Town of Marblehead

Greenhouse Gas Inventory Report

Prepared by

Sustainable Marblehead
Preserving Our Past by Protecting Our Future

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www.SustainableMarblehead.org

Contents

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Sustainable Marblehead's lead author on this report was John Walters, a Massachusetts Clean Energy Center intern, who worked under the direct supervision of Sustainable Marblehead Executive Director John Livermore. The report review team included the following individuals.

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- Sustainable Marblehead Founding Committee Members
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Executive Summary

Respected scientific organizations around the globe have documented that climate change due to human-generated greenhouse gas[1] (also known as carbon) emissions is dramatically altering the world's climate systems and threatening human health and survival. As senior climate scientist James Hansen has said, "If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO2 will need to be reduced… to at most 350 ppm (from the current 407 ppm)."[2] In fact, some climate experts think we have fewer than 20 years to significantly reduce carbon emissions in order to avoid crossing an irreversible climate tipping point.[3]

According to climate scientists, the Earth's temperature has already warmed by two degrees Fahrenheit, causing polar ice caps to melt, oceans to rise, and coral reefs and other sensitive habitats to die. Without significant reductions in carbon emissions, seas could rise by as much as 10 feet by the end of the century, with Boston and nearby communities like Marblehead likely to experience a 25% higher increase than other parts of the planet.[4]

These developments pose a clear and urgent threat to our community that Marblehead's new sustainability organization, Sustainable Marblehead, (www.SustainableMarblehead.org) has been formed to help address. Our mission is to reduce carbon emissions and connect, support, and empower Marblehead citizens, businesses, and town officials to foster a sustainable, healthy, and resilient community. To meet these objectives, our carbon emissions along with the carbon emissions of communities across the U.S. and around the world will need to be ramped down quickly and phased out over time. To this end, Sustainable Marblehead offers the Town of Marblehead this report, which provides a baseline from which to measure our progress in reducing future carbon emissions.

In order to gauge our current greenhouse gas emissions, Sustainable Marblehead has completed a town-wide greenhouse gas (GHG) inventory, which highlights the major community sectors that produce carbon pollution. In the spirit of the business maxim that "what gets measured gets managed" the goal of the inventory is to quantify and understand how much each of these sectors contributes to global climate

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[1] Greenhouse Gas - Any of the atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of the Earth's surface. They include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and water vapor.

[2] Target Atmospheric CO2: Where Should Humanity Aim?, James Hansen et al. https://arxiv.org/vc/arxiv/papers/0804/0804.1126v2.pdf

[3] Earth Will Cross the Climate Danger Threshold by 2036, Michael Mann. https://www.scientificamerican.com/article/earth-will-cross-the-climate-danger-threshold-by-2036/

[4] The Boston Globe, http://www.bostonglobe.com/metro/2018/01/05/threat-rising-sea-levels-hits-home/kRSnmY2avJ2kLbvcYEYRbP/story.html?s_campaign=8315

change. Our hope is that the GHG data will inform and raise awareness among residents, municipal officials, businesses, and others about the impact of climate change on our iconic New England town. The data in this report is the best information currently available, and is intended to be a baseline for future comparison.

The inventory was conducted using 2016 data primarily, and addresses activities throughout our community as well as processes that involve surrounding communities, e.g. waste water treatment. Scope 1 (direct on-site use) and 2 (electricity production) emissions data were carefully gathered and integrated in order to quantify these key emission types. Scope 3 emissions (plane travel and production of purchased materials) were more simply calculated and should be assessed more thoroughly in future reports for more comprehensive results. See Figure 6 in the Inventory Scope section on page 15 for more detail on scope categories 1, 2 and 3. See Table 1 in the Results section on page 27 for the emissions results by scope.

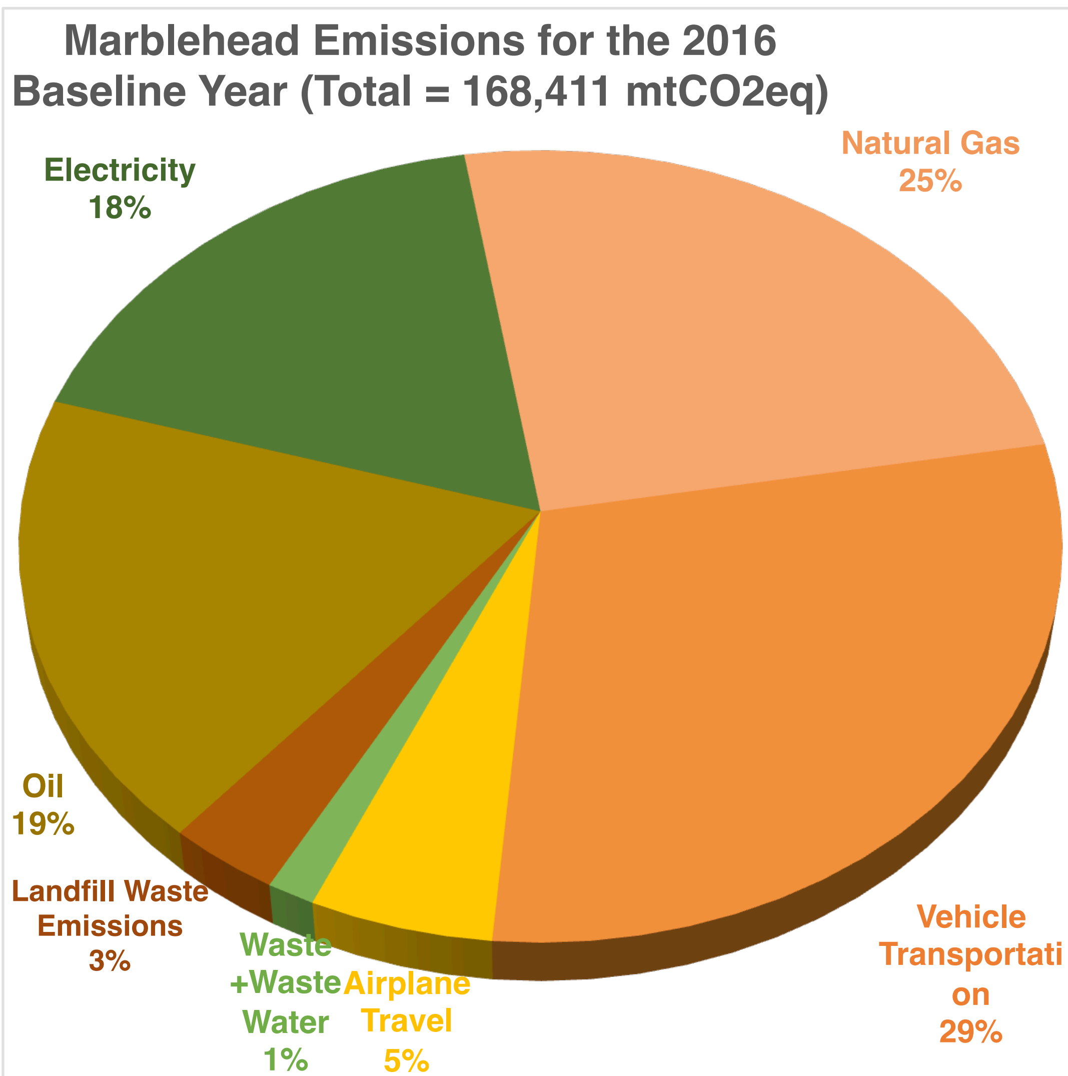

Figure 1 - Marblehead emissions for the 2016 baseline year by percentage of the total.

Key Findings

- Resident passenger vehicle emissions represent the single largest contributor (27%) to Marblehead's total carbon emissions (see Figure 2). Non-resident (commercial and municipal) vehicle emissions contribute approximately 2%.
- Natural gas use, predominantly for heating, accounts for a quarter (25%) of Marblehead's total carbon emissions.
- The burning of home heating oil represents 19% of the town's carbon emissions since approximately 4 out of 10 Marblehead households still heat with oil.
- Since the Marblehead Municipal Light Department (MMLD) purchases electricity from non-carbon emitting sources, including nuclear, wind and hydroelectric power, emissions from electricity (18%) are smaller than the three other major categories.
- Airplane travel emissions, calculated using estimates based on statewide averages, represent a relatively small slice, at 5%.

Recommendations

- Using the town's carbon emissions baseline as a starting point, it is recommended that the Town of Marblehead, in partnership with Sustainable Marblehead and other organizations, develop a Climate Action and Sustainability Plan with specific targets and actions for carbon emission reductions.
- With 29% of emissions coming from gasoline combustion (cars and trucks) and 19% of emissions from heating oil, there is an opportunity to dramatically reduce emissions from these sectors. It is recommended that we embark on an effort to convert fossil fuel-burning technologies to electric technologies (transportation: electric vehicles[5][6]; and heating: ductless heat pumps), employ energy storage, and decarbonize the electric grid, with the goal of producing 100% of electricity from renewable energy sources.
- Develop and foster a culture of mindful vehicle transportation. This could take the form of advocating for carpooling, electric vehicles, and more sustainable modes of transportation (bike, rail, ferry, bus, etc.), including walking.

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[5] "Electric vehicles (EVs) are from 30% to 80% lower in greenhouse gas emissions (than combustion engine vehicles)" according to Gina Coplon-Newfield, director of Sierra Club's Electric Vehicles Initiative. If you drive an EV 15,000 at current electricity rates ($0.16/kWh) you'll pay about $650 per year to charge your battery, but you'll save about $1,600 in gas (assuming $3.00 per gallon and a 28 mile per gallon vehicle). The $950 savings represents an approximately 60% reduction in fueling costs. https://content.sierraclub.org/evguide/myths-vs-reality

[6] A 2017 Chevrolet Bolt charged in Marblehead produces about as much global warming pollution as a gasoline vehicle getting 122 miles per gallon. https://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-emissions-tool#z/01945/2017/Chevrolet/Bolt

- ➢ Continue to engage residential, business, and municipal leaders on energy reduction strategies such as weatherizing homes and businesses, and informing citizens of their ability to take simple actions at home to reduce their electricity, gas, and oil usage.
- ➢ For future updates to this report, create a streamlined method for businesses, municipal departments, and other sectors to submit energy use data via a convenient automatic online platform.

