Beverly and Salem Community and Municipal 2018 Greenhouse Gas Emissions Inventory Summary Report

Prepared by Kim Lundgren Associates
11/2020

Table of Contents

Table of Tables

Table of Figures

This report was funded by the Massachusetts Executive Office of Energy and Environmental Affairs Municipal Vulnerability Preparedness (MVP) program

Introduction

In 2020 the Cities of Salem and Beverly partnered to undertake a joint Beverly and Salem Climate Action and Resiliency Plan – *Resilient Together*. The purpose of the joint plan is to advance the resiliency objectives of both cities across all sectors of the community and to reduce each community's contribution to climate change. The development of and prioritization of actions from both communities is best informed by an understanding of the size and variety of greenhouse gas generating sources in each community. By creating a benchmark of performance from a single year, progress can be evaluated, and actions refined as needed to maintain progress towards emissions reductions. A greenhouse gas (GHG) inventory provides those pieces of information. This is particularly important given the recent commitment by both cities to achieving 100% clean energy targets. *Resilient Together* will use this GHG inventory to identify reduction strategies that will best meet Beverly and Salem's goals of equitable and cost-effective emission reductions that transition them to a clean energy economy.

This GHG inventory report was created following guidance and methodologies outlined in the *ICLEI, US Community Protocol (ICLEI, 2019)* and *The Local Government Operation Protocol (LGOP) (California Air Resources Board [CARB], 2010)*. The data used in the community inventory is generally drawn from public data sources that capture all activity, such as building energy use from across the community, whereas government operations data was provided by each for sources and activities it manages directly. These inventories reflect a 'geographic' or sometimes called a 'production-based' perspective of emissions accounting that focuses on sources that are directly impacted by activities in each community and within the GHG inventory of the State of Massachusetts. Alternative perspectives can consider the emissions that occur throughout global supply chains as a result of the goods and services used by residents and businesses in a community. This 'consumption-based' perspective can be informative for considering the wide range of climate impacts that local policy as well as individual decision making can have, but is beyond the scope of this project to quantify.

Emissions factors and other conversions used throughout the inventory are largely drawn from the protocols listed above. Emissions from grid electricity are based on the 2018 ISO New England regional mix[1] and represent a geographic perspective of electricity related GHGs as required by many reporting and disclosure programs.

This inventory covers calendar year 2018 for both cities, primarily due to it being the most recent year of energy utility data currently available. The inventory includes the three primary GHGs; carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) and are presented in terms of CO_2e or CO_2 equivalent throughout this document, calculated using the IPCC 4th Assessment Global Warming Potential values for CH_4 and N_2O

This report summarizes the independent GHG inventories conducted for each city, but presents them together to illustrate similarities, differences, and opportunities for joint GHG reduction efforts.

[1] https://www.iso-ne.com/static-assets/documents/2020/05/2018_air_emissions_report.pdf

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Inventory Context

The communities of Beverly and Salem are alike in several ways. The populations of the two communities only differ by roughly 1,000 residents. The mix of energy sources they rely on to heat buildings are very similar. They share waterways that are home to recreational and commercial boating. Transit connections to Boston utilize the same rail lines and the cities also share some key pieces of infrastructure in the provision of clean water from the Beverly-Salem Water District with significant facilities in Beverly and in the treatment of wastewater at the South Essex Sewerage District in Salem. For all these reasons, combined planning efforts will be able to benefit both communities and leverage efficiencies of scale and coordination.

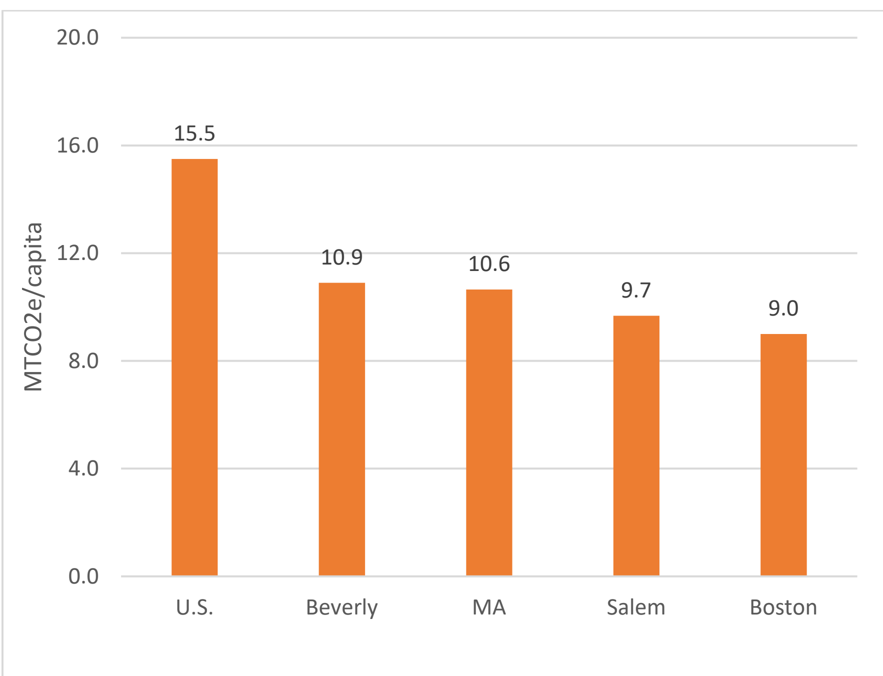
The largest difference between the two is that Beverly has more inbound daily commuters which increases Beverly's transportation emissions. There are a few other differences within the transportation sector; Beverly has a small municipal airport and Salem has ferry service to Boston and more bus lines that run throughout the city. However, these differences overall have little impact on GHGs. The following sections summarize GHG inventory findings for both communities.

Community Scale Greenhouse Gas Emissions

In 2018 activities by residents, visitors, and workers resulted in GHG emissions of 419,005 $MTCO_2e$ in Salem and 461,449 metric tons of CO_2 equivalent ($MTCO_2e$) in Beverly.

As can be seen in **Figure 1**, emissions per person in both communities is lower than the national average but Beverly is slightly higher than the State of Massachusetts average at 10.9 $MTCO_2e$ per capita. Salem, at 9.7 $MTCO_2e$ per capita, falls between the state level average and Boston.

Figure 1. $MTCO_2e$ per capita comparisons



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Throughout this inventory, there were many similarities of the emissions profile of each community. The largest single difference between the two is attributable to the higher portion of in-bound commuters to Beverly, though Beverly also had slightly higher waste and energy use numbers as well.

