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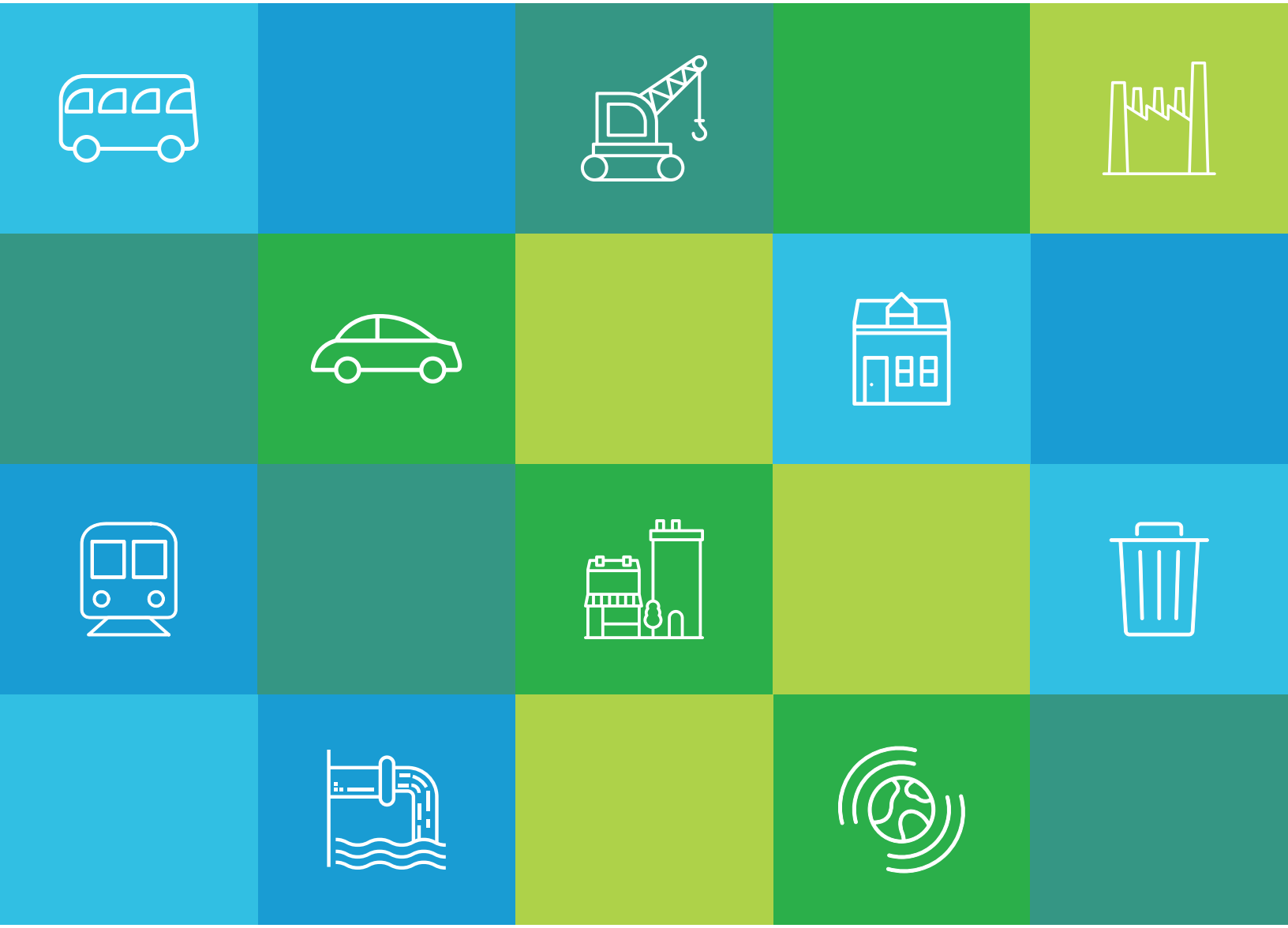
A **STEP**-BY-**STEP** GUIDE

Greenhouse Gas Inventories for Massachusetts Cities & Towns

A companion document to MAPC's Community Greenhouse Gas Inventory Tool



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Acronym Key

The following acronyms will be used frequently throughout the guide. Terms will be defined upon first use.

CNG – Compressed Natural Gas

CO2 – Carbon Dioxide

CO2e – Carbon Dioxide Equivalent

EPA – Environmental Protection Agency

GHG – Greenhouse Gas

GPC – Global Protocol for Community-Scale Greenhouse Gas Inventories (also referred to as Global Protocol)

kWh – kilowatt hour

IOU – Investor Owned Utility

ISO – Independent System Operator

MassDEP or DEP – Massachusetts Department of Environmental Protection

MAVC – Massachusetts Vehicle Census

MEI – MassEnergyInsight

MOVES – Motor Vehicle Emission Simulator

MPG – Miles Per Gallon

MT – Metric Ton

MWRA – Massachusetts Water Resources Authority

NAICS – North American Industry Classification System

RTA – Regional Transit Authority

VMT – Vehicle Miles Travelled

INTRODUCTION TO THE GUIDE

This guide will help you and your community to develop data-informed climate action plans. Using this guide, you will be able to identify and target the largest sources of local greenhouse gas ("GHG") emissions. This guide was created by the Metropolitan Area Planning Council ("MAPC") and DNV GL Energy Services, Inc., ("DNV GL") to simplify and streamline the process for Massachusetts cities and towns to create local GHG inventories.

This guide will provide you with:

1. A consistent and Massachusetts-specific approach to calculating greenhouse gas emissions from the primary sources of emissions in your community.
2. Instructions on where to collect local activity data and how to estimate activity where actual data is not readily available.
3. Guidance on how to use MAPC's Community Greenhouse Gas Inventory Tool for accounting and tracking your community's GHG emissions over time.

This guide was designed to provide a brief overview of the need-to-know basics of developing a community GHG inventory. It includes instructions on where to find state and local sources to increase the accuracy and relevance of GHG inventory data, and a process for using the tool to establish a GHG inventory baseline and update these data on a regular basis to inform local planning and implementation efforts. This guide should be used to support use of MAPC's Community Greenhouse Gas Inventory Tool ("the Tool").

This guide was created with municipal staff and volunteers in mind as the primary users. A basic working knowledge of Excel spreadsheets and experience managing small- to medium-sized datasets will be useful to fully leverage the Tool for your community's GHG inventory. You will need to be able to answer questions about services and programs that your municipality participates in that relate to the different sources of GHG emissions covered by the Tool.

We recommend having a copy of the Global Protocol for Community-Scale Greenhouse Gas Inventories ("Global Protocol") on hand while reviewing the guide and using the Tool. You do not need the Global Protocol to complete a GHG inventory using the Tool, but some users may find it helpful to reference the methods and calculations. All the primary methods used come from this resource, and specific sections of the Global Protocol will be referenced throughout this guide to connect users to additional background on the calculations used in the Tool.

Download the Global Protocol at
https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities

Project Background

This guide and the accompanying Tool were developed as a part of MAPC's *Planning for Net Zero by 2050 project*. This project seeks to create a suite of resources for Massachusetts cities and towns to set ambitious climate goals and create plans to take action. This project was funded by the Executive Office of Energy and Environmental Affairs and match funds from the project partners (MAPC, DNV GL, City of Melrose, Town of Arlington, and Town of Natick). The first version of the tool, published in 2020, was for a 2017 inventory year. This version, published in 2025, is for a 2022 inventory year.

STEP 1
COVER THE BASICS

A greenhouse gas ("GHG") inventory can be developed to guide the actions of local decision-makers and municipal staff and focus work to reduce GHG emissions in their community. A GHG inventory provides a baseline from which to measure progress against and a method for benchmarking the effectiveness of local climate mitigation programs and policies. The data produced provides a local understanding of how residents, businesses, and municipal operations contribute to the community's GHG emissions footprint.

Establishing a robust GHG inventory baseline is an important first step to take to set climate goals and inform implementation of local climate action.

What is a Greenhouse Gas Inventory?

A GHG inventory accounts for the emissions resulting from a defined geographic area (e.g., city, town, state, etc.) in a given year. GHG emissions can be accounted for through different methods, the most common of which is to look at emissions that result from activities occurring within the city or town boundary.

INTERESTED IN TAKING CLIMATE ACTION?

Check out MAPC's resources on net zero planning and find out more about how your GHG inventory can inform bold local actions to reduce GHG emissions. www.mapc.org/net-zero

WHICH GREENHOUSE GASES ARE INCLUDED?

The primary greenhouse gases included in a typical community-scale inventory are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). For accounting purposes, CH_4 and N_2O are converted to total metric tons (MT) of CO_2 equivalent (CO_2e) converted based on their Global Warming Potential (GWP).

The Global Protocol also covers four other greenhouse gases: perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3). This guide does not address these gases because they primarily result from industrial processes and product use (IPPU) and agriculture, forestry, and land use (AFOLU), which are not covered in the Tool.

What is included in the Tool?

This guide and the accompanying Tool follow the methods put forth by the Global Protocol for Community-Scale Greenhouse Gas Inventories ("Global Protocol").

The sectors and subsectors included in the Tool align most closely with the BASIC level reporting for Global Protocol inventories. By using these resources, your GHG inventory will account for emissions resulting from your community's homes, businesses and industries, municipal operations, large energy production facilities, passenger and commercial vehicles, public transportation, natural gas leaks, electricity line losses[1], municipal solid waste, and wastewater.

1 As electricity is distributed across a service area a percentage of that energy is "lost" in supplying the total end amount consumed. Including this in your GHG inventory accounts for inefficiencies in the transmission and distribution of electricity.

WHAT IS THE GLOBAL PROTOCOL?

The Global Protocol was developed by the World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability. This protocol was designed to provide guidance to local governments across the globe on developing effective community GHG inventories. It establishes reporting requirements for all community GHG inventories and provides detailed accounting guidance for quantifying GHG emissions associated with a range of sources and activities.

The Global Protocol provides communities with two levels for reporting GHG emissions: BASIC and BASIC+. BASIC level reporting includes GHG emissions sources that most commonly occur in communities and, for the most part, have readily available data. BASIC+ level reporting expands on the sources covered by BASIC and is a more comprehensive inventory of all GHG emissions.

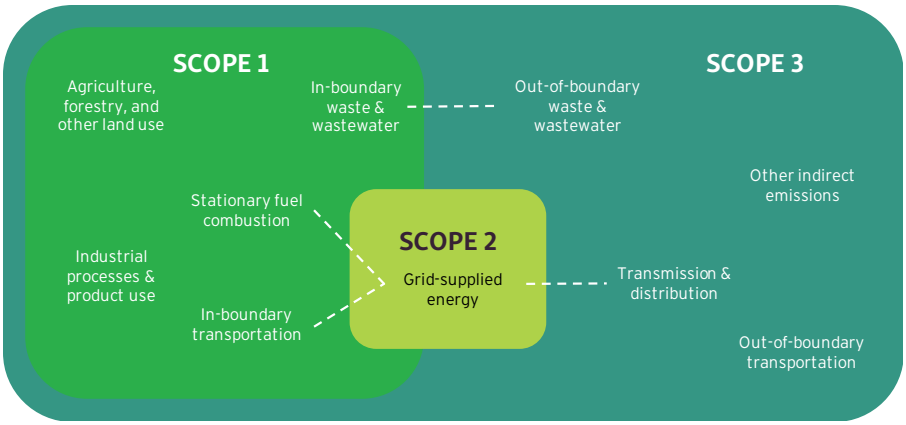
Sectors and subsectors included in the Tool

Sector	Sub-sector	Emissions sources	Energy types
Stationary Energy	Residential	Energy use in residential buildings as well as losses from distribution systems	Electricity Natural gas Heating fuel oil Petroleum Products
	Commercial, Industrial, and Manufacturing	Energy use in commercial, government and institutional buildings, manufacturing and industrial facilities, as well as losses from distribution systems.	
	Construction and Landscaping	Energy use from construction and landscaping equipment and activities.	
	Energy Industries	Stationary combustion of fuel in various equipment, such as boilers and generators.	Various – may include natural gas, propane, diesel, and waste-to-energy
Transportation	On-road vehicles	All trips taken by passenger and commercial vehicles registered in the community. Portion of trips taken within the community boundary by on-road buses and trackless trolleys.	Gasoline Diesel CNG Electricity
	Railways	Portion of trips taken within the community boundary by public light and heavy rail.	
Waste	Solid Waste	Municipal solid waste disposed in/by landfills, incineration, composting, and anaerobic digestion	Landfill gas (methane)
	Wastewater	Process and fugitive emissions from treating wastewater	Not applicable

What are scopes?

The Global Protocol is based on a scopes framework for reporting emissions to allow cities and towns to attribute GHG emissions based on where they are taking place. Scope 1 emissions are physically occur within the geographic boundary, scope 2 emissions occur as a result of use of grid-supplied electricity, heat, steam and/or cooling) within the city boundary, and scope 3 emissions occur outside of the geographic boundary but are driven by activities within the geographic boundary.

Figure A: Emissions Scopes Chart, adapted from the Global Protocol



TO LEARN MORE...

To learn more about GPC scopes and sectors, go to Chapter 3 of the GPC.

What is not included in the Tool?

Our primary goal for this guide is to simplify the process of developing a GHG inventory by using publicly available data sets, while maintaining high levels of accuracy and relevance in the data used. As such, some sources of GHG emissions that are covered by the BASIC level for Global Protocol inventories are not included in the current version of the Tool. The following subsectors are excluded from the Tool because public statewide data sets were either not available or not robust enough to support a method of estimating GHG emissions from community to community.

Stationary Energy

Agriculture, forestry, and fishing activities: emissions that result from direct fuel combustion to support these activities (e.g., machinery, generators, pumps, etc.)

Transportation

Commercial and national railways: passenger and freight activities associated with commercially owned railways servicing or running through communities

Waterborne navigation and aviation: ships, ferries, and other boats operating within the community boundary, and air travel occurring within the community boundary.

Off-road vehicles: emissions that result from airport equipment, agricultural tractors, chain saws, forklifts, snowmobiles, etc.

Waste

Industrial waste: waste generated from industrial processes and technologies.

For two subsectors, we have provided the option for communities to input local data where it is available. These are GHG emissions from (1) regional transit agencies (outside of the MBTA) and (2) private waste haulers servicing commercial facilities. While a comprehensive data source is not currently available for these subsectors, communities have the flexibility to input this data if they have access.

