Marblehead Net Zero Roadmap Appendix B - Marblehead's Greenhouse Gas Inventory Methodology

The Town of Marblehead used the Metropolitan Area Planning Council's (MAPC) Community Greenhouse Gas Inventory Tool ("the Tool"). This technical documentation summarizes the inventory methodology used for the Tool and the supporting data sources for Marblehead's GHG Inventory. The inventory methodologies are described in detail by sector and subsector.

METHODOLOGY BASICS

The Tool is designed to enable communities in Massachusetts to complete a community-wide inventory that follows the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories ("Global Protocol") which was developed by the World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability and is required by The Global Covenant of Mayors for Climate and Energy (Global Covenant).[1]

EMISSION SECTORS AND SOURCES

The Tool accounts for emissions from the following sources, as required by the Global Protocol's BASIC level of reporting:

- Stationary energy use from residents, businesses and off-road equipment
- On-road private and public transportation and rail transportation
- Solid waste and wastewater disposal and treatment

As part of this process, DNV GL and MAPC assessed the possibility of including emissions from product use, industrial processes, and land-use. Due to the limited data availability for these activities, they were not included. Table 1 summarizes the sectors, sub-sectors, emissions sources and energy types included in the Tool.

SECTORS, SUB-SECTORS, EMISSIONS SOURCES AND ENERGY TYPES INCLUDED IN THE TOOL

Sector	Sub-sector	Emissions sources	Energy types
Stationary Energy	Residential Buildings	Energy use in residential buildings as well as losses from distribution systems	Electricity Natural gas Heating Fuel Oil Petroleum Products
	Commercial and & Institutional Buildings & Manufacturing Industries	Energy use in commercial, government, industrial and institutional buildings as well as losses from distribution systems	
	Construction	Energy use associated with construction activities	
	Energy Industries*	Stationary combustion of fuel in various equipment, such as boilers and generators.	Various – may include natural gas, propane, and diesel

[1] The Global Covenant of Mayor's for Climate and Energy is the new designation for the Compact of Mayors. The Compact of Mayors was launched by UN Secretary, C40 Cities Climate Leadership Group (C40), ICLEI – Local Governments for Sustainability (ICLEI) and the United Cities and Local Governments (UCLG) –with support from UN-Habitat, the UN's lead agency on urban issues.

Transportation	Transportation	All on-road vehicles Railways Off-road vehicles/equipment	Gasoline Diesel CNG Electricity
Waste	Solid Waste	Landfills Incineration of waste generated in the community	Landfill gas (methane)
	Wastewater	Process and fugitive emissions from treating wastewater	Not applicable

*Note: Reporting of Energy Industries emissions is not required under GPC BASIC reporting requirements. For this reason, Energy Industries emissions are included for informational purposes only

GEOGRAPHIC BOUNDARY

For the Tool, the administrative boundary for each community has been chosen as the geographic boundary for inventory purposes. Establishing this geographic boundary does not exclude emissions related to community activities that occur outside the community geographic limits (e.g. electricity generation or landfilled waste emissions).

INVENTORY YEAR

Marblehead used V4.2 of the Tool to develop the Town's inventory. V4.2 of the Tool is set up to quantify GHG emissions for an inventory year of 2017, based on the availability of public data sets. The Tool identifies the additional data sets that will need to be updated to quantify GHG emissions for a year other than 2017.

QUANTIFYING GREENHOUSE GAS EMISSIONS

All emissions in this inventory are quantified using activity-based methodologies, which calculate emissions using activity data from each sector and emission factors. To calculate emissions accordingly, the basic equation is:

Activity Data (units) x Emission Factor (MT of GHG / unit) = Emissions (MT GHG).

Activity data refer to the relevant measurement of energy use or other GHG-generating processes such as fuel consumption by fuel type, metered annual electricity consumption, and annual vehicle miles traveled. Known emission factors are used to convert energy usage or other activity data into associated quantities of GHG emissions. Emissions factors are usually expressed in terms of emissions per unit of activity data (e.g., metric tons of CO2 per kWh of electricity).

STATIONARY ENERGY – ELECTRICITY

DATA SUMMARY

Grid-supplied electricity is provided throughout each community and powers the residential, commercial, and industrial sectors, in addition to community infrastructure and many transport systems. Electricity consumption data were provided by the Marblehead Municipal Light Department.

The Global Protocol also requires accounting of losses from transmission and distribution systems. A Massachusetts-specific electricity transmission and distribution grid loss factor of 5.13% (for the year 2017) was calculated using guidance from the U.S. Energy Information Administration. The loss factor was

determined by dividing the state's estimated losses by the result of total disposition minus direct use. Direct use electricity is the electricity generated mainly at non-utility facilities and that is not put onto the electricity transmission and distribution grid, and therefore direct use electricity does not contribute to transmission and distribution losses. This data is provided by EIA in their state electricity profile for Massachusetts within Table 10: Supply and Disposition of Electricity.

