Greenhouse Gas Inventory Protocol

FOR SOUTHERN MAINE CITIES AND TOWNS

Southern Maine Planning and Development Commission

KARINA GRAETER | SUSTAINABILITY COORDINATOR

SEPTEMBER 2021

SMPDC
SOUTHERN MAINE PLANNING & DEVELOPMENT COMMISSION
Regional Sustainability and Resilience Program

Contents

1. Introduction

Motivation

Climate change is impacting Maine with warmer air and ocean temperatures, shorter winters, and new pests and diseases. These changes are primarily driven by an increase of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in the atmosphere, largely due to the combustion and use of fossil fuels. These GHGs trap heat in the Earth's atmosphere. They let sunlight pass through the atmosphere but prevent the heat that the sunlight brings from leaving the atmosphere. As we burn more and more fossil fuels, GHGs continue to build up in the atmosphere, trapping an ever-greater amount of heat. This global warming is leading to significant shifts in global and regional climate patterns, including the changes that we are already experiencing in Maine and expect to continue and intensify in the future.

In 2019, the Governor and Legislature created the Maine Climate Council, an assembly of scientists, industry leaders, bipartisan local and state officials, and engaged citizens tasked with guiding the state in how to reduce GHG emissions to prevent the worst impacts of climate change. The council developed Maine Won't Wait: A Four Year Plan for Climate Action to put Maine on a trajectory to reduce emissions by 45% by 2030 and at least 80% by 2050, and achieve carbon neutrality by 2045.

Southern Maine communities want to do their part in mitigating climate change and adapting to a low-carbon future. A GHG inventory helps a municipality understand ongoing activities and major sources of emissions, identify areas to focus emission reduction efforts, establish goals and track progress towards those goals, and facilitate decision-making about future policies and strategies. However, completing a first GHG inventory is a difficult and time-consuming task, particularly for small municipalities that lack the municipal capacity and expertise in energy management. While there are extensive protocols and methodologies available for conducting community-wide GHG inventories (i.e. *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions*, ICLEI – Local Governments for Sustainability USA), these protocols are not state/region specific, and have limited applicability to smaller communities.

Until now, the piecemeal GHG inventory efforts and lack of regional coordination have limited the functionality of southern Maine GHG inventories as tools for guiding emissions reduction strategies. Without a standardized methodology and data quality oversight and consistency, it is impossible to compare inventories across municipalities or between years. This makes it difficult to prioritize emissions reduction strategies or evaluate their impacts, and it hinders the development of regional emission reduction strategies.

Purpose

To assist member municipalities with creating community-wide GHG inventories, the SMPDC Regional Sustainability and Resilience Program created a standardized, southern Maine GHG inventory protocol. This guide summarizing the protocol includes methodologies for collecting energy use data and calculating the associated GHG emissions across the inventory sectors.

This protocol is based on the 2014 Global Protocol for Community-Scale Greenhouse Gas Inventories. It is also informed by the ICLEI – Local Governments for Sustainability *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions*, and the Metropolitan Area Planning Council *Greenhouse Gas Inventories for Massachusetts Cities and Towns*.

While applicable to most small cities and towns, the protocol takes special consideration of the data sources and emissions factors applicable to Maine communities. The standardized and simplified protocol means that inventories produced using this protocol may be compared across communities and used to evaluate the impacts of emission reduction strategies in future years.

2. Background

What is a Greenhouse Gas Inventory?

This protocol was developed to conduct *community-wide* GHG inventories. A community-wide GHG inventory estimates the amount of GHG emissions associated with community sources and activities, meaning those of a municipality's residents, workforce, visitors, and economy. An inventory is usually calculated for a specific analysis year. By conducting subsequent inventories every 3-5 years, local communities can aid local decision-makers and municipal staff in prioritizing and evaluating emission reduction strategies.

A *community-wide* GHG inventory is a different tool than a *municipal* GHG inventory (also called a local government operations inventory). A municipal GHG inventory looks only at the emissions occurring because of local government operations, including those from government buildings and facilities, government fleet vehicles, wastewater treatment and potable water treatment facilities, landfill facilities, and other operations. The Local Government Operations Protocol provides an overview and methodology for municipal GHG inventories.

While a community-wide GHG inventory inherently includes all the emissions associated with municipal operations, this protocol does not specifically call out those emissions that that would fall into the municipal operations category. There are benefits and weaknesses to both types of inventories, summarized in the table below. For those communities wishing to tackle GHG emissions at all levels, we recommend completing a community-wide inventory of GHG emissions, supplementing the community-wide GHG inventory with additional indicators (described on page 7), and pulling out emissions from local government operations with a municipal GHG inventory.

Pros and Cons of community-wide and municipal GHG inventories

	Community-wide GHG inventory	Municipal GHG inventory
Pros	• Comprehensive view of all emissions occurring in the community • Provides insight into regulatory/educational/community emission reduction strategies • Helps set community-wide targets and strategies that can be implemented by the local government, residents, businesses, and region	• Provides clear picture of emissions directly controlled by the local government • Leads to concrete and implementable strategies for reducing municipal emissions • Easier and faster to complete
Cons	• More complex and time consuming to complete • Relies more heavily on modeled data and regional/national averages, leading to some uncertainty in results	• Only a small portion of a community's overall emissions • Limited impact of resulting emission reduction strategies on community-wide emissions • Doesn't provide insight on regulatory/educational/community emission reduction strategies

What Greenhouse Gases are Included?

The primarily GHGs included in a community-wide GHG inventory are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Each GHG contributes differently to warming in the atmosphere, where some are far more potent than others in the same quantities. Because CH_4 and N_2O absorb far more energy than CO_2 in the atmosphere, global warming potentials (GWP) are needed to account for the warming impact of each gas. A GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2). To show the total emissions impact, emissions of CO_2 and N_2O are converted to metric tons of CO_2 equivalent (MT CO_2e) using each gas' GWP.

There are many other types of greenhouse gases, including perfluorocarbons, hydrofluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. This protocol does not address these gases because they primarily result from sectors not included in the protocol, such as Industrial, and Agriculture, Forestry & Land Use.

What Types of Emissions are Included?

The inventory estimates emissions resulting from the activities of a community's members, including its residents, workforce, and visitors. The GHG emissions may be either directly created (e.g., through household heating or vehicle fuel combustion) or indirectly created (e.g., through grid electricity use) by community members. For the inventory, emission types are divided into different sectors and subsectors. The Inventory Checklist (section 9) shows the GHG inventory broken down by data collection steps.