Sectors and subsectors covered within the Global Protocol's BASIC+ level reporting are also not covered by this guide. This includes GHG emissions from industrial processes and product use (IPPU), and agriculture, forestry, and land use (AFOLU), as well as Scope 3 emissions (i.e., occurring outside of the geographic boundary but driven by activities within the geographic boundary) from the stationary energy and transportation sectors.

Getting Started

Before diving into data collection and calculation of emissions, there are two key decisions that need to be made for a community-scale GHG inventory.

What year am I calculating GHG emissions for?

If your community is developing a GHG inventory for the first time, we recommend selecting the most recent year for which data are widely available. In some instances, where communities have set specific GHG emissions reductions goal from a specific year, you may want to calculate emissions for the baseline year if data is available. It can be more difficult to access historic data depending on how far back the comparison year is (e.g. 2002 vs. 2013).

At the time of publishing, the most complete year of available data was 2022. For this reason, the Tool is auto-populated with several sets of inputs associated with 2022. To use the tool for an alternate inventory year, you can follow the guidance provided in **Appendix C** to collect the associated data for the new inventory year. Keep in mind that depending on the year selected, data set availability may vary across different sources.

What is the geographic boundary for this GHG inventory?

We recommend selecting your city or town's administrative geographic boundary for the purposes of developing a community-scale GHG inventory. This selection will align most closely with many of the data source recommendations that follow.

These are both important items to come to consensus on with the necessary stakeholders prior to data collection as they will both inform how you approach decisions later in the process.

STEP 2
GATHER THE DATA

It is time to collect all the data you need to complete a community GHG inventory. The data that you need to collect is defined by characteristics that make your community unique. Where available, we provide options for data collection that can be input directly into the Tool for GHG emissions calculation. In some instances, a direct source of data may not be easily accessible. Where this is the case, we provide recommended methods to estimate activity data for inclusion in your GHG inventory.

Best Practices for Data Collection

The data sources recommended in this guide are informed by local experience and the Global Protocol's principles for data collection. Please keep these principles in mind as you consider any substitutions or alternate data sources to the ones recommended throughout the guide. Follow these principles and you will be well on your way to being a GHG inventory whiz!

Principle	Global Protocol Definition	Key Questions to Ask
Relevance	The reported GHG emissions shall appropriately reflect the emissions occurring as a result of activities and consumption patterns of the city.	Does the data set directly relate to the geographic boundary of the GHG inventory?
Completeness	Cities shall account for all required emissions sources within the inventory boundary. Any exclusion of emission sources shall be justified and clearly explained.	Does the data set include all information for the selected baseline year?
Consistency	Emissions calculations shall be consistent in approach, boundary, and methodology.	Does the data adhere to the methods of the GHG inventory? Can the same methods be used year over year?
Transparency	Activity data, emissions sources, emissions factors, and accounting methodologies require adequate documentation and disclosure to enable verification.	Can the data be readily documented and shared with the public?
Accuracy	The calculation of GHG emissions shall not systematically overstate or understate actual GHG emissions.	How close to reality is any of the estimated data being used?

TO LEARN MORE...

To learn more about these guiding principles, go to Chapter 2 of the Global Protocol.

Create a Process

There are a few best practices to create a clear and replicable process for updating your GHG inventory periodically.

- **Identify a department, committee, or other appropriate party who will be responsible for periodic GHG inventory updates.** By designating where the responsibility for the GHG inventory lies, you can set the foundation for maintaining capacity and knowledge over time. It may be beneficial to make sure that at least two people understand how to update the GHG inventory and are familiar with the data sources to create a contingency in case of a transition.
- **Store all files and supporting data in a central location.** This may seem like a no-brainer, but a well-organized and clearly labeled file storage system will set you up for success moving forward. This ensures that in the future, staff will be able to identify what data sources were used and replicate the methods to consistently update the community's GHG inventory.
- **Log changes made to the data and methods.** This practice is important to maintain transparency and consistency in how your data is reported publicly. One of the limitations of using a spreadsheet-based tool is that there is no streamlined way to track changes that are made to formulas or input data. A best practice to remedy this limitation is to maintain a separate document where users can log the data inputs and any method changes made, along with the date and rationale for making the change.

Checklist to Define Local Characteristics

Review the following questions and check-off all characteristics that apply to your community. This will provide you with a high-level guide on what community-specific data you need to collect for your GHG inventory.

STATIONARY ENERGY

A Who provides your community with electricity and natural gas?

- ○ Invester Owned Utilities
- ○ Municipal Utilities
- ○ Both

B Does your community have access to municipal energy consumption data through MassEnergy

- ○ Yes
- ○ No

C Does your community have a green municipal aggregation program in place?

- ○ Yes
- ○ No

TRANSPORTATION

A Which MBTA railways provide service within your municipality? (check all that apply)

- ○ Light rail - Green line
- ○ Heavy rail - Blue, orange, and.or red line
- ○ Commuter rail

WASTE

A Does your Department of Public Works collect data on municipal solid waste (MSW) by method of

- ○ Yes
- ○ No

B Has your community recently completed a waste characterization survey?

- ○ Yes
- ○ No

C Do your municipal solid waste collection services cover all residents, school buildings, and businesses? (check all that apply)

- ○ Yes - all of the above
- ○ Some residents
- ○ Some businesses
- ○ School buildings

D Do you know which landfill your community's waste goes to?

- ○ Yes
- ○ No

E Is your community's wastewater treated at Deer Island or the Lawrence, Rockland, Clinton, or Pittsfield treatment facilities? (check all that apply)

- ○ Deer Island
- ○ Lawrence Treatment
- ○ Rockland Treatment
- ○ Clinton Treatment
- ○ Pittsfield Treatment
- ○ None of the above

Step-by-Step

Stationary Energy

Stationary energy accounts for GHG emissions resulting from the use and production of all fuels by non-mobile sources. This includes the direct emissions from the combustion of fuels and indirect emissions from consumption of grid-supplied electricity. Primarily, this represents GHG emissions from the buildings within your community – homes, businesses, and municipal operations. GHG emissions from any energy industries located within your community are also accounted for in stationary energy. This guide also provides an approach to account for GHG emissions resulting from construction and landscaping activities. Stationary energy also accounts for any fugitive emissions, such as electricity transmission and distribution losses and natural gas leaks.

Electricity and Natural Gas

Calculating emissions from the electricity and natural gas consumed in your community requires collection of total kilowatt hours (kWh) and therms consumed by all buildings during the inventory year. Where you go to collect this data depends on the electricity and natural gas service providers in your community.

The electricity and natural gas consumed by municipally owned buildings is accounted for in the Commercial and Industrial account data reported by the Investor Owned Utilities (IOUs). If your community is interested in tracking municipal GHG emissions separately from community wide GHG emissions, additional data on electricity, natural gas, and other heating fuels (oil and/or propane) needs to be collected. If your community is a designated Green Community, this data will be available annually in reports completed by your city or town.

1A

Question 1A

Who provides your community with electricity and natural gas service?

◯ **My community is served by an investor owned utility for electricity and/or natural gas.**

As of 2015, all of the investor owned utilities ("IOUs") in Massachusetts have been publishing electricity and natural gas consumption data broken out by municipality online. MassSaveData provides community-wide kWh and therm usage by year. This will be broken out by **Residential and Low Income** and **Commercial and Industrial** customer segments.

Download your community's MassSaveData at www.masssavedata.com

WHAT IF MY COMMUNITY'S DATA IS NOT ON MASSSAVEDATA?

For some municipalities, data may not be available due to the utility's privacy restrictions. This occurs when there are less than 100 residential customers and/or less than 15 commercial and industrial customers in a community. Additionally, MassSaveData is not available prior to 2013 and, as of publishing this Guide, is available through 2023.

◯ **My community is served by a municipal utility for electricity and/or natural gas.**

Communities served by municipal utilities, or without data available on MassSaveData, will need to make a request for sector-level consumption data to their electricity provider directly.

	Total kWh for inventory year	Total therms for inventory year
Residential customers	XX	XX
Commercial and industrial customers	XX	XX

1B

Question 1B:
Does your community have access to municipal energy consumption data through MassEnergyInsight?

○ **Yes**

Great! You can download the data needed on electricity and natural gas consumption, as well as all other fuels consumed by your municipal facilities, through the state's online energy benchmarking platform, MassEnergyInsight. You will need to download the report titled "Energy Reduction Plan Guidance Table 3 (Fuel Units)". Make sure to switch the data view to calendar year by selecting the "Fiscal Year Start Month" of January.

Access MEI using your log-in credentials at www.massenergyinsight.net/

While you are there, make sure to download your municipal vehicle fleet's gasoline and diesel consumption. This will be needed in the Transportation section.

○ **No**

You may choose to collect the electricity, natural gas, oil, and propane consumption total for your municipal buildings separately. Reach out to your facilities and accounting departments to identify how to collect this data for your baseline year.

Electricity Emission Factors

The Global Protocol allows communities to use either a location-based or market-based approach to calculated emissions from grid-supplied electricity. The Tool applies a market-based approach to determine the emissions factors for electricity. The Tool includes default annual emissions factors from MassDEP's GHG emissions reporting summaries.

For more information see MassDEP's Emission Factor Calculations https://www.mass.gov/lists/massachusetts-greenhouse-gas-ghg-reporting-program-data.

Those communities with green municipal aggregation programs in place may choose to customize the emissions factors applied to the electricity consumed by residential and commercial customers subscribed to the program. This requires the collection of additional data about your aggregation program.

WHAT IF MY COMMUNITY'S INVENTORY YEAR IS NOT 2022?

While the Tool was created for easy calculation of emissions for the inventory year of 2022 (the most recent year of available data at the time of publishing), you may modify the electricity emissions factor data to support alternative years.

If using a year other than 2022 for your inventory, see **Appendix C** for additional data collection guidance to adjust the default settings in the Tool accordingly.

1C

Question 1C:
Does your community have a green municipal aggregation program in place?

◯ **Yes – we do have a green municipal aggregation program.**

Great! You will need to request data from your aggregation provider to calculate a custom emissions factor that takes into consideration the additional renewables procured through your aggregation. You will need to know the amount of kWh consumed during the baseline year by (1) customers subscribed to the base aggregation rate, (2) customers who opted up to higher percentages of renewables, and (3) customers who opted out of the program entirely.

You will also need to access the aggregation's **Disclosure Label** for the inventory year. The Disclosure Label is a brief document that your aggregation provider is required to provide you that includes the rate structures for that period of the program.

◯ **No – we do not have a green municipal aggregation program in place.**

You can move onto the next section for data collection. While some individual residents and businesses may be purchasing green power from a retail electricity provider, we recommend using the default annual emissions factors for Massachusetts published by MassDEP.

WHAT IS GREEN MUNICIPAL AGGREGATION?

Municipal aggregation (also known as community choice aggregation) allows a city or town to determine where its electricity comes from. In a municipal aggregation, a city or town contracts with an electricity supplier on behalf of residents and businesses who have not already selected a competitive supplier. A green municipal aggregation program seeks to exceed the state's requirements for renewable energy by requiring additional percentages of renewables within the community's electricity supply. Learn more about green municipal aggregation with MAPC: https://www.mapc.org/our-work/expertise/clean-energy/green-municipal-aggregation/

Transmission and Distribution

The Tool also accounts for losses from the electricity and natural gas distribution systems. For electricity transmission and distribution losses, a standardized approach is taken to account for any losses associated with the total amount of electricity consumed community-wide during the baseline year. For natural gas leaks, an average leak factor of 2.5 percent is applied to the total amount of natural gas consumed community-wide during the baseline year.[1] No additional data is needed to calculate emissions associated with this subsector.

WHERE IS THE 2.5 PERCENT FACTOR FROM?

Harvard University led research on methane emissions from natural gas infrastructure in the Boston area. The 2021 study, published in the Proceedings of the National Academy of Sciences, found that the average loss rate from all components of the natural gas system (inclusive of transmission, distribution, and end use) was 2.5 percent.

1 Sargent, et al., "Majority of US urban natural gas emissions unaccounted for in inventories," PNAS, published October 25, 2021, https://doi.org/10.1073/pnas.2105804118

Heating Fuel Oil

Unlike electricity and natural gas, there is no publicly available data source for actual consumption of heating fuel oil. The Tool's default approach will be to use a method of estimating consumption based on publicly available national and state datasets.

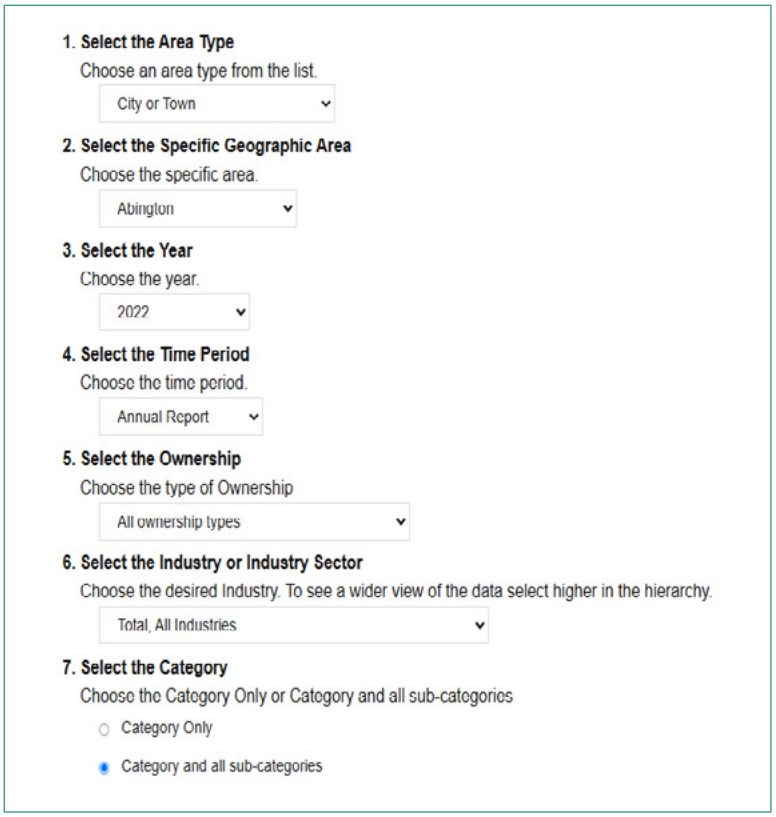
For residential heating fuel oil use the Tool uses US Census Bureau data on household heating fuel from the American

- Community Survey. The data needed for your municipality are: **Housing Tenure by Fuel Type** and **Housing Tenure by Units in Structure, aggregated at the municipal level.**

Download the housing tenure data for your community at: datacommon.mapc.org/browser/Housing

For commercial and industrial heating fuel oil use the Tool calculates a share of the statewide heating oil usage, based on number of businesses and industries located within the municipality. This third data set comes from the Massachusetts Executive Office of Labor and Workforce Development. The data needed are from their Employment and Wage (ES-202) survey. To download the data needed for the heating oil estimation, fill out the fields as follows, making the necessary adjustments for Specific Geographic Area and Selected Year. You will only need to input data for the **3-digit** North American Industry Classification System (NAICS) codes.