For municipally-owned buildings and facilities, electricity consumption data were provided by the Town of Marblehead.

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

In accordance with Section 6.5 of the Global Protocol, the market-based approach for determining electricity emission factors was used in the Tool. The Global Protocol allows communities to use either a location-based or market-based approach to calculate emissions from grid-supplied electricity. The Tool includes default annual emissions factors for 2017 from MassDEP's GHG emissions reporting summaries.[2] Per guidance from DEP, and in accordance with the State's GHG inventory, the "Massachusetts-based approach" non-biogenic electricity emissions factor was used as the base assumption. CO2, CH4 and N2O electricity emission factors are provided in the DEP data.

Once the state-level default emission factor is determined, the Tool enables utility-specific adjustments to the electricity emission factors based on that utility's percent of total electricity sales reported to the DEP as non-emitting. Some utilities voluntarily report the percent of electricity sales from non-emitting resources to the DEP. If a utility voluntarily reports this information to the DEP, it is used as an input in the Tool to adjust the default State electricity emissions factor accordingly. If a utility does not voluntarily report this information to the DEP, the State average percent of electricity sales from non-emitting resources is used as a default in the Tool.

Reported emissions from all grid-supplied electricity consumed within the community boundary are reported as Scope 2 emissions. BASIC/BASIC+ reporting avoids double counting by excluding Scope 1 emissions from electricity generation supplied to the grid.

Communities with municipal aggregation programs have multiple electricity emission factors depending on the specific service offering (e.g., 5% Class I RECs, 50% Class I RECs, 100% Class I RECs). If a community has a municipal aggregation program, this data on the percent of Class I RECs by service offering is also used as an input in the Tool to adjust the default State electricity emissions factor.

STATIONARY ENERGY – NATURAL GAS

DATA SUMMARY

Grid-supplied natural gas is provided throughout most cities in Massachusetts and is primarily used by the residential, commercial, and industrial sectors for heat and hot water production. Natural gas is provided to communities either by an investor- owned utility (IOU) or through a municipal utility.

A majority of Massachusetts communities served by IOUs have access to aggregated community-wide natural gas consumption data through the MassSaveData website. For this reason, MassSaveData was used as the source for natural gas consumption data for most cities in the Tool. Natural gas consumption data from MassSave is broken out into two sectors – Residential and Commercial & Industrial.

[2] MassDEP. "Draft 2017 Greenhouse Gas (GHG) Emission Factors to be used by Retail Sellers of Electricity Reporting under 310 CMR 7.71(9) 'Reporting Requirements for Retail Sellers of Electricity." 2019. https://www.mass.gov/files/documents/2019/05/30/rsef17-tsd.pdf

The Global Protocol also requires accounting of losses from distribution systems. Based on an assessment of several studies that have been done on the subject of gas leakage from the distribution system network in and around the Boston, the Tool uses an average leakage rate of 2.7%. According to the Harvard study in the Boston area, 2.7%[3] is the average fractional loss rate of natural gas to the atmosphere from all downstream components of the natural gas system, including transmission, distribution, and end use.

For municipally-owned buildings and facilities, natural gas consumption data were provided by the Town of Marblehead.

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

In accordance with Section 6.3 of the Global Protocol, real consumption data for each fuel type, disaggregated by sector was used for the inventory. Reported emissions from the usage of natural gas within the community's boundaries were reported as Scope 1 emissions. A universal emission factor provided by The Climate Registry was used to calculate natural gas emissions.[4]

TABLE A1: NATURAL GAS COMBUSTION EMISSIONS RATE

Type of Emission	CO2 Emission Factor (kg CO2 / MMBtu)	CO2 Emission Factor (MT CO2 / Therm)	Source
Natural Gas Consumption	53.06	0.0053	TCR

*Note CH4 or N2O are not included because these emissions are considered to be de minimis

Methane (CH4) emissions associated with distribution system leakage is also accounted for in the Tool. The total CO2 equivalent (CO2e) emissions factor for fugitive emissions from natural gas leakage was determined based on:

- Volume of natural gas per heat energy (m3 gas/therm gas)
- A density value of natural gas of 0.7 kg/m3 based on values provided in the GHG Protocol stationary combustion tool
- The IPCC Tier 1 default for the mass fraction of methane in delivered natural gas (93.4%)
- A carbon dioxide content of 1.0% in the delivered natural gas

The overall emissions factor was then calculated to be 0.0518 MT CO2e/leaked therm.