Sectors and Subsectors **included** in the Southern Maine GHG inventory protocol

SECTOR	SUBSECTOR	EMISSIONS SOURCES	ENERGY TYPE
STATIONARY ENERGY	Residential	Energy use in buildings as well as losses from distribution systems	Electricity
			Natural Gas
		Energy use in buildings	Discrete Fuel
	Commercial	Energy used in commercial, government, and institutional buildings as well as losses from distribution systems	Electricity
			Natural Gas
		Energy used in commercial, government, and institutional buildings	Discrete Fuel
	Industrial	Energy used in manufacturing and industrial facilities as well as losses from distribution systems	Electricity
			Natural Gas
		Energy used in manufacturing and industrial facilities	Discrete Fuel
TRANSPORTATION	Passenger Vehicles	Fuel combusted from all passenger vehicle trips that are attributable to the municipality	Gasoline, Diesel, Electricity
	Commercial Vehicles	Fuel combusted from all commercial vehicle trips that are attributable to the municipality	Gasoline, Diesel, Electricity
	Public Transit	Fuel combusted due to passenger miles travelled on public transit	Gasoline, Diesel, Electricity
	Marine Vessels	Fuel combusted by boats that are refueled at community harbors	Gasoline, Diesel
WASTE	MSW - Landfilling	Landfill gas (CH_4) emissions resulting from all trash generated by residential and commercial activity in the community and sent to landfill	Landfill Gas
	MSW - Incineration	GHG emissions resulting from the incineration of all trash generated by residential and commercial activity in the community that is sent to an incineration plant	Incineration Emissions
	Wastewater	Process and fugitive emissions from treating wastewater from all residential and commercial activities	Aerobic and Anaerobic Digestion

What Types of Emissions are Excluded?

We developed this protocol to simplify the process of developing a GHG inventory by using easily accessible data sources. It excludes sectors where data are less readily available, are significantly inaccurate, and/or have little relevance to municipal climate action planning. Communities may add in additional subsectors depending on relevance and data availability.

Sectors and Subsectors **excluded** in the Southern Maine GHG inventory protocol

SECTOR	SUBSECTOR	EMISSIONS SOURCES	ENERGY TYPE
TRANSPORTATION	Passenger Rail	Fuel combusted due to passenger miles travelled on passenger rail	Gasoline, Diesel, Electricity
	Freight Rail	Emissions from the movement of freight on rail lines through a community	Gasoline, Diesel, Electricity
	Off Road Equipment	Emissions that result from airport equipment, agricultural tractors, chain saws, forklifts, snowmobiles	Gasoline, Diesel, Electricity
	Aviation	Fuel combusted from passenger and commercial air travel	Jet Fuel
WASTE	Compost	GHG emissions resulting from the breakdown of all composted material generated by residential, commercial, and schools	Aerobic and Anaerobic Digestion
INDUSTRIAL	Industrial Process Emissions	Process and fugitive emissions from industrial facilities	Combustion and other Chemical Emissions
	Product Use	Emissions from the use of products such as refrigerants, foams, or aerosol cans	Combustion and other Chemical Emissions
AGRICULTURE, FORESTRY, MARINE	Livestock	Emissions from manure management and enteric fermentation	Enteric fermentation and manure management
	Land	Emissions and sequestration of GHGs from land use changes	Soil and Land Management Changes

Additional Indicators

For a community to develop mitigation initiatives and set clear goals, we recommend collecting an additional set of *indicators* that can accompany your GHG inventory. These indicators do not directly translate to GHG emissions in MT CO_2e, but they help provide a clearer picture of the progress your community is making on specific actions that municipalities in Maine utilize to reduce emissions.

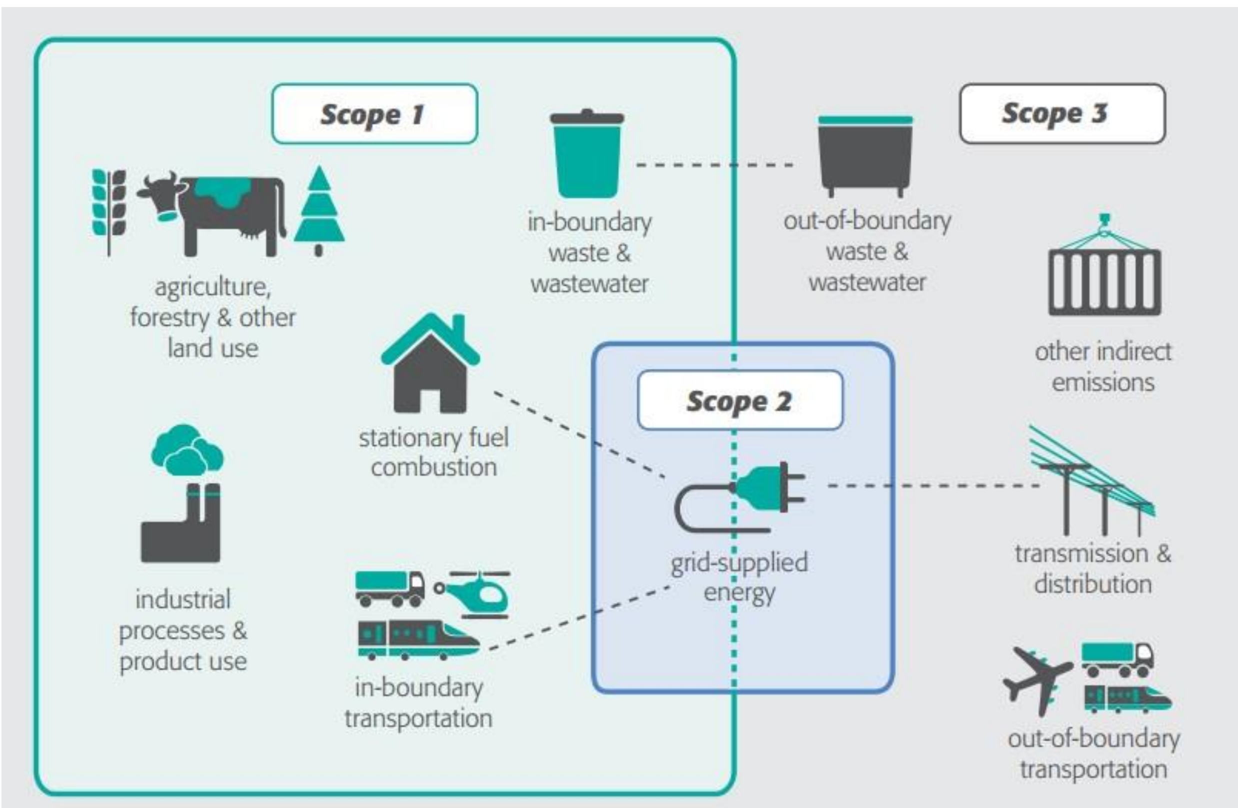
Emission Scopes

Community-wide GHG emissions are also categorized by scope. Scopes designate the location and control of the emissions. Emission scopes by sector are identified throughout the protocol to aid communities in understanding emission sources and in inventory reporting and disclosure. They are defined as follows:

Scope 1 emissions are those that physically occur within the boundary of the community (such as the combustion of fossil fuels for home heating).

Scope 2 emissions are those that result from energy use within the boundary of the community but whose emissions occur outside the boundary (such as grid-supplied electricity).

Scope 3 emissions occur outside of the community boundary but are driven by activities within the community (such as landfilling community waste outside the community).