Emissions by sector comparing each community are shown in **Figure 2** and **Table 1**.

Figure 2. Beverly and Salem's GHG Emissions by Sector ($MTCO_2e$)

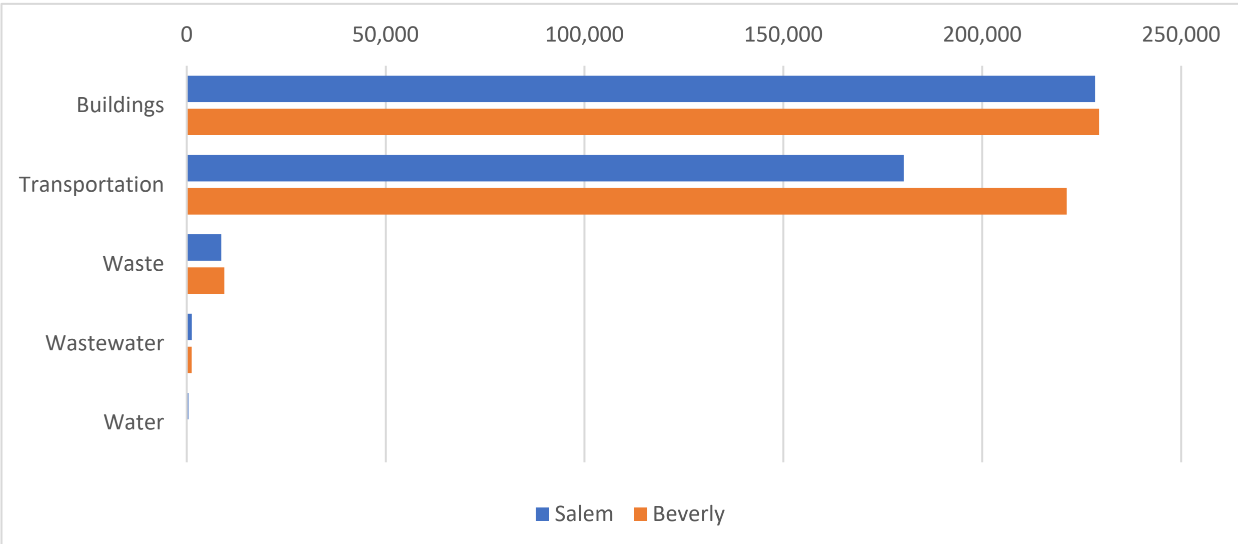

Table 1. Beverly and Salem 2018 Community Greenhouse Gas Emissions by Sector ($MTCO_2e$)

Sectors	Salem	Percent	Beverly	Percent
Buildings	228,347	54.5%	229,363	49.8%
Transportation	180,263	43.0%	221,237	47.9%
Waste	8,702	2.1%	9,468	2.1%
Wastewater	1,264	0.3%	1,232	0.3%
Water	428	0.1%	200	0.04%
Total	419,005	100%	461,499	100.0%

Buildings

As shown in **Table 1**, the majority of Salem's emissions, 54.5%, came from the use of electricity, natural gas, and other fuels in buildings and nearly half of Beverly's emissions at 49.8%. **Table 2** shows that building heating fuels such as kerosene and fuel oil, and natural gas use accounted for 30.1% of total emissions in Salem and 25.9% of total emissions in Beverly.

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Across all fuel types, buildings in Beverly consumed 3,030,712 million Btu (MMBtu) worth of energy and 3,045,141 MMBtu in Salem. While building energy is measured in Btu, food energy is more often measured in Calories and there are about 252,000 Calories in every MMBtu. For part of the year it may seem like Beverly and Salem run on Halloween candy, but it would take 1.25 times the energy from **all** the Halloween candy consumed each year in the country[2] to run our cities!

For both cities, measures that target conversion to electrical heating will be particularly important. **Figure 3** shows the relative contribution of each source to total emissions in each city while **Figure 4** shows the contributions of electricity, natural gas and heating fuels to GHG emissions by residential and commercial sector for each city.

Table 2. Beverly and Salem Community Greenhouse Gas Emissions by Source (MTCO$_2$e)

Source	Salem	Salem %	Beverly	Beverly %
Gasoline	147,803	35.3%	185,662	40.2%
Electricity	82,323	19.6%	91,276	19.8%
Natural Gas	81,005	19.3%	75,662	16.4%
Heating Fuels	43,901	10.5%	42,264	7.5%
Diesel	32,460	7.7%	34,402	4.4%
Fugitive Natural Gas	21,546	5.1%	20,124	4.4%
MSW Incinerated	8,370	2.0%	9,144	2.0%
Process and Fugitive	492	0.1%	480	0.1%
Biosolids Incinerated	772	0.2%	752	0.2%
Biosolids Landfilled	332	0.1%	324	0.1%
Propane	0	0.0%	236	0.1%
Aviation Gasoline	0	0.0%	1,172	0.3%
Grand Total	419,005		461,499	

[2] https://www.energy.gov/maps/energygov-s-spooky-energy-units-calculator

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Figure 3. Beverly and Salem's GHG Emissions by Source ($MTCO_2e$)