Access the ES-202 survey data at: https://lmi.dua.eol.mass.gov/lmi/EmploymentAndWages



TO LEARN MORE...

To learn more about our methodology for estimating heating oil consumption for residential, commercial, and industrial buildings, please see **Appendix A.**

Energy Industries

Following the BASIC reporting principles of the Global Protocol and to avoid the possibility of double counting emissions from local energy producers, the GHG inventory tool assumes that the emissions from these facilities are captured in the community-wide electricity or natural gas consumption data. Facilities that use natural gas to produce electricity and heat (co-generation) for use on-site are accounted for in the community-wide natural gas consumption data. The emissions from facilities within the community boundary that produce electricity to supply to the electric grid are accounted for in the grid-supplied electricity emissions factor.

TRACKING EMISSIONS FROM POWER PRODUCERS

For informational purposes, it may be useful to consider the emissions from local energy producers if the community has plans to work directly with these entities to reduce emissions at those facilities. This includes power plants, natural gas and oil production and processing facilities, co-generation, and waste-to-energy or bioenergy facilities. For the most part, municipalities do not have a high level of influence over decisions made to reduce GHG emissions at these facilities. However, your community might choose to track GHG emissions from power producing facilities separately in instances where mitigation actions may impact their GHG emissions.

If your community chooses, emissions from these facilities may be tracked in the Tool. This supplementary data will not be added to your inventory total, but you can choose to track emissions separately using publicly available data. Generators that emit more than 25,000 MT CO2e annually are required to report their GHG emissions to the U.S. Environmental Protection Agency. This data has been prepopulated in the Tool for 2022. You may access this data for other reporting years at **https://ghgdata.epa.gov/ghgp/main.do?site_preference=normal**.

Landscaping, Construction and Manufacturing Emissions

GHG emissions from off-road mobile activities are categorized according to how they occur. There are two sources of off-road mobile emissions that are of primary concern locally – these are emissions from landscaping, construction, and manufacturing activities. These GHG emissions are included in the Stationary Energy sector because the combustion of fuel is localized and occurs off public roadways.

GHG emissions from landscape and construction equipment and manufacturing can be derived from a publicly available U.S. Environmental Protection Agency (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, which then need to be scaled down to the municipal scale.

For communities using an inventory year of 2022, MAPC has generated the county level MOVES outputs for public use. This is available at: https://datacommon.mapc.org/browser/datasets/410

For landscaping, community level emissions are proportional to county-level data and based on the ratio of landscaped area in your community versus the total landscaped area in the county. Emissions from construction equipment are estimated using a proportion of square footage of commercial development under construction at the county and community level. For manufacturing, community level emissions are proportional to county-level data and based on a ratio of manufacturing jobs in your community versus the manufacturing jobs in your county.

To allocate the county-level emissions figure for landscaping emissions from MOVES to your municipality, you will need to create a proportion of total square footage of landscaped area in your municipality to total landscaped area in the county. Where available, we recommend using local GIS datasets to obtain this information. However, MassGIS publishes a land cover dataset that can be used to approximate total landscaped area. MAPC has provided one data set to assist, by aggregating the amount of "Developed Open Space" in the 2016 Land Cover/Land Use data set produced by MassGIS at the county and municipal levels.

◯ **Download the land cover data for your community at:**

https://datacommon.mapc.org/browser/datasets/411

To allocate the county-level emissions figure for construction emissions from MOVES to your municipality, you will need to create a proportion of **total square footage of commercial development under construction** in your municipality during the inventory year to the total square footage of commercial development under construction in your county.

You can access this data from the commercial real estate database, CoStar, by submitting a data request to MAPC's Analytical Services Group: https://www.mapc.org/our-work/expertise/data-services/ and copying MAPC's Clean Energy Team (CleanEnergy@mapc.org)

To allocate the county-level emissions figure for manufacturing emissions from MOVES to your municipality, you will need to collect data from the American Community Survey on **total employment** and **manufacturing employment** for your county and municipality.

◯ **Download the data for your county and municipality at:**

data.census.gov

Step-by-Step

Transportation

Emissions from on-road transportation and railways are calculated within the Transportation sector. GHG emissions in this sector are caused directly, through the combustion of fuel, and indirectly, through the consumption of grid-supplied electricity. Municipalities intersected by public transportation routes – regardless of whether there is a stop within their boundary – must also account for these emissions. Public transportation that occurs on roadways, by buses and trolley buses, is accounted for in the on-road transportation subsector. Public transportation that occurs on railways, by commuter rail, heavy rail, and light rail, is accounted for in the railways subsector. This guide provides data for public transportation operated by the MBTA for the 2022 base year.

On-road Passenger and Commercial Vehicles

All municipalities, regardless of size and location, must calculate emissions generated by the vehicles moving along their roadways. There are a few approaches for doing so; this guide employs the resident activity method, where each municipality quantifies the impact of only those vehicles registered within their city. This method is preferred because it can be replicated on an annual basis and reduces the risk of double counting emissions from the allocation of cross-boundary trips across multiple communities.

The Massachusetts Vehicle Census (MAVC), which is available for download on MAPC's website, is the recommended source when using the **resident activity method**. The MAVC combines information from vehicle registrations, inspection records, mileage ratings, and other sources to document the ownership and mileage history of each vehicle.

To access the required information, you will need to download the MAVC tables for your community. Once downloaded, you will need to navigate to the row with information on your municipality and copy data from the following fields.

Download the MAVC data for your community at:
https://datacommon.mapc.org/browser/datasets/483

TO LEARN MORE...

Read more about the Vehicle Census here: https://geodot-homepage-massdot.hub.arcgis.com/pages/massvehiclecensus

Public Transportation (On-road and Railway)

Municipalities should begin their calculations by identifying what public transportation operates within their boundaries.

On-road buses and trolleys

- ◯ The MBTA operates buses in 55 municipalities in Massachusetts. If your municipality has MBTA bus service, you should account for these emissions in your inventory. MAPC has prepared these figures by municipality for 2017, 2021, and 2022.

Railways

This guide covers calculations for three different types of rail emissions: light rail and heavy rail, which use electricity, and commuter rail, which uses diesel fuel. MAPC has prepared data tables for each line with information on miles traveled by line and by fuel type for each municipality served by the MBTA in 2017, 2021, and 2022.

Download the MBTA frequency weighted trip miles data for your community at: https://datacommon.mapc.org/browser/datasets/408

2A **Question 2A:**
Which MBTA railways provide service within your municipality? (Select ALL OPTIONS that are relevant)

- ◯ **The MBTA operates Light Rail in my municipality.**
  The Green Line and the Mattapan Trolley are both light rail systems operated by the MBTA. As of the writing of this guidethe Green Line serves Boston, Brookline, Cambridge, and Newton and the Mattapan Trolley serves Boston and Milton. Municipalities that are not served by the Green Line or Mattapan Trolley do not need to include light rail calculations in their inventory.

- ◯ **The MBTA operates Heavy Rail in my municipality.**
  The MBTA operates three heavy rail lines: Blue, Orange, and Red. As of the writing of this guide, at least one of these lines serves the following municipalities: Boston, Braintree, Cambridge, Malden, Medford, Milton, Quincy, Revere, and Somerville. Municipalities outside this territory do not need to include heavy rail calculations in their inventory.

- ◯ **The MBTA operates Commuter Rail in my municipality.**
  MBTA-operated commuter rail service extends to 101 out of the 351 municipalities in the Commonwealth. Municipalities outside this territory do not need to include commuter rail calculations in their inventory.

- ◯ **None of the above – the MBTA does not operate any railways in my municipality.**
  If this is the case, please proceed to the next set of questions.

Step-by-Step

Waste

The waste sector is composed of all emissions that result from the disposal of solid waste and treatment of wastewater generated within the geography boundary of the GHG inventory. This guide covers data collection for municipal solid waste and for

wastewater generated within the community.

Solid waste is generated by residents and visitors, businesses, public entities, and other organizations in the community. There are two main sources of emissions from solid waste: waste sent to landfill and waste sent to incineration. Emissions from composting and anaerobic digestion are also considered.

Municipal Solid Waste

Landfilled waste results in methane emissions as organic materials decompose in the anaerobic (non-oxygen) environment of a landfill. Organic materials (e.g., paper, plant debris, food waste, and so forth) generate methane while non-organic materials do not (e.g., metal, glass, and so forth). Landfill emissions estimates are based on a variety of factors, including whether it is an open or closed landfill, the volume of waste, and whether the landfill has a landfill gas collection system.

- For **landfilled** waste, GHG inventories should account for methane emissions. These emissions are estimated using the Methane Commitment Model, which assigns the total lifetime emissions based on the amount waste sent to landfill in a given year.
- **Incineration** of waste results in carbon dioxide, methane, and nitrous oxide emissions as the waste is burned. GHG emissions from waste generated within the city boundary that is incinerated outside the city are included but are considered as Scope 2 emissions (i.e., those emissions resulting from the consumption of grid supplied electricity) and included as part of the grid-supplied electricity emissions factor.
- The biological treatment of waste through either **composting** or **anaerobic digestion** results in methane and nitrous oxide emissions. The emissions factors used are determined based on type of treatment occurring and any methane gas recovery that may be occurring onsite.

You will need to collect information on the amount of waste generated by residents and businesses, characteristics of the waste stream, and how the waste is disposed of in your community to determine the amount of waste management related emissions.

This guide does not cover all waste generated outside of the Municipal Solid Waste stream. However, depending on who is served by your municipal solid waste collection services, some additional data may need to be collected to ensure that all waste generated by residents and municipal operations is included in your GHG inventory.

WHY ISN'T RECYCLING INCLUDED IN A GHG INVENTORY?

Any energy consumed on-site to recycle the materials would be accounted for in the stationary energy sector from any electricity use or combusted fuel. Recyclables also do not emit any methane gas during the refurbishing processes, so the total tonnage of recycling does not need to be accounted for in a methane commitment model.

TO LEARN MORE...

To learn more about the Methane Commitment Model, go to Chapter 8 of the Global Protocol.

3A

Question 3A:

Does your Department of Public Works collect data on municipal solid waste (MSW) by method of disposal?

◯ **Yes – we have data on MSW by method of disposal.**

Great! To complete your inventory, you will need to collect the total tons of municipal solid waste generated during the inventory year. You will also need to determine a breakdown in total tonnage for MSW sent to landfill, incineration, composting, and anerobic digestion. You can choose to do this by applying your known percentages to the total tons of MSW, or by providing the specific tons by disposal method. Any reported yard waste collected should be added to either compost or anaerobic digestion – depending on the method through which it is disposed.

Disposal Method	Tons Generated in Inventory Year	Percentage of Total MSW
Landfill		%
Incineration		%
Composter		%
Anaerobic digestion		%

◯ **No – we do not have data on MSW by method of disposal.**

The tool uses a default diversion rate of 90% of solid waste goes to incineration and 10% goes to landfill. This aligns with the Massachusetts statewide average.

NOT SURE IF THE MA AVERAGE IS APPROPRIATE IN YOUR COMMUNITY?

There are a few characteristics that may guide whether to use the MA statewide average for diversion. Most municipalities that send their solid waste to an incinerator have long-term contracts that require **all waste** be sent to that location only. In this case, you could assume a 100% diversion rate to incineration. However, municipalities that use transfer stations are likely sending a portion of the waste to landfills. In this case, we recommend using the MA statewide average in the absence of local data from your Department of Public Works.

3B

Question 3B:
Has your community recently completed a waste characteristics survey?

○ **Yes – We recently completed a waste characteristics survey.**

Great! You will need to collect this information to identify the percent of waste content in household trash. You will need to align the content categories from your local survey with the following as much as possible: Food Waste, Garden and Plant Waste, Paper, Wood, Textiles, and Industrial Waste. For categories that include multiple categories from your survey, you will need to sum the percentages accordingly.

% of waste content	Inventory Category	Categories Included from Survey
	Food Waste	Ex: organic materials, compost
	Garden and Plant Waste	Ex: yard waste, leaf collection
	Paper	Ex: recyclable items, other trash
	Wood	Ex: construction or demolition debris
	Textiles	
	Industrial Waste	Ex: household hazardous waste

○ **No – We have not done a waste characteristics survey.**

You will use the weighted averages found in the Massachusetts Summary of Waste Combustor class II Recycling Program Waste Characterization Studies.[2] The average waste characteristics from this study will be automatically populated in the Tool.

2 https://www.mass.gov/guides/solid-waste-master-plan#-waste-characterization-&-capacity-studies-

3C

Question 3C:

Do your municipal solid waste collection services cover all residents, school buildings and businesses?

- ◯ **Yes – Our municipal solid waste collection covers all residents, schools, and/or businesses.**

  This means that no residents are served by private waste haulers in your community. You can input the data for trash tonnage disposal from the Municipal Solid Waste & Recycling Survey Responses published my MassDEP:

  https://www.mass.gov/lists/recycling-solid-waste-data-for-massachusetts-cities-towns

- ◯ **No – Some residents are served by private waste haulers.**

  To determine this, you will need to input the total number of households in your community and the total households served by the municipal collection service from the Municipal Solid Waste & Recycling Survey Responses published by MassDEP: https://www.mass.gov/lists/recycling-solid-waste-data-for-massachusetts-cities-towns.

- ◯ **No – Our public schools are serviced separately from municipal solid waste.**

  You may choose to estimate emissions from public schools separately as an optional input to include in the Tool for tons of waste collected by private waste haulers. To do so, you will need to collect data to support an estimation of the amount of solid waste generated by public schools. You will need to collect data on the number of students enrolled at each school during the inventory year and the type of school (e.g., elementary, middle, or high school).