Source: [Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories]

3. Inventory Boundaries

Inventory Year

It is best practice to complete a GHG inventory every three to five years to track progress on emissions reduction efforts. For the first inventory, a community should select the most recent year for which data are widely available. Because of different data sources, the most recent data available in one subsector might not be the same as in another subsector (e.g., you might have 2019 data for residential electricity but only 2018 data from on-road transportation). Data may be averaged over multiple years when available (e.g., natural gas data from 2018-2020). This guide suggests clearly reporting the time-period reflected by the data collected for each sector/subsector. This will allow for comparison in future inventories.

Geographical Boundary

The logical geographic boundary for a community-wide GHG inventory is a town or city's administrative boundary. This selection aligns most closely with available data sources. All emissions that happen inside the municipality's administrative boundary are included and classified as scope 1. All emissions that happen outside of the municipality's administrative boundary as a direct result of community activity within the boundary (i.e. electricity use, landfilling of waste) are also included in the inventory, but classified as either Scope 2 or Scope 3.

4. Collecting the data

Community-wide emissions are calculated by multiplying activity data (e.g., fuel consumption) by the corresponding emission factors (e.g., tons CO_2 emitted per gallon of fuel combusted) for each activity. The quality and availability of GHG emissions data varies across sectors and subsectors. The protocol describes how to collect the highest quality data available according to the following hierarchy:

1. **Real consumption data for each fuel type or activity, disaggregated by subsector.** When available, this type of data can be obtained from a utility or fuel provider (e.g., for grid electricity).
2. **A representative sample set of real consumption data from surveys**.
3. **Modeled energy consumption/activity data.**
4. **Regional or national fuel consumption data scaled down using population or other indicators.**

The quality of available data may significantly impact confidence in the GHG emissions estimate for particular subsectors of emissions. Similarly, the current scientific understanding and/or simplifications that must be made influence our confidence in the emissions factors used to convert activity data to emissions estimates. To highlight these uncertainties, we indicate our confidence in each activity data and emissions factor as either low, medium, or high according to the guidelines provided in the 2014 Global Protocol for Community-Scale Greenhouse Gas Inventories.

Data Quality	Activity Data	Emission Factor
High	Detailed activity data	Specific emission factors
Medium	Partial or modeled activity data using robust assumptions	More general emission factors
Low	Highly-modeled or uncertain activity data	Default emission factors

Source: Table 5.3 in 2014 Global Protocol for Community-Scale Greenhouse Gas Inventories.

This protocol provides guidance for acquiring activity data for southern Maine community-wide GHG inventories. It also details the methodologies used for converting activity data into GHG emissions. Many cities and towns in southern Maine have chosen to use the ICLEI ClearPath Platform to calculate and categorize emissions data. This methodology describes what steps are needed to collect and enter GHG emissions data into the ClearPath platform. Additional guidance is available through the ClearPath Users Guide available on the platform. Alternatively, cities and towns may choose to keep their own records of activity data and emissions using excel or other data worksheets.

Data collection should be managed by a responsible party who has an understanding of the GHG inventory process and good working knowledge of data management. We also encourage municipalities to reach out to their local regional planning office for guidance and assistance.

5. Stationary Energy

The Stationary Energy sector includes GHG emissions resulting from energy use by buildings and industries. It includes the direct emissions from the combustion of fossil fuels (Scope 1) and the indirect emissions from the consumption of grid-supplied electricity (Scope 2). It also includes the losses from the transmission and distribution systems of grid-supplied electricity and natural gas (Scope 3).

Stationary Energy sectors included in the Southern Maine GHG inventory protocol

SECTOR	SUBSECTOR	EMISSIONS SOURCES	ENERGY TYPE
STATIONARY ENERGY	Residential	Energy use in buildings as well as losses from distribution systems	Electricity
			Natural Gas
		Energy use in buildings	Discrete Fuel
	Commercial	Energy used in commercial, government, and institutional buildings as well as losses from distribution systems	Electricity
			Natural Gas
		Energy used in commercial, government, and institutional buildings	Discrete Fuel
	Industrial	Energy used in manufacturing and industrial facilities as well as losses from distribution systems	Electricity
			Natural Gas
		Energy used in manufacturing and industrial facilities	Discrete Fuel

Data collection for Stationary Energy may be completed in the following groups:

1. Electricity: collected for Residential, Commercial, and Industrial subsectors from the local utility(ies)
2. Natural Gas: collected for the Residential subsector and for the combined Commercial/Industrial subsectors from the local utility
3. Discrete Fuel: estimated for the Residential subsector and for the combined Commercial/Industrial subsectors using national and statewide data

Electricity Data Details

Scopes:

- Electricity use = Scope 2
- Transmission & Distribution losses = Scope 3

Activity Data Quality: HIGH

Electricity

Data collection methodology

Real consumption data for community-wide electricity use is available from Maine's electric utilities. In southern Maine, the electric utility is Central Maine Power (CMP), a subsidiary of Avangrid. Avangrid maintains electricity consumption data separated by subsector. Data are typically available from 2016 or 2017 onward. The following steps detail the method for collecting community-wide electricity data from Avangrid/CMP or another electric utility:

1. Identify what electricity grid serves your community.
2. Identify the Key Accounts Manager for your region. SMPDC may be able to help you identify this contact.
3. Reach out to the Key Accounts Manager via email.
    a. Ask for community-wide electricity data for your community, broken out by month and by Residential, Commercial, and Industrial subsectors.
    b. Ask for data from one or more years. The more data you have, the more flexibility you have in your inventory. The Key Accounts Manager will be able to give you up-to-date data, but you may want data from earlier years since many of your other inventory datasets will not be as up-to-date.
    c. Ask for usage data (kilowatt hours used) and number of accounts by month and by subsector.
    d. The Key Accounts Manager should be able to provide you with all the electricity data you need. You may need to prove you have approval from municipal leadership via an email authorization.
4. Check data quality. Data should appear like the table below, with electricity usage and number of accounts listed by subsector for each month.
    a. Identify if any months have missing or outlying data. For example, some records might not be complete for earlier years.
5. Sum data by inventory year by subsector
    a. You may need to reformat the data from the Key Accounts Manager to do this.