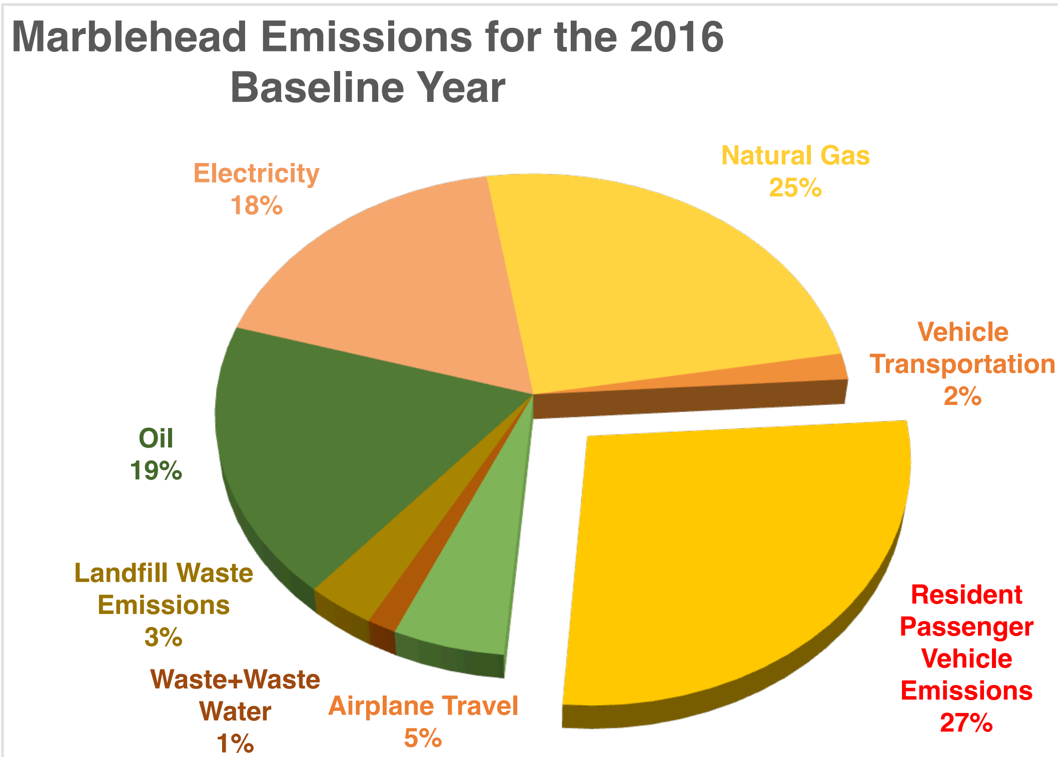

Figure 2 – Resident Passenger Vehicle Emissions is expanded out to show its impact. It is the largest emission source in the Marblehead community.[7]

Inventory Results

Marblehead's Scope 1, 2 and 3 emissions totaled **168,411 mtCO_2eq**. See the Software/Methodology section on page 10 for an explanation of mtCO_2eq. The majority of the emissions came from vehicle transportation (residential, commercial and municipal). Additionally, emissions from natural gas, oil and purchased electricity were considerable as well. The Scope 3 emissions of solid waste, wastewater and water and

[7] Figure 2 shows a similar pie-chart graphical representation as Figure 1 except the transportation emissions slice is further divided into "Non-Resident Vehicle Transportation" and "Resident Passenger Vehicle Emissions."

airplane travel were all estimated based on accepted average values. Figure 1 on page 5 describes the overall emissions mix in the town for 2016. Appendix A lists the calculations used to construct this inventory.

Future Inventory Refinements

In future inventories, the methodology should be expanded to include more granular data sources, which will result in even more precise data for the town's emissions. Even as better methods are deployed, careful analysis of the data is essential in order to observe discrepancies from year to year. The goals for future inventories include: acquiring more granular data from various town sectors; enhancing the data collection methodology; and pursuing more automated ways to gather data.

Introduction

Marblehead, Massachusetts, was founded in 1629 and is known for its "unsurpassed contributions to the American Revolution and Civil War."[8] A vibrant coastal community, Marblehead's character is embodied in its iconic and historic homes and buildings and its beautiful harbor. Equally vibrant are the town's 19,808[9] residents who are passionate about their town and committed to preserving its unique quality of life for future generations of Marbleheaders.

This Greenhouse Gas (GHG) Inventory Report provides a pathway to protect the natural resources that make this quality of life possible. By quantifying carbon emissions and reducing and eventually eliminating them over time, Marblehead will be poised to be a national leader in sustainability and climate change mitigation just as it was a leader in the founding and preservation of our United States.

This inventory was developed using the following protocols and tools:

1. "U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions" by the ICLEI – Local Governments for Sustainability USA**,** July 2013
2. "Local Government Operations Protocol: For the quantification and reporting of greenhouse gas emissions inventories," May 2010
3. "Mass Power Forward Greenhouse Gas Inventory"
4. "Local Climate Action Planning" by Michael R. Boswell, Adrienne I. Greve, and Tammy L. Seale, 2012
5. EPA Climate Leaders Simplified GHG Emissions Calculator (SGEC), Version 2.8

Overall, this inventory was constructed using guidelines derived from the Local Government Operations Protocol, which specifies the need to use processes that meet the following criteria:

Relevance: The greenhouse gas inventory should appropriately reflect the greenhouse gas emissions of the local government and should be organized to reflect the areas over which local governments exert control and hold responsibility in order to serve the decision-making needs of users.
Completeness: All greenhouse gas emission sources and emissions-causing activities within the chosen inventory boundary should be accounted for. Any specific exclusion should be justified and disclosed.

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[8] Town of Marblehead. (2017). *About Marblehead.* Retrieved July 7, 2017, from https://www.marblehead.org/about-marblehead
[9] https://suburbanstats.org/population/massachusetts/how-many-people-live-in-marblehead

Consistency: Consistent methodologies should be used in the identification of boundaries, analysis of data and quantification of emissions to enable meaningful trend analysis over time, demonstration of reductions, and comparisons of emissions. Any changes to the data, inventory boundary, methods, or any relevant factors in subsequent inventories should be disclosed.
Transparency: All relevant issues should be addressed and documented in a factual and coherent manner to provide a trail for future review and replication. All relevant data sources and assumptions should be disclosed, along with specific descriptions of methodologies and data sources used.
Accuracy: The quantification of greenhouse gas emissions should not be systematically over or under the actual emissions. Accuracy should be sufficient to enable users to make decisions with reasonable assurance as to the integrity of the reported information.[10]

Baseline Selection

Using the protocols and tools, the emissions profile of the Town of Marblehead was chosen and calculated using a baseline of 2016. Two sets of emissions data were from 2014, passenger and commercial vehicle and airplane travel, which were the most recent available data sets for these particular sectors. Averages based on yearly emissions were calculated where exact data was not readily available and were computed primarily using the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions.

Software/Methodology

The EPA Climate Leaders Simplified GHG Emissions Calculator (SGEC) was utilized for the majority of the GHG emission calculations. In order to properly calculate the intended emission categories, verified carbon emission factors were used that were up-to-date as of summer 2017. All methodologies and default values provided are based on the most current Climate Leaders Greenhouse Gas Inventory Protocol guidance, which were inputted into a spreadsheet for ease of use. Calculating emissions for several categories involved simply filling in the appropriate values required to solve the Marblehead GHG emissions puzzle.

The SGEC categorizes emissions into Carbon Dioxide-Equivalents (e-CO_2). E-CO_2 is a measure of the combined global warming potential of GHGs that can affect the overall impact on climate change and expresses them in terms of amounts of carbon dioxide released. The SGEC calculates emissions in mtCO_2eq or “metric tons of equivalent carbon dioxide,” based on 3 of the most common GHGs produced by human

[10] Local Government Operations Protocol. *For the quantification and reporting of greenhouse gas emissions inventories.* Version 1.1, 2010, p. 9.

activity: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The following conversions exist for the relationship between the climate change impact 1 ton of CO_2 versus the other mentioned chemicals:

- 1 ton CO_2 = 1 ton of e-CO_2
- 1 ton CH_4 = 21 tons e-CO_2
- 1 ton N_2O = 310 tons of e-CO_2

As mentioned, emission factors were utilized to calculate Marblehead's emissions. Emissions factors are assigned to each type of fuel that produces GHGs, including the following: electricity, natural gas, fuel oil, gasoline and diesel. These factors characterize the fuel based on its efficiency. As fuel efficiency is improved in the future, these emission factors may change, and they will need to be updated when new inventories are completed.

Marblehead Electricity Power

Electricity power for the community is purchased by the Marblehead Municipal Light Department (MMLD), which is a member of the Massachusetts Municipal Wholesale Electric Company (MMWEC). Electricity is then distributed by the MMLD to the community. The electricity mix purchased by MMLD changes on a month-to-month basis based on market value and availability of specific energy types (see Figure 3 for the energy mix purchased in 2016). On average in Massachusetts communities, the mix consists of various sources (natural gas, fuel oil, nuclear, hydro, bio-fuel, wind and solar). After extensive research and multiple communications with Andrea Denny[11] at the U.S. EPA, a default Massachusetts electricity mix emissions factor was used in the SGEC tool, called the NEWE (NPCC New England) eGRID2015 Emission Factors by Sub-region.[12] This resource takes into account the MMWEC power mix and the larger ISO-NE power grid mix, and allows for calculations of CO_2, CH_4 and N_2O.

The Berkshire Wind Project provides roughly 4% of the purchased electricity for the town.

Included in Figure 3 is a percentage of the electricity purchase mix that is labeled "ISO System Power – 57,307 56%." The ISO System is defined as the "amount of

[11] Andrea Denny, U.S. EPA's State & Local Clean Energy Program, denny.andrea@epa.gov, 202-343-9268
[12] Emission factors are from eGRID2015, which represents 2012 national data.

electricity produced by generators in New England and imported from other regions to satisfy all residential, commercial, and industrial customer demand."[13] According to the MMWEC website, which explains the various energy types included in the ISO System Power category, there are several different sources that make up this part of the mix for a town like Marblehead. There is a variable mix of the pooled electricity sources depending on which regions need the electricity in order to meet Net Energy for Load (NEL), or the amount of energy needed to keep the lights on. Figure 4 shows the amount of energy included in the ISO System category in 2016 according to the MMWEC website.

For future amendments to this report, a more nuanced detailing of electricity sourcing for Marblehead will result in a more granular representation of the town's electricity emissions, and could include emission reductions based on renewable energy production within the town.

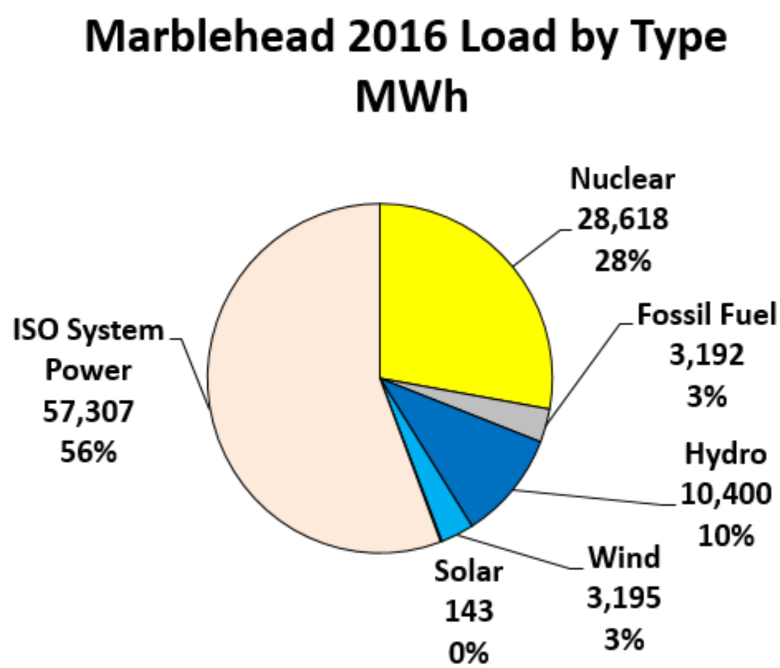

Figure 3 - MMLD purchased energy mix for CY 2016 by percentage of source.[14]

[13] https://www.iso-ne.com/about/key-stats/resource-mix
[14] The Massachusetts Municipal Wholesale Electric Company (MMWEC): http://www.mmwec.org/

	GWH (a)	% OF GENERATION	% OF NEL
Total Generation (b)	105,572	100.0%	84.9%
Gas	52,059	49.3%	41.8%
Nuclear	32,745	31.0%	26.3%
Renewables	10,231	9.7%	8.2%
Refuse	3,316	3.1%	2.7%
Wood	3,200	3.0%	2.6%
Wind	2,519	2.4%	2.0%
Solar	658	0.6%	0.5%
Landfill Gas	496	0.5%	0.4%
Methane	42	0.04%	0.03%
Steam	0	0.0%	0.0%
Hydro	7,465	7.1%	6.0%
Coal	2,555	2.4%	2.1%
Oil	517	0.5%	0.4%
Other (c)	0	0.0%	0.0%
Net Flow over External Ties (d)	20,803		16.7%
Québec	12,285		
New Brunswick	4,842		
New York	3,675		
Pumping Load (e)	1,959		-1.6%
Net Energy for Load (f)	124,416		100.00%

(a) GWh stands for gigawatt-hour.