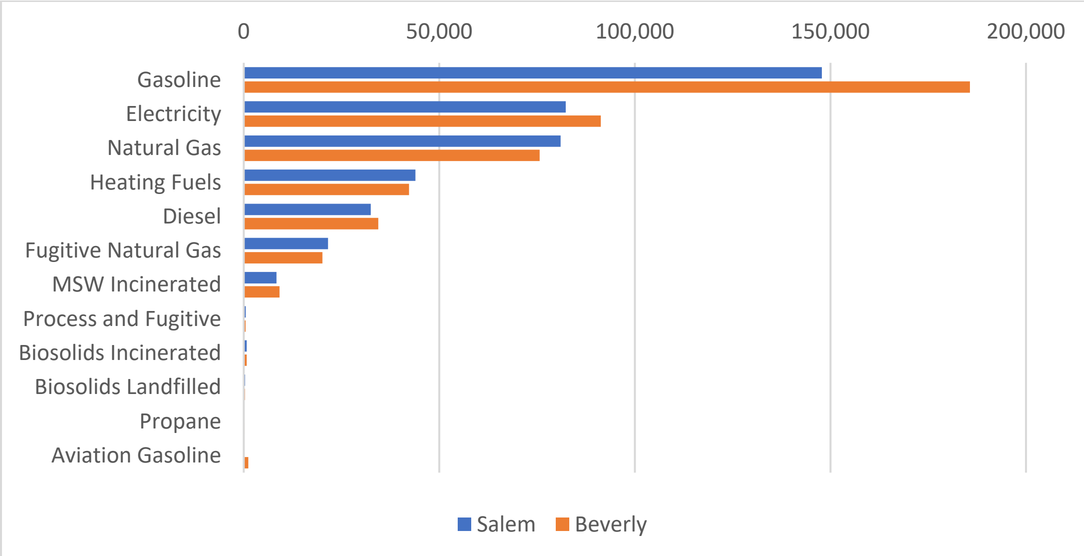

Figure 4.Residential and Commercial $MTCO_2e$ by Energy Type

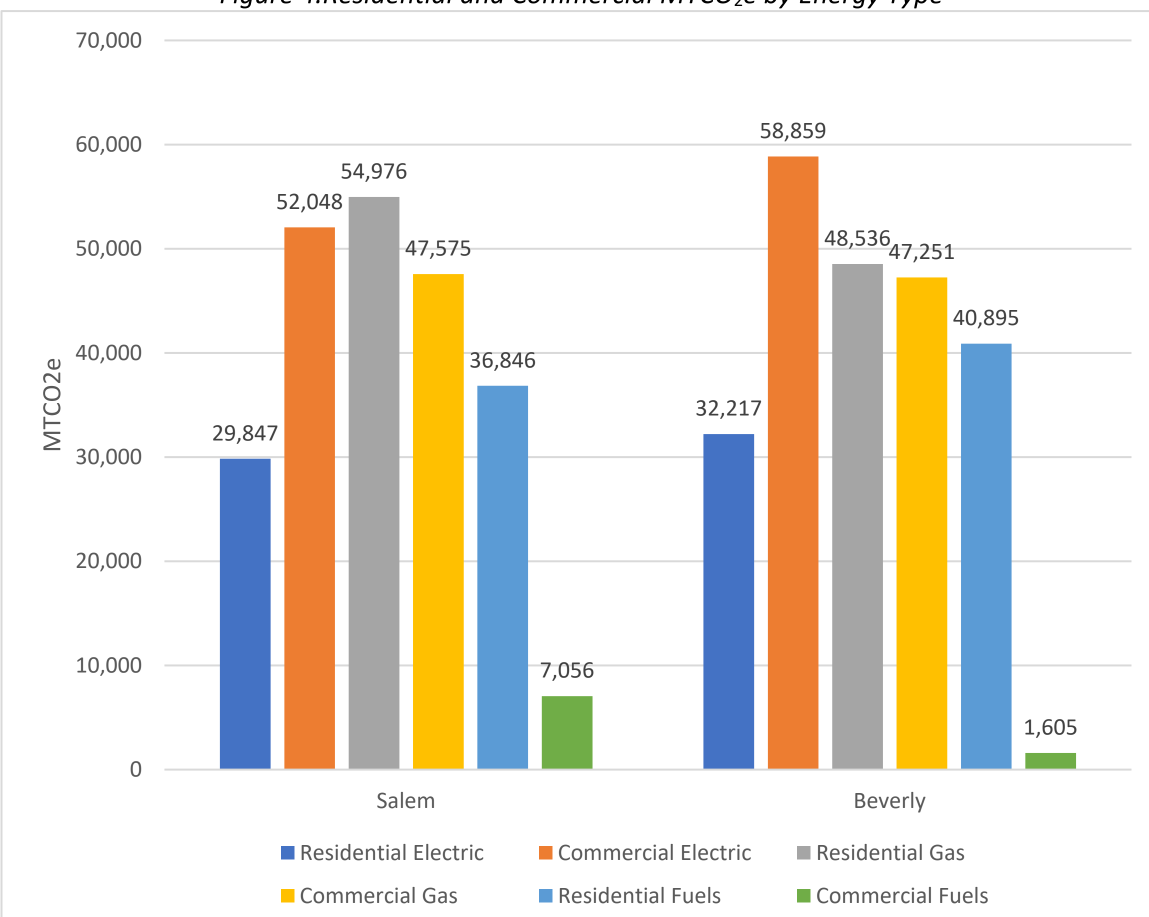

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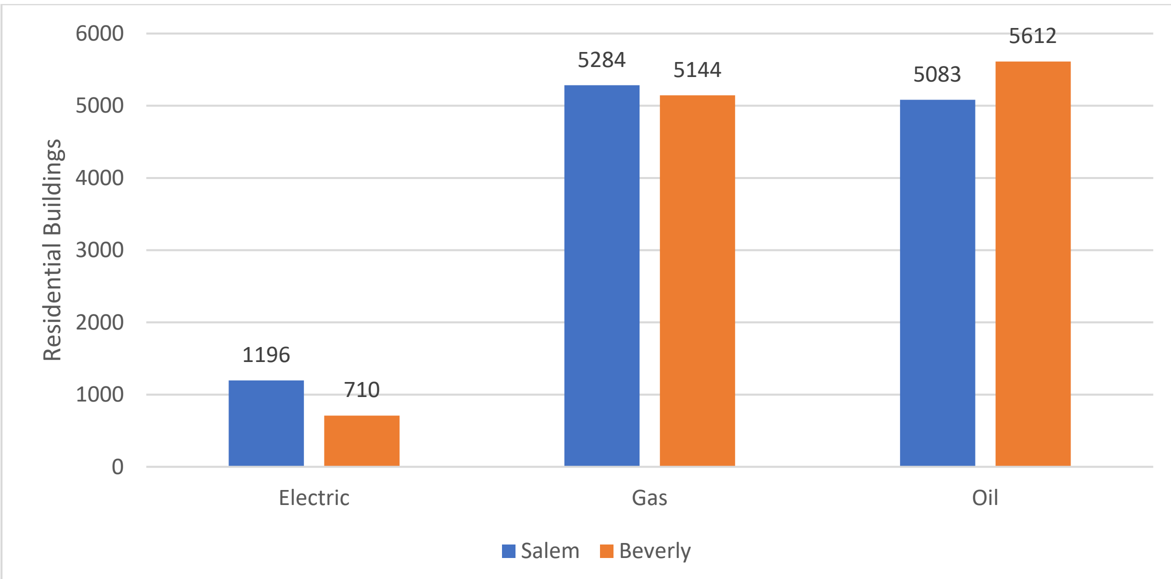
Figure 4 shows that both cities have significant natural gas emissions in both the residential sectors that can be reduced through conversion to electricity. This also shows that in both cities, residences account for the majority of heating fuel use, making the residential sector the primary target for fuel switching to high efficiency electric heat pumps. As the electricity grid incorporates increased amounts of renewable power, conversions from fuel oils and natural gas will become increasingly effective at reducing GHGs. As illustrated in **Figure 5**, the count of residential buildings using each fuel type is similar across both communities. While the economics of retrofit upgrades depends on the efficiency of the existing system, replacing fuel oil with electric heat pumps are always a smart move. Assuming $1,100 per year in savings[3], if all residential oil furnaces were replaced, Salem residents would have $5.5 million and an additional $6.1 million for Beverly residents to keep circulating within the local economy.