Example of community-wide electricity data

Calendar Year/Month	JAN 2017	JAN 2017	FEB 2017	FEB 2017	MAR 2017	MAR 2017
	Usage	Number of Accounts	Usage	Number of Accounts	Usage	Number of Accounts
ADID	KWH		KWH		KWH	
Overall Result	649,1666	9,278	685,8519	9,320	6,332,542	9370
Commercial Customer	199,7276	884	226,0122	889	2,072,448	897
Industrial Customer	308,909	19	311,755	19	311,981	19
Residential Customer	418,5481	8,374	428,6642	8,411	3,948,113	8453

Example of yearly electricity data by subsector

Account type	2017	2018	2019
Total (KWH)	89,306,992	96,751,893	96,819,242
Residential (KWH)	50,518,657	55,840,220	55,633,047
Commercial (KWH)	33,588,630	35,189,684	35,421,772
Industrial (KWH)	5,081,006	5,220,972	5,252,827

6. Calculate Electricity Emissions
    a. If using the ICLEI ClearPath Platform:
        i. Enter your electricity usage data (in KWH) directly into the platform using the "Emissions from Grid Electricity" calculator for Residential Energy, Commercial Energy, and Industrial Energy tabs.
        ii. Select the most recent NPCC New England (NEWE) eGRID Grid Electricity conversion factor (for all Maine communities).
    b. If NOT using the ICLEI ClearPath Platform: Convert electricity usage from kilowatt hours to MT CO_2e emitted using the correct conversion factor.
        i. In Maine, the majority of residential and commercial electricity consumers receive the standard offer electricity rate. Therefore, the best available emissions factor is the grid-average emissions factor for the New England Region (NPCC New England or NEWE). The Emissions & Generation Resource Integrated Database (eGRID), published by the U.S. Environmental Protection Agency (EPA) is the best source for emissions data for the electric power generated in the United States. The most recent eGRID data are available from the eGRID website. At the time of publishing, the most recent eGRID emissions factors are from 2019. An inventory should apply the emissions factor available that is closest to the inventory year.
        ii. Emissions factor applied in this protocol is the NEWE eGRID 2019 Subregion Output emission rate, available here:

$$\frac{0.000224\, MT\ CO_2e}{1\ KWH}$$

Example of yearly electricity emissions by subsector

Account type	2017	2018	2019
Total (MT CO_2e)	20,003.35	21,670.89	21,685.98
Residential (MT CO_2e)	11,315.38	12,507.33	12,460.92
Commercial (MT CO_2e)	7,523.32	7,881.93	7,933.92
Industrial (MT CO_2e)	1,138.07	1,169.42	1,176.55

7. Calculate emissions from transmission and distribution losses.
    a. Transmission and distribution loss (T&D loss) is an estimate of the energy lost in the process of supplying electricity to consumers. These losses mainly occur from energy dissipated in the conductors, transformers, and other equipment used for transmission, transformation, and distribution of power. eGRID provides an estimate of T&D losses for the NEWE region, which they refer to as the Gross Grid Loss (available here). For example, the Gross Grid Loss for NEWE 2019 was 5.1%.
    b. If using the ICLEI ClearPath Platform: Use the “Emissions from Electric Power Transmission and Distribution Losses” calculator under the Upstream Impacts of Activities tab.
        i. Separately enter the electricity use (in KWH) for each subsector (Residential, Commercial, and Industrial).
        ii. Select the most recent NPCC New England (NEWE) eGRID Grid Electricity conversion factor (for all Maine communities).
        iii. Supply the correct Gross Grid Loss Factor (i.e. 5.1% for NEWE 2019).
    c. If NOT using the ICLEI ClearPath Platform:
        i. T&D losses are calculated by multiplying the electricity emissions by subsector and the Gross Grid Loss factor.

Example of yearly electricity T&D losses by subsector

Account type	2017	2018	2019
Total Losses (MT CO2e)	1,020.17	1,105.22	1,105.98
Residential Losses (MT CO2e)	577.08	637.87	635.51
Commercial Losses (MT CO2e)	383.69	401.98	404.63
Industrial Losses (MT CO2e)	58.04	59.64	60.00

Electricity data quality

In general, electricity use data are real consumption data that is accurate and of high quality. Data are usually available up to the month of the data request. Older data (2016 or earlier) is typically not available due to changes in utility accounting systems.

Recommendations for methodology improvement

At this time, electricity use data collection is somewhat onerous for both the inventory’s responsible party and the utility staff. This process would be vastly improved if all investor-owned utility companies in the state were required to publish electricity consumption data broken out by municipality. For example, Massachusetts requires that all utilities in the state publish community-wide usage by year. The data are also available for residential, commercial, and industrial as well as low-income customer segments.

Currently, the Maine Department of Environmental Protection does not calculate a Maine-specific electricity emission factor. As a result, Maine communities must rely on the New England average emissions factor, which includes electricity generated throughout new England. Because Maine has enacted aggressive renewable portfolio standards for Maine’s electricity consumption, it would be useful to have a Maine-specific emissions factor for estimating community-wide electricity emissions.

Natural Gas Data Details

Scopes:

- Natural Gas use = Scope 1
- T&D losses = Scope 3

Activity Data Quality:

- Natural Gas use: HIGH
- T&D losses: LOW

Emission Factor Quality: HIGH

Natural Gas

Data collection methodology

Only a small proportion of Maine's communities have access to natural gas. For those that do, real consumption data for community-wide natural gas use is available from natural gas utilities. There are a handful of natural gas utilities in Maine. In southern Maine, the primary natural gas utility is Unitil. Unitil maintains natural gas consumption data separated by subsector. Data are typically available from 2018 onward. The following steps detail the methodology for collecting community-wide natural gas data from Unitil:

1. Identify whether your community is served by a natural gas utility. You can look at the territory map or you may need to contact the utility directly to determine this.
2. Reach out to Unitil's Municipal Services department here to request natural gas usage data.
    a. The inventory's responsible party will likely need authorization from a Town Manager or other municipal official to get access to the community-wide natural gas usage data.
    b. Request monthly usage amounts and meter amounts by subsector (although at this time Unitil groups Commercial and Industrial accounts) for the inventory year or a few years.
3. Check data quality. Data should appear like the table below, with natural gas usage and number of meters listed by subsector for each month.
    a. Identify if any months have missing or outlying data. For example, some records might not be complete for earlier years, or there might be a big jump in number of meters for residential customers due to reclassification of utility rates.

Example of monthly community-wide natural gas data

		2018		**2019**	
		Residential	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**
	Therms	16,929	1,470,110	16,929	1,470,110
January	Meters	195	247	195	247

4. Sum community-wide natural gas data by year and by subsector.

Example of annual community-wide natural gas usage data

	2018		**2019**		**2020**	
	Residential	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**
Total Usage (Therms)	108,721	11,782,218	149,524	11,483,810	207,975	11,232,186

5. Convert natural gas usage from Therms to Metric Tons CO_2e emitted.
    a. If using the ICLEI ClearPath Platform: Use the "Emissions from Stationary Fuel Combustion" calculator for the Residential Energy and Commercial Energy tabs.
        i. Since Unitil groups Commercial and Industrial Natural Gas use, report the combined Commercial and Industrial natural gas use under the Commercial Energy Tab. Make a note of this in the "Notes" section.
        ii. Select *Fuel Type*: Natural Gas.
        iii. Enter fuel use, making sure you are using the correct unit (i.e. Therms).
        iv. Enter *Data Source*: Measured Usage.
    b. If NOT using the ICLEI ClearPath Platform: Emissions factors for natural gas and other fuels come from the EPA Emissions Factors for Greenhouse Gas Inventories Document. This document includes the emissions factors for natural gas for CO_2, N_2O, and CH_4. Emissions of N_2O and CH_4 must be converted to CO_2e using global warming potentials (GWP). Currently, GWP used to convert those emissions to CO_2e come from the IPCC fifth assessment report. We calculated the combined emissions factor for Natural Gas combustion to be:

$$\frac{0.0053187\ MT\ CO_2e}{1\ Therm}$$

Example of yearly natural gas emissions by subsector

	2018		**2019**		**2020**	
	Residential	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**
Total Usage (MT CO_2e)	578.25	62,666.09	795.27	61,078.94	1,106.16	59,740.63