(b) As of January 2016, this chart approximates the amount of generation by individual fuels used by dual-fuel units, such as natural-gas-fired generators that can switch to run on oil and vice versa. Previously, the report attributed generation from such units only to the primary fuel type registered for the unit. The new reporting flows from changes related to the Energy Market Offer Flexibility Project implemented December 2014. See the notes in the Net Energy and Peak Load by Source Report for more details.

(c) "Other" represents resources using a fuel type that does not fall into any of the existing categories. Other may include new technologies or new fuel types that come onto the system but are not yet of sufficient quantity to have their own category.

(d) Tie lines are transmission lines that connect two balancing authority areas. A positive value indicates a net import; a negative value represents a net export.

(e) The energy used to operate pumped storage plants.

(f) Generation
+ net interchange
- pumping load.

Figure 4 - The MMWEC information about the ISO System mix for the New England region for 2016.

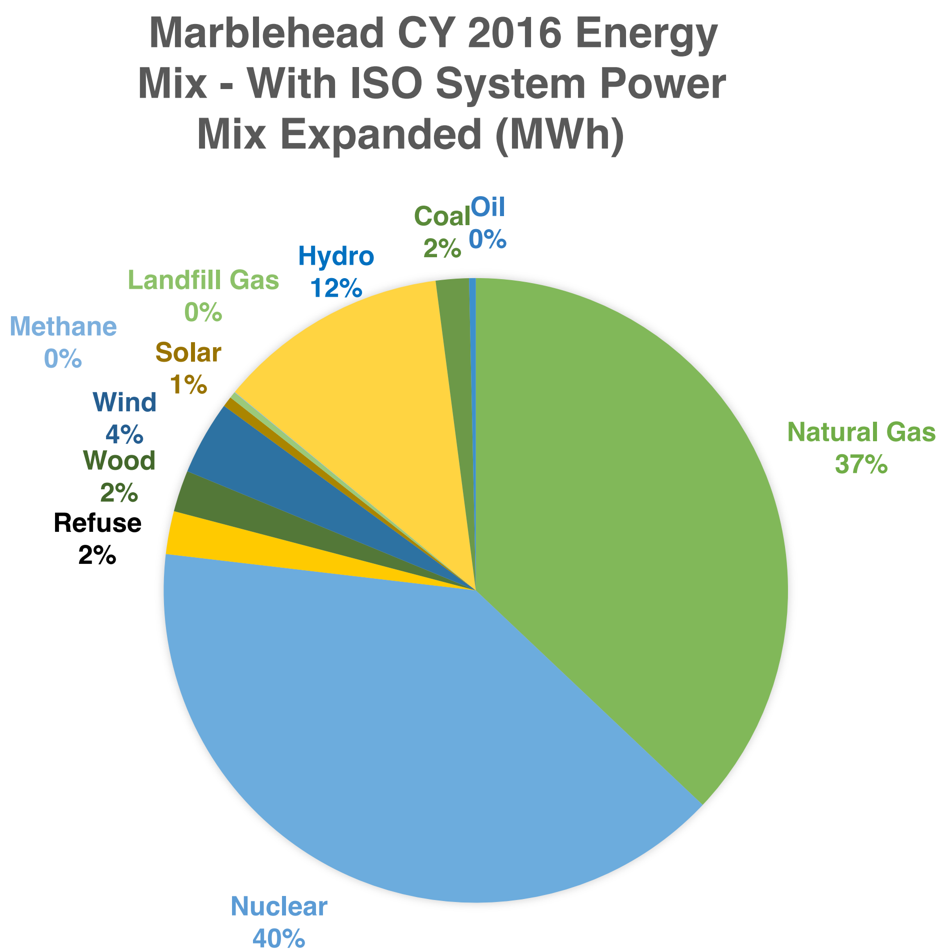

Figure 5 - MMLD purchased energy mix for CY 2016 by percentage of source. Includes the ISO System Power (Figure 5) added to the Figure 4 specified load type sources.

This inventory does not seek to report on Criteria Air Pollutants (CAPs) that are not contributors to global climate change, although they are often produced by the processes described in this document. The following chemicals are regarded as CAPs: NO_x, SO_x, VOCs, CO and PM_{10}. In the future, it may be advisable to include them as they affect human health.

Inventory Scope

The ICLEI and SGEC were combined to analyze the emissions that were focused within the geographical community boundaries of Marblehead, MA. This includes isolating waste emissions to only those produced within the community boundaries of the town, the natural gas and electricity usage by occupants, among other metrics. Most of the data was isolated to Scope 1 and Scope 2 emissions, although Scope 3 air travel and waste disposal emissions were also assessed for this report. Figure 6 shows which emission types fall into each scope category. In the future, other Scope 3 emissions, such as the purchase of produced goods consumed in the Town, could be inventoried. However, for the sake of the baseline inventory, these emissions were excluded.

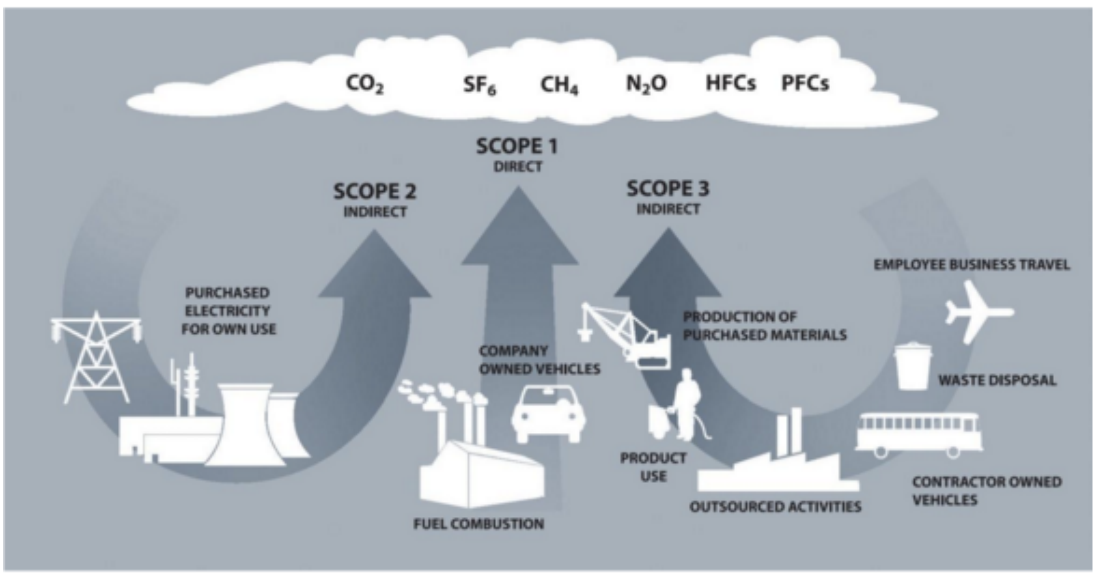

Figure 6 - Diagram of the emissions scopes. Primarily Scopes 1 and 2 were included for the Marblehead inventory. An estimate of airplane travel (Scope 3) was also analyzed.[15]

Government Sector Inventory Methodology

The municipal data for this inventory was gathered for the 2016 Calendar Year (CY) and was supplied by the Town of Marblehead municipal departments. Figure 9 on page 21 shows the municipal emissions in Marblehead for CY 2016.

➢ **Municipal Electric data**

[15] Gardner, M. *Corporate sustainability strategy* [PDF document]. Retrieved from Harvard Extension School lectures.

- This is based on the consumption for the municipal accounts and infrastructure, and was 5,852,767 kilowatt-hours (kWh).
- From the Marblehead Municipal Light Department (MMLD).
- From Colin Coleman in the MMLD finance department.

➢ **Municipal Natural Gas data**
- Gathered for the municipal buildings.
- Received from National Grid with the assistance of John McGinn, Marblehead Town Administrator

➢ **Municipal Fuel Oil data**
- Only the Gerry Elementary School uses fuel oil in the municipal sector.
  - Fuel oil type is Distillate #4 oil
  - The school will be renovated, and will cease to use oil in the next year or two
- Data provided by the office of the Superintendent of Schools.

➢ **Municipal Fleet Vehicles**
- Based on gasoline and diesel usage by town vehicles.
- Recorded per vehicle with a focus on type, model and year of the vehicles.
- Data was provided by Town Administrator John McGinn

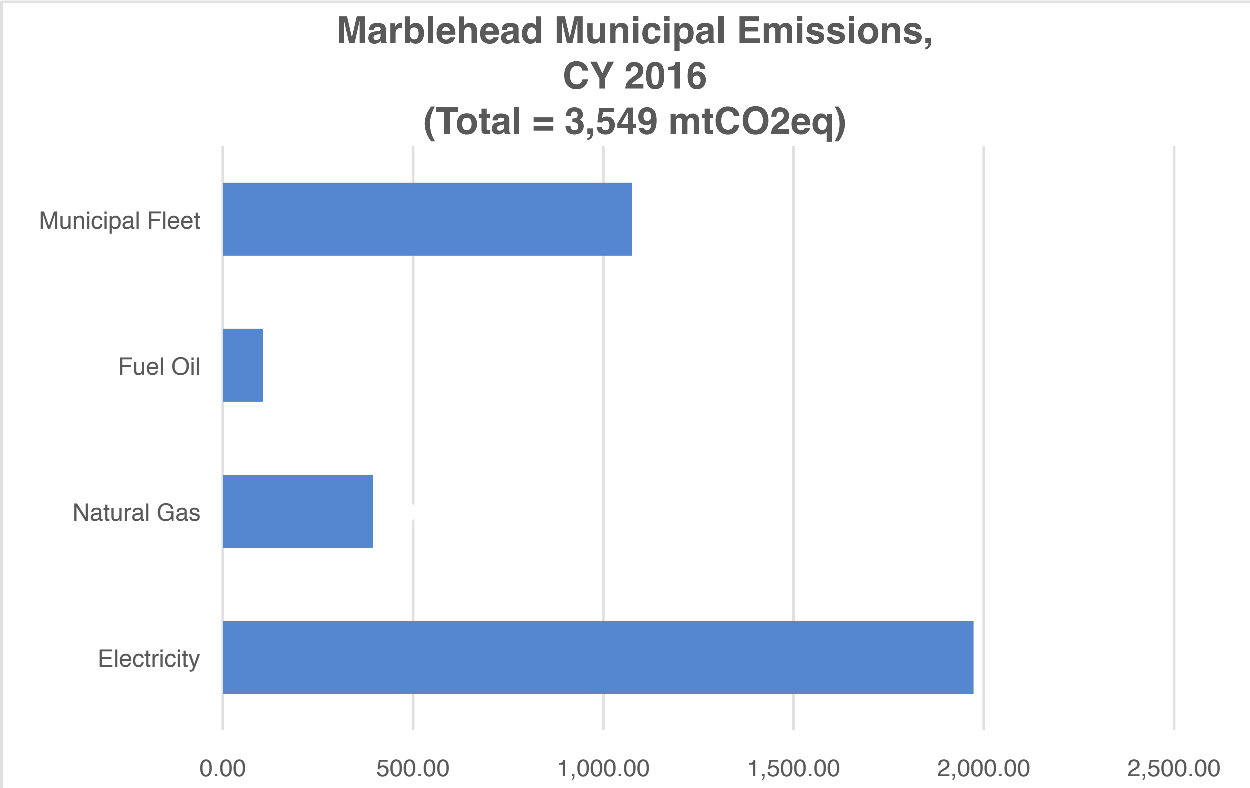

Figure 7- Marblehead, MA municipal emissions for the 2016 baseline year.

Community-Wide Sector Inventory

The following sectors of the Marblehead community were analyzed by the amount of emissions for the baseline 2016 year. The overall usage amounts can be found below in Table 1.