Figure 5 Residential Units by Primary Heating Fuel



Transportation

Transportation was the second largest emitting sector in Salem (180,015 $MTCO_2e$) and the largest emitting sector for Beverly (220,732 $MTCO_2e$). The 2014 Massachusetts Vehicle Census was the primary source of data used to estimate on-road travel from each community as it is the most recently available measurement of resident transportation activity. (MAPC, 2014). This value was then scaled by the Statewide average annual increase in vehicle miles traveled (VMT) to obtain a value for 2018 (Mass DOT, 2019). According to the Vehicle Census, both communities are on the lower end of miles per household in the state. Salem was the 11th lowest in Massachusetts at 34 miles per household per day, whereas Beverly is 34th lowest at 45 miles per household per day.

Travel from vehicles within each community is only part of the story of emissions from private vehicles as both communities draw in daily commuters to jobs in those jurisdictions. This is

[3] http://wepowr.com/sites/default/files/Basic%20Savings%20-%20ASHP%20%28Mass%20Energy%29.pdf

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more pronounced for Beverly with proportionally more inbound commuters. The US Census On-The-Map application presents data from the Longitudinal Employer-Household Dynamics survey and shows approximately 21,148 jobs in Beverly and 15,939 jobs in Salem are filled by residents of neighboring jurisdictions (US Census, 2020). **Figure 6** displays screenshots of the On-The-Map application displaying the number of individuals that commute into (dark green arrow), out of (light green arrow), and within (circular arrow) each community.

Figure 6. Worker Travel Flows from US Census, On-The-Map

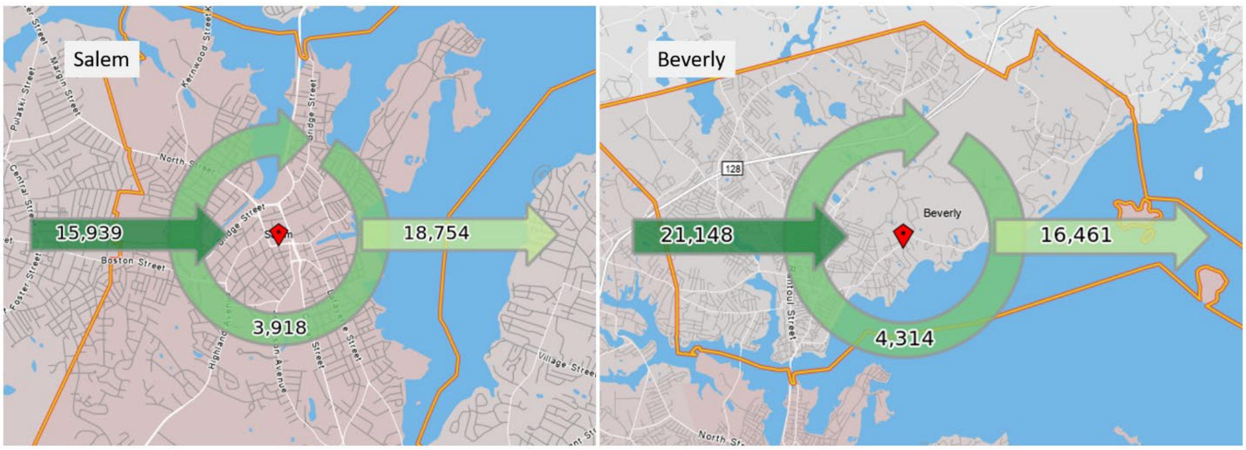
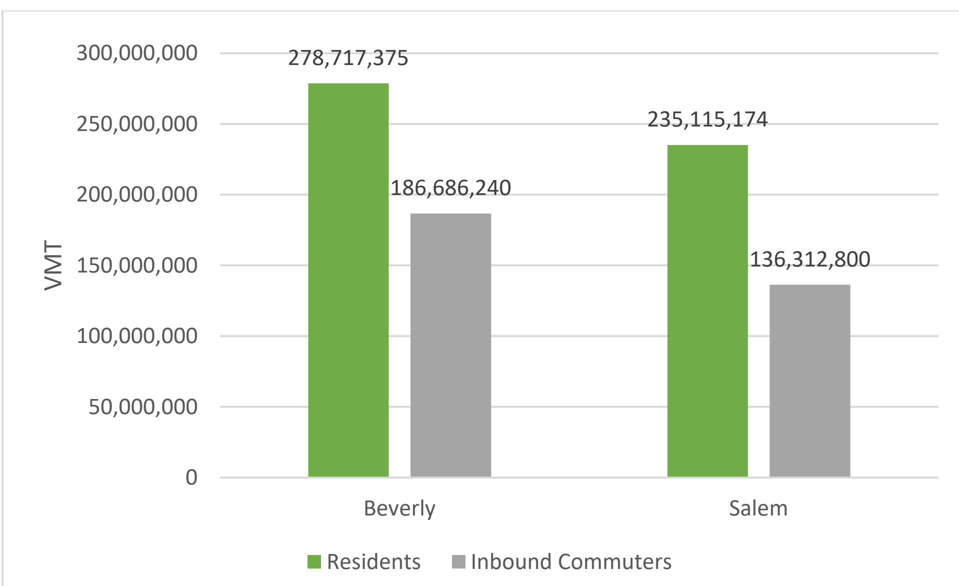


Figure 7 shows VMT from vehicles registered to residents of Beverly and Salem and estimated VMT from commuter trips that begin outside of each city. These additional miles attributed to each community illustrate the potential for working to better balance convenient housing near employment centers as well as developing transit connections to serve these locations.