6. Calculate emissions from natural gas transmission and distribution losses.
    a. Transmission and Distribution loss (T&D loss) is an estimate of the energy lost in the process of supplying natural gas to consumers. It occurs during the production, processing, transmission, and storage of natural gas to a region as well as the during the local distribution of natural gas to houses and commercial users. Because we do not consider the upstream emissions of other fuel and energy sources, we account for only the T&D loss that occurs due to local distribution for the community-wide inventory. We

estimate this local distribution leakage (i.e. natural gas T&D loss rate) to be 0.3%, as estimated in the EDF Natural Gas leakage Rate Modeling Tool.

b. If using the ClearPath Platform: Use the "Fugitive Emissions from Natural Gas Distribution" calculator under the Process and Fugitive Emissions tab.
    i. Separately enter the natural gas usage (in therms) for each subsector. (Residential, Commercial – i.e. combined Commercial and Industrial)
    ii. Do not worry about changing any of the standard factors included in the calculator.

c. If NOT using the ICLEI ClearPath Calculator: Natural Gas T&D losses are difficult to calculate because you need to estimate the energy density and physical properties of the natural gas. Convert T&D losses of natural gas to MT CO_2e using the following formula based on assumed natural gas properties (the same as used in the ClearPath Platform):

$$T\&D\ losses\ (MT\ CO_2e) = X\ Therm \times \frac{0.1\ MMBTU}{Therm} \times \left(\frac{6.1939 \times 10^{-5}\ MT\ CH_4}{1\ MMBTU} \times \frac{28\ MT\ CO_2e}{1\ MT\ CH_4} + \frac{6.6316 \times 10^{-7}\ MT\ CO_2}{1\ MMBTU}\right)$$

Example of yearly natural gas T&D losses by subsector

	2018		**2019**		**2020**	
	Residential	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**	**Residential**	**Commercial & Industrial**
T&D Losses (MT CO_2e)	18.86	2,044.16	25.94	1,992.39	36.08	1,948.73

Natural gas data quality

In general, natural gas use data are real consumption data that is accurate and of high quality. Data are usually available up to the month of the data request. Older data are typically not available due to changes in utility accounting systems. It is unfortunate that currently available data combines commercial and industrial subsectors. While in southern Maine where industrial businesses do not make up a large portion of energy use or activity, it would be useful to be able to understand the relative energy uses of the two subsectors.

Estimates of natural gas T&D losses are relatively rough, relying on general EPA data for natural gas leakage rates. However, there remain significant uncertainties associated with leakage estimates. Leakage estimates also vary depending on the source of the natural gas, such as shale gas versus conventional gas. The emissions factors for natural gas T&D loss should be considered to be low quality. However, they are important to consider as natural gas is often touted as a lower emission fuel source than other fossil fuels, but those qualities may be negated due to significant leakage issues.

Recommendations for methodology improvement

At this time, it is somewhat onerous for both the inventory's responsible party and the utility staff to collect natural gas usage data. This process would be vastly improved if all investor-owned utility companies in the state were required to publish natural gas consumption data broken out by municipality. Improving estimates of T&D losses for natural gas will require national and academic research.

Discrete Fuel - Data Details

Scope: Scope 1

Activity Data Quality: LOW

Emission Factor Quality: HIGH

Discrete Fuel Use

Discrete fuel use for stationary energy includes fuels used for building heating such as fuel oil, kerosene, and propane. For discrete fuel use, we used different calculation methodologies for Residential, Commercial/Industrial, and Large Emitting Facilities (Industrial).

Data collection methodology – Residential

Currently, there is no record of real consumption data for Residential heating fuel use in Maine communities. Instead, we must rely on three representative sample data sets:

- Statewide home heating characteristics from survey results
- Community home heating characteristics from survey results
- Statewide residential real fuel consumption data

The following steps detail the methodology used to calculate emissions from discrete fuel use for the Residential subsector:

1. Compile the required datasets.
    a. Maine statewide home heating characteristics: Every few years, the Census Bureau conducts the American Community Survey (ACS). Data from the ACS can be viewed on the Census Data Explorer. To collect the Maine statewide home heating characteristics data, search the data explorer for "Maine DP04" (DP04 is the *Selected Housing Characteristics* table ID).
        i. On the right side of the header of the table, you can use a dropdown menu to select the *product* (i.e. the survey year). Select the *20XX: ACS 5-Year Estimates Data* that aligns closest with your inventory year. Using the 5-year average prevents data outliers in your inventory year.
        ii. Scroll down the table to the section titled *HOUSE HEATING FUEL*. You will need to copy the estimates for all the fuel use data (including the number of Occupied housing units) into a spreadsheet. The 2016-2019 5-year average House Heating Fuel estimates are presented in the table below:

Maine House Heating Fuel Characteristics from the ACS for 2016-2019

	# of units			
Year	**2016**	**2017**	**2018**	**2019**
Occupied housing units	551,109	554,061	556,955	559,921
Utility gas	35,834	38,464	41,237	42,107
Bottled, tank, or LP gas	48,153	52,708	55,461	60,299
Electricity	29,389	32,239	34,834	38,999
Fuel oil, kerosene, etc.	350,795	345,805	344,816	344,425
Coal or coke	1,857	1,613	1,469	1,287
Wood	72,713	69,657	65,451	59,761
Solar energy	521	629	781	874
Other fuel	10,525	11,409	11,238	10,450
No fuel used	1,322	1,537	1,668	1,719

b. Community home heating characteristics: community-specific home heating characteristics are also available through the ACS using the Census Data Explorer. To collect local housing data, search the data explorer for "[Your community], Maine DP04" (DP04 is the *Selected Housing Characteristics* table ID). You may need to play around with the name of your community to find the correct data (ex. "Kennebunk CDP, Maine" Ogunquit town, Maine", and "York town, York County, Maine").
   i. On the right side of the header of the table, you can use a dropdown menu to select the *product* (i.e. the survey year). Select the *20XX: ACS 5-Year Estimates Data* that aligns closest with your inventory year. Using the 5-year average prevents data outliers in your inventory year.
   ii. Scroll down the table to the section titled *HOUSE HEATING FUEL*. You will need to copy the estimates for all the fuel use data (including the number of Occupied housing units) into a spreadsheet. The data format should be identical to the statewide HOUSE HEATING FUEL Data.

c. Statewide residential fuel consumption data: Annual statewide residential fuel consumption is available through the US Energy Information Administration. Maine Communities will need Table CT4: Residential Energy Consumption Estimates. The data will need to be re-organized to fit the fuel type categories used in the House Heating Fuel datasets as shown in the following table:

Comparison of ACS House Heating Fuel types and EIA fuel type categories

ACS House Heating Fuel category	Equivalent EIA Fuel Category
Utility gas	Natural Gas
Bottled, tank, or LP gas	HGL
Electricity	Electricity
Fuel oil, kerosene, etc.	Distillate Fuel Oil + Kerosene
Coal or coke	Coal
Wood	Wood
Solar energy	Solar
Other fuel	Geothermal
No fuel used	N/A

i. The most recent consumption data are from 2016-2018 and is shown below. Note that residential Electricity use has been removed since that energy use is accounted for in the Electricity subsector of the GHG inventory protocol.