- Residential
  - Electricity
  - Natural Gas
  - Fuel Oil
  - Water and Wastewater Treatment
- Commercial
  - Electricity
  - Natural Gas
  - Fuel Oil
- Transportation

- Residential Passenger Cars
- Commercial Vehicles

➢ Water and Wastewater Treatment
➢ Landfill Waste

Residential

The residential electricity data for the 8,541 households in Marblehead was gathered from the MMLD and was for CY 2016. As mentioned previously, the data was analyzed by the SGEC tool using the emissions factor NEWE (NPCC New England). Residential electricity produced more emissions than the other categories of commercial and municipal electricity usage, at 66,301,364 kilowatt-hours (kWh).

Natural gas use was also analyzed for the residential community. National Grid provided yearly usage for the residential accounts in therms, which were converted to 100 ft^3 of natural gas (ccf) in order to calculate emissions in the SGEC. In the future, it would be beneficial to acquire month-to-month usage data to gauge seasonal variation.

The amount of fuel oil use by residents was also assessed. Approximately 3,242 Marblehead households use fuel oil, or about 38% of the total number of households. On average, households in Massachusetts used 807 gallons per customer, according to 2016 values.[16]

Electricity, natural gas and fuel oil used by the residential community in Marblehead is provided in the Results section in Table 1 on page 27.

Commercial

Commercial electricity use was also gleaned for the 565 commercial businesses in the Marblehead community boundary. Overall, the commercial sector used 29,785,276 kWh of electricity in CY 2016.

Natural gas amounts for the commercial sector were gathered through National Grid, which provided comprehensive data that extended back several years. However, this inventory is using 2016 as the baseline, so that amount was used.

Fuel oil for the commercial sector was unable to be collected for this report because of the complexity of this emissions type. It is estimated that commercial sector fuel oil usage is minimal since almost all commercial facilities in town have access to natural gas. In future reports, one option would be to estimate the amount of fuel oil used by multiplying the total square footage of the entire commercial built community in Marblehead by the average amount of oil used per commercial square foot in

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[16] Mass.gov data

Massachusetts.

Transportation

Data for the miles traveled and gallons of fuel burned by vehicles in the Marblehead community was acquired from one major source. A data series provided by the Metropolitan Area Planning Council (MAPC)/MA RMV called the Massachusetts Vehicle Census: Municipal Summary Statistics, for Q2 of 2014, was used.[17] The data included in this reference included the number of non-commercial passenger vehicles as well as the number of commercial vehicles. In addition, having the average miles per vehicle type allowed for an estimated of total vehicle miles by both class of Marblehead vehicles. In order to calculate emissions for transportation, the average age of the vehicles is required. The MAPC data set includes the average age of vehicles on the roads when the data was collected (Q2 of 2014). Subtracting the average age of vehicles on the road in Marblehead from the year the data was reported results in an average age of 2006 for Residential and Commercial vehicles in the town. Using the value in the data, the average age of vehicles in Marblehead was acquired and is shown below.

Marblehead is unique in that there are no major highways within the town boundary. This makes analyzing the through-town commuter traffic impact a little simpler and distinguishes it from a community like Wellesley, MA, which completed an inventory several years ago. In the process of gathering their emissions data, the creators of that inventory had to include major highway traffic, including from Routes 128 and 9, which was difficult to quantify.

Additionally, public transit poses a series of questions for future iterations of this report. There are no commuter rail lines in Marblehead, which cuts down on the direct public transportation emission category. However, some Marblehead commuters use the commuter rail to get to their places of employment. The emissions data for the avoidance of vehicle travel because of the commuter rail should be included in future reports. Also, bus routes connect Marblehead with neighboring communities and the City of Boston, and these vehicles should be included in the future.

The Marblehead Town Assessor and the MAPC Director of Data Services have agreed on 14,937 vehicles as the most accurate number for our GHG inventory. This data is as of May 15, 2014.

[17] http://data.mapc.org/datasets

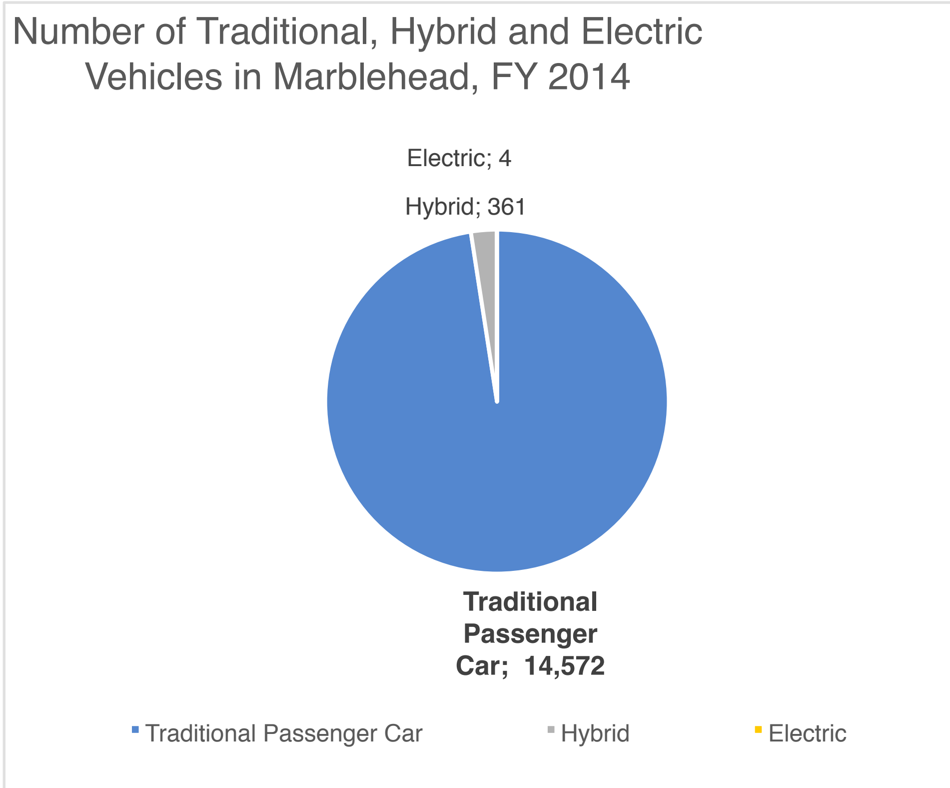

Figure 8 – The number of registered cars in the Marblehead community by type.[18]

Residential Vehicle Transportation

Key data required from the Massachusetts Vehicle Census: Municipal Summary Statistics:

1. Total Passenger Vehicle Miles Traveled, on average, per day.
2. Average fuel economy per passenger vehicle (SGEC data).
3. Average car age: 2006

These data were then inputted into the SGEC tool to get the necessary emissions.

Commercial Transportation

Key data required from the Massachusetts Vehicle Census: Municipal Summary Statistics:

1. Total Commercial Vehicle Miles Traveled, on average, per day.
2. Average fuel economy per passenger vehicle (SGEC data).
3. Average car age: 2006

[18] http://data.mapc.org/datasets

These data were then inputted into the SGEC tool to get the necessary emissions.

Even after changing the average age of both residential and commercial vehicles for Marblehead from 2006 to 2010 in the SGEC tool, the difference in the $mtCO_2eq$ for vehicle transportation in the community was 49,031 $mtCO_2eq$ versus 48,953 $mtCO_2eq$, respectively. Therefore, the number of miles traveled is the greatest indicator of emissions from transportation for a community like Marblehead, rather than the age of the vehicle, especially as many inhabitants commute great distances to their jobs or for other reasons. This will most likely change when more hybrid and electric vehicles are purchased or leased by Marblehead residents.

Airplane Travel

Airplane travel for the town of Marblehead and its 19,808 residents was calculated using online resources. Primarily, the report created by the U.S. Department of Transportation's Bureau of Transportation Statistics, *Passenger Travel Facts and Figures 2016,* was consulted for average airline miles traveled by people in the United States.[19] This same average was applied to the number of residents in Marblehead and was calculated as a Scope 3 emission, which garnered values related to emissions per passenger. Overall, Marblehead residents traveled an estimated 54,070,244 miles in 2014. In the future, additional measures to obtain a more accurate number of times Marblehead residents travel by airplane, possibly via survey results of residents, could help more exactly track this data type.

Marine Activity

No specific emissions were collected for marine activity in the Marblehead community, because the amount of data needed to make a rough estimation was prohibitively large and complex. What is known, from the Office of the Harbormaster, is that Marblehead houses 526 sailboats and 2,331 power boats (including dinghies and inflatables on the docks with motors) in the harbor. In the future, the town should refer to the ICLEI 2013 U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions: Appendix D: Transportation and Other Mobile Emission Activities and Sources in order to make more accurate estimations of emissions from the housed fleet in the harbor based on several specific data values. Also, the 2009 EPA report on emissions calculations for marine emissions is an outstanding tool and should be utilized in future amendments to this report.[20]

Ferry activity is also an emissions source that impacts Marblehead because of the preference of some residents to commute via this option. While there is no

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[19] https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/PTFF%202016_full.pdf

[20] EPA (2009) Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories.

calculation for ferry emissions in the town in this report, this will be a future endeavor in additional amendments.

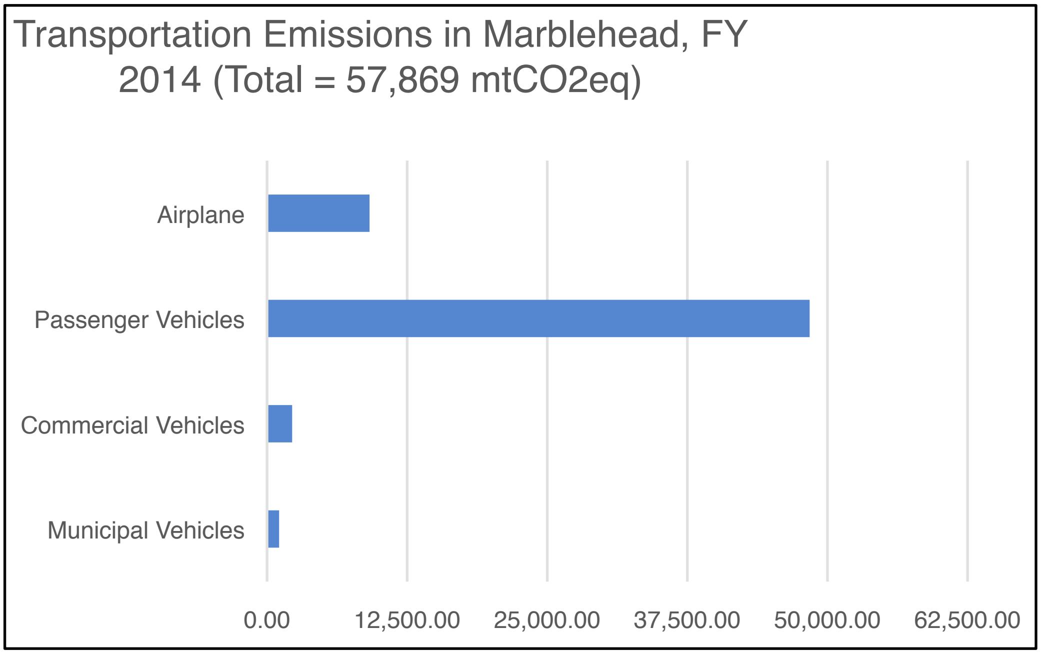

Figure 9 – Transportation emissions for the 4 sources analyzed in this report: Airplane travel for the Marblehead inhabitants, passenger, commercial and municipal vehicle emissions.

Water and Wastewater Treatment

The potable water supply for the Marblehead community is sourced from the Massachusetts Water Resources Authority (MWRA), which is located outside the town boundary. Therefore, an estimate of the emissions was made based on the ICLEI guidelines for a situation like this when an estimation of the impacts of water sourcing is required.

Similarly, the waste water from the Marblehead community is delivered for processing to the South Essex Sewerage District (SESD) Board in the City of Salem MA, which is located outside the town boundary. Therefore, an estimate of the emissions for wastewater treatment for Marblehead was made based on the ICLEI guidelines for this situation.