STATIONARY ENERGY – FUEL OIL

DATA SUMMARY

Residential Buildings

[3] McKain, Et al., 2014. "Methane emissions form natural gas infrastructure and use in the urban region of Boston, Massachusetts." https://www.pnas.org/content/pnas/112/7/1941.full.pdf

[4] 2015 Climate Registry Default Emissions Factors, released April 2015

For the Tool, residential oil usage data was based on the number of housing units in each community by type from the 2017 American Community Survey (ACS), and a percentage of units determined to be heated with fuel oil from the 2017 ACS. The property types identified were:

- Single-Family, Detached
- Single-Family, Attached
- Multi-Family, 2-4 Units
- Multi-Family, 5+ Units
- Mobile Homes

The average residential site fuel oil consumption by property type in Massachusetts was estimated using data from the U.S. Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) on the average fuel oil consumption by property type and percent of total housing units by residential building type in the U.S., the number of housing units in Massachusetts by property type in Massachusetts, and the average fuel oil consumption averaged across all residential building types in Massachusetts. National-level and state-level data was used in places where community- level data was not available. This combination of national-level, state-level and community-level data was used to estimated annual fuel oil consumption by property type in the community.

Commercial Buildings

For the Commercial sector, fuel oil use estimates were based on the total number of employees and total number establishments by Primary Building Activity (PBA) in each community and the average expected energy use per employee in the Northeast region. The Executive Office of Labor and Workforce Development (EOWLD) ES-202 Employment and Wages Survey lists the number of employees and establishments by industry for each community, sorted by North American Industry Classification System (NAICS) codes.[5] The EIA 2012 Commercial Building Energy Survey (CBECS) analyzes energy use and consumption data per employee in the northeast based on Primary Building Activity (PBA). Table A2 below (generated by EIA) correlates the PBA codes used in CBECS with standard three-digit NAICS codes.

TABLE A2: COMMERCIAL PRIMARY BUILDING ACTIVITY (PBA) NORTH AMERICAN INDUSTRY CLASSIFICATION SYSTEM (NAICS) CODES

PBA	NAICS Code (3-digit)
Education	611
Food Sales	445
Food Service	722
Inpatient Health Care	622
Lodging	623,721
Office	454, 481, 511, 516, 517, 518, 519, 521, 522, 523, 524, 525, 531, 533, 541, 551, 561, 624, 921, 923, 924, 925, 926, 928
Other	562, 927
Outpatient Health Care	621

[5] Executive Office of Labor and Workforce Development. "EOWLD ES-292 Employment and Wages Survey" http://lmi2.detma.org/lmi/ lmi_es_a.asp

Public Assembly	482, 485, 487, 512, 515, 711, 712, 713
Public Order/ Safety	922
Religious Worship	813
Retail (Mall)	446, 448
Retail (Non-mall)	441, 442, 443, 444, 451, 452, 453, 532
Service	447, 483, 484, 488, 491, 492, 811, 812
Warehouse/Storage	423, 424, 493

Fuel oil consumption by building type was not available for all PBAs but natural gas use for all PBAs was available. For these building types, a comparison between average fuel oil use to average natural gas use in the same building types was used, using Office buildings as a baseline. So, for example, if a specific PBA that uses natural gas uses 50% more natural gas than an Office building using natural gas, the analysis assumes that if the same PBA used fuel oil, it would use 50% more fuel oil than an Office building. This is the preferred method, as it yields a more conservative estimate.

Industrial Buildings

For the industrial sector, data was collected similarly to commercial data. Fuel oil use estimates were based on the total number of employees and total number of establishments by PBA in each community and the average expected energy use per employee in the Northeast region. The EOWLD ES-202 Employment and Wages Survey lists the number of employees and establishments by industry for each community, sorted by NAICS codes.[6] The EIA 2014 Manufacturing Energy Consumption Survey (MECS) analyzes energy use and consumption data based on PBA. Table A3 below (generated by EIA) correlates the PBA codes used in MECS with standard three-digit NAICS codes. Industrial energy uses between 100 and 200 (such as power generation and utility operations) were not incorporated in this methodology.

TABLE A3: INDUSTRIAL NAICS CODES

PBA	NAICS Code (3-digit)
Apparel	315
Beverage and Tobacco Products	312
Chemicals	325
Computer and Electronic Products	334
Electrical Equip., Appliances, and Components	335
Fabricated Metal Products	332
Food	311
Furniture and Related Products	337
Leather and Allied Products	316
Machinery	333

[6] Executive Office of Labor and Workforce Development. "EOWLD ES-292 Employment and Wages Survey" http://lmi2.detma.org/lmi/ lmi_es_a.asp

Miscellaneous	339
Nonmetallic Mineral Products	327
Paper	322
Petroleum and Coal Products	324
Plastics and Rubber Products	326
Primary Metals	331
Printing and Related Support	323
Textile Mills	313
Textile Product Mills	314
Transportation Equipment	336
Wood Products	321

For municipally-owned buildings and facilities, natural gas consumption data were provided by the Town of Marblehead. Fuel oil is manually entered into MEI on an annual basis for Green Communities reporting. For those communities not participating in the Green Communities program, municipal government will have to work with internal departments or heating oil companies to determine the total fuel oil consumption associated with municipally-owned buildings and facilities in a given calendar year.

