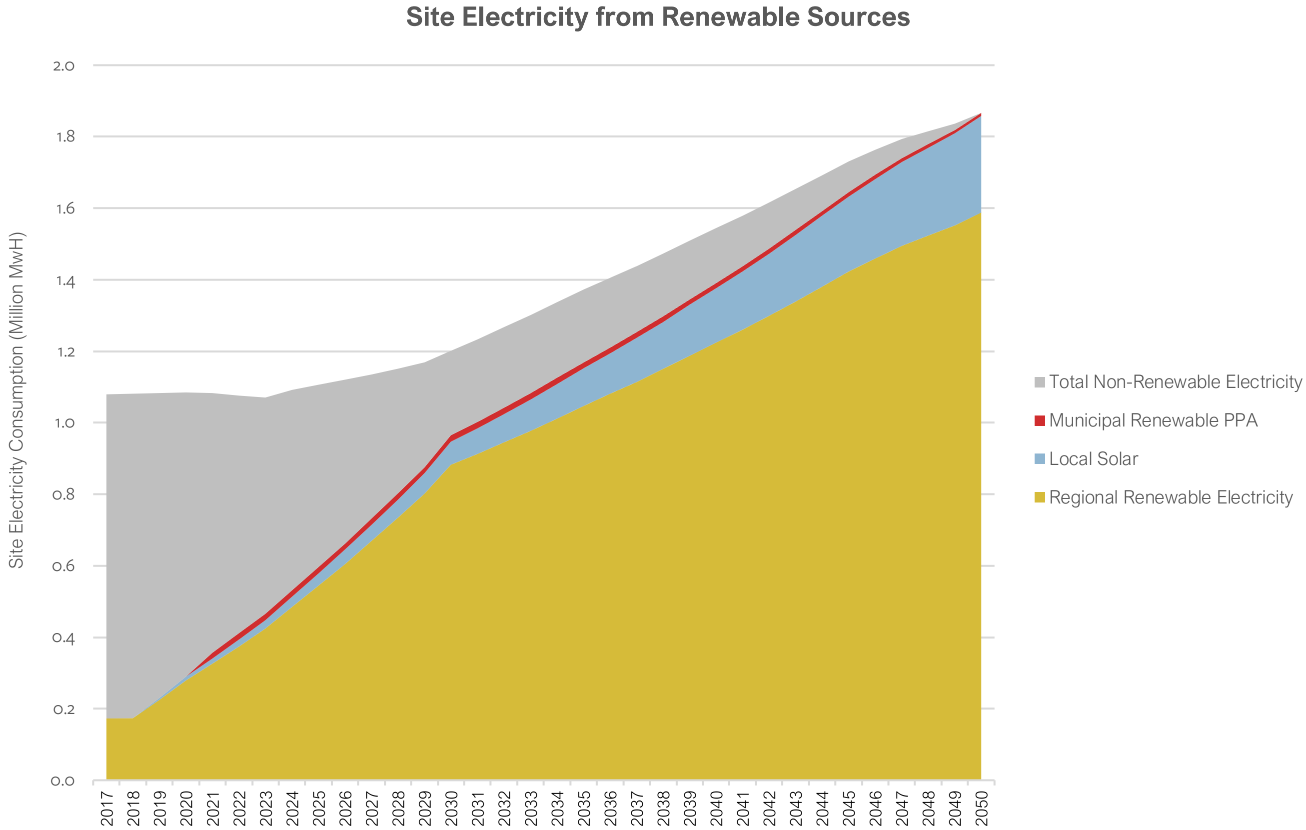

Figure 11. Site electricity from renewable sources.

Table 31. Site electricity from renewables in 2017 (baseline), 2030, 2040, and 2050.

Site Electricity from Renewables	2017 (MWh)	2030 (MWh)	2040 (MWh)	2050 (MWh)	% of Electricity in 2050
Regional Renewable Electricity (outside the Cities)	172,786	928,057	1,271,816	1,663,150	85.1%
Local Solar Electricity	-	67,679	158,418	282,055	14.4%
Municipal Renewable Electricity Power Purchase	-	14,543	16,268	9,640	0.5%
Total Renewable Electricity	172,786	1,010,279	1,446,502	1,954,844	100%
Total Electricity Consumption	1,079,913	1,259,978	1,605,416	11,954,844	
Total Non-Renewable Electricity	907,127	249,699	158,915	0	0%
% of Electricity that is Renewable	16%	80%	90%	100%	100%