Both water and wastewater treatment produce emissions in myriad ways that were taken into account for this inventory. First, wastewater treatment releases CH_4 in the processes that accompany the breakdown of wastes by microorganisms. Additionally, during collection and treatment, sometimes the wastewater is processed under anaerobic (without oxygen) conditions, thereby releasing some of the trapped methane. N_2O can also be expelled during wastewater treatment when excess nitrogen is removed from the water, which can release the gas to the atmosphere. Also, CO_2

emissions are released from the use of fossil- fuel-derived methanol for biological nitrogen removal in a waste treatment. Water treatment also has the potential to release GHGs. Most often, the emissions from water treatment come by way of the energy necessary to extract the water from the aquifers and to pump the water over distances for treatment. Figure 10 shows the lifecycles of both wastewater and water treatment, illustrating the various steps that often use energy and, thus, result in emissions in Marblehead.

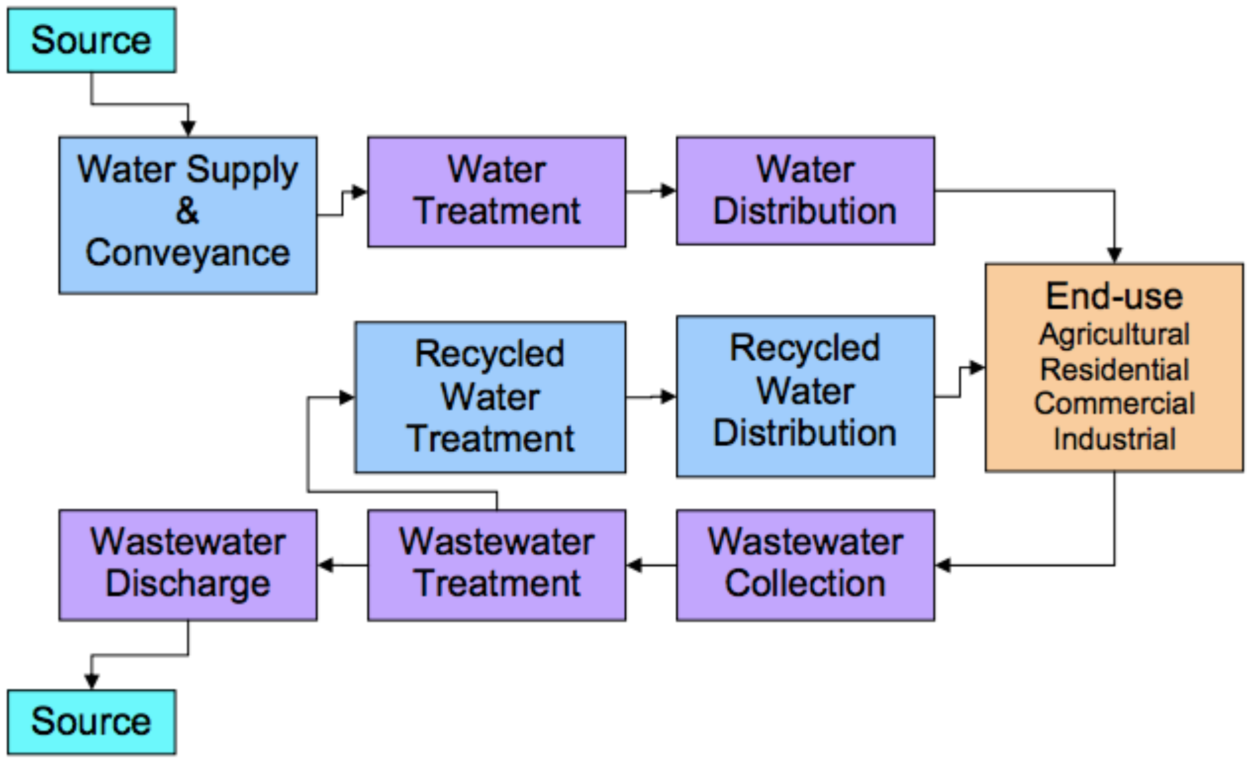

Figure 10 - The wastewater and water cycles in Marblehead.[21]

[21] Klein, Gary, Ricardo Amon, Shahid Chaudhry, Loraine White, et al. California's Water-Energy Relationship: Final Staff Report. Nov. 2005. California Energy Commission. Available at: http://www.energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF

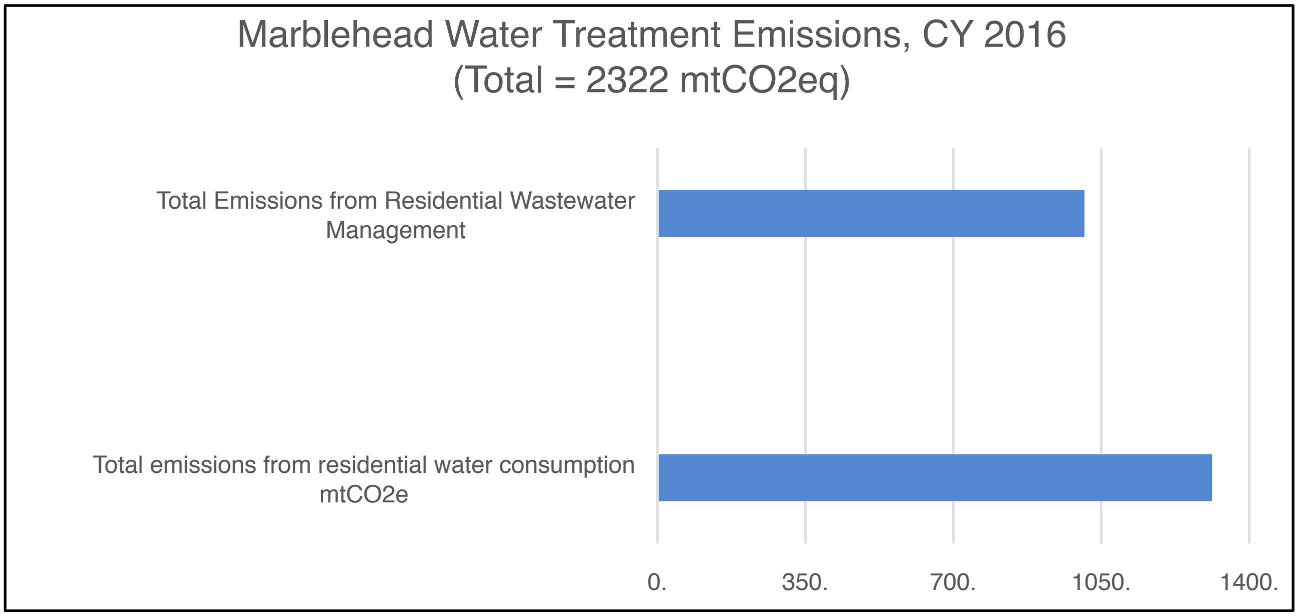

Figure 11 - Water treatment emissions for Marblehead, MA.

Waste

The amount of waste in the Marblehead community was reported by the Marblehead Health Department in tons for CY 2016. The total was 4,766 tons for the 8,541 households as well as municipal operations and commercial entities. Methane (CH_4) is the primary GHG emitted from landfills. In addition, 2,498 tons of materials were recycled in CY 2016. These materials were hauled away to be sorted in outlying communities, as mentioned below:

- Recyclables collected curbside were brought to the JRM single stream facility in Peabody.
- Cardboard, paper, comingled items (glass, aluminum and plastic) and rigid plastic brought to the transfer station are hauled to Salem for processing.
- Metals are hauled to Second Street.
- Electronics are hauled away by RMG.
- Tires are hauled away by a private vendor.

The emissions associated with the 2016 landfilled waste in Marblehead, along with hauling and processing the recycling in the community, are the following:

1. Landfill CH_4 emissions ($mtCO_2eq$) = 5404
2. Diverted Emissions ($mtCO_2eq$) for recycling = -6994

Per the Community Protocol, this inventory will not subtract the recycling emissions from the total because it must stand as its own line item. This is due to the fact that additional reductions in a community's GHG emissions will be reported in future inventories after the initial baseline (this report). The reductions must be separated in the baseline report from the gross emissions.

There is now a composting system at the town Transfer Station as of 2017, which is usable by town residents in Marblehead. Composting can have a large effect on lowering emissions in a community since the organics will be diverted from being placed in the landfill and creating methane there. Figures 12 and 13 on page 25 show example calculations for recycling and composting from a hypothetical community. With more recycling and compost data for Marblehead, more exact calculations of emissions diverted can be made. Future report updates should include these calculations, as rates of recycling and composting increase.

Recycling one pound of material results in approximately one pound of carbon dioxide emissions reduction.[22] *Composting one pound of food waste can divert 3.8 pounds of greenhouse gas emissions into the atmosphere.*[23]

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22 Sustainable Clackamas County, 2017.

23 GRACE Communications Foundation, 2017.

Example calculations for diverting recycling[24] and compost[25] from the waste stream.

Example 4.1 Emissions/Reductions from Recycling Transport and Displacement of Virgin Materials
A community recycles 2,000 tons of plastic and 10,000 tons of paper. The end markets (as defined in Box 4.1) for both materials are outside the community, and the community inventory does not include supply chain or consumption-based emissions.
Plastic Emissions (metric tons CO2e)= 2,000 tons * (0.17 + 0.53 + 0 + (-0.12) + (-1.31) + (-0.25))MT CO2e/ton =2,000 tons *(-0.98 MTCO2e/ton) =-1,960 MTCO2e **Paper** Emissions (metric tons CO2e)= 10,000 tons* (0.02 + 0.63 + 0 + (-0.12) + (-0.99) + (-0.01) + (-3.06) MT CO2e/ton =10,000 tons * (-3.53 MTCO2e/ton) =-35,300 MTCO2e **Total** = -1,960 MTCO2e + (-35,300 MTCO2e) = -37,260 MTCO2e

Figure 12 - An example of the $mtCO_2eq$ reductions for recycling.

Example 3.2 Emissions Reductions from Composting
A community composts 3,000 tons of food waste and 7,000 tons of yard trimmings. If not recycled, the waste would have been sent to a landfill with landfill gas collection and energy recovery.
Emissions (MTCO2e) = (3,000 tons + 7,000 tons)*(-0.03 MTCO2e/ton) + 3,000 tons *(-0.21 MTCO2e/ton) + 7,000 tons * (-0.11 MTCO2e/ton) =-300 MTCO2e + (-630 MTCO2e) + (-770 MTCO2e) =-1,700 MTCO2e

Figure 13 - An example of the $mtCO_2eq$ reductions for composting.

[24] Recycling and Composting Emissions Protocol: For Estimating Greenhouse Gas Emissions and Emissions Reductions Associated with Community Level Recycling and Composting, Version 1.0. July 2013 by ICLEI—Local Governments for Sustainability USA, p. 29.
[25] Ibid, p. 21.

Results

Table 1 below lists the relevant data associated with greenhouse gas emissions in Marblehead. One point to note is that fuel oil, natural gas and transportation all contribute methane to the overall emissions of the town.

According to the EPA, during the process of fracking for natural gas, which is one of the common ways to procure gas, methane can be released when the gas is extracted underground. Also, leaks in the natural gas system can result in methane being released.[26] [27] It should be noted that the natural gas emissions figures in this inventory do not include methane escaping from gas pipeline leaks.

In oil acquisition, methane is also released. The EPA comments that methane also resides alongside petroleum underground and, through drilling for oil and in its production, refinement and transportation, methane can be released into the atmosphere.[28] Therefore, fuel oil, along with gasoline used in transportation, has upstream methane release effects that must be accounted for and are included in Table 1 on page 27.

[26] https://www.epa.gov/newsreleases/epa-releases-first-ever-standards-cut-methane-emissions-oil-and-gas-sector

[27] Rep. Lori Ehrlich spearheaded legislation to require Massachusetts gas utilities to report on and systematically repair their gas leaks. National Grid is in the process of addressing the numerous gas leaks in Marblehead.