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

In accordance with Section 6.3 of the Global Protocol, and as detailed above, a collection of representative consumption surveys, modelled energy consumption, and regional and national fuel consumption data was used to properly characterize fuel oil consumption in each community within the Tool. Reported emissions from the usage of fuel oil within each community's boundaries were reported as Scope 1 emissions. Universal emission factors provided by the U.S. Environmental Protection Agency (EPA) was used to calculate fuel oil emissions.

TABLE A4: FUEL OIL COMBUSTION EMISSIONS RATES

Type of Emission	CO2 Emission Factor (MT CO2 / MMBtu)	CH4 Emissions Factor (MT CH4 / MMBtu)	N2O Emissions Factor (MT N2O / MMBtu)	Source
Fuel Oil Combustion (Distillate Fuel Oil #2)	0.07396	0.000003	0.0000006	EPA

STATIONARY ENERGY – OFF-ROAD VEHICLES AND EQUIPMENT

DATA SUMMARY

The off-road data is derived from a publicly available U.S. EPA emission modeling system called the Motor Vehicle Emission Simulator (MOVES). MOVES estimates emissions for mobile non-road sources at the national and county level for criteria air pollutants, greenhouse gases, and air toxics. The Tool is designed to take county-level off-road emissions data for each county and apportion it to individual communities based on a proportionality multiplier.

The MOVES2014b modeling tool multiplies equipment population, average load factor expressed as an average fraction of available power, available power in horsepower, hours of use per year, and emission factors with deterioration and/or new standards. Emissions are then temporally and geographically allocated using appropriate allocation factors. This produces emissions estimates attributable to many non-road activities but does not include aircraft, commercial marine vessels, or rail, which are the primary non-road transportation sources contributing to GHG emissions.

Table A5 summarizes the methodologies used for each of the off-road emission sources.

TABLE A5: OFF-ROAD EMISSIONS SOURCES AND METHODOLOGIES

Off-Road Mobile Emission Source	Proportionality Multiplier Source	Category
Industrial Equipment	Manufacturing Jobs	Manufacturing Industries
Lawn and Garden Equipment	Square Feet of Developed Open Space	Comm. & Inst. Buildings
Light Commercial Equipment	Total Jobs Excluding Manufacturing Jobs	Comm. & Inst. Buildings
Construction Equipment	Square Feet of Commercial Development Under Construction	Construction

Data on manufacturing employment and total employment at both the community and county level is derived from the U.S. Census. MAPC generated a supporting dataset on square feet of developed open space by municipality and county from the 2016 Land Cover / Land Use data set produced by MassGIS. Aggregated data from CoStar was used to determine square feet of commercial development under construction by municipality and county.

GPC QUANTIFICATION METHOD USED

In accordance with Section 6.3 and 7.7 of the Global Protocol, the community-wide inventory used the modeling tool MOVES2014b data, disaggregated by sub-sector. Emissions factor modeling parameters in MOVES2014b were developed and used to produce emissions factors and the emissions outputs were restricted to county-level geographic bounds, the smallest subdivision possible in the model.

STATIONARY ENERGY – ENERGY INDUSTRIES

DATA SUMMARY

Data on emissions generation by the energy industry for each community was provided by the EPA's Greenhouse Gas Reporting Program (GHGRP). All facilities included in the database, excluding landfills that do not generate electricity, are included in the Tool. These facilities are required to report biogenic CO2 emissions and CO2 emissions excluding biogenic CO2 separately.

For co-generation power plants, if the electricity generated from these facilities is consumed directly within the community (e.g. co-generation facility at large business or university), the emissions from this power plant should be captured under BASIC/BASIC+ GPC reporting guidelines. The natural gas consumption and associated emissions required to generate electricity at these power plants is captured in the utility data used to calculate emissions from the Stationary Energy: Buildings sector and included in the total reported emissions. Therefore, the EPA data on emissions associated with each co- generation facility is provided for informational purposes only.

For traditional power plants without co-generation, all electricity produced is sent directly to the regional electrical grid. This energy is part of the regional electricity mix and consumed by all communities that use electricity from the regional grid.

For this reason, the direct emissions from these power plants should not be captured under BASIC/BASIC+ GPC reporting guidelines. In other words, the emissions from these power plants are dispersed across the region instead of solely being attributed to the community in which the power plant is physically located. The emissions are captured in the Tool as part of the regional electricity emission factor that influences Scope 2 emissions from electricity consumption associated with the regional grid.