Maine Residential Energy Consumption Estimates reorganized to match the fuel type categories of the American Community Survey

Fuel type	ME total residential energy use by fuel type (trillion BTU)		
	2016	2017	2018
Utility gas	2.6	2.8	3.2
Bottled, tank, or LP gas	6.5	6.6	7.8
Electricity	0	0	0
Fuel oil, kerosene, etc.	32.5	32.8	33.2
Coal or coke	0	0	0
Wood	16.8	16.9	20.3
Solar energy	0.3	0.4	0.5
Other fuel	0.1	0.1	0.1
No fuel used	0	0	0

2. Calculate Maine Statewide Residential fuel use per household by fuel type.
    a. For each available year and fuel type, divide the “Maine Residential Energy Consumption Estimates” by the “Maine House Heating Fuel Characteristics”. This will result in an average energy use per Maine household by fuel type (shown below).
        i. Make sure to convert the energy use from trillion BTU to MMBTU by multiplying by 1,000,000 MMBTU/trillion BTU.

Maine average household energy use by Fuel Type

Fuel type	ME total residential heating energy use by fuel type (trillion BTU)		
	2016	**2017**	**2018**
Utility gas	72.56	72.80	77.60
Bottled, tank, or LP gas	134.99	125.22	140.64
Electricity	0.00	0.00	0.00
Fuel oil, kerosene, etc.	92.65	94.85	96.28
Coal or coke	0.00	0.00	0.00
Wood	231.05	242.62	310.16
Solar energy	575.82	635.93	640.20
Other fuel	9.50	8.77	8.90
No fuel used	0.00	0.00	0.00

3. Calculate the Community household energy use by fuel type.
    a. For each year and fuel type, multiply the "Maine average household energy use by Fuel Type" with the "Community Home Heating Characteristics by Fuel Type" to get the Community residential energy use by fuel type.
4. Remove Fuel Types that are not needed for emissions inventory.
    a. Electricity: To prevent double counting, energy use from electricity for residential heating should be removed, since that energy use is included in the Electricity subsector data calculated previously.
    b. Solar Energy: This fuel type should be removed because solar energy produces no emissions, and the quality of this data are currently poor.
    c. Other Fuel: The only known fuel type in this category is geothermal heat, which produces no emissions. This should be removed as the data quality is also poor.
    d. No Fuel used: Homes where no fuel is used do not generate any emissions for heat. This category may be ignored.
    e. Natural Gas: Since real natural gas use data are available in communities with natural gas service, it is preferred to use the real consumption data for residential natural gas use over this estimate. Remove the Natural Gas category if you already have natural gas use data for your community or know that there is no natural gas service in your community. If you know your community has natural gas service but you are unable to obtain the data, you may use this estimate instead. The discrepancies between the real consumption data and this estimate highlights the low data quality of the discrete fuel emissions estimate using ACS and EIA data sample data.
5. Convert energy use into emissions using emission factors.
    a. If using ICLEI ClearPath platform: Use the "Emissions from Stationary Fuel Combustion" calculator under the Residential Energy Tab to separately calculate emissions for each stationary fuel.
        i. Choose the correct fuel type.
        ii. Choose the correct fuel unit (i.e. MMBTU).

b. If NOT using the ICLEI ClearPath platform: Use the emissions factors and GWP factors below to convert the energy use to MT CO_2e according to the following formula:

$$Fuel\ type\ emissions\ = Fuel\ type\ energy \times \begin{bmatrix} CO_2\ Emission\ Factor \\ CH_4\ Emission\ Factor\ \times\ GWP_{CH4} \\ N_2O\ Emission\ Factor\ \times GWP_{N2O} \end{bmatrix}$$

Emissions factors by Fuel type from ICLEI ClearPath

Fuel Type	**CO_2 (kg/MMBtu)**	**CH_4 (kg/MMBtu)**	**N_2O (kg/MMBtu)**
Utility gas	53.02	0.005	0.0001
Bottled, tank, or LP gas	62.98	0.01087	0.001087
Fuel oil, kerosene, etc.	73.96	0.01087	0.00072464
Coal or coke	113.67	0.011	0.0016
Wood	93.8	0.316	0.0042

Global warming potentials (GWP) from the IPCC 5th assessment report

Global warming potentials	GWP
CH_4	28
N_2O	265

Data collection methodology – Commercial/Industrial

Like residential discrete fuel use, there is no real consumption data accessible for commercial or industrial discrete fuel use. You may estimate commercial and industrial heating fuel use for all establishments (excluding those using natural gas) using local Annual Industry Establishment data available from the State of Maine using the following steps:

1. Download community industry establishment data.
    a. Maine *Industry Employment and Wages* data are derived from the state's Quarterly Census of Employment and Wages program. The Interactive Viewer allows you to download data for each Maine town/city. Download the data for the inventory year for your community for each ownership type (private, local, state, and federal) using the following steps:
        i. Click the data tab for "City/Town".
        ii. Specify your community.
            1. Under the *City/Town* column, unselect "All".
            2. Click the search icon and type in your community's name. Select your community.
        iii. Specify annual data by clicking "Annual" under *Time Period*.
        iv. Specify the date range as the inventory year under *Date Range*.
        v. Specify the *Ownership* type: Private, Federal, Local, or State.
        vi. Download the data into an excel sheet using the download button.

vii. Repeat for all Ownership types (You do not want to use the “Total” option as it underestimates certain types of Ownership)

viii. Combine different ownership datasets into one master dataset.