  These inputs can then be used to estimate food waste (i.e., organic waste) generated by schools in your community following guidance from RecyclingWorks Massachusetts:
  https://recyclingworksma.com/wp-content/uploads/2018/06/Elementary-and-Secondary-Schools.pdf

- ◯ **No – Businesses are served by private waste haulers.**

  You may exclude this category from the inventory since this will be a small portion of the overall GHG emissions. At the time of publishing this guide, localized and/or industry specific waste generation factors do not exist at a level robust enough to support inclusion of an estimation methodology for waste disposed by private haulers. In the interim, the Tool provides open input fields for communities that do have access to robust data or estimates on commercial waste.

3D

Question 3D:

Do your know which landfill your community's waste goes to?

- ◯ **Yes – Our waste is sent to one of the following landfills:**
  The following landfills have data for the fraction of methane gas that is collected from the landfill: Northampton Landfill, Granby Sanitary Landfill, Chicopee Sanitary Landfill, Martone Landfill & Gas Generating Facility, Southbridge Recyclying & Disposal Park, Fitchberg Westminster Landfill Recycling Center, Plainville Landfill, Taunton Sanitary Landfill, Carver-Marion-Wareham Landfill, Middleborough Landfill, Halifax Landfill, and Haverhill Landfill. The tool is pre-populated with 2022 data from the EPA's FLIGHT tool: https://ghgdata.epa.gov/ghgp/main.do?site_preference=normal

- ◯ **No – We don't know which landfill our waste is sent to or it is sent to a landfill not listed above.**
  The tool uses a default value equal to the average methane recovery rate of the landfills above. No additional data collection is required.

Wastewater

Wastewater treatment can result in methane and/or nitrous oxide emissions. The wastewater from many Boston-area communities is treated at the Deer Island Wastewater Treatment Plant in Boston. Typically, very little methane is released from the treatment process at Deer Island. The plant uses up to 97% of the methane for heating the digester tanks or a cogeneration system where it is used to heat buildings and generate electricity via steam turbine generators. Similarly, treatment plants in Lawrence, Rockland, Clinton and Pittsfield use methane capture systems that significantly reduce the release of GHG emissions. Because of this, methane emissions associated with wastewater treatment can be excluded from communities served by these facilities. If your community's wastewater is not treated at one of these facilities, methane emissions will be estimated using default population-based emissions factors use by MassDEP for the statewide emissions inventory.

Nitrous oxide emissions also occur as a bi-product of the wastewater treatment process after it is discharged into waterways. At Deer Island nitrous oxide emissions are primarily from treated effluent being discharged into the ocean. For communities by any wastewater treatment facility, the nitrous oxide emissions from the treated effluent also needs to be accounted for. To determine the amount of nitrous oxide emissions from wastewater treatment effluent, the total population of the community served by the treatment facility is needed as well as the per capita protein consumption value.

3E **Question 3E:** Is your community's wastewater treated by the Deer Island, Lawrence, Rockland, Clinton, or Pittsfield treatment facilities?

◯ **Yes – we are served by one or more of these treatment facilities.**

Only nitrous oxide emissions will be estimated for the wastewater that is sent to these facilities. You will need to contact your Department of Public Works for the number of people in your community served by a treatment plant in the Tool.

For those in your community who are not served by these facilities, both Methane and nitrous oxide emissions will be estimated. You will input the annual estimates for your community's population from the U.S. Census Bureau's City and Town population data set.

Access population data at: https://datacommon.mapc.org/broswer/datasets/316

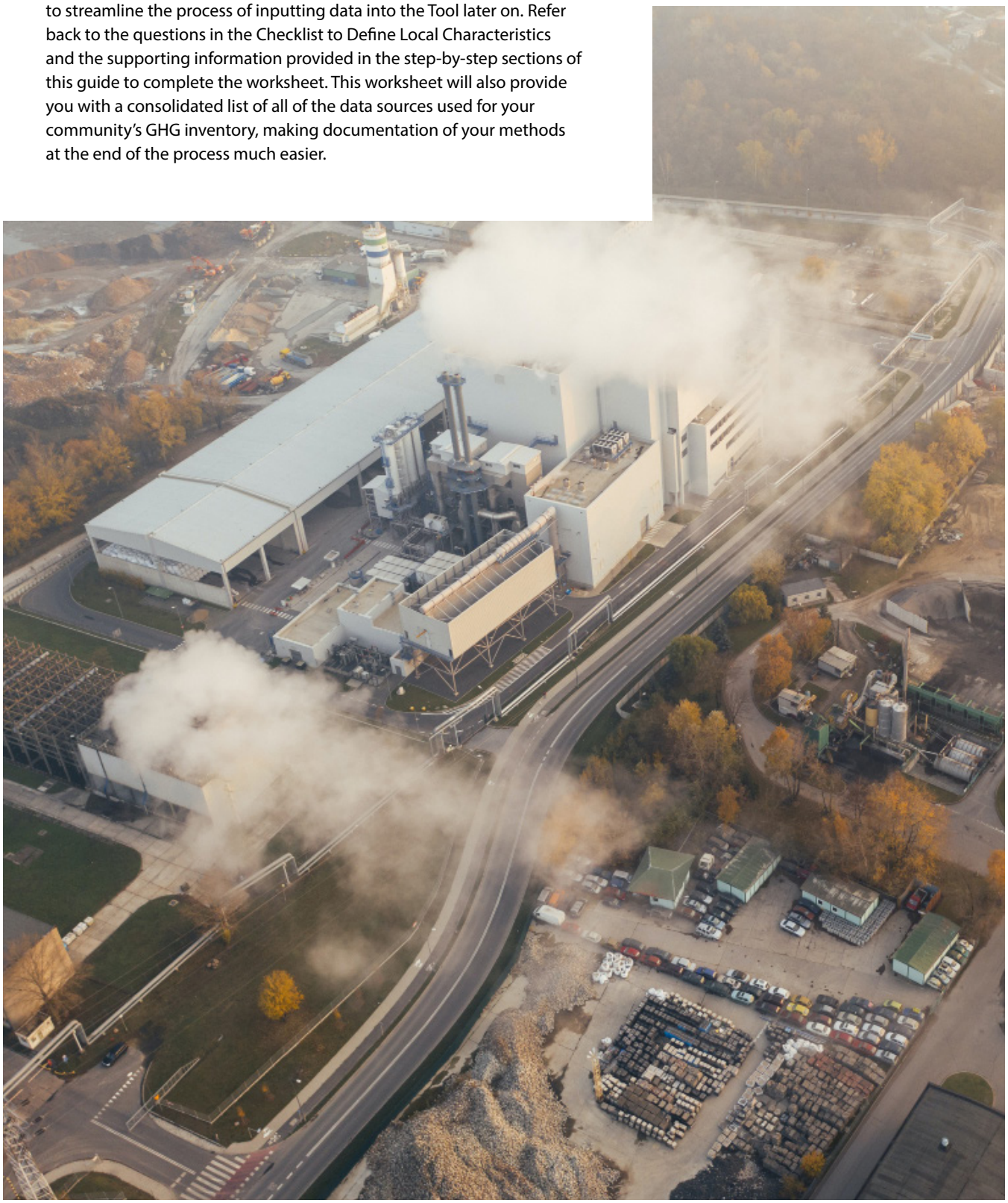
◯ **No – we are not served by any of these facilities.**

Both Methane and nitrous oxide emissions will be estimated for your entire community. You will input the annual estimates for your community's population from the U.S. Census Bureau's City and Town population data set.

Access population data at: https://datacommon.mapc.org/broswer/datasets/316

Data Collection Worksheet

This worksheet can be used to collect the necessary data in one place to streamline the process of inputting data into the Tool later on. Refer back to the questions in the Checklist to Define Local Characteristics and the supporting information provided in the step-by-step sections of this guide to complete the worksheet. This worksheet will also provide you with a consolidated list of all of the data sources used for your community's GHG inventory, making documentation of your methods at the end of the process much easier.



Data Collection Worksheet

Use this worksheet to collect all the necessary input data to complete your community's greenhouse gas inventory. This is a single location for you to collect all of the information and document any data sources specific to your community. This worksheet correlates directly with the INPUTS tab of the Tool.

Stationary Energy

1A Question 1A: Electricity & Natural Gas (Mandatory)

Data source: _____ Data year:_____

	Total MWh	Total therms
Residential customers		
Commercial and Industrial customers		

1B Question 1B: Municipal Operations (Optional)

Data source: _____ Data year:_____

	Total kWh	Total therms	Total gallons oil	Total gallons propane
Municipal Buildings				

	Total gallons diesel	Total gallons gasoline
Municipal Vehicles		

1C Question 1C: Electricity Emissions (If YES)

Data source: _____ Data year:

	Total Annual Electricity Consumption (kWh/ Year)	% of Class I Voluntary RECs
Residential Rate 1		
Residential Rate 2		
Residential Rate 3		
Residential Rate 4		
Commercial & Industrial Rate 1		
Commercial & Industrial Rate 2		
Commercial & Industrial Rate 3		
Commercial & Industrial Rate 4		

1D Construction, Landscaping, & Manufacturing (If YES)

Part 1: Landscaping

Data source: _____ Data year:_____

	Total square footage (municipality)	Total square footage (country)
Estimated landscaped area		

Part 2: Construction

Data source: _____ Data year: _____

	Total square footage (municipality)	Total square footage (country)
Commercial construction under development		

Part 3: Manufacturing

Data source: _____ Data year: _____

	Country Employment	City/Town Employment
Total Employment		
Manufacturing Employment		

1E

Heating Oil

Collect the following inputs to support estimation of heating oil across residential, commercial, and industrial buildings.

Part 1: Housing Tenure by Units in Structure

Data source: ____________________ Data year: __________

Units in Structure	Number of Households
1-unit, detached	
1-unit, attached	
2 units	
3 or 4 units	
5 to 9 units	
10 to 19 units	
20 or more units	
Mobile homes	

Part 2: Housing Tenure by Fuel Type

Data source: ____________________ Data year: __________

Heating Fuel	Percent Occupied Housing Units in Community
Fuel oil, kerosene, etc.	

Part 3: Industry Employment and Wages

Data source: ____________________ Data year: __________

NAICS Code	Number of Establishment	Avg. Monthly Employment

Transportation

On-road passenger, commercial, municipal, and state vehicles (Mandatory)

Data source: _____ Data year: _____

Vehicle Fuel	Annual Vehicle Miles Traveled (VMT)	Annual fuel consumption (gal)
Passenger Vehicles		
Gasoline		
Diesel		
FlexFuel		
Hybrid Electric Vehicle		
Plug-In Hybrid Electric Vehicle		
Compressed Natural Gas		
Propane		
Hydrogen Fuel Cell		
Electric		
Other		
Commercial Vehicles		
Gasoline		
Diesel		
FlexFuel		
Hybrid Electric Vehicle		
Plug-In Hybrid Electric Vehicle		
Compressed Natural Gas		
Propane		
Hydrogen Fuel Cell		
Electric		
Other		
Municipal Vehicles		
Gasoline		
Diesel		
FlexFuel		
Hybrid Electric Vehicle		
Plug-In Hybrid Electric Vehicle		
Compressed Natural Gas		
Propane		
Hydrogen Fuel Cell		
Electric		
Other		
State Vehicles		
Gasoline		
Diesel		
FlexFuel		
Hybrid Electric Vehicle		
Plug-In Hybrid Electric Vehicle		
Compressed Natural Gas		
Propane		
Hydrogen Fuel Cell		
Electric		
Other		

2A Question 2A: On-road buses and trolley buses

Data source: _____ Data year: _____

	City/Town Frequency -weighted Route Distance
MBTA Silver Line	
Trackless Trolley	
All MBTA Bus (Excluding Silver Line)	

2B Question 2B: MBTA Railways

Data source: _____ Data year: _____

	City/Town Frequency -weighted Route Distance
Blue Line (Heavy Rail)	
Orange Line (Heavy Rail)	
Red Line (Heavy Rail)	
Green Line (Light Rail)	
Mattapan Trolley (Light Rail)	
Commuter Rail	

Waste

3A Question 3A: Municipal Solid Waste Disposal (If YES)

Data source: _____ Data year: _____

	Tons Generated in Inventory Year	Percentage of Total MSW
Landfill		%
Incineration		%
Composting		%
Anaerobic digestion		

3B Question 3B: Waste Characterization (If YES)

Data source: _____ Data year: _____

% of waste content	Inventory Category
	Food Waste
	Garden and Plant Waste
	Paper
	Wood
	Textiles
	Industrial Waste

3C Question 3C: Share of Residents Served (If NO)

Data source: _____ Data year: _____

	# of households
Served by MSW collection	
Total in Municipality	

Question 3C: Public Schools (If NO)

Data source: _____ Data year: _____

	# of students enrolled	# of schools
Elementary Schools		
Middle Schools		
High Schools		

	Mass of Waste
Mass of Solid Waste Disposed by Landfill and Incineration	
Mass of Solid Waste Disposed by Composting and Anaerobic Digestion	