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

For the reasons stated in the data summary above, emissions from this subsector are not quantified to avoid double counting.

TRANSPORTATION – ON-ROAD PASSENGER AND COMMERCIAL VEHICLES

DATA SUMMARY

At the time of releasing the Tool, 2014 was the most recent year of complete and accurate data available from the Massachusetts Registry of Motor Vehicles as they transition to a new system for storing their data. Communities should use more recent years as they become available in the future.

The private on-road vehicle data is derived from the Massachusetts Vehicle Census (MAVC)[7], which is a catalog of information about vehicles registered in the Commonwealth from 2009 to 2014 developed by MAPC. The MAVC combines information from vehicle registrations, inspection records, mileage ratings, and other sources to document the ownership and mileage history of each vehicle (Massachusetts Vehicle Census v.3, 2009 – 2014 Technical Documentation October 10, 2016).

In the context of the Tool, the MAVC provides counts of the number of vehicles garaged in each municipality broken out by passenger and commercial vehicles and by fuel type. Fuel types included gasoline, diesel, flex fuel, hybrid, and electric. In addition to counts, the MAVC provides average vehicle miles travelled (VMT) and average fuel efficiency of vehicles. The MAVC data for 2009 to 2014 include commercial vehicle fleets and rental cars but do not include municipally-operated vehicles, such as police cars or school buses.

TABLE A6: DETAILED ATTRIBUTES REPORTED FOR ON-ROAD VEHICLES GARAGED IN MASSACHUSETTS

Attribute	Details
Count	Total vehicles, based on the municipality where the vehicle is garaged. For the Inventory Tool, counts are tabulated by vehicle type (non-commercial passenger vehicles and commercial vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid, and electric).
Count of Vehicles with Valid Mileage Estimate and Fuel Economy Rating	Total vehicles that have a valid mileage estimate and drive less than 200 miles per day, based on the municipality where the vehicle is garaged, and have a valid fuel economy rating. As with the overall count, counts for vehicles with a valid mileage estimate and fuel economy rating are tabulated by vehicle type (non-commercial passenger vehicles and commercial vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid, and electric).

[7] https://www.mapc.org/learn/data/#vehiclecensus

Average Daily Vehicle Miles Travelled (DVMT) by Fuel Type	Average daily mileage for vehicles with a valid mileage estimate and fuel economy rating. Calculated by vehicle type (non-commercial passenger vehicles and commercial vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid, and electric).
Average Fuel Economy Rating (mpg) by Fuel Type	Average fuel economy rating for vehicles with valid mileage estimates, weighted by average daily mileage. Calculated as total estimated fuel consumption (gallons/day) for vehicles with valid mileage estimates and fuel economy ratings, divided by total daily miles for same vehicles. Calculated by vehicle type (non-commercial passenger vehicles and commercial vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid, and electric).

TABLE A7: VEHICLE DATA COLLECTED FROM MASSENERGYINSIGHT

Type and Use	Unit
Municipal Vehicle Fleet Gasoline	Gallons
Municipal Vehicle Fleet Diesel	Gallons

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

In accordance with Section 7.3 of the Global Protocol, the resident activity method was used to quantify on-road transportation emissions. This method quantifies emissions from transportation activity undertaken by community residents and businesses that garage their vehicles in the community.

Universal emission factors were used to calculate gasoline and diesel emissions. Because electric vehicles registered in one community may charge in multiple communities, the average electricity emission factor of Eversource & NGRID was used to approximate emissions associated with charging electric vehicles.

TABLE A8: PRIVATE ON-ROAD VEHICLES EMISSIONS FACTORS

Fuel Type	Emission Factor	Emission Factor Units	Source
Gasoline	0.00878	MT CO2e / gallon	TCR
Diesel	0.01021	MT CO2e / gallon	TCR
Electricity	0.000225813	MT CO2 / kWh	Eversource & NGRID Average

TRANSPORTATION – PUBLIC ON-ROAD AND RAIL-BASED TRANSPORTATION

DATA SUMMARY

Public transportation, consisting of buses, rapid transit, and commuter rail, spans the on-road and rail-based transportation subsectors. For on-road and rail-based public transportation in Greater Boston, the Tool uses consumption and route data provided by the MBTA. At the time of publishing for the Tool, the MBTA only had access to system-wide fuel and electricity consumption data. MAPC, therefore, developed a method to allocate system-wide totals to individual municipalities using route length and route frequency. The specifics of the calculations MAPC used to produce the supporting MBTA data set used in the Tool are

provided in the supporting technical documentation for the Tool.[8] The calculations produce an estimated number of annual vehicle miles travelled that is based on the length and frequency of routes that take place within the geographic boundary of the inventory. These annual vehicle miles travelled are used to portion out the system-wide fuel and electricity consumption data to each respective municipality.