1. You will need to remove the summary rows with the NAICS Title: “Total, All Industries”.

Example data from the Maine Industry Employment and Wages program

Area Name	NAICS	NAICS Title	Establishments	Average Employment	Total Wages	Average Weekly Wage	Ownership
Kennebunk	11	Agriculture, Forestry, Fishing and Hunting	4	26	$1,063,072	$791	Private
Kennebunk	23	Construction	47	234	$11,208,275	$920	Private
Kennebunk	48-49	Transportation and Warehousing	2	23	$1,312,339	$1,122	Federal
Kennebunk	61	Educational Services	4	441	$19,144,212	$834	Local
Kennebunk	62	Health Care and Social Assistance	1	42	$1,140,746	$523	Local
Kennebunk	92	Public Administration	1	5	$164,893	$692	State

2. Use EIA Commercial Buildings Energy Consumption Survey (CBECS) to match NAICS Title to a Primary Building Activity (PBA). The EIA collects data on building energy use for commercial buildings based on the buildings’ PBA. For each NAICS Title listed in your community’s Industry Employment and Wages data, match it to the correct PBA using the following table:

PBA lookup table (Source: Description of CBECS building types)

NAICS Title	PBA
Agriculture, Forestry, Fishing and Hunting	Other
Utilities	Office
Construction	Other
Manufacturing	Other
Wholesale Trade	Warehouse and Storage
Retail Trade	Mercantile
Information	Office
Finance and Insurance	Office
Real Estate and Rental and Leasing	Office
Professional and Technical Services	Office
Public Administration	Office
Management of Companies and Enterprises	Office

Administrative and Waste Services	Service
Health Care and Social Assistance	Health Care
Arts, Entertainment, and Recreation	Public Assembly
Accommodation and Food Services	Lodging/Food Service
Other Services, Except Public Administration	Service
Transportation and Warehousing	Warehouse and Storage
Educational Services	Education
Mining, Quarrying, and Oil and Gas Extraction	Other
Other	Other

3. Sum the total number of establishments by PBA for your community

Example of Total Establishments by PBA for a community

PBA	# of establishments
Other	68
Office	185
Warehouse and Storage	43
Mercantile	54
Service	70
Health Care	79
Public Assembly	14
Lodging/Food Service	53
Education	12

4. Estimate the total square footage of all establishments by PBA.
    a. Multiply the number of establishments by the estimate of building square footage by PBA provided by the CBECS as shown in the table below:

PBA sqft lookup table (source: 2018 CBCES Table 1. Preliminary estimates summary table for all buildings, 2018)

PBA	Mean sq. ft. per building
Education	31,200
Food sales	6,600
Food service	4,900
Health Care	29,500
Health care - Inpatient	269,100
Health care - Outpatient	13,600
Lodging	32,500
Mercantile	20,600
Office	17,300
Public Assembly	14,900

Public Order and Safety	20,400
Religious Worship	13,000
Service	7,400
Warehouse and Storage	17,300
Other	21,500
Vacant	7,900

5. Estimate the fuel oil usage in gallons based on the total square footage of establishments by PBA. The CBECS estimates fuel oil intensity in the northeast region by PBA, as provided below:

PBA fuel oil lookup table (source: [CBECS Table C35. Fuel oil consumption and conditional energy intensity by Census region, 2012. Used North-east](#))

PBA	Northeast fuel oil intensity (gal/sq. ft.)
Education	0.15
Food sales	0.11
Food service	0.11
Health care	0.15
Lodging	0.11
Mercantile	0.11
Office	0.06
Public assembly	0.11
Public order and safety	0.11
Religious worship	0.11
Service	0.11
Warehouse and storage	0.11
Other	0.11
Vacant	0.06

   a. To simplify this estimate, we assume that all establishments not heated with natural gas are heated with Fuel Oil.
   b. Estimate fuel oil usage using the following formula:

$$Fuel\ oil\ use\ (gal) = area\ by\ PBA(sqft) \times fuel\ oil\ intensity\ (\frac{gal}{sqft}) \times (1 - \frac{\#\ C\&I\ natural\ gas\ accounts}{total\ \#\ all\ establishments})$$

6. Estimate Commercial Fuel Oil emissions.
   a. If using the ICLEI ClearPath Platform: Use the “Emissions from Stationary Fuel Combustion” calculator under the Commercial Energy Tab to calculate Commercial and Industrial Fuel Oil Emissions.
      i. Since the Maine *Industry Employment and Wages* data doesn’t separate out establishments by Commercial or Industrial categories, report the combined Commercial and Industrial Fuel Oil use under the Commercial Energy Tab. Make a note of this in the Notes Section.

ii. Select “Distillate Fuel Oil No. 2” as the Fuel Type.
iii. Select “Gallons” as Fuel Use Units.

b. If NOT using the ICLEI ClearPath Platform: Calculate Commercial and Industrial Fuel Oil Emissions by multiplying the total fuel oil use for all PBAs by the emissions factor for Distillate Fuel Oil No. 2 fuel oil:

$$1\ gal\ Fuel\ Oil\ =\ 0.010269\ MT\ CO2e$$

Data collection methodology – Large emitting facilities

The EPA’s Greenhouse Gas Reporting Program (GHGRP) collects GHG data from large emitting facilities, suppliers of fossil fuels and industrial gases that result in GHG emissions when used, and facilities that inject carbon dioxide underground. The Facility Level information on Greenhouse gases Tool (FLIGHT) provides information about GHG emissions from these facilities. Some activities at large emitting facilities, like natural gas use and electricity generation, are already accounted for in other sectors and subsectors of the inventory. Discrete fuel use, such as heating oil for a combined heat and power plant, need to be accounted for in this section.

Only a few communities in Maine have a large emitting facility. Use FLIGHT’s map to navigate to your community and see whether there is a facility that must be accounted for in your inventory in the industrial subsector. If there is a large emitting facility in your community:

1. Click on the icon of the facility.
2. Select the year of the inventory in “Data Year”.
3. Determine the purpose of the large emitting facility. You may need to look at the Bureau of Air Quality’s air license for the facility, which should be readily available online.
   a. If the facility produces market electricity, emissions from this facility should be **excluded** from the GHG inventory (e.g., Westbrook Energy Center – a natural gas electricity plant or Wyman F Wyman – An oil-powered electricity plant). To follow the reporting principles of the Global Protocol and to avoid the possibility of double counting emissions, the GHG inventory assumes that emissions are accounted for in the electricity emissions factor.
   b. If the Facility uses Natural gas for heating or combined heat and power, emissions from this facility should be **excluded**, as this data should be accounted for in community-wide natural gas use data.
   c. If the Facility uses a discrete fuel (i.e. Distillate Fuel Oil No. 2 or Residual Fuel Oil No. 6) for on-site heating or combined heat and power, these emissions should be **included**, as these emissions are not accounted for yet in any other stationary energy subsector. (If the facility uses both natural gas and discrete fuel, only count those emissions associated with discrete fuel oil combustion).
4. Click “Review reported data”.
   a. Find the *Fuel Emissions Details* for the Discrete fuel use. Record the amount of fuel used for your inventory year.
      i. If using the ICLEI ClearPath Platform: Use the “Emissions from Stationary Fuel Combustion” or “Emissions From Stationary Fuel Combustion At Energy Industries” calculator (depending on use) under the Industrial Energy Tab to calculate Industrial Fuel Oil Emissions.

1. Select "Do you wish to use Custom or Default Emissions Factors": Use Default (Energy Industries only).
2. Select "Energy End Use Type".
3. Select "Fuel Type".
4. Insert "Fuel Use" with correct units.
5. Select "Data Source": EPA mandatory reporting (Energy Industries only).
6. Insert "Energy Use Attribution": likely 100% (Energy Industries only).

ii. If not using the ICLEI CLearPath Platform: Record the emissions estimate for the discrete fuel use provided in the *Fuel Emissions Details* in the reported data on the EPA FLIGHT tool.