[28] https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Table 1. 2016 Marblehead, MA Greenhouse Gas Inventory Data							
Emission Source		Consumption Amount (kWh, ccf, etc.)	CO_2 (kg)	CH_4 (kg)	N_2O (kg)	eCO_2 (Metric Tons)	%Total Emissions (eCO_2)
Scope 1	Residential Natural Gas	597,466,990 ccf	32,502,204	615,391	59,747	**32,534**	19
	Residential Oil	2,616,294 gal	30,859,188	4,307,977	234,981	**31,023**	19
	Commercial Gas	127,116,749 ccf	6,915,151	130,930	12,712	**6,922**	4
	Municipal Natural Gas	7,248,369 ccf	394,311	7,466	725	**395**	0.23
	Municipal Oil	10,376 gal	105,267	15,830	863	**106**	0.06
	School Gas	33,967,390 ccf	1,847,826	34,986	3,397	**1,850**	1
	Transportati on	5,805,409 gallons 129,846,962 miles	51,386,412	1,908	1,023	**49,031**	29
Scope 2	Purchased Electricity	102,854,662 kWh	21,120,177	2,412	355	**29,987**	18
Scope 3	Solid Waste	4765.74 tons				**5,404**	3
	Diverted Emissions for recycling	2498 tons				**-6,994**	
	Water/Wast ewater	N/A				**2,322**	1
	Airplane Travel	54,070,244 miles	8,759,380		254	**8,838**	5
Totals	Scope 1		**124,010,360**	**5,114,488**	**313,447**	**121,859**	72
	Scope 2		**21,120,177**	**2,412**	**355**	**29,987**	18
	Scope 3		**8,759,380**		**254**	**16,564**	10
	Scope 1+2		**145,130,537**	**5,116,900**	**313,801**	**151,846**	90

	Scope 1+2+3		**153,889,917**	**5,116,900**	**314,055**	**168,411**	100

Conclusion

The data gathered for this report demonstrate that there are several areas of very significant carbon emissions that make up approximately 9/10th of total emissions for the Town of Marblehead.

- Transportation: 29%
- Natural Gas: 25%
- Heating Oil: 19%
- Electricity: 18%

The other three primary emission categories total approximately 1/10th.

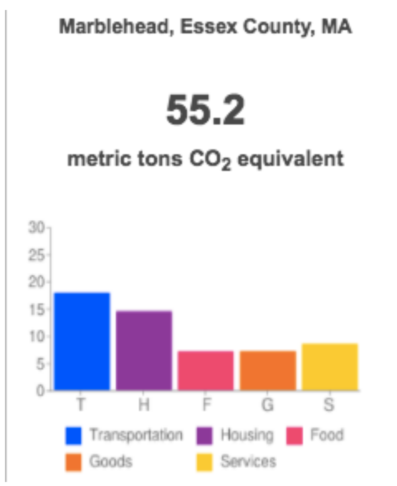
- Airplane Travel: 5%
- Landfill Waste: 3%
- Waste & Waste Water: 1%

Based on the emission categories covered in this report, the average emission amounts per Marblehead household and resident are below:

➢ Average mtCO_2eq per household (Marblehead) = 20.0
➢ Average mtCO_2eq per resident (Marblehead) = 8.6

When adding in carbon emissions associated with *food, goods* and *services,* however, total average emission amounts increase significantly:

➢ Average mtCO_2eq per household (including food, goods & services) = 55.2
➢ Average mtCO_2eq per resident (including food, goods & services) = 23.8[29]



[29] Wilson, 2017.

Figure 14 – A screenshot of the estimated mtCO_2eq/household in Marblehead, MA per the CoolClimate Network out of Berkeley, CA (Source: CoolClimate Network).

As seen in Figure 14, the estimated average mtCO_2eq that was calculated by the CoolClimate Network was 55.2 mtCO_2eq per household, which was far above the 20.0 calculated for this report. This inventory did not take into account the following emission sources that are responsible for the difference between our inventory findings and the CoolClimate Network's findings:

- Emissions associated with the production and transportation of food.
- Goods and services purchased, for instance:
    - Long-distance freight movement
    - Cement for buildings
    - Supply chains for materials like glass, carpets, etc.

When compared to the cities or towns of Brookline, Wellesley and Nantucket[30], the following per capita comparisons are found in Figure 15. There are multiple potential reasons for the differences between the four Massachusetts towns, and it is challenging to make a direct comparison. Below, however, are descriptions of some of these reasons.

Brookline/Wellesley → Marblehead

It is possible that the towns of Wellesley and Brookline, though larger than Marblehead in population, may have not accounted for the same emissions groups that were identified for this report. Both of their inventories were collected and analyzed in 2007, 10 years prior to the Marblehead inventory. In that time, the ICLEI methodology, along with other standards used in this Marblehead baseline, most likely changed and were enhanced in order to accommodate more emissions types when inventorying. The largest emission source for Marblehead was the transportation category, ostensibly due to the commuter culture that exists in town coupled with its distance from Boston. Both Wellesley and Brookline lie closer to Boston and offer some public transit options into the city, thereby possibly resulting in a lower emissions potential per resident.

Nantucket → Marblehead

Marblehead is different from Nantucket, the other town in Figure 15, in multiple ways. Nantucket has a strong culture of boating, most notably the ferry system to and from the mainland, which adds a considerable emissions amount from the diesel fuel used in the boats. Also, Nantucket has power generation on the island to meet the needs of the population, which results in emissions from that process that have a direct impact on the island itself. This is different from the purchased municipal electricity used

[30] Three of only a handful of comparable towns in Eastern Massachusetts that have completed a greenhouse gas inventory.

in Marblehead, which does not result in direct, gaseous emissions to the town. Finally, while the yearly population of Nantucket is 11,060 permanent residents, this doesn't take into account the tens of thousands of people who flock to the island every year for vacation. The per capita emissions for Nantucket are a yearly average, and one that varies wildly depending on the time of year.

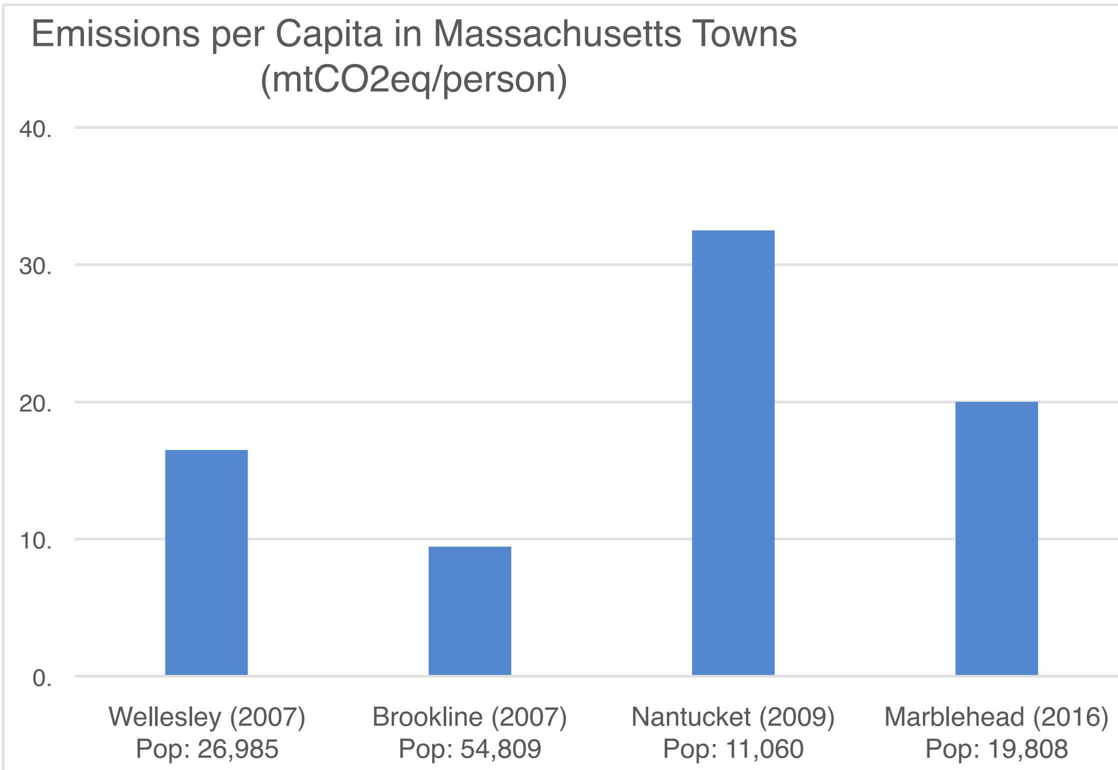


Figure 15 – Comparison of Massachusetts towns and cities based on per capita GHG Emissions.

Overall, the data collection for this inventory was complex because there were a number of key stakeholders who had access to the necessary data. However, all were amenable to the project, knowing that it could provide invaluable information for the Town of Marblehead. Subsequent inventories will reveal new data sources, novel methodologies, and new strategies for the town. In the meantime, this document is intended to provide a benchmark for future sustainability activities and, with proper care, a valuable tool to facilitate continued momentum toward Marblehead becoming a more sustainable community.

Limitations of Current Inventory

There are several limitations to the current inventory methodology as it stands, many of which should be addressed in future inventories. Overall, the data gathered was concise, and additional fine-tuning will occur in inventory updates.

- **Overall**
  - Future inventories should include additional month-to-month usage rates to gauge seasonal variation, for instance. An example would be to acquire natural gas usage in winter months versus summer months to illustrate the importance of resource conservation
  - Refrigeration and fire suppression emissions should be included if possible in inventory amendments.
    - Refrigerants and fire suppressants are very potent GHGs and have Global Warming Potential (GWP) values of up to many thousand times that of CO_2. For example, HFC-134a, a very common refrigerant, has a GWP of 1300, or 1300 times that of CO_2. Therefore, even small amounts of leaked refrigerants can have a significant effect on GHG emissions.[31]
    - The University of Connecticut, with 18,602 students, an approximately equal population to Marblehead, had 2% of their emissions for 2009 come from Refrigerants and Chemicals. It was a small percentage of their overall emissions total, so ideally it will not represent a large GHG category for future inventories.
  - Methane Calculations
    - The method by which methane emissions were estimated was recommended by the ICLEI and IPCC. It takes into account the impacts that methane has over a period of 100 years as this gas can remain in the atmosphere for a large amount of time. In a 100-year timeframe, it is 21x as potent as CO_2 as a greenhouse gas. This is a conservative approach to methane accounting, as used by ICLEI, IPCC, and that other methods treat methane as much more potent. In the future, if the town chose to address methane in a 20-year timeframe, where methane has an 80x greater potency than CO_2, different calculations would need to be employed. For now, the ICLEI and IPCC guidelines are adequate.
    - Methane emissions from natural gas pipeline leaks have not been quantified and are not included in this report. Repairing the multiple leaks in Marblehead and eliminating these methane emissions is a priority. Town Administration is in communication with National Grid Gas on leak repair progress.
- **Municipal Electric data**

[31] 2010 Town of Yountville Government Operations Greenhouse Gas Emissions Inventory http://www.townofyountville.com/Home/ShowDocument?id=4564

- This should be parsed out per municipal building in the community to determine where the local Marblehead government could focus on reducing energy expenditures.