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

Trackless trolley and bus emissions were calculated in accordance with Section 7.3 of the GPC. Heavy rail, light rail, and commuter rail emissions were quantified in accordance with Section 7.4 of the GPC.

Universal emission factors provided by The Climate Registry were used to calculate gasoline and diesel emissions. Because electricity used in public transportation spans across multiple communities, the average electricity emission factor of Eversource & NGRID was used to approximate emissions associated with electricity consumption in public transportation vehicle.

TABLE A9: PUBLIC TRANSIT EMISSIONS FACTORS

Fuel Type	Emission Factor	Emission Factor Units	Source
Diesel	0.01021	MT CO2e / gallon	TCR
CNG	0.05294	MT CO2e / MMBTU	TCR
Electricity	0.000225813	MT CO2 / kWh	Eversource & NGRID Average

WASTE – SOLID WASTE DISPOSAL & INCINERATION

DATA SUMMARY

For most communities in Massachusetts, solid waste is collected through a combination of a municipal curbside-pick up and private waste haulers. To calculate the emissions associated with solid waste, information is needed on the amount of solid waste collected from residents and businesses as part of the curbside pickup, as well as the amount of solid waste collected by private haulers. Information on where the MSW is disposed of (landfill or incineration facility) is also needed. Marblehead collected data on total tons of municipal solid waste collected in 2017. Nearly 100% of Marblehead's municipal solid waste is sent to landfill.

The amount of methane generated by landfilled waste is highly dependent on the amount of degradable organic carbon in the landfilled waste. To determine the amount of organic carbon in landfilled waste, communities can provide data from a community-specific waste characterization study. If community does not have this information, the Tool assumes the State- level waste composition based on data from MA DEP's Summary of Waste Combustor Class II Recycling Program Waste Characterization Studies. The waste subcategories from the Massachusetts waste composition study (e.g. "Waxed Cardboard") were mapped to the GPC waste categories (e.g. "Paper") in order to use the appropriate Global Protocol equations to calculate emissions from landfilled and incinerated waste. See Table A10 below for default State waste composition data and the corresponding Global Protocol categories.

TABLE A10: OVERALL MASSACHUSETTS WASTE COMPOSITION BY DETAILED MATERIAL CATEGORY MAPPED TO GLOBAL

[8] http://www.mapc.org/wp-content/uploads/2020/03/04102020_MAPC-Step-by-Step-GHG-Inventory-Guide.pdf

Protocol Waste Categories Waste Category/Sub-category	Weighted Average	Global Protocol Waste Category
Paper		
Uncoated Corrugated Cardboard/Kraft Paper	9.2%	Paper
Waxed Cardboard	0.3%	Paper
High Grade Office Paper	0.5%	Paper
Magazines/Catalogs	0.8%	Paper
Newsprint	0.7%	Paper
Other Recyclable Paper	3.6%	Paper
Compostable Paper	5.8%	Paper
Remainder/Composite Paper	0.7%	Paper
Plastic		
PET Beverage Containers (non-MA deposit containers)	0.7%	Other
PET Containers other than Beverage Containers	0.2%	Other
Plastic MA Deposit Beverage Containers	0.1%	Other
HDPE Bottles, colored and natural	0.4%	Other
Plastic Tubs and lids (HDPE, PP, etc.)	0.4%	Other
Plastic Containers #3-#7 (which originally contained non-hazardous material)	0.5%	Other
Expanded Polystyrene Food Grade	0.4%	Other
Expanded Polystyrene Non-food Grade	0.2%	Other
Bulk Rigid Plastic Items	1.6%	Other
Film (non-bag clean commercial and industrial packaging film)	0.5%	Other
Grocery and other Merchandise Bags	0.5%	Other
Other Film means plastic film	4.9%	Other
Remainder/Composite Plastic	2.8%	Other
Metal		
Aluminum Beverage Containers (non-MA deposit containers)	0.0%	Other
Aluminum MA Deposit Beverage Containers	0.1%	Other
Tin/Steel Containers	0.6%	Other
Other Aluminum	0.3%	Other
Other Ferrous and non-ferrous	0.8%	Other
White Goods	0.2%	Other
Remainder/Composite Metal	1.6%	Other
Glass		