3D Question 3D: Landfill

Data source: _____ Data year: _____

Landfill: _____

3E Question 3E: Wastewater Treatment

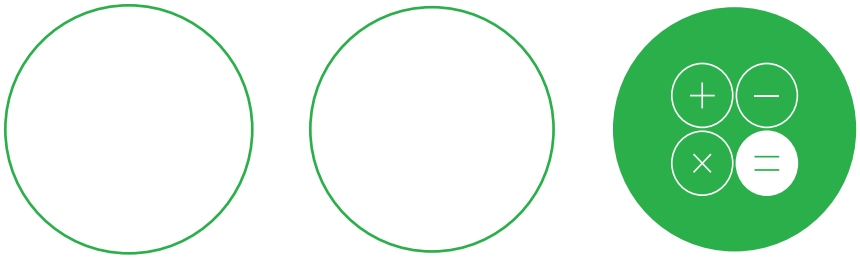
Data source: _____ Data year: _____

Total Population	
% of Population served by Wastewater Treatment Plant	

Population Data

Data source: _____ Data year: _____

Population	
Population of Community	
Population of Massachusetts	



STEP 3

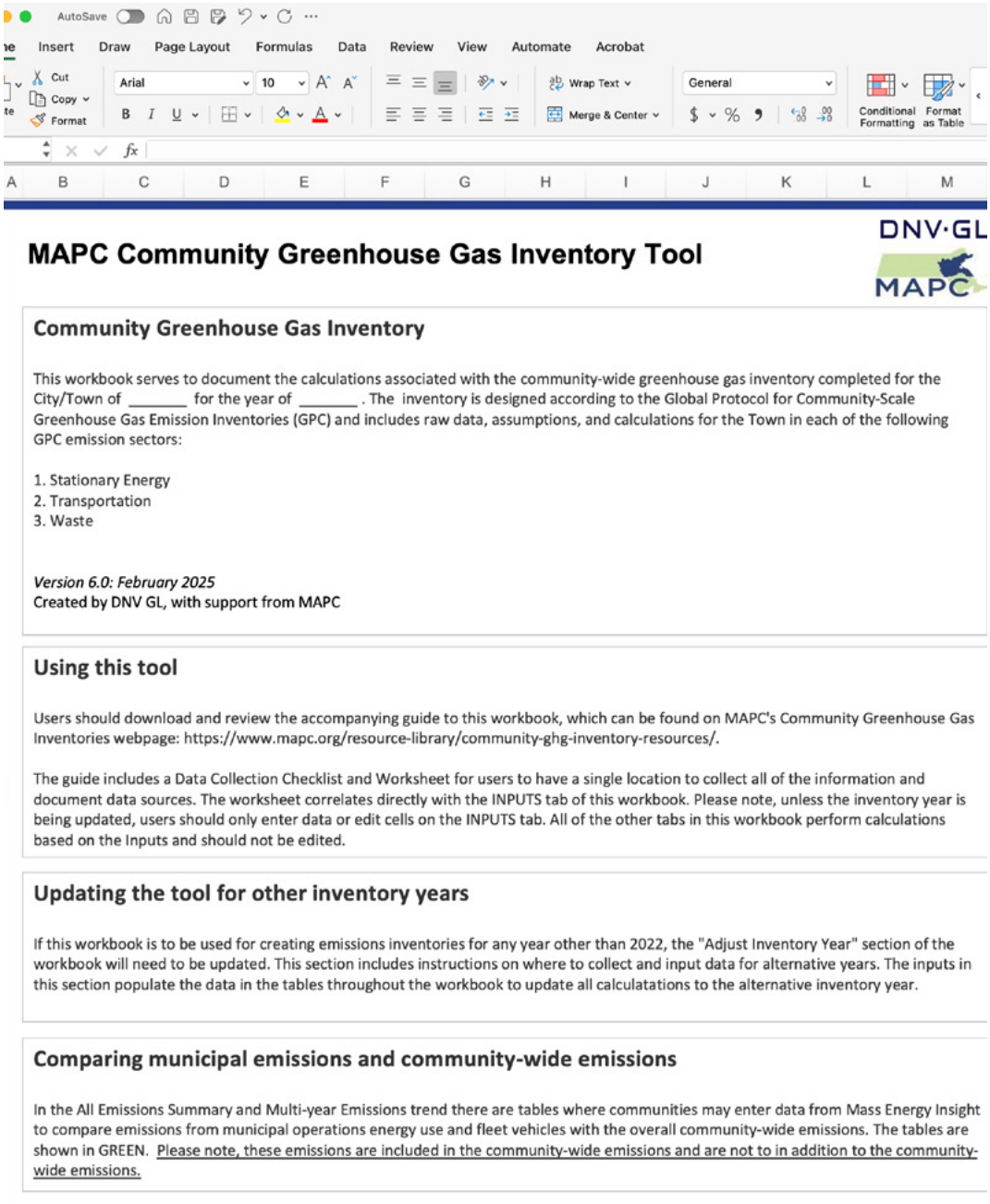
CALCULATE EMISSIONS USING THE TOOL

The next step to completing your GHG inventory will be to input all the data you have collected in the corresponding fields in the "Inputs" section of the Tool. To proceed in this section you will need:

- A completed data collection worksheet for your community with data for the appropriate inventory year
- A blank copy of the Tool to input the data

Navigating the Tool

When using the Tool, the only tab you will need to add your data to is the "Inputs" sheet of the spreadsheet. This tab is connected to all of the summary sheets and sector-specific sheets. You can also update the "Introduction" sheet to reflect the name of your municipality and appropriate inventory year.



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A B C D E F G H I J K L M

MAPC Community Greenhouse Gas Inventory Tool

DNV·GL MAPC

Community Greenhouse Gas Inventory

This workbook serves to document the calculations associated with the community-wide greenhouse gas inventory completed for the City/Town of _____ for the year of _____ . The inventory is designed according to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) and includes raw data, assumptions, and calculations for the Town in each of the following GPC emission sectors:

1. Stationary Energy
2. Transportation
3. Waste

Version 6.0: February 2025
Created by DNV GL, with support from MAPC

Using this tool

Users should download and review the accompanying guide to this workbook, which can be found on MAPC's Community Greenhouse Gas Inventories webpage: https://www.mapc.org/resource-library/community-ghg-inventory-resources/.

The guide includes a Data Collection Checklist and Worksheet for users to have a single location to collect all of the information and document data sources. The worksheet correlates directly with the INPUTS tab of this workbook. Please note, unless the inventory year is being updated, users should only enter data or edit cells on the INPUTS tab. All of the other tabs in this workbook perform calculations based on the Inputs and should not be edited.

Updating the tool for other inventory years

If this workbook is to be used for creating emissions inventories for any year other than 2022, the "Adjust Inventory Year" section of the workbook will need to be updated. This section includes instructions on where to collect and input data for alternative years. The inputs in this section populate the data in the tables throughout the workbook to update all calculatations to the alternative inventory year.

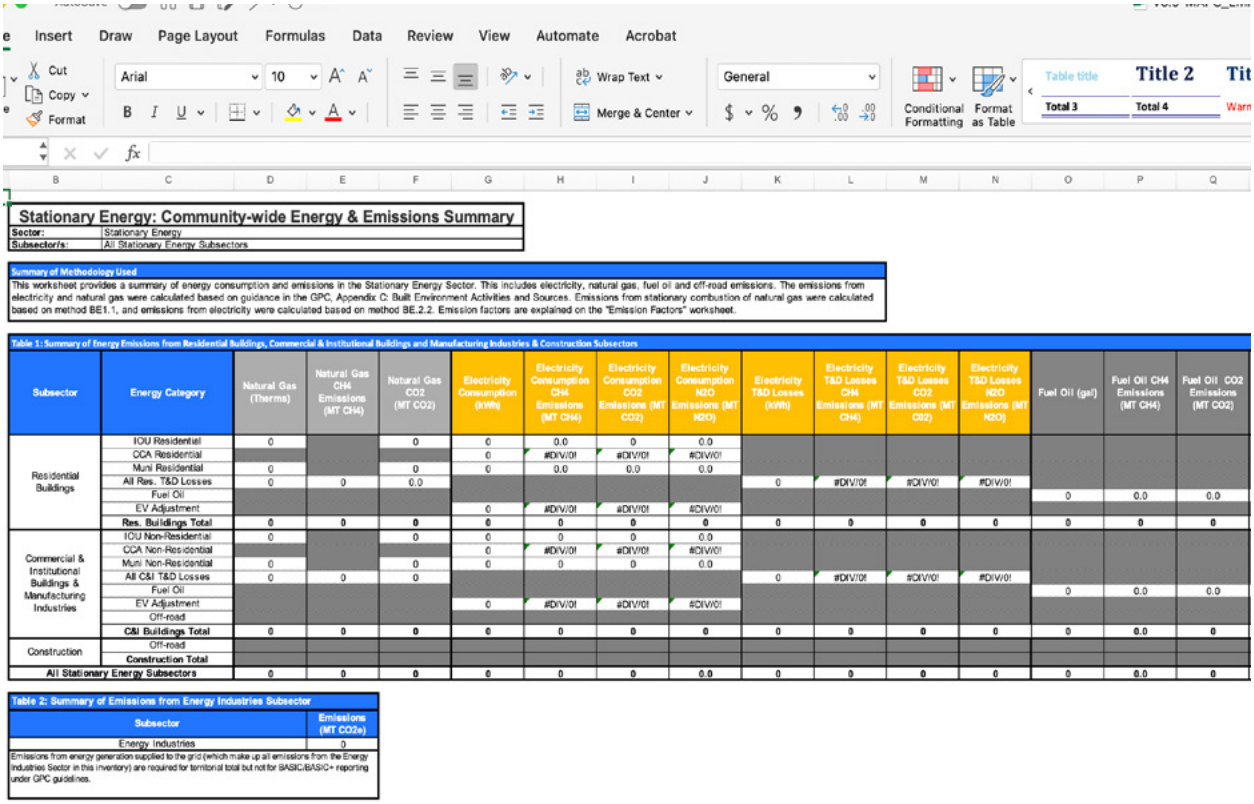
Comparing municipal emissions and community-wide emissions

In the All Emissions Summary and Multi-year Emissions trend there are tables where communities may enter data from Mass Energy Insight to compare emissions from municipal operations energy use and fleet vehicles with the overall community-wide emissions. The tables are shown in GREEN. Please note, these emissions are included in the community-wide emissions and are not to in addition to the community-wide emissions.

The "All Emissions – Summary" sheet and "Report Charts" is where you can view all of your emissions data outputs. These two sheets provide you with summary tables and charts by sector, subsector, fuel type, and scope.

Each sector (Stationary Energy, Transportation, and Waste) has summary sheets that will populate with the output data from the subsectors covered by the sector.

Example: Stationary Energy – Summary



Stationary Energy: Community-wide Energy & Emissions Summary

Sector:	Stationary Energy
Subsector/s:	All Stationary Energy Subsectors

Summary of Methodology Used

This worksheet provides a summary of energy consumption and emissions in the Stationary Energy Sector. This includes electricity, natural gas, fuel oil and off-road emissions. The emissions from electricity and natural gas were calculated based on guidance in the GPC, Appendix C: Built Environment Activities and Sources. Emissions from stationary combustion of natural gas were calculated based on method BE1.1, and emissions from electricity were calculated based on method BE.2.2. Emission factors are explained on the "Emission Factors" worksheet.

Table 1: Summary of Energy Emissions from Residential Buildings, Commercial & Institutional Buildings and Manufacturing Industries & Construction Subsectors

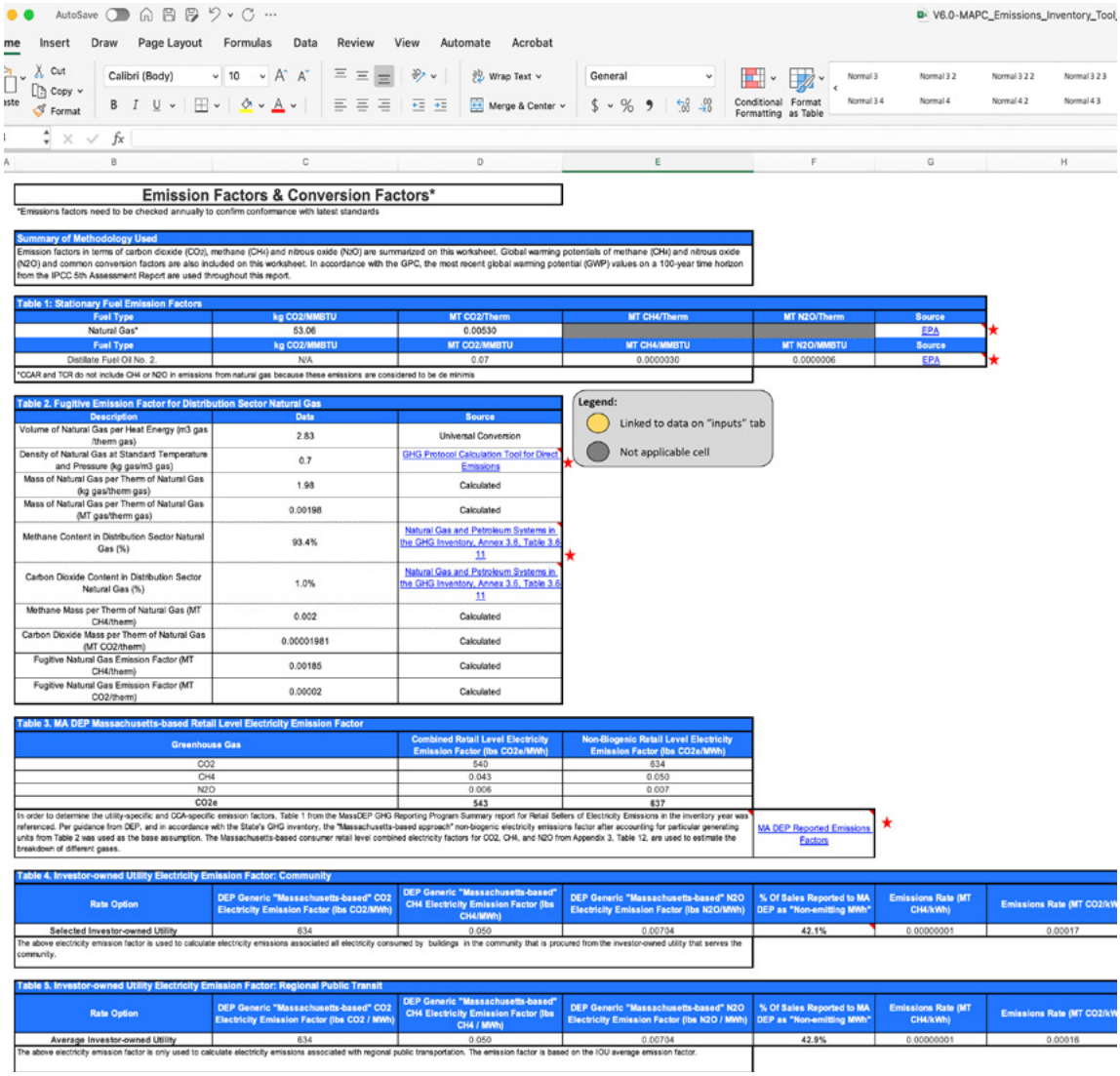
Subsector	Energy Category	Natural Gas (Therms)	Natural Gas CH4 Emissions (MT CH4)	Natural Gas CO2 (MT CO2)	Electricity Consumption (kWh)	Electricity Consumption CH4 Emissions (MT CH4)	Electricity Consumption CO2 Emissions (MT CO2)	Electricity Consumption N2O Emissions (MT N2O)	Electricity T&D Losses (kWh)	Electricity T&D Losses CH4 Emissions (MT CH4)	Electricity T&D Losses CO2 Emissions (MT CO2)	Electricity T&D Losses N2O Emissions (MT N2O)	Fuel Oil (gal)	Fuel Oil CH4 Emissions (MT CH4)	Fuel Oil CO2 Emissions (MT CO2)
Residential Buildings	IOU Residential	0		0	0	0.0	0	0.0							
	CCA Residential				0	#DIV/0!	#DIV/0!	#DIV/0!							
	Muni Residential	0		0	0	0.0	0.0	0.0							
	All Res. T&D Losses	0	0	0.0					0	#DIV/0!	#DIV/0!	#DIV/0!			
	Fuel Oil												0	0.0	0.0
	EV Adjustment				0	#DIV/0!	#DIV/0!	#DIV/0!							
	Res. Buildings Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Commercial & Institutional Buildings & Manufacturing Industries	IOU Non-Residential	0		0	0	0	0	0.0							
	CCA Non-Residential				0	#DIV/0!	#DIV/0!	#DIV/0!							
	Muni Non-Residential	0		0	0	0	0	0.0							
	All C&I T&D Losses	0	0	0					0	#DIV/0!	#DIV/0!	#DIV/0!			
	Fuel Oil												0	0.0	0.0
	EV Adjustment				0	#DIV/0!	#DIV/0!	#DIV/0!							
	Off-road														
	C&I Buildings Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**
Construction	Off-road														
	Construction Total														
All Stationary Energy Subsectors		**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**

Table 2: Summary of Emissions from Energy Industries Subsector

Subsector	Emissions (MT CO2e)
Energy Industries	0

Emissions from energy generation supplied to the grid (which make up all emissions from the Energy Industries Sector in this inventory) are required for territorial total but not for BASIC/BASIC+ reporting under GPC guidelines.