Figure 7. Vehicle Miles Traveled from Residents and Inbound Commuters



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Other transportation sources accounted for include public transit on MBTA commuter rail and buses, the Beverly Shuttle and marine vessels in both communities. In both cities, private vehicles made up the vast majority of emissions – 95.9% in Salem and 97.5% in Beverly. Given the large contribution of emissions from on-road vehicles, facilitating other transportation modes like transit, walking and biking will be key to reducing emissions from this sector. **Figures 8 and 9** show the contribution of each activity in the Transportation sector.

Figure 8. Salem Transportation Sources ($MTCO_2e$)

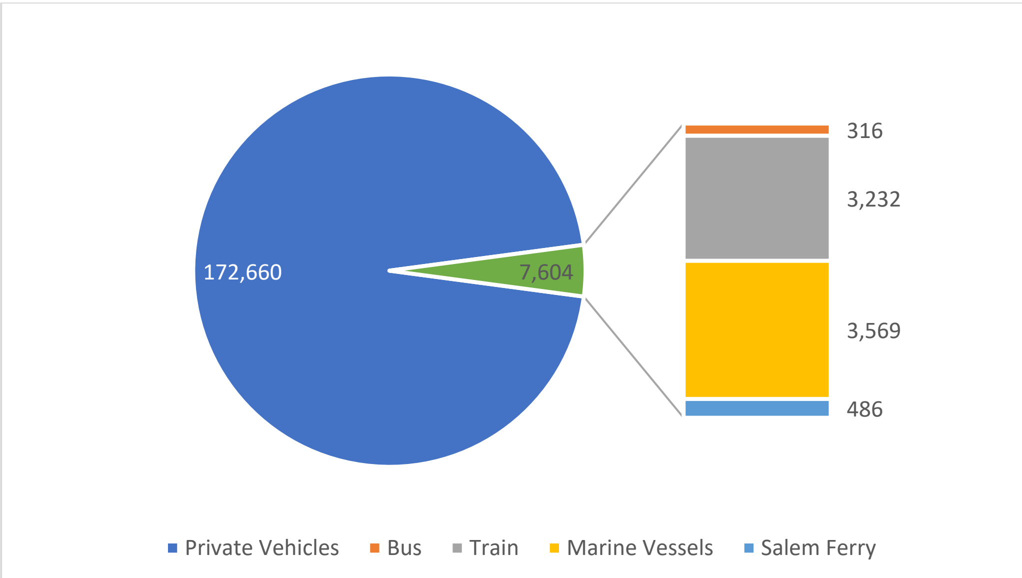
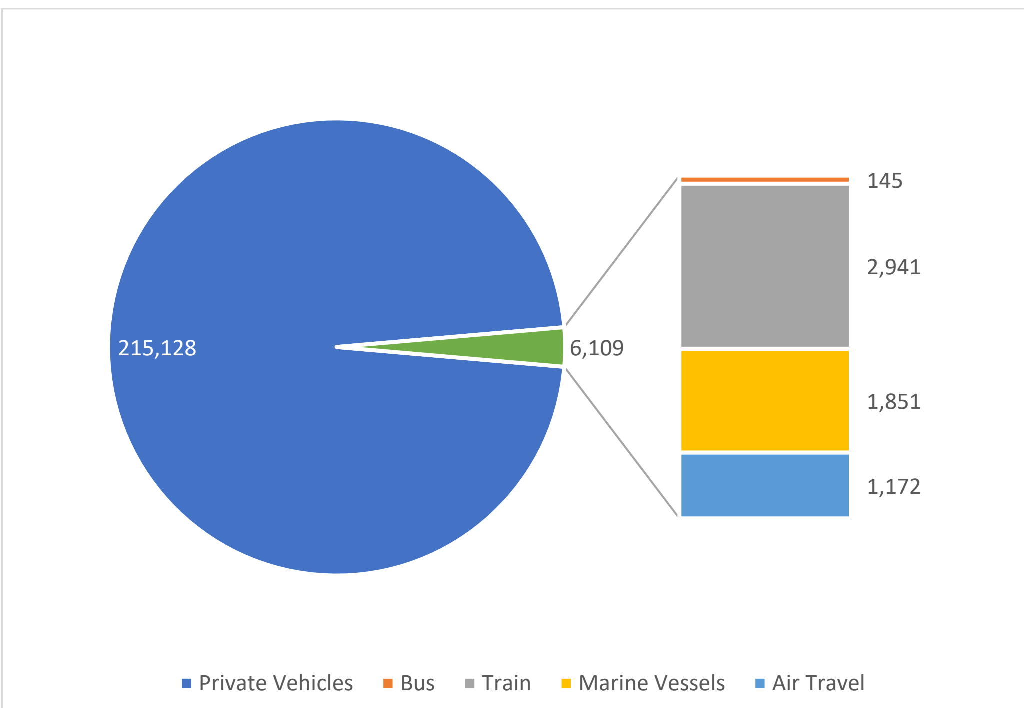


Figure 9. Beverly Transportation Sources ($MTCO_2e$)



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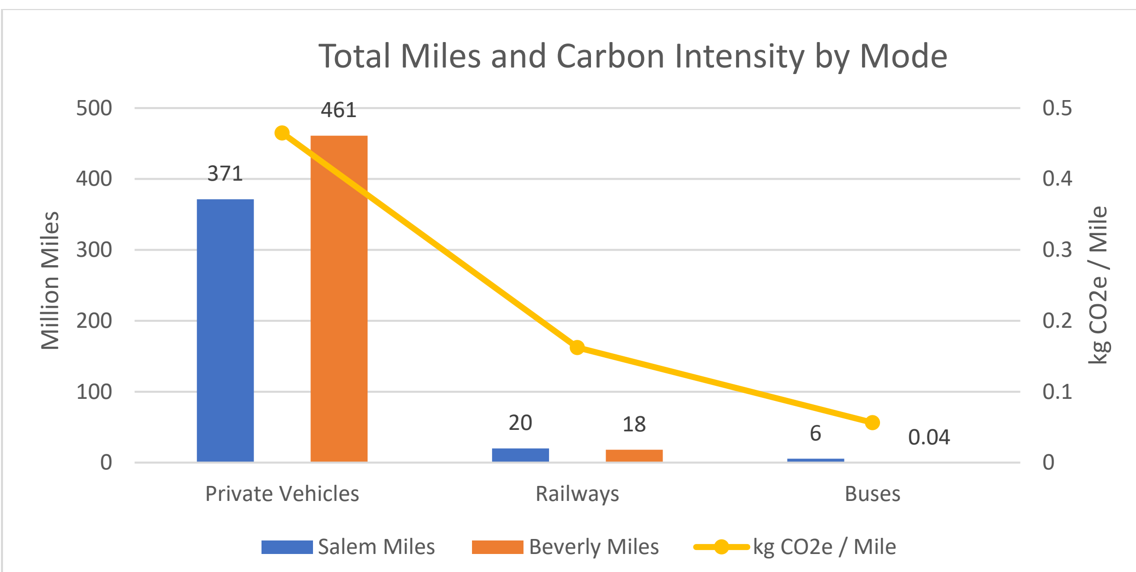
As compared to single occupancy passenger cars and light trucks, emissions per mile from railway transit are less than half that of single occupancy vehicles, and bus passenger miles are one-fifth that of private vehicles. **Table 3** shows the lower carbon intensity in kilograms (kg) CO_2e/mile of public transit by rail or bus. It should be noted that this inventory only takes account of those modes that generate greenhouse gases. Walking and cycling generate no GHGs and are thus the most sustainable choices of all.