Glass Beverage Containers (non-MA deposit containers)	0.5%	Other
Other Glass Packaging Containers (non-MA deposit containers)	0.3%	Other
Glass MA Deposit Beverage Containers	0.3%	Other
Remainder/Composite Glass	0.4%	Other
Organic Materials		
Food Waste	26.0%	Food
Branches and Stumps	0.1%	Garden Waste and Plant Debris
Prunings, Trimmings, Leaves and Grass	2.5%	Garden Waste and Plant Debris
Manures	0.1%	Garden Waste and Plant Debris
Remainder/Composite Organic	2.6%	Garden Waste and Plant Debris
Construction and Demolition (in the MSW stream)		
Asphalt Pavement, Brick, and Concrete	0.1%	Other
Aggregates, Stone, Rock	0.4%	Other
Wood – Treated	5.7%	Wood
Wood – Untreated	2.0%	Wood
Asphalt Roofing	0.3%	Other
Drywall/Gypsum Board	0.6%	Other
Carpet and Carpet Padding	3.3%	Other
Remainder/Composite Construction and Demolition	2.6%	Other
Household Hazardous Waste		
Ballasts, CFLs, and Other Fluorescents	0.0%	Other
Batteries – Lead Acid	0.0%	Other
Batteries – Other	0.0%	Other
Paint	0.1%	Other
Bio-Hazardous	3.3%	Other
Vehicle and Equipment Fluids	0.1%	Other
Empty Metal, Glass, and Plastic Containers	0.1%	Other
Other Hazardous or Household Hazardous Waste	0.2%	Other
Electronics		
Computer-related Electronics	0.2%	Other
Other “brown goods”	0.7%	Other
Televisions and Computer Monitors	0.2%	Other

Other Materials		
Tires and other rubber	0.7%	Other
Textiles	5.8%	Textiles
Bulky Materials	0.9%	Other
Mattresses	0.1%	Other
Restaurant Fats, Oils and Grease	0.1%	Food
Other Miscellaneous	1.0%	Other
Total	100%	

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

Landfilled Waste

Solid waste sent to landfills produces methane (CH_4). For waste sent to landfills, methane emissions were calculated using Global Protocol Equations 8.1, Equation 8.3, and Equation 8.4.

- Equation 8.1 is used to calculate the total degradable organic carbon (DOC) in the landfilled waste based on the fraction of landfilled waste that is food, garden waste and other plant debris, paper, wood, textiles, and industrial waste.
- Equation 8.4 uses the DOC estimate derived from Equation 8.1 to calculate the overall methane generation potential of the waste sent to landfill. Equation 8.4 assumes a methane correction factor of 1.0 because landfills in Massachusetts are actively managed, assumes a default GPC input of 0.6 for the fraction of degradable organic carbon degraded variable, assumes a default GPC input of 0.5 for the fraction of methane in landfill gas, and uses the DOC variable calculated in Equation 8.1.
- GPC Equation 8.3 uses the total mass of waste sent to landfill, the methane generation potential of the waste calculated in GPC Equation 8.3, a GPC default fraction of methane recovered at landfills of 0 and a default oxidation factor of 0.1 because landfills in Massachusetts are actively managed. The methane generation potential of waste sent to landfill calculated by GPC Equation 8.4 is used to calculate the overall methane commitment for solid waste sent to landfill in GPC Equation 8.3.

Incinerated Waste

Solid waste that is incinerated produces methane (CH4), nitrous oxide (N2O) and carbon dioxide (CO2). GHG emissions from incineration of municipal solid waste are calculated using Global Protocol Equation 8.6, Equation 8.7, and Equation 8.8. Emissions generated as a result of incineration out of community boundaries is considered Scope 3 emissions.

- Equation 8.8 is used to calculate the N2O emissions from waste incineration using the mass of waste incinerated, the percent of waste in each organic material category, and the default N2O emission factor for municipal solid waste from Global Protocol Table 8.6.
- Equation 8.7 is used to calculate the CH4 emissions from waste incineration using the mass of waste incinerated, the percent of waste in each organic material category, and the default CH4 emission factor for continuous incineration: stoker from Global Protocol Table 8.5.
- Equation 8.6 is used to calculate the non-biogenic CO2 emissions from waste incineration using the mass of waste incinerated, the percent of waste in each organic material category, and the

default values from Global Protocol Table 8.4 on dry matter content by material type, fraction of fossil fuel carbon in each material type, and oxidation factor.

The emissions factors associated with solid waste disposal and incineration are embedded in the assumptions in the Global Protocol equations used to calculate emissions from landfilled waste (Equations 8.1, 8.2 and 8.4) and the Global Protocol equations used to calculate emissions from incinerated waste (Equations 8.6, 8.7 and 8.8). See Global Protocol Quantification Method Used section directly above for explanations on assumptions used in those equations.

WASTE – BIOLOGICAL TREATMENT

DATA SUMMARY

To calculate the emissions associated with biological treatment, information is needed on the amount of separated organic waste collected in the community from residents and businesses as part of the curbside pickup, as well as the amount of separated organic waste collected by private haulers. Information on where the separated organic waste is disposed of (compositing facility or anaerobic digestion facility) is also needed. Data on the total weight of separated organic waste collected that is destined for composting or anaerobic digestion must be provided by individual municipal waste collection programs and individual private haulers.