- **Transportation**
  - More attention to quantifying in-boundary emissions related to commuting. There are methods to do this that include surveying residents, etc.
  - Maritime activity should be included, including boat and ferry traffic in the Marblehead harbor.
  - Determining the commuter traffic that uses the train or other public transit to get to work.
  - The bus routes in Marblehead will need to be assessed for their emission amounts.
- **Residential**
  - Water and waste water treatment
    - Future inventories will need to include exact emissions for these processes, not just approximate values based on existing averages.
- **Commercial**
  - Fuel Oil
    - The amount of fuel oil used by the commercial sector will be averaged based on the square feet of commercial space in Marblehead, multiplied by the average fuel usage in Massachusetts by commercial businesses.
      - A Marblehead map of the gas leaks in the community shows that much of the commercial area in the town has natural pipelines running through it.[32]
      - From the data available on gas pipe access in Marblehead, all of the major commercial and business areas of town appear to have access to gas and are likely using gas for heat and other end uses. As such, we estimate that commercial/business heating oil usage is very low to nonexistent. This data category will need further refinement going forward.
- **Landfill waste**
  - More emissions-based information will be helpful to accurately calculate the emissions in town. This includes having more precise measurements of methane released so that those values can be used in the SGEC tool instead of average emission amounts.
  - Often, businesses and some residences contract individually with trash haulers to take their trash. In the future, Sustainable Marblehead

[32] https://www.google.com/maps/d/viewer?mid=1Ip0qNKX6K-Dd8RK-88ZuWy7LRMU&ll=42.49857470934149%2C-70.87208663523552&z=13

should seek to have better accounting for those haulers in the community, including asking the haulers to report annual tonnage to the Health Department. Sustainable Wellesley ran into a similar roadblock in their inventory, and they also mentioned the importance of having these data for the future.

- Accounting for composting as a waste diversion practice would help to reinforce the importance of doing this in a community like Marblehead. Also, a more accurate description of the weights and associated types of recycling done in the community would shed more light on this emissions-reducing practice.
  - Future data sources necessary for these calculations:
    - Types and amounts of recycling diverted from the landfill
    - Amount of organic compost waste

Future Initiatives

There are several different data-based initiatives that could be incorporated into future GHG inventories. Appendix 1 shows some of the key sources and activities that could be included, which are highlighted.

Additionally, as the University of Connecticut inventory team alludes to in their 2009 report, an automated data reporting process could significantly assist with data collection in the future (p. 44).[33] Marblehead residents, businesses, and municipal departments, for example, could assist in streamlining future iterations of this GHG inventory report by completing user-friendly, sector-customized forms in interfaces that could be easily gathered by future inventory teams.

[33] The University of Connecticut Climate Action Plan: Guiding the Path toward Carbon Neutrality: http://ecohusky.uconn.edu/wp-content/uploads/sites/2041/2017/01/Initiatives-Climate-Section2_UConnGHGInventory.pdf

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Appendix A - Calculations

As previously mentioned, the majority of the emissions calculations were conducted in the EPA Climate Leaders Simplified GHG Emissions Calculator (SGEC), Version 2.8, which has pre-filled emissions factors for many of the categories. However, some calculations were done using equations listed in the "U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions" by the ICLEI – Local Governments for Sustainability USA**,** July 2013.

Electricity

All electricity sources utilize the same equation sets in order to calculate the amounts of the 3 most common GHGs, CO_2, CH_4 and N_2O. Below are the example equations for Residential emissions in Marblehead.

Residential CO_2 = usage in kWh*CO_2 emissions factor (lb CO_2/MWh) /1000
= 66,301,364 * 637.90/1000
= 42,293,640 lb CO_2
Residential CH_4 = usage in kWh*CH_4 emissions factor (lb CH_4/MWh) /1000
= 66,301,364 * 0.07284 /1000
= 4,829 lb CH_4
Residential N_2O = usage in kWh*N_2O emissions factor (lb N_2O/MWh) /1000
= 66,301,364 * 0.01071/1000
= 710 lb N_2O

Commercial = see above
Municipal = see above

Overall mtCO_2eq electricity = ((Total kWh/1000) / 2205) * ((Total lbs CO_2+Total lbs CH_4 *21+Total lbs N_2O*310))
= (102,854,662/1000)/2205) * (638 + 21 * 0.07284 + 310 * 0.01071)
= 29,987 mtCO_2eq for electricity usage in Marblehead

Natural Gas

kg of CO_2 (emissions) = Quantity combusted * 0.0544
= 41,659,493 kg
g of CH_4 (emissions) = Quantity combusted * 0.00103

= 788,773 g
g of N_2O (emissions) = Quantity combusted *0.0001
= 76,580 g

Overall mtCO_2eq natural gas = (kg of CO_2 (emissions) + ((g of CH_4 (emissions)/1000)*21) + ((g of N_2O (emissions)/1000)*310))/1000
= **41,700 mtCO_2eq natural gas**

<u>Fuel Oil</u>

<u>Distillate Fuel Oil (#1, 2 & 4)</u>

kg of CO_2 (emissions) = Quantity combusted * (426/42)
= 105,267 kg
g of CH_4 (emissions) = Quantity combusted * (5.825/42)*11
= 15,830 g
g of N_2O (emissions) = Quantity combusted (5.825/42)*0.6
= 863 g

<u>Residual Fuel Oil (#5 & 6)</u>

kg of CO_2 (emissions) = Quantity combusted * (495/42)
= 30,859,188 kg
g of CH_4 (emissions) = Quantity combusted * (6.287/42)*11
= 4,307,977 g
g of N_2O (emissions) = Quantity combusted * (6.287/42)*0.6
= 234,981 g
Overall mtCO_2eq fuel oil = (kg of CO_2 (emissions) + ((g of CH_4 (emissions)/1000)*21) + ((g of N_2O (emissions)/1000)*310))/1000
= **31,129 mtCO_2eq fuel oil**

<u>Transportation</u>

<u>Residential</u>

= (Total Miles per Day Passenger Vehicles) * 365 = 124,107,881 miles CY 2014
= ALL Passenger vehicles miles in 2014 in Marblehead = 124,107,881 miles

Residential miles = (Passenger – (Commercial + Municipal miles))
Residential miles = (124,107,881 miles – (5,739,081 miles + 966,812 miles)
= 117,401,988 residential vehicle miles in 2014

Average year of Marblehead residential vehicles = 2014 – (Total Vehicle Age (Passenger Vehicles))
= Q2 2014 – 8.42 years
= 2006

Commercial
= (Total Miles per Day Commercial Vehicles) * 365 = 5,739,081 miles CY 2014
Average year of Marblehead commercial vehicles = 2014 – (Total Vehicle Age (Commercial Vehicles))
= 2005

Municipal

*Data was comprehensive for the municipal vehicle fleet in Marblehead and provided by the Town Administrator.

**Please see the SGEC Excel spreadsheet, tab Direct 2.0 for the various emissions factors based on vehicle age, mileage and fuel type.

Overall mtCO_2eq vehicle travel = ((Fuel Usage Gasoline and Diesel) + (CH_4 emissions (g)*21/1000) + (N_2O emissions (g))*310/1000))/1000
= 49,031 mtCO_2eq for vehicle transportation

Airplane Travel

Average annual Marblehead resident airplane travel =
((Total air travel U.S. passenger miles 2014) / Population of the United States[34]) * Population of Marblehead

= (2730 * 19,808 Marblehead residents)
= 55,940,101 miles flown by Marblehead residents 2014

"Air Travel Type" flown by Marblehead residents was NOT known for this analysis, so the "Medium Haul (>= 300 miles, < 2300 miles)" option was selected in the SGEC tool as an approximate, middle average.

kg of CO_2 (emissions) = Passenger Miles * (0.162)
= 9,062,296 kg
g of CH_4 (emissions) = 0 g
g of N_2O (emissions) = Passenger Miles * (0.0047)
= 262,918 g

[34] https://www.census.gov/popclock/

Overall $mtCO_2eq$ airplane travel in Marblehead =
((kg of CO_2 (emissions)) + (g of CH_4 (emissions)/1000 * 21) + (g of N_2O (emissions))/1000 *310)/1000
= **8,838 $mtCO_2eq$ airplane travel in Marblehead**

Waste Emissions

**The methodology to calculate the landfill and recycling emissions were taken from the

Recycling and Composting Emissions Protocol:
For Estimating Greenhouse Gas Emissions and Emissions Reductions Associated with Community Level Recycling and Composting
By the ICLEI—Local Governments for Sustainability USA

Landfill

Methane emissions for the Marblehead **landfill** =

= 21 * (1 – Default LFG collection) * (1 – oxidation rate) * total mass of waste entering landfill (wet short ton)) * Proportion of total waste material * emission factor for material ($mtCH_4$/wet short ton)

= 21 * (1- 0.0) * (1 – 0.10) * 4765.74 * 1 * 0.060 = 5404.3 $mtCO_2eq$

Overall $mtCO_2eq$ landfilled waste in Marblehead = 5404 $mtCO_2eq$

Recycling

**Values for the calculations of recycling emissions reductions from Tables A1 and A2 on page 32.

Diverted emissions by **recycling** outside the Marblehead community =
Ton of recycling in 2016 = 2498 tons

= (2497.84) * ((0.02+0.23+0.08+(-0.05)+(-0.48)+(-0.15)+(-2.45)))
= -6994 $mtCO_2eq$

A: Material	Emissions (+) or reductions (-)[v] from:		
	B: Transporting recyclables to market	C: Use of recycled materials in manufacturing processes, energy	D: Use of recycled materials in manufacturing processes, non-energy
Mixed Recyclables	0.02	0.23	0.08

Table A1 - Positive emissions from recycling. "Mixed Recyclables" was used for the Marblehead inventory because specific types of recyclables were not available.

A: Material	Emissions (+) or reductions (-)[vi] from:			
	B: Reduced transportation of virgin materials	C: Reduced use of virgin materials in manufacturing processes: energy	D: Reduced use of virgin materials in manufacturing processes: non-energy	E: Change in forest carbon flux due to paper and wood recycling[vii]
Mixed Recyclables	-0.05	-0.48	-0.15	-2.45
Aluminum Cans	-0.07	-7.37	-3.50	NA
Aluminum Ingot	-0.04	-4.24	-2.96	NA
Steel Cans	[illegible]	[illegible]	[illegible]	NA

Table A2 - Negative emissions from recycling. "Mixed Recyclables" was used for the Marblehead inventory because specific types of recyclables were not available.

Water and Wastewater Treatment

The water and wastewater treatment calculations were in-depth and included many emissions factors. Below is a summary of the values used for Marblehead in Table A3 on page 33, which acquires its water outside the boundary of the town and sends its wastewater out of the community as well. These values were taken from the U.S. Community Protocol
for Accounting and Reporting of Greenhouse Gas Emissions:
Appendix F: Wastewater and Water Emission Activities and Sources, Version 1.1, July 2013.

Table A3 - Data for Marblehead's water activities based on the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions: Appendix F: Wastewater and Water Emission Activities and Sources, Version 1.1, July 2013.

Energy-related Emissions from Water Distribution and Treatment		Energy-Related Emissions from Wastewater Collection and Treatment	
Data	Value	Data	Value

Population	19,808	Population	19,808
Per Capita Water Use	135 gal/day/capita	Per Capita Wastewater Generation	165 gal/day/capita
Groundwater Supplied (fraction of population served by groundwater)	0.236	Centralized Percentage	0.82
Surface Water Supplied (fraction of population served by surface water)	0.684	Percentage Served by Lagoons	0
Groundwater Extraction Energy Intensity	540 kWh/MG	Percentage Served by Attached Growth	0.01
Water Conveyance Energy Intensity	3000 kWh/MG	Percentage Served by Conventional Activated Sludge	0.43
Daily Flow to Treatment Plant	2.5 MGD	Percentage Served by NDN (nitrification or nitrification/denitrification)	0.37
Surface Water Treatment Energy Intensity	750 kWh/MG	Process Energy Intensity for Wastewater Collection	280 kWh/MG
Water Distribution Energy Intensity	540 kWh/MG	Process Energy Intensity for Wastewater Treatment by Lagoons	1150 kWh/MG
Electricity Emission Factors	1,528.76 lb CO2 eq./MWh (693.44 kg CO2 eq./MWh)	Process Energy Intensity for Wastewater Treatment by Attached Growth System	1500 kWh/MG
Conversion from gallons to million gallons (MG/gal)	0.000001	Process Energy Intensity for Wastewater Treatment by Conventional Activated Sludge Sample Calculation	2300 kWh/MG
Conversion from kWh to MWh (MWh/kWh)	0.001	Process Energy Intensity for Wastewater Treatment by NDN	3300 kWh/MG
Conversion from kg to MT (MT/kg)	0.001		
Days in a year	365.25	Days in a year	365.25

Figures A1 and A2 on page 34 are the equations from the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions: Appendix F: Wastewater and Water Emission Activities and Sources, Version 1.1, July 2013, pp. 99-100.