Table 3. kgCO2e per vehicle mile traveled of Passenger Mile for Private Vehicles and Transit Modes

Source	kgCO_2e/VMT or Passenger mile	Unit
Average Beverly and Salem Private Vehicles	0.5	VMT
MBTA Commute Rail	0.2	Passenger mile
MBTA Buses	0.1	Passenger mile

Figure 10 illustrates the emissions intensity of each mode along with the total number of miles traveled in each mode in 2018. With the vast majority of travel in the highest carbon intensity mode, it is easy to understand how nearly all the emissions from each city's transportation sector are from private vehicle traffic.

Figure 10. 2018 Million Miles Traveled and kg CO_2e/mile by Mode



Shifts towards more compact and transit-oriented development will encourage a mode shift from private vehicles to railway and bus transit. Many of these actions have the co-benefit of making Beverly and Salem more walkable and attractive destinations for residents and visitors.
The rise in electric vehicles will be an important way to reduce the carbon intensity of on-road travel over time. The number of electric vehicles is not well established in public data sets at this time, but these will begin to show up in future inventories for electric transportation. State and Federal incentive programs are an important driver to sustain changes as the automotive industry

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transitions to electric and advocacy from local levels to maintain these programs will be important for Beverly and Salem to stay on track to meet reduction goals.

Both Beverly and Salem are waterfront cities with active recreational and commercial boating. Emissions from boats that call either Beverly or Salem their home port, are based on rough estimates of the number of boats and their fuel use provided by the Harbormaster in each community. In both cities, marine vessels were estimated to be very small contributors to transportation emissions overall. Despite being highly visible parts of life in the area, recreational and commercial boats made up only 1% of Beverly's transportation emissions and 2% for Salem.

Emissions from the Beverly airport are limited to estimates of fuel consumed during take-off and landing at the Beverly Airport. Focusing on take-offs and landings allows for accounting for all flight operations consistently without needing to estimate fuel loaded on inbound aircraft or account for the distance of each outbound flight. According to the Federal Aviation Administration, in 2018 there were a total of 5,049 take-off or landing operations (FAA 2020)[4] at Beverly Airport. Emissions from these operations accounted for 1,172 $MTCO_2e$, only 0.5% of transportation emission in 2018.

While Beverly has the unique aspect of an airport, Salem has regular ferry service to and from Boston. The ferry operated by Boston Harbor Cruises is estimated to consume approximately 94,000 gallons of diesel per year. As the Ferry serves both Salem and Boston, half of that fuel use, 47,000 gallons, was attributed to Salem, resulting in 486 $MTCO_2e$.

Waste, Wastewater and Water

The Waste, Wastewater and Water sectors are bundled together here because summed together for each city, they make up less than 3% of total emission in each inventory. Though they are not large contributors to the GHG inventory, there are opportunities to reduce emissions from these sectors through water efficiency measures, retrofits, compost/recycling, and zero waste programs.

Waste generated and not recycled by either community is currently sent to waste-to-energy incineration plants. A large portion of the electricity generated at these facilities is from plastics which are made from oil and other petrochemicals. Combusting these materials is no different than other fossil fuels and this alternative to landfilling waste has its own problems from the fossil GHGs created. The best way to reduce emissions from waste is to reduce plastics in the waste stream by recycling or avoiding their use as much as possible.

The rate of waste disposal for both communities is higher than the national average. As illustrated in **Figure 11**, waste disposed per resident per day in Beverly totaled 3.4 lbs. and 3.1 lbs. per resident per day in Salem, whereas the national average is 2.9 lbs. (US EPA. 2020).[5]

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[4] https://aspm.faa.gov/tfms/sys/Airport.asp

[5] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#Generation

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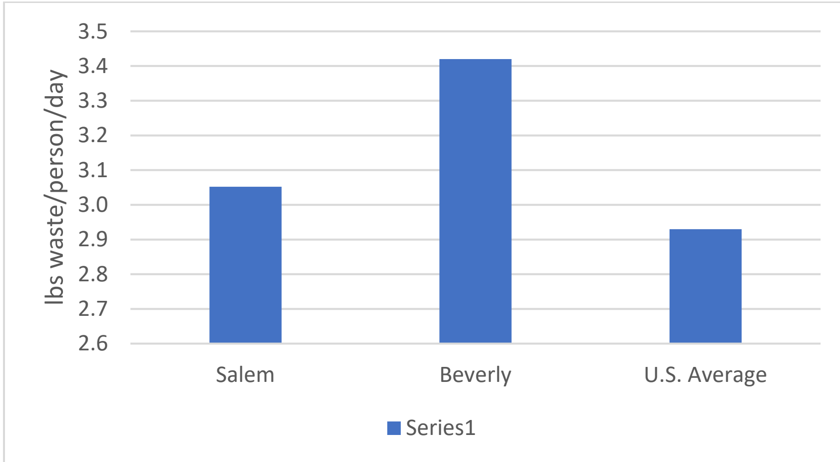
Figure 11. Pounds Waste Disposed per Person per Day



Targeting a benchmark of 2.9 lbs/person/day may be a useful interim target for reducing waste emissions or improving recycling programs on a pathway to eliminating nearly all waste.