The final "Emissions Factors" sheet in the spreadsheet is where you can view all of the information about the emissions factors and other conversion factors applied throughout the Tool. This is where you can see the methodology applied if your community has a Green Aggregation Program (Question 1C).



Emission Factors & Conversion Factors*

*Emissions factors need to be checked annually to confirm conformance with latest standards

Summary of Methodology Used

Emission factors in terms of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are summarized on this worksheet. Global warming potentials of methane (CH_4) and nitrous oxide (N_2O) and common conversion factors are also included on this worksheet. In accordance with the GPC, the most recent global warming potential (GWP) values on a 100-year time horizon from the IPCC 5th Assessment Report are used throughout this report.

Table 1: Stationary Fuel Emission Factors

Fuel Type	kg CO2/MMBTU	MT CO2/Therm	MT CH4/Therm	MT N2O/Therm	Source
Natural Gas*	53.06	0.00530			EPA
Fuel Type	**kg CO2/MMBTU**	**MT CO2/MMBTU**	**MT CH4/MMBTU**	**MT N2O/MMBTU**	**Source**
Distillate Fuel Oil No. 2	N/A	0.07	0.0000030	0.0000006	EPA

*CCAR and TCR do not include CH4 or N2O in emissions from natural gas because these emissions are considered to be de minimis

Table 2. Fugitive Emission Factor for Distribution Sector Natural Gas

Description	Data	Source
Volume of Natural Gas per Heat Energy (m3 gas /therm gas)	2.83	Universal Conversion
Density of Natural Gas at Standard Temperature and Pressure (kg gas/m3 gas)	0.7	GHG Protocol Calculation Tool for Direct Emissions
Mass of Natural Gas per Therm of Natural Gas (kg gas/therm gas)	1.98	Calculated
Mass of Natural Gas per Therm of Natural Gas (MT gas/therm gas)	0.00198	Calculated
Methane Content in Distribution Sector Natural Gas (%)	93.4%	Natural Gas and Petroleum Systems in the GHG Inventory, Annex 3.6, Table 3.6-11
Carbon Dioxide Content in Distribution Sector Natural Gas (%)	1.0%	Natural Gas and Petroleum Systems in the GHG Inventory, Annex 3.6, Table 3.6-11
Methane Mass per Therm of Natural Gas (MT CH4/therm)	0.002	Calculated
Carbon Dioxide Mass per Therm of Natural Gas (MT CO2/therm)	0.00001981	Calculated
Fugitive Natural Gas Emission Factor (MT CH4/therm)	0.00185	Calculated
Fugitive Natural Gas Emission Factor (MT CO2/therm)	0.00002	Calculated

Legend:
- Linked to data on "inputs" tab
- Not applicable cell

Table 3. MA DEP Massachusetts-based Retail Level Electricity Emission Factor

Greenhouse Gas	Combined Retail Level Electricity Emission Factor (lbs CO2e/MWh)	Non-Biogenic Retail Level Electricity Emission Factor (lbs CO2e/MWh)
CO2	540	634
CH4	0.043	0.050
N2O	0.006	0.007
CO2e	**543**	**637**

In order to determine the utility-specific and DCA-specific emission factors, Table 1 from the MassDEP GHG Reporting Program Summary report for Retail Sellers of Electricity Emissions in the inventory year was referenced. Per guidance from DEP, and in accordance with the State's GHG inventory, the "Massachusetts-based approach" non-biogenic electricity emissions factor after accounting for particular generating units from Table 2 was used as the base assumption. The Massachusetts-based consumer retail level combined electricity factors for CO2, CH4, and N2O from Appendix 3, Table 12, are used to estimate the breakdown of different gases.

MA DEP Reported Emissions Factors

Table 4. Investor-owned Utility Electricity Emission Factor: Community

Rate Option	DEP Generic "Massachusetts-based" CO2 Electricity Emission Factor (lbs CO2/MWh)	DEP Generic "Massachusetts-based" CH4 Electricity Emission Factor (lbs CH4/MWh)	DEP Generic "Massachusetts-based" N2O Electricity Emission Factor (lbs N2O/MWh)	% Of Sales Reported to MA DEP as "Non-emitting MWh"	Emissions Rate (MT CH4/kWh)	Emissions Rate (MT CO2/kW
Selected Investor-owned Utility	634	0.050	0.00704	42.1%	0.00000001	0.00017

The above electricity emission factor is used to calculate electricity emissions associated all electricity consumed by buildings in the community that is procured from the investor-owned utility that serves the community.

Table 5. Investor-owned Utility Electricity Emission Factor: Regional Public Transit

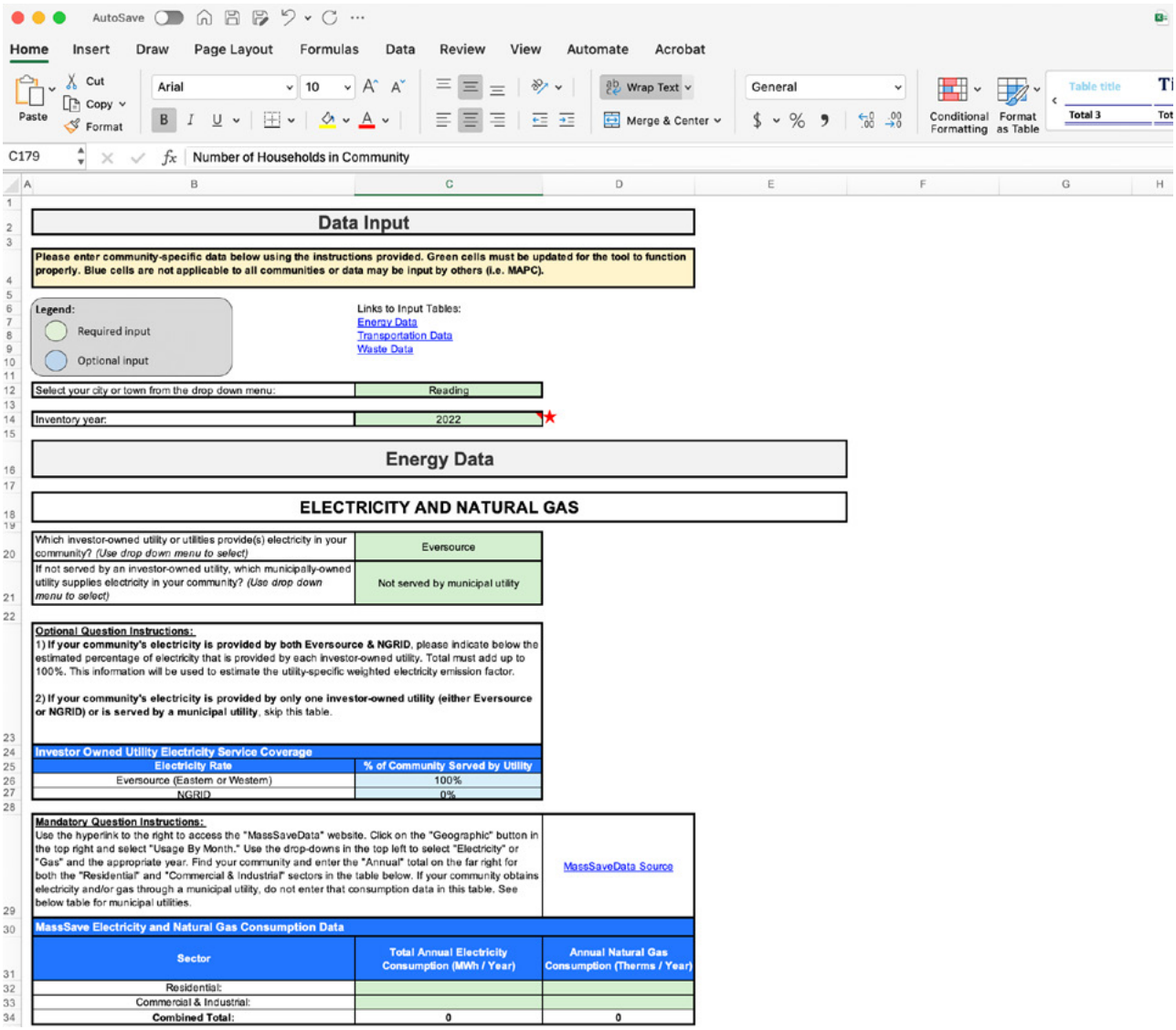
Rate Option	DEP Generic "Massachusetts-based" CO2 Electricity Emission Factor (lbs CO2 / MWh)	DEP Generic "Massachusetts-based" CH4 Electricity Emission Factor (lbs CH4 / MWh)	DEP Generic "Massachusetts-based" N2O Electricity Emission Factor (lbs N2O / MWh)	% Of Sales Reported to MA DEP as "Non-emitting MWh"	Emissions Rate (MT CH4/kWh)	Emissions Rate (MT CO2/kW
Average Investor-owned Utility	634	0.050	0.00704	42.9%	0.00000001	0.00018

The above electricity emission factor is only used to calculate electricity emissions associated with regional public transportation. The emission factor is based on the IOU average emission factor.

Input the collected data

The "Inputs" sheet provides guidance as you walk through each sector and subsector on how to gather and where to add the data collected. You will need to enter community-specific data from your worksheet using the instructions provided.

Green cells must be updated for the Tool to function properly (mandatory inputs). **Blue cells** are not applicable to all communities (optional inputs). Read the instructions provided throughout the "Inputs" sheet to determine if the orange cells are applicable to your community.



AutoSave

Home Insert Draw Page Layout Formulas Data Review View Automate Acrobat

Paste Cut Copy Format | Arial 10 | Wrap Text | Merge & Center | General | Conditional Formatting | Format as Table | Table title | Total 3

C179 | Number of Households in Community

Data Input

Please enter community-specific data below using the instructions provided. Green cells must be updated for the tool to function properly. Blue cells are not applicable to all communities or data may be input by others (i.e. MAPC).

Legend:
- Required input
- Optional input

Links to Input Tables:
Energy Data
Transportation Data
Waste Data

Select your city or town from the drop down menu:	Reading
Inventory year:	2022

Energy Data

ELECTRICITY AND NATURAL GAS

Which investor-owned utility or utilities provide(s) electricity in your community? *(Use drop down menu to select)*	Eversource
If not served by an investor-owned utility, which municipally-owned utility supplies electricity in your community? *(Use drop down menu to select)*	Not served by municipal utility

Optional Question Instructions:
1) **If your community's electricity is provided by both Eversource & NGRID**, please indicate below the estimated percentage of electricity that is provided by each investor-owned utility. Total must add up to 100%. This information will be used to estimate the utility-specific weighted electricity emission factor.

2) **If your community's electricity is provided by only one investor-owned utility (either Eversource or NGRID) or is served by a municipal utility**, skip this table.

Investor Owned Utility Electricity Service Coverage

Electricity Rate	% of Community Served by Utility
Eversource (Eastern or Western)	100%
NGRID	0%

Mandatory Question Instructions:
Use the hyperlink to the right to access the "MassSaveData" website. Click on the "Geographic" button in the top right and select "Usage By Month." Use the drop-downs in the top left to select "Electricity" or "Gas" and the appropriate year. Find your community and enter the "Annual" total on the far right for both the "Residential" and "Commercial & Industrial" sectors in the table below. If your community obtains electricity and/or gas through a municipal utility, do not enter that consumption data in this table. See below table for municipal utilities.

MassSaveData Source

MassSave Electricity and Natural Gas Consumption Data

Sector	Total Annual Electricity Consumption (MWh / Year)	Annual Natural Gas Consumption (Therms / Year)
Residential:		
Commercial & Industrial:		
Combined Total:	**0**	**0**

Review all inputs and summary tables and charts

Once you have completed entry of all of your data, review the "All Emissions – Summary" and "Charts" tab to verify that the data is displaying correctly and there are no errors in the formulas.

Once everything looks good, you are ready to incorporate your GHG inventory results into other documents as context on GHG emissions within your community!

Document your choices

Using the information in your completed inventory, Check List on Local Characteristics, and Data Collection Worksheet, you can move on to document the methodology choices made in the Methodology Template in Appendix A.

The Methodology Template will provide you with the base documentation of all of the calculations and data sources used in the guide and the space to document the key decisions you made on what data to collect and include in your inventory. The Template also provides a space for communities to input their data sources and estimation approach for any of the optional data inputs, such as regional transit authorities and waste collected by private haulers.

The Methodology Template is organized to align with the questions raised throughout the guide, so that you can easily check off the data decisions and applicable method sections to use to document the methodology supporting your GHG inventory.

FURTHER RESOURCES AND TOOLS

This guide is meant to be a companion to MAPC's Community Greenhouse Gas Inventory Tool and relies on several key resources to support its technical methods and approaches. The authors recommend that users of this guide also refer to the following resources and tools for additional support and detail on the supporting methodologies.

The **Global Protocol for Community-Scale Greenhouse Gas Emission Inventories ("GPC")** is the foundational resource that guided the development of this guide. Published by World Resources Institute, C40 Cities Climate Leadership Group and ICLEI – Local Governments for Sustainability (ICLEI) in 2014 – this is the globally accepted framework for creating an inventory of greenhouse gas emissions at the community level. The framework provides communities with guidance on how to calculate emissions for each sector and what activity data is needed to calculate these emissions. The GPC refers to and relies on methodologies put forth in the IPCC guidelines and scales the national approach down to the community-scale.