If a community knows the percent of their collected separated organic material that is sent to a composting facility versus an anaerobic digestion facility, they can enter that data into the Tool. If a community does not have this information, the Tool assumes the State-level percent of disposed separated organic material sent to composting (50.0%) and anaerobic digestion (50.0%).

For the Town's 2017 inventory, the Town of Marblehead sent two tons of food waste to compost.

GPC QUANTIFICATION METHOD USED

Compositing of separated organic material produces nitrous oxide (N2O) and methane (CH4), while anaerobic digestion of separated organic material produces only methane (CH4). Global Protocol Equation 8.5 is used to calculate emissions from both composting and anaerobic digestion and uses the mass of organic waste treated by each treatment type, the default CH4 emission factor from Global Protocol Table 8.3 based on treatment type, the default N2O emission factor from Global Protocol Table 8.3 based on treatment type, and the estimated percentage of CH4 that is recovered at each facility. Compositing facilities in Massachusetts do not have CH4 recovery, while anaerobic digestion facilities have 100% CH4 recovery.

The emissions factors associated with biological treatment of separated organic material are embedded in the assumptions in the Global Protocol Equation 8.5 used to calculate emissions from compositing and anaerobic digestion facilities. See Global Protocol Quantification Method Used section directly above for explanations on assumptions used in those equations.

WASTE – WASTEWATER

DATA SUMMARY

Data used to estimate wastewater emissions in communities served by the Massachusetts Water Resources Authority (MWRA) uses a combination of default values from the EPA and the GPC and data on methane recovery rates at MWRA facilities. Data used to estimate wastewater emissions in communities not served

by the MWRA uses data from the Massachusetts Department of Environmental Protection (DEP) "Statewide Greenhouse gas Emissions Level: 1990 Baseline and 2020 Business as Usual Projection Update" report.

GLOBAL PROTOCOL QUANTIFICATION METHOD USED

Indirect nitrous oxide (N2O) emissions from wastewater effluent and CH4 generation emissions from wastewater treatment were calculated using the methodology outlined in the Massachusetts Department of Environmental Protection (DEP) "Statewide Greenhouse gas Emissions Level: 1990 Baseline and 2020 Business as Usual Projection Update" report. This methodology is in compliance with methodologies recommended by the Global Protocol. Communities that are not served by an MWRA wastewater treatment plant do have some methane emissions associated with wastewater treatment because methane capture and co-generation systems are not in place.

The Massachusetts DEP equation for calculating methane (CH4) emissions includes the total population served by the wastewater treatment plant, total statewide CH4 emissions from municipal wastewater treatment, and the total State population not served by MWRA. The general approach is to use that State's data on total methane emissions from wastewater treatment (13,706 MT CH4/year) and the total State population not served by MWRA (4,279,130 people) to determine a per capita wastewater treatment methane emissions factor (0.003203 CH4/year/capita) that can be used by all Massachusetts cities not served by MWRA to estimate CH4 emissions from wastewater treatment.

The Massachusetts DEP equation for calculating nitrous oxide (N2O) emissions includes the total population served by the wastewater treatment plant, total statewide N2O emissions from municipal wastewater treatment, and the total State population not served by MWRA. The general approach is to use that State's data on total nitrous oxide emissions from wastewater treatment (308.4 MT N2O /year) and the total State population not served by MWRA (4,279,130 people) to determine a per capita wastewater treatment methane emissions factor (0.000072 N2O /year/capita) that can be used by all Massachusetts cities not served by MWRA to estimate N2O emissions from wastewater treatment.

For the portion of the population served by an MWRA wastewater treatment plant (Clinton, Deer Island, Greater Lawrence, Pittsfield, Rockland) indirect nitrous oxide emissions from wastewater effluent were calculated using GPC Equation 8.11. For these MWRA facilities, no methane is released from the treatment process. Methane is captured and diverted to co-generation systems where it is used to heat buildings and generate electricity via steam turbine generators. Equation 8.11 include the total community population served by the wastewater treatment plant, the annual per capita protein consumption provided by the EPA, and the default Global Protocol factors for adjustment of non-consumed protein, fraction of nitrogen in protein, factor for industrial and commercial co-discharged protein into the sewer system, nitrogen removed from sludge, and emissions factor for N2O emissions from discharged wastewater. Emissions generated as a result of methane capture and co-generation occurring outside of a community's boundary are considered Scope 3 emissions.

According to the Global Protocol, wastewater used to generate energy is considered a stationary energy source. Stationary energy sources outside of each community's boundary are not included in the inventory.