Figure A1 - Equations with example values for the energy and emissions associated with Water Distribution and Treatment

Annual CO_2e Emissions= Extraction + Conveyance + Treatment + Distribution	
Sample Calculation:	
Annual Groundwater Extraction Emissions	*= (50,000 x 145 x 365.25 x 0.39 x 0.000001 x 540 x 693.44 x 0.001 x 0.001)* *= **387 mtCO_2e***
Annual Groundwater and Surface Water Conveyance Supply Emissions	*= (50,000 x 145 x 365.25 x (0.39 + 0.35) x 0.000001 x 3000 x 693.44 x 0.001 x 0.001)* *= **4073 mtCO_2e***
Annual Surface Water Treatment Emissions	*= (50,000 x 145 x 365.25 x 0.35 x 0.000001 x 750 x 693.44 x 0.001 x 0.001)* *= **482 mtCO_2e***
Annual Groundwater and Surface Water Distribution Emissions	*= (50,000 x 145 x 365.25 x (0.39 + 0.35) x 0.000001 x 540 x 693.44 x 0.001 x 0.001)* *= **737 mtCO_2e***
Total Emissions from Residential Water Consumption	*= 387 + 4073 + 482 + 737* ***= 5679 mtCO_2e***

Figure A2 - Equations with example values for the energy and emissions associated with Wastewater Distribution and Treatment

Sample Calculation:

Annual Collection Emissions	*= (50,000 x 186 x 365.25 x 0.84 x 0.000001 x 280 x 693.44 x 0.001 x 0.001)* ***= 558 $mtCO_2e$***
Annual Wastewater Treatment Emissions	*= (50,000 x 186 x 365.25 x 0.000001 x ((0.04 x 1150) + (0.12 x 1500) + (0.58 x 2300) + (0.1 x 3300)) x 693.44 x 0.001 x 0.001)* ***= 4,451 $mtCO_2e$***
Total Emissions from Residential Wastewater Management Water Consumption	*= 558 + 4451* ***= 5,300 $mtCO_2e$***

Appendix B

Data Required for Future Reporting

Table B1. Sources and activities, which produce emissions. Highlighted options could be analyzed further in future GHG inventories (*Source: ICLEI p. 12).*	
In-boundary GHG Emissions Sources	**Activities Resulting in GHG Emissions**
Built Environment	
Use of fuel in residential and commercial stationary combustion equipment (e.g., boilers and furnaces)	Use of fuel in residential and commercial stationary combustion equipment (e.g., boilers and furnaces)
Industrial stationary combustion sources	
Power generating facilities	Use of electricity by the community.[i]
District heating or cooling facilities	**Use of district heating or cooling by the community**
Industrial processes	
Refrigerant and fire suppression leakage	
Transportation and Other Mobile Sources[ii, iii, iv, v]	
On-road passenger vehicles operating within the community boundary	On-road passenger vehicle travel associated with community land uses
On-road freight and service vehicles operating within the community boundary	On-road freight and service vehicle travel associated with community land uses
On-road transit vehicles operating within the community boundary	
Transit rail vehicles operating within the community boundary	**Use of transit rail travel by the community**

Inter-city passenger rail vehicles operating within the community boundary	
Freight rail vehicles operating within the community boundary	
Marine vessels operating within the community boundary	**Use of ferries by the community**
Off-road surface vehicles and other mobile equipment operating within the community boundary	
	Use of air travel by the community
Solid Waste	
Operation of solid waste disposal facilities	Generation and disposal of solid waste by the community
Wastewater and Water	
Operation of water delivery facilities	Use of energy associated with use of potable water
	Use of energy associated with generation of wastewater
Process emissions from operation of wastewater treatment facilities	Process emissions associated with generation of wastewater
Operation of septic systems	Use of septic systems by the community
Agricultural Livestock	
Domesticated animal production	
Manure decomposition and treatment	
Upstream Impacts of Community-Wide Activities	
	Upstream impacts of fuels used in stationary applications by the community
	Upstream and transmission and distribution (T&D) impacts of purchased electricity used [vi] by the community

	Upstream impacts of fuels used for transportation in trips associated with the community
	Upstream impacts of fuels used by water and wastewater facilities for water used and wastewater generated within the community boundary
	Upstream impacts of select materials (concrete, food, paper, carpets, etc.) used by the whole community. Note: Additional community-wide flows of goods & services will create significant double counting issues.

i

Emissions associated with the use of purchased electricity should include delineation of electricity used in stationary applications vs. transportation vehicles to the extent possible.

ii

Community refers to residents, businesses, industries, and government co-located within a defined jurisdiction. Across each mode, travel by members of the community often involves crossing the community boundary with a portion of travel occurring outside the community.

Quantifying emissions associated with the use of travel by the community generally involves estimating emissions associated with the entire length of in-boundary and trans-boundary trips, and allocating a portion of those emissions to the community for which emissions are being reported. See Chapter 3 for further detail.

iii

Vessels operating within the community boundary include docked or idling vessels.

iv

Emissions associated with use of travel by the community include energy used while vehicles are docked or charging.

v

Some communities with transportation hubs or ports may be interested in tracking emissions associated with fuel loaded into aviation,

marine, or rail vessels departing from those hubs or ports. These vessels often transport people and goods associated larger geographic regions, and often most of the fuel loaded into them is combusted outside the community boundary. These emissions are not included in Table 2 for these reasons, but local governments may choose to report on them in addition to the GHG sources and activities listed in Table 2.

vi

Upstream impacts of the use of purchased electricity can include consideration of associated transmission and distribution losses.

Appendix C

Marblehead Community GHG Emissions Report Summary Table

This appendix has a table of the types of data in this inventory and if the data is present or absent within the report. The list of Key Terms below highlights the different abbreviations in the table. This was modeled after the table in the ICLEI protocol.[35]

Key Terms

Legend for Reporting Frameworks Used Required Activities:

- Five Basic Emissions Generating Activities

Strongly Encouraged:

SI – Local Government Significant Influence

CA – Community-Wide Activities

HC – Household Consumption

Also Encouraged:

IB – In-Boundary Sources

GC – Government Consumption

FC – Full Consumption-based Inventory

LB – Life Cycle Emissions of Community Businesses

[35] U.S. Community Protocol for Accounting And Reporting Of GHG Emissions • Version 1.1 • July 2013 • ICLEI–Local Governments For Sustainability USA, P. 63.

IS – Individual Industry Sectors

OS – Create Your Own Story

Notation Keys for Excluded Emission Sources and Activities

IE – Included Elsewhere: Emissions for this activity are estimated and presented in another category of the inventory. The category where these emissions are included should be noted in explanation.

NE – Not Estimated: Emissions occur but have not been estimated or reported (e.g., data unavailable, effort required not justifiable).

NA – Not Applicable: The activity occurs but does not cause emissions; explanation should be provided.

NO – Not Occurring: The source or activity does not occur or exist within the community.

Emissions Type	Source or Activity?	Included, under reporting frameworks:		Excluded (IE, NA, NO, or NE)	Explanatory Notes (optional)
		SI	CA		
Built Environment					
Use of fuel in residential and commercial stationary combustion equipment	Source AND Activity	•	•		Commercial oil in progress
Industrial stationary combustion sources	Source			NO	No industrial facilities in the community

Electricity	Power generation in the community	Source	•		NE	Some solar, but this is a small source
	Electricity purchased and used by the community	Source AND Activity	•	•		
District Heating/ Cooling	District heating/cooling facilities in the community	Source			NE	
	Use of district heating/cooling by the community	Activity			NE	
Industrial process emissions in the community		Source			NO	No industrial facilities in the community
Refrigerant leakage in the community		Source			NE	No data available
Transportation and Other Mobile Sources						
On-road Passenger Vehicles	On-road passenger vehicles operating within the community boundary	Source	•	•		
	On-road passenger vehicle travel associated with community land uses	Activity	•	•		

On-road Freight Vehicles	On-road freight and service vehicles operating within the community boundary	Source	•	•		
	On-road freight and service vehicle travel associated with community land uses	Activity	•	•		
On-road transit vehicles operating within the community boundary		Source			NE	

Emissions Type		Source or Activity?	Included, Required Activities	Included, under reporting frameworks:		Excluded (IE, NA, NO, or NE)	Explanatory Notes (optional)
				SI	CA		
Transit Rail	Transit rail vehicles operating within the community boundary	Source				NE	
	Use of transit rail travel by the community	Activity				NE	Scoped to include, but no data available

Inter-city passenger rail vehicles operating within the community boundary		Source				NO	
Freight rail vehicles operating within the community boundary		Source				NO	
Marine	Marine vessels operating within the community boundary	Source				NE	
	Use of ferries by the community	Activity				NE	
Off-road surface vehicles and other mobile equipment operating within the community boundary		Source				NE	
Use of air travel by the community		Activity			•		Scope 3 SGEC tool calculated
Solid Waste							
Solid Waste	Operation of solid waste disposal facilities in the community	Source		•			We operate the landfill

	Generation and disposal of solid waste by the community	Activity	•			IE	Transportation within the community by service vehicles
Water and Wastewater							
Potable Water - Energy Use	Operation of water delivery facilities in the community	Source	•	•	•		
	Use of energy associated with use of potable water by the community	Activity	•	•	•		
Use of energy associated with generation of wastewater by the community		Activity	•	•	•		

Emissions Type	Source or Activity?	Included, Required Activities	Included, under reporting frameworks:	Excluded (IE, NA, NO, or NE)	Explanatory Notes (optional)

				SI	CA		
Centralized Wastewater Systems - Process Emissions	Process emissions from operation of wastewater treatment facilities located in the community	Source		•			
	Process emissions associated with generation of wastewater by the community	Activity			•		
Use of septic systems in the community		Source AND activity				NE	
Agriculture							
Domesticated animal production		Source				NE	
Manure decomposition and treatment		Source				NE	

Upstream Impacts of Community-Wide Activities						
Upstream impacts of fuels used in stationary applications by the community	Activity				NE	
Upstream and transmission and distribution (T&D) impacts of purchased electricity used by the community	Activity				NE	
Upstream impacts of fuels used for transportation in trips associated with the community	Activity		•	•		
Upstream impacts of fuels used by water and wastewater facilities for water used and wastewater generated within the community boundary	Activity				IE	Included in rows 32 and 33
Upstream impacts of select materials (concrete, food, paper, carpets, etc.) used by the whole community. Note: Additional community-wide flows of goods & services will create significant double counting issues.	Activity				NE	

Emissions Type	Source or Activity?	Included, Required Activities	Included, under reporting frameworks:		Excluded (IE, NA, NO, or NE)	Explanatory Notes (optional)
			SI	CA		
Independent Consumption-Based Accounting						
Household Consumption (e.g., gas & electricity, transportation, and the purchase of all other food, goods and services by all households in the community)	Activity				NE	To prioritize, we focused on Significant Influence and Community-wide Activities and not Consumption-Based
Government Consumption (e.g., gas & electricity, transportation, and the purchase of all other food, goods and services by all governments in the community)	Activity				NE	

Life cycle emissions of community businesses (e.g., gas & electricity, transportation, and the purchase of all other food, goods and services by all businesses in the community)	Activity				NE	