The GPC also draws on methods produced in the **IPCC Guidelines for National Greenhouse Gas Inventories**. These guidelines were updated in 2019 at the request of the United Nations Framework Convention on Climate Change (UNFCCC). These guidelines serve as good practice guidance on internationally agreed upon methodologies for use by countries to estimate greenhouse gas inventories to report to the UNFCCC. Each chapter provides detailed guidance on the appropriate methods to account for GHG emissions and average factors to use at the national level. These national factors are often used in local GHG inventories in the absence of more localized information.

ICLEI – Local Governments for Sustainability is a global network for local and regional governments and provides resources and support through the network. ICLEI USA has produced several accompanying protocols, including the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions, the Local Government Operations Protocol, and the Recycling and Composting Emissions Protocol. Another free resource to ICLEI members is ClearPath, which is an online GHG emissions inventory development tool that is available to all ICLEI members and consultants supporting ICLEI members.

Appendix A:
MAPC Community Greenhouse Gas Inventory Tool Methodology Template

This Appendix summarizes the inventory methodology used for the Metropolitan Area Planning Council's (MAPC) Community Greenhouse Gas (GHG) Inventory Tool ("the Tool"). The inventory methodologies are described in detail by sector and subsector.

Throughout the appendix, you will be prompted to add information and select the appropriate sections that apply to your community based on the data collection decisions you made in creating your GHG inventory using the Tool.

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.

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.

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 build-ings 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
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 Biological treatment of waste	Landfill gas (methane)
	Wastewater	Process and fugitive emissions from treating wastewater	Not applicable

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).

Municipality	

Inventory Year

V6 of the Tool is set up to quantify GHG emissions for an inventory year of 2022, 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 2022.

If your community chose a year other than 2022 for the GHG Inventory, indicate the appropriate year in the following table.

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. A majority of Massachusetts communities served by investor-owned utilities have access to aggregated community-wide electricity consumption data through the MassSaveData website. For this reason, MassSaveData was used as the primary source for electricity consumption data in the Tool. Electricity consumption data from MassSave is broken out into two sectors – Residential and Commercial & Industrial.

The Global Protocol also requires accounting of losses from transmission and distribution systems. A Massachusetts-specific electricity transmission and distribution grid loss factor of 5.16% (for the year 2022) 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 those communities served by municipal utilities or whose data is not available through MassSaveData:

In this instance, electricity data may have been collected separately through a direct request to the electric utility serving your community. Please document the data source for your electricity data in the table provided below.

Utility Name	Contact Name and Email	Data Year	Date Received

For those communities that collected data for their GHG inventory in response to ***Question 1B***:

For municipally-owned buildings and facilities, electricity consumption data is sourced from MassEnergyInsight (MEI). MEI is an online energy benchmarking tool provided to Massachusetts cities and towns that are designated through the Massachusetts Department of Energy Resources (DOER) Green Communities Program.

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 2022 from MassDEP's GHG emissions reporting summaries.[1] 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.

For those communities that collected data for their GHG Inventory in response to ***Question 1C***:

Cities with municipal aggregation programs will 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.

Please document the data source for your community's green municipal aggregation program in the table provided below.

Aggregation Provider	Contact Name and Email	Data Year	Date Received

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 cities 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.

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 region, the Tool uses an average leakage rate of 2.5%. According to the Harvard study in the Boston area, 2.5%[2] 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 those communities served by municipal utilities or whose data is not available through MassSaveData:

In this instance, natural gas data may have been collected separately through a direct request to the natural gas utility serving your community. Please document the data source for your natural gas data in the table provided below.

Utility Name	Contact Name and Email	Data Year	Date Received

For municipally-owned buildings and facilities, natural gas consumption data is sourced from MassEnergyInsight (MEI). MEI is an online energy benchmarking tool provided to Massachusetts cities and towns that are designated through the Massachusetts Department of Energy Resources (DOER) Green Communities Program.

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 U.S. EPA's GHG Emissions Factor Hub.[3]

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	EPA

*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

For the Tool, residential oil usage data was based on the number of housing units in each community by type from the 2022 American Community Survey (ACS), and a percentage of units determined to be heated with fuel oil from the 2022 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.[4] The EIA 2018 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
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.[5] 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
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 those communities that collected data for their GHG inventory in response to ***Question 1B***:

For municipally-owned buildings and facilities, natural gas consumption data is sourced from MassEnergyInsight (MEI). 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 2021 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, 2022 was the most recent year of complete and accurate data available from the Massachusetts Registry of Motor Vehicles. 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)[6], which is a catalog of information about vehicles registered in the Commonwealth from 2020 through 2024. The MAVC combines information from vehicle registrations, inspection records, mileage ratings, and other sources to document the ownership and mileage history of each vehicle.

Using the MAVC data, MAPC created a database of the vehicles garaged in each municipality broken out by passenger, commercial, municipal, and state vehicles and by fuel type. Fuel types included gasoline, diesel, flex fuel, hybrid electric, plug-in hybrid electric, compressed natural gas, propane, .hydrogen fuel cell, and electric. In addition to vehicle counts, the dataset includes total vehicle miles travelled (VMT) in the calendar year and total fuel consumed in the calendar year.

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, commercial vehicles, municipal vehicles, and state vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid electric, plug-in hybrid electric, compressed natural gas, propane, hydrogen fuel cell and electric).
Annual Vehicle Miles Travelled (DVMT) by Fuel Type	Total annual mileage calculated by vehicle type (non-commercial passenger vehicles, commercial vehicles, municipal vehicles, and state vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid electric, plug-in hybrid electric, compressed natural gas, propane, hydrogen fuel cell, and electric).

Annual Fuel Consumption	Total annual fuel consumption (gallons) calculated by by vehicle type (non-commercial passenger vehicles, commercial vehicles, municipal vehicles, and state vehicles) and by fuel type (gasoline, diesel, flex fuel, hybrid electric, plug-in hybrid electric, compressed natural gas, propane, hydrogen fuel cell, and electric).

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: On-road Vehicles Emissions Factors

Fuel Type	Emission Factor	Emission Factor Units	Source
Gasoline	0.00878	MT CO2e / gallon	EPA
Diesel	0.01021	MT CO2e / gallon	EPA
Electricity	0.000287335	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 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 Appendix B. 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.

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 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.

Data on the total weight of waste collected that is destined for landfill or incineration must be provided by individual municipal waste collection programs and individual private haulers. If a community knows the percent of their collected waste that is sent to a landfilling versus incineration facility, they can enter that data into the Tool. If a community does not have this information, the Inventory Tool assumes the State-level percent of disposed waste sent to landfill (10%) and incinerated (90%) based on data in MA DEP 2022 Solid Waste Update.

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

Protocol Waste Categories Waste Category/Sub-category	Weighted Average	Global Protocol Waste Category
Paper		
Uncoated Corrugated Cardboard/Kraft Paper	5.8%	Paper
Waxed Cardboard	0.5%	Paper
High Grade Office Paper	0.5%	Paper
Magazines/Catalogs	0.4%	Paper
Newsprint	0.3%	Paper
Other Recyclable Paper	3.9%	Paper
Compostable Paper	7.2%	Paper
Remainder/Composite Paper	3.2%	Paper
Plastic		
PET Beverage Containers (non-MA deposit containers)	0.8%	Other
PET Containers other than Beverage Containers	0.5%	Other
Plastic MA Deposit Beverage Containers	0.1%	Other
HDPE Bottles, colored and natural	0.6%	Other
Plastic Tubs and lids (HDPE, PP, etc.)	0.4%	Other
#5 PP Bottles and Containers	0.9%	Other
Plastic Containers #3-#7 (which originally contained non-hazardous material)	0.9%	Other
Other Plastic Bottles & Containers	0.3%	Other
Expanded Polystyrene Food Grade	0.4%	Other
Expanded Polystyrene Non-food Grade	0.2%	Other
Bulk Rigid Plastic Items	1.8%	Other
Film (non-bag clean commercial and industrial packaging film)	1.0%	Other
Grocery and other Merchandise Bags	0.3%	Other
Other Film means plastic film	5.7%	Other
Remainder/Composite Plastic	2.5%	Other
Metal		
Aluminum Beverage Containers (non-MA deposit containers)	0.1%	Other
Aluminum MA Deposit Beverage Containers	0.3%	Other
Tin/Steel Containers	0.8%	Other

Other Aluminum	0.4%	Other
Other Ferrous and non-ferrous	1.6%	Other
White Goods	0.2%	Other
Remainder/Composite Metal	1.5%	Other
Glass		
Glass Beverage Containers (non-MA deposit containers)	0.8%	Other
Other Glass Packaging Containers (non-MA deposit containers)	0.5%	Other
Glass MA Deposit Beverage Containers	0.4%	Other
Remainder/Composite Glass	0.5%	Other
Organic Materials		
Food Waste	21.6%	Food
Branches and Stumps	0.4%	Garden Waste and Plant Debris
Prunings, Trimmings, Leaves and Grass	1.3%	Garden Waste and Plant Debris
Manures	0.2%	Garden Waste and Plant Debris
Remainder/Composite Organic	6.0%	Garden Waste and Plant Debris
Construction and Demolition (in the MSW stream)		
Asphalt Pavement, Brick, and Concrete	0.1%	Other
Aggregates, Stone, Rock	0.6%	Other
Wood – Treated	3.4%	Wood
Wood – Untreated	3.0%	Wood
Asphalt Roofing	0.3%	Other
Drywall/Gypsum Board	0.9%	Other
Carpet and Carpet Padding	1.9%	Other
Remainder/Composite Construction and Demolition	2.1%	Other
Household Hazardous Waste		
Ballasts, CFLs, and Other Fluorescents	0.0%	Other
Batteries – Lead Acid	0.0%	Other
Batteries – Other	0.1%	Other
Paint	0.1%	Other
Bio-Hazardous	3.5%	Other
Vehicle and Equipment Fluids	0.0%	Other
Empty Metal, Glass, and Plastic Containers	0.1%	Other
Other Hazardous or Household Hazardous Waste	0.1%	Other
Electronics		
Computer-related Electronics	0.1%	Other
Other "brown goods"	0.2%	Other
Televisions and Computer Monitors	0.0%	Other
Other Materials		
Tires and other rubber	0.4%	Other
Textiles	5.2%	Textiles

Bulky Materials	2.2%	Other
Mattresses	0.1%	Other
Restaurant Fats, Oils and Grease	0.0%	Food
Other Miscellaneous	2.3%	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 fraction of methane recovered at landfills of 0.86 (average of Massachusetts landfills) or the value for the specific landfill,[7] 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 contiuous 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.

7

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%).

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

Wastewater emissions are estimated using the data and methodology from Appendix C of MassDEP's Greemhouse Gas Baseline & Inventory. This methodology complies with the methodologies recommended by the GPC.

For communities served by wastewater treatment plants (WWTP) with anaerobic digestion (AD), including the Clinton, Deer Island, Greater Lawrence, Pittsfield, and Rockland WWTPs, only indirect nitrous oxide (N2O) emissions from waster effluent is calculated. These wastewater treatment plants do not release methane (CH4) because the methane is captured during an anaerobic digestion (AD) process and diverted to co-generation systems where it is used to heat buildings and generate electricity via steam turbine generators. Emissions generated as a result of methane capture and co-generation occurring outside of a city's boundary are considered Scope 3 emissions. According to the GPC, wastewater used to generate energy is considered a stationary energy source. Stationary energy sources outside of the city's boundary are not included in the inventory. If a wastewater treatment power plant is located inside the city's boundary, it is accounted for in the Stationary Energy: Energy Industries sector.

For communities served by a wastewater treatment plant without anaerobic digestion, indirect nitrous oxide emissions from wastewater effluent and methane generation emissions from wastewater treatment are calculated using the methodology outlined in the Massachusetts DEP Greenhouse Gas Baseline & Inventory report. Communities that are served by WWTPs without AD do have some methane emissions associated with wastewater treatment because methane capture and co-generation systems are not in place. The methane emissions are calculated using MassDEP's factors for WWTP biochemical oxygen demand, WWTP maximum methane producing potential, WWTP methane correcting factor, WWTP emission factor for wastewater treatment, and the population served by the WWTP.

Some communities are only partially served by WWTPs, and the remainder of the population is on septic systems. For the portion of the community's population on septic systems, the methane emissions are calculated using MassDEP's factors for septic biochemical oxygen demand, septic maximum methane producing potential, septic methane correction factor, septic factor for wastewater treatment, fraction of population managing their septic tank in compliance with the sludge removal instruction of their septic system, and the population on septic.

Indirect nitrous oxide emissions for all wastewater treatment methods are calculated using MassDEP's factor for N2O process emissions and the community population.

Appendix B:
MAPC Calculation Methods for MBTA Data

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.

This appendix details the specific methods MAPC applied to the MBTA data to support communities in Greater Boston with completion of GHG inventories.

Preparation of Fuel and Electricity Consumption Data

The MBTA provided MAPC with system-wide consumption data for calendar years 2017 and 2018, for the following fuel types and uses:

Table B1: Data Provided by the MBTA by Fuel Type and Use

Type and Use	Unit
ULS ("Ultra-low-sulfur") Diesel for Buses	Gallons
ULS Diesel for Ferries*	Gallons
ULS Diesel for Commuter Rail	Gallons
Non-Revenue Diesel for Commuter Rail	Gallons
Non-Revenue Gasoline for Commuter Rail*	Gallons
MBTA Non-Revenue Gasoline*	Gallons
Gasoline for The RIDE*	Gallons
CNG for Buses	MMBTU
Heating Oil (#1/#2 Diesel Fuel)*	Gallons
Natural Gas for Buildings*	Therms
Jet Fuel*	Gallons
Electricity (System-wide)	MWh
Steam for Buildings*	Klbs.

*Asterisks denote consumption data not used by MAPC.

Another challenge presented by the consumption data provided by the MBTA is the presence of a single figure for electricity. Based on conversations with MBTA representatives, an estimated 60% of electricity consumption is used to power vehicles, and the remaining 40% powers buildings. MAPC applied this ratio to the data.

Route Length and Frequency Calculations

To estimate route lengths and frequencies, MAPC downloaded General Transit Feed Specification (GTFS) schedule data archived on the MBTA's website.[1] The MBTA publishes a GTFS feed every time there is a known change in service, which means there are multiple versions for a single year. For example, in 2017, the MBTA published 48 GTFS feeds.