Energy use from the treatment and distribution of potable water was calculated in terms of kWh per million gallons using a combination of the energy used at the Salem/Beverly Water Supply Board treatment facility in Beverly with the energy from each city's local distribution pumps.

Table 4. Water Supply Energy Intensity

Community	kWh/MG
Beverly	579.13
Salem	749.28

These values are low compared to national averages. For example, combined median value for treatment and distribution from the US Community Protocol is 1,240 kWh/MG. Some reasons to attribute the low energy use of this system is the high water quality of the Wenham reservoir, which reduces the amount of treatment needed to provide clean water to residents. In addition, the changes in elevation between the reservoir and water customers allows gravity to perform much of the work of the distribution system. Salem's annual water use is approximately 1.9 billion gallons and Beverly's use is 1.1 billion gallons. These resulted in 428 and 200 $MTCO_2e$, respectively.

All wastewater treatment processes emit some amount of nitrous oxide (N_2O) from the treatment process, usually as a result of removal of nitrogen from wastewater before it is released to the environment (process emissions). Some N_2O emissions then occur from remaining nitrogen in effluent released by the facility (fugitive emissions).These emissions were estimated for the South Essex Sewerage District and attributed to each community based on their proportion of the service population of that plant. In addition, the GHGs released from disposal of residual solids from the facility were attributed to each community. These emissions totaled 1,596 $MTCO_2e$ for Salem and 1,556 $MTCO_2e$ for Beverly.

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Municipal Operations Greenhouse Gas Emissions

All municipal operations emissions are captured within the community-wide total for each city; however, looking specifically at municipal operations can reveal opportunities for local government to pursue in order to both lead by example and become more efficient providers of public services. In both Beverly and Salem, GHGs from municipal operations represent about 2% of total community emissions.

Table 5. Municipal Operations GHGs by Sector and Source (metric tons CO_2 equivalent)

Sector and GHG Source		Salem	Beverly
Buildings		**6,667**	**5,239**
	Natural gas	2,651	2,788
	Electricity	3,843	2,095
	Fuel Oil No.2	173	356
Solid Waste		**405**	**426**
	Waste Incinerated	405	426
Streetlights and Traffic Signals		**521**	**914**
	Electricity	521	914
Vehicle Fleet		**1,194**	**1,360**
	Diesel	422	636
	Gasoline	772	723
Water Supply*		**112**	**554**
	Electricity	109	519
	Natural gas	3	35
Wastewater Pumping		-	**131**
	Electricity	-	131
Total		**8,899**	**8,625**

*Note that Beverly electricity includes energy from the shared Beverly-Salem Water Supply Board treatment facility.

This greenhouse gas inventory captures a snapshot of emissions from each community in 2018. It should be noted that investments in efficiency and clean energy have been ongoing since that time and recent improvements are not reflected here. Municipal energy use is tracked by both communities using the Mass Energy Insight software tool provided through the Massachusetts Green Communities Program. It should be noted that each community has participated in the Green Communities Program since its inception and has utilized the expertise of staff, volunteer commissions as well as student resources to identify efficiency opportunities and obtain grants to implement energy and money saving projects.

Emissions from building energy in 2018 for each city's municipal operations are summarized below. Due to the variety of individual buildings and mix of use cases, direct comparisons of

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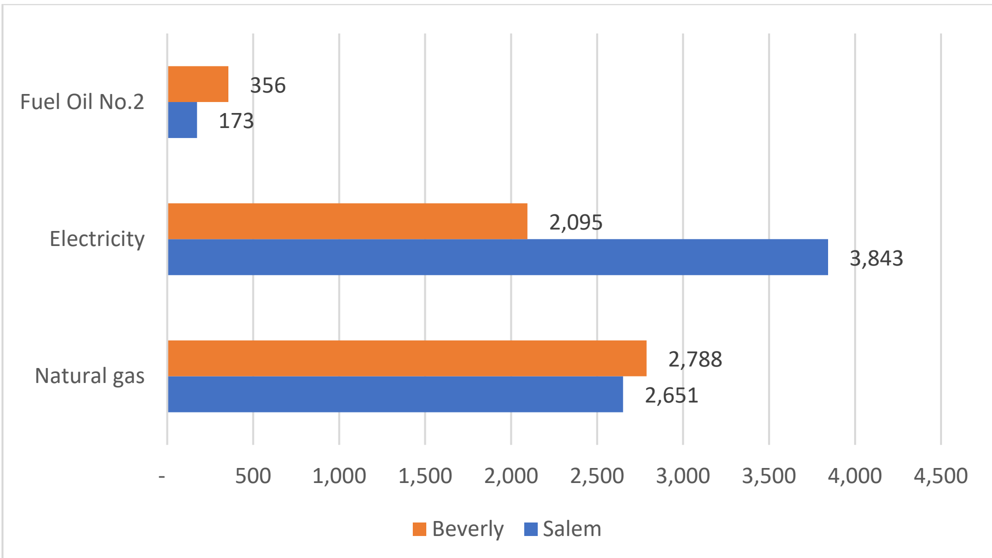
relative performance cannot be made. Large values do indicate opportunities for large reductions. While each community has different departments and a few different use cases, both have schools and these large facilities that support a number of activities throughout long daily operating hours tend to be the largest consumers of energy in all municipalities. The same is true in this case with Salem Schools consuming 74% of building electricity and 80% natural gas and Beverly Schools consuming 65% of building electricity and 70% of natural gas. These patterns likely helped Salem to prioritize using Green Communities grants for lighting retrofits at several schools in its district[6].

Figure 12. Municipal Operations GHGs by Energy Type



Similarly, Beverly in 2018 was using over 2 million kWh for streetlights and traffic signals as compared to 1.1 million kWh in Salem. In 2019 Beverly used Green Communities funds to retrofit all streetlighting to LED and the project savings are expected to reduce over 1.3 million kWh[7]. Both cities have been consistently using the Green Communities Program to deliver energy and cost savings to their constituents and are continuing to win grants to go further.

Vehicle Fleet

Within municipal fuels, each community uses similar quantities of gasoline, but Beverly uses significantly more diesel fuel in its operations. School transportation is the largest contributor here as well, using 30% of all diesel used by the city and another 19% used by the Highways and Snow and Ice removal divisions. With over 1.8 times the land area to cover as Salem, it is not surprising to see a greater demand for diesel from Beverly. With increasing availability of electric school buses, there are significant opportunities for emissions reductions from school busing in both communities.

[6] https://www.salem.com/sustainability-energy-and-resiliency-committee-serc/pages/buildings
[7] http://www.beverlyma.gov/departments/engineering/projects/green-communities/

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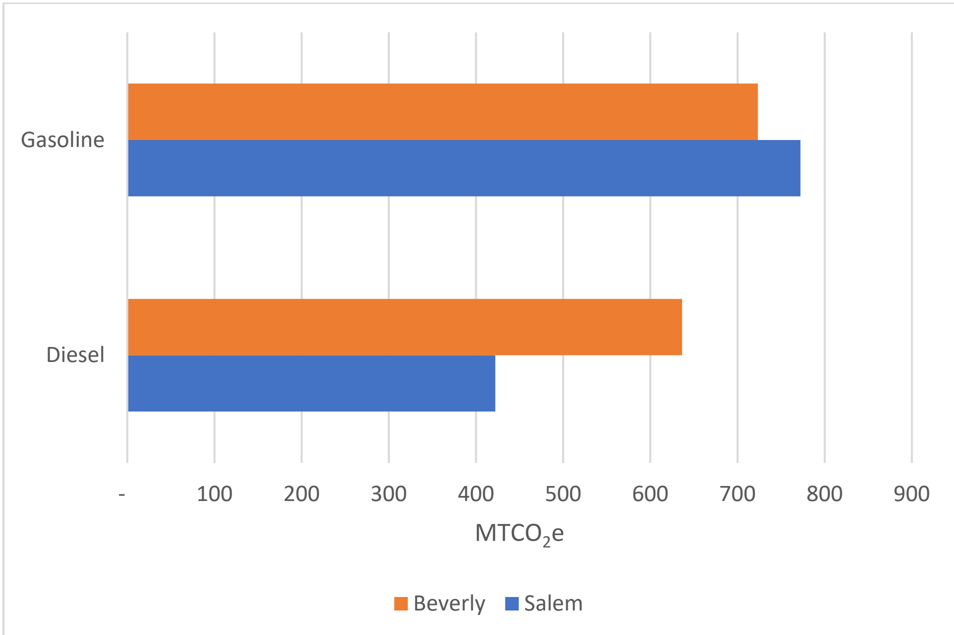
Figure 13 GHGs from Fleet Fuel Use



Solid Waste

Waste generation for each municipality was estimated from size and scheduled pick up frequency of containers serving municipal facilities. Overall, this is a small contributor to each inventory. A waste audit of facilities might be useful for revealing opportunities for more recycling. The recent success of a composting program at Beverly High School[8] illustrates an opportunity where service learning could be applied to generate more data on waste quantity and composition that could inform further reduction strategies in the future.

Water Supply & Wastewater Pumping

Both communities operate pumping stations throughout their communities to distribute potable water to their residents and businesses and the energy used in that process is tracked in Mass Energy Insight. Beverly has some additional pieces of water infrastructure that do not occur within Salem's operations. Most significantly Beverly's Mass Energy Insight records contain electricity used at the Salem and Beverly Water Supply Board and have been attributed to Beverly here. In addition, Beverly needs some amount of wastewater pumping to overcome elevation changes and to cross the harbor to reach the South Essex Sewerage District wastewater treatment plant. Wastewater in Salem relies on gravity to reach the same destination. For these reasons, Beverly has greater energy use in this section.

[8] https://www.changeissimple.org/news/2020/2/12/people-making-change-sydney-anderson-beverly-high-school

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Table 6. 2018 Water System Electricity Use

Community	Type	kWh
Salem	Potable Water Pumping	363,165
Beverly	Potable Water Treatment & Pumping	1,725,012
Beverly	Wastewater Pumping	436,695

Energy use at the South Essex Sewerage District is not included in either municipal operations total as records were not immediately available. Energy use at this facility has improved significantly over the past two decades and recently included the installation of a combined heat and power system[9]. This new system allows the treatment plant to generate its own electricity and remain operational in the case of power outages, reducing risk of untreated wastewater being released into the harbor.

Process and Fugitive N_2O emissions from the facility have been attributed to each community scale inventory based on the proportion of the service population of each community.

Power Generation and Renewable Energy

Salem is home to the Footprint Power Salem Harbor Station natural gas combined cycle power plant. This facility was recently reopened after converting from a primarily coal fueled power generation system. This change delivered direct improvement to the air quality in the area reducing a number of pollutants however it is still a large source of GHGs. In fact, at 453,590 $MTCO_2e$ in 2018, it emits more GHGs than all other sources in Salem combined[10]. Because it is a grid connected system located in the Salem community boundary, emissions associated with these facilities are not attributable to Salem alone and are the responsibility of all users of grid electricity in the region and included in the emissions factor used to calculate GHGs from electricity use throughout the region and are blended in the carbon footprints of both communities in the gird emissions factors used to calculate GHGs from electricity consumption.

The Salem Power Choice Program has been supplying customers in Salem with higher than average renewable energy mix since 2016 and as of 2019 include 100% renewable energy options with the ability to source all power from renewable energy projects from within New England. This program and other community choice aggregation programs are important mechanisms driving investment to change the power supply mix at a large scale and the impacts are real. However, accounting conventions for greenhouse gas inventories place an emphasis on the carbon intensity of the grid in order to understand better where additional conservation efforts can reduce GHGs and where inefficiencies make it harder to let go of fossil fuel supply. Salem Power Choice and future CCA's offered in Beverly do allow for communities to claim the difference these programs make in their mix of actions they will use to reach long term reduction

[9] http://www.newea.org/wp-content/uploads/2020/02/13.-AC20_MRibeiro.pdf
[10] https://ghgdata.epa.gov/ghgp/service/facilityDetail/2018?id=1012869&ds=E&et=&popup=true

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goals and a range of additional renewable energy development and procurement options will be in consideration throughout the *Resilient Together* plan development process. It is important to keep in mind that even at 100% renewable energy, every kWh that can be saved through efficiency is a clean kWh that goes to the next community. To meet targets like carbon neutrality, Beverly and Salem will need to be net exporters of clean electricity.

Next Steps

This greenhouse gas summary is the first in a series of analyses to inform greenhouse gas reduction pathways for Beverly and Salem. As the plan takes shape these values will be revisited to project future emissions from each community under no-action, business-as-usual trajectories as well as with the priority actions developed in the *Resilient Together* plan applied.

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This report was funded by the Massachusetts Executive Office of Energy and Environmental Affairs Municipal Vulnerability Preparedness (MVP) program