Each of the MBTA's GTFS feeds consist of 22 tables, of which MAPC utilized six for our calculations:

- The Calendar table defines dates when service is available for particular routes. This file specifies start and end dates, as well as the days of the week when service is available.
- The Stops table defines the locations of stops on the network by latitude and longitude
- The Stop Times table defines the times that a vehicle arrives at and departs from stops for each trip.
- The Trips table defines trips for each route. A trip is a sequence of two or more stops that occur during a specific time period.
- The Shapes table provides a geospatial representation of the path followed by the transit vehicles on each route
- The Routes table provides additional descriptive information on each route

The MBTA aggregates GTFS feeds into four seasonal feeds per year (winter, spring, summer, and fall). MAPC combined the data from each seasonal feed as described below.

MAPC joined the Calendar, Stops, and Stop Times tables by Service ID field, and then joined this table to the Trips table using the Trip ID field. MAPC calculated the total number of days in the year that each route was in service using the start and end dates from the Calendar table and the days of week the service is running. We then calculated the total number of annual trips for each service ID by multiplying the number of trips per Service ID per day from the Trips table with the number of annual operating days.

Vehicle Miles Traveled Calculation

MAPC used the Shapes tables to calculate the length in miles of each route. However, not every trip on a route covers the entire length of the route defined in the Shapes table. Many trips cover only partial distances of the route, depending on day of week and alternate service schedules. MAPC used the Trips, Stops, and Stop Times tables to identify which trips travel the full length of the route, and which trips travel only a part of the route, by examining the origination stop and ending stop for each trip. For the trips that do not travel the full route distance, MAPC used the Google Distance Matrix API and Google Directions API to obtain the transit mode travel distance between the originating stop and the ending stop locations listed in the Trips table. MAPC also export a shapefile for each of these partial-route trips, in order to allocate them properly across municipal boundaries.

To obtain annual vehicle miles travelled, MAPC multiplied the annual number of trips for each route by the route length in miles. This yielded an annual vehicle miles traveled figure for each route which could be used to allocate system-wide consumption.

Commuter Rail

To estimate commuter rail emissions by municipality, MAPC first allocated the system-wide diesel fuel consumption total for commuter rail for the 2017 calendar year[2] to individual routes by multiplying the fuel consumption total by a ratio of annual vehicle miles traveled for each commuter rail route to annual vehicle miles traveled for all commuter rail routes. MAPC then multiplied the consumption total for the commuter rail route by a ratio of vehicle miles traveled for that route in each municipality and the sum of vehicle miles traveled for the route.

Heavy Rail, Light Rail, and Trackless Trolleys

Heavy rail, light rail, and trackless trolleys are all powered by electricity, so, as a first step in estimating emissions by municipality, MAPC allocated the system-wide electricity figure for transit (60% of the total system-wide figure) to each electricity-consuming transit mode. MAPC based this distribution on vehicle miles traveled. In the 2017 calendar year, 78.2 percent of total vehicle miles traveled was from heavy rail (red, blue, and orange lines), 19.8 percent was from light rail (green lines and the Mattapan Trolley), and 2.0 percent was from trackless trolley lines (bus routes 71, 72, 73, and 77).[3]

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1 https://cdn.mbta.com/archive/archived_feeds.txt

2 We counted both revenue (ULS Diesel for Commuter Rail) and non-revenue commuter rail diesel (Non-Revenue Diesel for Commuter Rail) towards commuter rail consumption.

3 This calculation assumes that electricity usage per vehicle mile traveled is roughly similar between heavy rail, light rail, trackless trolley, and Silver Line. Ideally, this value would be further weighted by an electricity efficiency factor.

MAPC then followed a process identical to that used for commuter rail routes, first allocating the electricity figure for each electricity-consuming transit mode to each route and then allocating the electricity figure for each route to each municipality. A percent of total electricity is also allocated to Silver Line buses as described in the following section.

Silver Line and Bus (Excluding Trackless Trolleys)

As of the writing of this guide, there are two Silver Line vehicle types in operation: dual mode Electric-Diesel and Battery Electric. Battery electric buses just started revenue service in April 2019, so only Electric-Diesel hybrid buses were present during the inventory base year of 2017. Using a method similar to the partial-route distance calculations described above, MAPC, split the Silver Line vehicle trips into electric and non-electric operation segments. The Silver Line Electric-Diesel hybrid buses rely on electric power only when travelling in the Transitway tunnel between South Station and Silver Line Way and operate in diesel-powered mode when elsewhere on their route. The vehicle miles travelled in electric mode are used to allocate electricity from the total system electricity consumption using the same method as for heavy rail / light rail / trackless trolley described above. For diesel consumption, MAPC followed a process identical to that used for commuter rail routes to allocate diesel consumption, first allocating the diesel fuel consumption totals to each bus route (including diesel-powered vehicle miles travelled by the Silver Line) and then allocating the consumption total for each route to each municipality. MAPC replicated this process for CNG, excluding Silver Line routes. [4]

4 This calculation assumes a geographically even distribution of CNG and Diesel busses. The MBTA does not currently have estimates of fuel mix by bus line.

Appendix C:
Adjusting the Tool for Alternate Inventory Years

Version 4 of the Tool (published March 2020) is auto populated to support the completion of an inventory for the year 2017. If your community would like to complete an inventory for an alternate year, additional inputs will need to be updated to datasets from the appropriate year. This appendix outlines guidance on what data you will need to collect and where to find it.

Please note that at the time of publishing this Tool, 2017 was the most recent year when the necessary data were widely available. Data availability from the sources listed below may vary depending on the alternate inventory year you have selected.

Table C1 lists all of the Tool's tables to review and update prior to creating an inventory for another year. The data collected can by input into the "Adjust Inventory Year" section of the Tool.

Table C1: Summary of Workbook Tables with Values to Update in the Tool

Workbook Sheet Name	Table
Emission Factors - All	Table 1: Stationary Fuel Emission Factors
	Table 3. MA DEP 2016 Massachusetts-based Retail Level Electricity Emission Factor
	Table 6. List Investor-owned Utilities and % Non-emitting Sales
	Table 7. Community Choice Aggregation Electricity Emission Factors
	Table 9. List of Municipal Utilities % Non-emitting Sales
	Table 11: IPCC AR5 100-Year Global Warming Potentials without Climate-carbon Feedbacks
	Table 12: Transportation Fuel Emission Factors
Stationary Energy - Build-ings	Table 7. Massachusetts Electricity Transmission & Distribution Grid Loss Factor
Transportation - On Road	Table 6: Private On-road Electric Vehicles Fuel Efficiency
Waste - Solid Waste	Table 3: Proportion of Massachusetts In-state Waste Disposed: Landfilled vs. Combusted by Waste Type for 2017
Waste - Wastewater	Table 3: Indirect N2O Emissions From Wastewater Effluent (GPC Equation 8.11) for Communities Served by MWRA WWTP
	Table 4: Indirect N2O Emissions From Wastewater Effluent and CH4 Generation from Wastewater Treatment for Communities Not Served by MWRA WWTP**

Data Not Included in the Adjustment Guidance

There are a few datasets that support calculations within the Tool and are updated on an infrequent basis. These datasets are sourced from the U.S. Energy Information Administration (EIA). These datasets support the heating oil estimation approach with in the Tool and are not a direct source activity data. For these reasons, it is not required to update these datasets to quantify emissions for alternate years. The list of the tables and data sources are provided in Table C2.

Table C2: Stationary Energy – Buildings Infrequently Updated Data Sources

Table	Data Source		Input Location
Table 3. Residential Fuel Oil Consumption and Emissions	US EIA Residential Energy Consumption Survey (RECS)	Table CE2.1 Annual Household Site Fuel Consumption in the U.S. - totals and averages	Column C, Column D
		Table HC2.8 Structural and Geo-graphic Characteristics of Homes in Northeast Region, Divisions, and States	Column E, Column F
		Table CE2.2 Household Site Fuel Consumption in the Northeast Region, Totals and Averages	Cell C47
Table 4. Com-mercial Fuel Oil Consumption and Emissions	US EIA Commercial Buildings Energy Consumption Survey (CBECS)	Table C34: US Commercial Building Fuel Oil Consumption and Expenditures	Column F, Column G, Column H,
		Table B22. Energy Sources, Number of Buildings	Column J
Table 5 Industrial Fuel Oil Consumption and Emissions	US EIA Manufacturing Energy Consumption Survey (MECS)	Table 6.1: Consumption Ratios of Fuel	Column E
		Table 1.1: First Use of Energy for all Purposes (Fuel and Nonfuel)	Column F
		Table 5.4: End Uses of Fuel Con-sumption	Column G

When appropriate, and funding is available, MAPC will release updated versions of the Tool to improve the accuracy of the estimation methodologies being applied to the heating oil estimates.

How to Adjust the Inventory Year

The "Adjust Inventory Year" section of the Tool is where you will input revised data for an alternate inventory year. This section is auto populated with all of the necessary data inputs for 2017 and links directly to each respective table in the Tool. Prior to making any changes to this section, make sure to save a copy of the existing workbook to preserve the 2017 inputs in the event they are needed again.

If you are adjusting the inventory year to report for a new year and have used MAPC's Tool for a prior year, make sure to copy and paste the values (not the formulas) for the current year of data as it appears in the "Multi-Year Emissions Trend" Tab into a different column. This will support you in tracking emissions over time when the new year of data populates.

Update All Emissions Factors

Depending on the inventory year selected, new or revised emissions factors may be available for combusted fuels like natural gas and fuel oil and vehicle fuels like diesel, gasoline, and compressed natural gas. Emissions factors can be sourced from either the Climate Registry or US EPA. Both are free resources and publicly available - however, you will need to create a free account to access the archive of emissions factors produced by the Climate Registry.

- ◯ Sign up for a free account to access the Climate Registry's emissions factors for natural gas, gasoline, diesel, and compressed natural gas: https://www.theclimateregistry.org/tools-resources/reporting-protocols/general-reporting-protocol/
- ◯ For fuel oil, access emissions factors from the US EPA for the appropriate inventory year: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

Updating the electricity emissions factors in the Tool requires the input of data reported by the Massachusetts Department of Environmental Protection (MassDEP). For the average emissions factors, you will need the values for the Massachusetts-based approach for non-biogenic CO2 equivalent, after accounting for particular generating units and the breakdown by each GHG (CO2, CH4, and N2O) for the Massachusetts-based electricity consumers retail-level emissions factors.

In the same MassDEP report, you will need to access the data from Appendix 2 that includes the percent of sales reported as MWh for each electric utility and municipal utility. These percentages support the production of utility specific market-based electricity emissions factors in the Tool.

Updating the electricity emissions factors in the Tool requires the input of data reported by the Massachusetts Department of Environmental Protection (MassDEP). For the average emissions factors, you will need the values for the Massachusetts-based approach for non-biogenic CO2 equivalent, after accounting for particular generating units and the breakdown by each GHG (CO2, CH4, and N2O) for the Massachusetts-based electricity consumers retail-level emissions factors.

In the same MassDEP report, you will need to access the data from Appendix 2 that includes the percent of sales reported as MWh for each electric utility and municipal utility. These percentages support the production of utility specific market-based electricity emissions factors in the Tool.

- ◯ Access MassDEP's GHG Reporting Program Summary Report for Retail Sellers of Electricity for the appropriate inventory year: https://www.mass.gov/guides/massdep-greenhouse-gas-emissions-reporting-program

If your community has a green municipal aggregation program (see Question 1C of the Guide), you will also need to update the minimum compliance percentage for Class I under the Massachusetts Renewable Portfolio Standard. Under Massachusetts General Law, this compliance percentage increases by one percent each year.

- ◯ Access the minimum compliance percentage for Class I (with carve outs) for the appropriate inventory year: https://www.mass.gov/service-details/annual-compliance-information-for-retail-electric-suppliers

Occasionally, the calculations used to assess Global Warming Potential (GWP) will be updated or revised. This change can be due to updated scientific estimates of the energy absorption or lifetime of the gases or to changing atmospheric concentrations of GHG emissions that result in a change in the energy absorption of one additional ton of a gas relative to another. The Tool defaults to use the GWP values provided by the Intergovernmental Panel on Climate Change (IPCC) in the Fifth Assessment Report (2014). The Global Protocol recommends using the most recent GWP values available.

These inputs should only be adjusted if an Assessment Report more recent than 2014 has been released by the IPCC with revised GWP values, or if this Tool is being used for a historic inventory requiring the use of older GWP values.

- ◯ Access historic GWP values at this link: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Update Stationary Energy Electricity Transmission and Distribution

A Massachusetts-specific electricity transmission and distribution grid loss factor is calculated per U.S. Energy Information Administration (EIA) instructions. To adjust your inventory year, you will need to collect the data from U.S. EIA's electricity profile for Massachusetts on total disposition, direct use, and estimated losses.

- ◯ Access Massachusetts' electricity profile: https://www.eia.gov/electricity/state/massachusetts/

Update Transportation Electric Vehicle Fuel Efficiency

The fuel efficiency of electric vehicles is rapidly progressing from year to year. To increase the accuracy of your GHG inventory for alternate years, you may choose to update the data supporting the average vehicle efficiency applied to electric vehicles in the Tool's calculations. To maintain consistency, select the seven top selling electric vehicles.

- ◯ Look up fuel economy for top selling electric vehicles: https://www.fueleconomy.gov/

Update Waste Disposal Proportions

This Tool assumes default State-level percent of disposed waste sent to landfill and combusted unless local data is entered on the "Inputs" tab of this workbook. This data can be found in MassDEP's Solid Waste Data Update for the state.

- ◯ Access MassDEP's Solid Waste Data update for the appropriate year: https://www.mass.gov/guides/solid-waste-master-plan#-solid-waste-data-updates-

The Tool also relies on data from the U.S. EPA's annual Inventory of U.S. Greenhouse Gas Emissions and Sinks to determine protein consumption per capita.

- ◯ Access to the most recent summary report released by EPA: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Update Wastewater Factors and State Data

The wastewater emissions analysis follows the approach used by the Massachusetts Department of Environmental Protection (DEP) to estimate wastewater treatment emissions for communities in Massachusetts that are not served by a Massachusetts Water Resources Authority (MWRA) wastewater treatment plant in the "Statewide Greenhouse gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection Update" report.

For those communities not served by MWRA, please contact MassDEP for the wastewater module of the State's GHG Inventory for the selected inventory year to obtain the following inputs. Data from the "Summary" tab of this workbook was used to obtain data on State total methane and nitrous oxide emissions from municipal wastewater treatment for 2017 and the Massachusetts state population not served by MWRA.