Discrete Fuel data quality

Because it is based on statewide data and national survey results, discrete fuel use emissions are a low-quality data estimate. Additionally, the lack of real consumption data means that data are not available for every year, making it hard to measure year to year changes. This methodology also does not account for year-to-year variability in temperatures and heating demands. Discrete fuel data estimates allow a community to understand how heating emissions compare generally to that of the other sectors and subsectors.

Recommendations for methodology improvement

Due to the localized nature of discrete fuel consumption and delivery, it will be difficult to centralize the collection of data. Home heating estimates may be improved using a local community survey of home heating types and average annual fuel use. Other types of data – while not directly convertible into GHG emissions – can reveal home heating trends that impact community-wide emissions, such as the number of heat pumps or weatherization updates completed each year (See Additional Indicators section for more discussion of this topic).

Commercial discrete fuel use data may be collected from building owners themselves. Many larger cities have established Commercial Energy Benchmarking Ordinances, requiring large commercial property and multi-unit residential property owners to report energy use data annually. South Portland, Maine recently enacted an Energy and Water Use Performance Benchmarking Ordinance. A state-wide benchmarking requirement would take the burden off individual communities for developing, enacting, and enforcing benchmarking requirements.

6. Transportation

The Transportation sector includes emissions from all mobile emissions sources, including on-road transportation, rail travel, marine travel, and aviation. The mobile nature of transportation poses challenges for GHG inventories, as transportation often crosses municipal boundaries into neighboring communities. This inventory includes emission estimates for passenger vehicles, commercial vehicles, public transit, and marine vessels. Due to limited data availability, it excludes emissions from freight rail, passenger rail, off-road equipment, and aviation. There is currently no quality data source for freight rail or off-road equipment for Maine communities. Passenger rail emissions may be estimated using boarding and alighting data from Amtrak, but emissions are currently assumed to be negligible on a community level in Maine. Aviation emissions may be estimated using a community-wide survey question asking about annual air travel by residents.

The transportation methodology is separated into the following sections:

1) On-road transportation: Passenger vehicles, commercial vehicles, and public transit
2) Marine Vessels

Transportation sectors included in the Southern Maine GHG inventory protocol

SECTOR	SUBSECTOR	EMISSIONS SOURCES	ENERGY TYPE
TRANSPORTATION	Passenger Vehicles	Fuel combusted from all passenger vehicle trips that are attributable to the municipality	Gasoline, Diesel, Electricity
	Commercial Vehicles	Fuel combusted from all commercial vehicle trips that are attributable to the municipality	Gasoline, Diesel, Electricity
	Public Transit	Fuel combusted due to passenger miles travelled on public transit	Gasoline, Diesel, Electricity
	Marine Vessels	Fuel combusted by boats that are refueled at community harbors	Gasoline, Diesel

On-Road Transportation - Data Details

Scope: Scope 1 and Scope 3

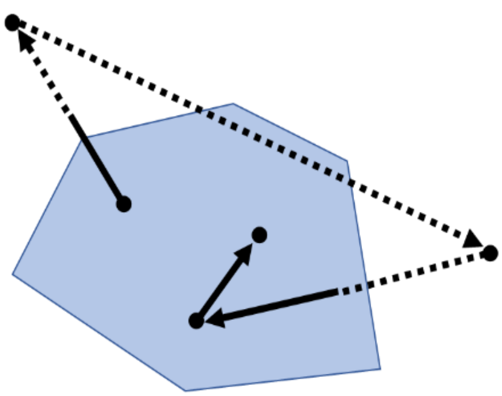
Activity Data Quality: MEDIUM

Emission Factor Quality: MEDIUM

On-Road Transportation Emissions – Passenger Vehicles, Commercial Vehicles, and Public Transit

Data Collection Methodology

Due to the large discrepancies in the type and quality of transportation data available to towns and cities, there are several methodologies that can be used to calculate on-road transportation GHG emissions. While the State of Maine calculates on-road transportation emissions based on state-wide fuel sales, this method is not possible for Maine communities. To assist York County communities in estimating their on-road transportation emissions SMPDC pioneered a methodology to estimate on-road transportation emissions for all towns and cities in York County. This methodology is detailed in the report, *Estimating On-Road Transportation Emissions in York County, Maine*. The process starts by calculating the total number of miles driven by vehicles (vehicle miles travelled or VMT) using Streetlight Data, a cloud-based transportation data and analysis platform that uses records from smartphones and navigation devices in connected cars and trucks. We estimated VMT using the *activity-based VMT* methodology (see figure below). Under this methodology, the VMT is based on all trips that occur as a result of people travelling to, from, and within a community. The activity-based VMT methodology provides an estimate of on-road transportation GHG emissions that is actionable and may serve to guide the region's transportation planning because the emissions directly correspond to the community's residents, workforce, and visitors.



Allocation for activity-based VMT methodology. Community is allocated 100% of VMT from trips that occur within the town boundary, and 50% of the VMT from trans-boundary trips that originate or end in the community (solid line). The community is not allocated any of the VMT from trips that pass through, but do not stop in the community.

On-road Transportation emissions (MT CO2e) by town in York County

Town	On-road transportation emissions (MT CO_2e)		Town	On-road Transportation emissions (MT CO_2e)	
	2018	2019		2018	2019
Acton	12,207	12,057	Limington	14,077	15,980
Alfred	13,562	12,684	Lyman	13,410	17,084
Arundel	15,953	16,595	Newfield	6,702	5,568
Berwick	23,689	25,817	North Berwick	21,833	21,874
Biddeford	119,943	112,924	Ogunquit	15,567	16,516
Buxton	30,182	32,978	Old Orchard Beach	45,377	49,361
Cornish	12,627	13,081	Parsonsfield	8,601	8,067
Dayton	7,127	8,111	Saco	83,907	89,556
Eliot	21,277	21,070	Sanford	94,837	95,965
Hollis	21,845	22,799	Shapleigh	8,791	11,589
Kennebunk	71,237	76,005	South Berwick	23,883	30,311
Kennebunkport	21,096	23,398	Waterboro	38,167	38,259
Kittery	62,886	68,115	Wells	64,926	66,876
Lebanon	25,261	26,925	York	71,901	79,648
Limerick	20,872	17,349			

Estimating On-Road Transportation Emissions in York County, Maine includes on-road transportation (ORT) VMT and emissions estimates for every town in York County for 2018. It also includes detailed step-by-step directions for conducting the ORT emissions analysis. This process is easily replicable and will be repeated as future data becomes available.

The GHG emission estimates provided in the report do not separate out emissions by passenger travel, commercial travel, and public transit. Emissions estimates were made using the 2017 York County Vehicle Population by class and fuel type, as well as national Annual Vehicle Distance Traveled and Fuel Efficiency data from the Federal Highway Administration (FHWA). These datasets are updated annually. Because vehicle population data was standardized throughout the whole region, it is simple to separate out emissions by on-road transportation type for York County Communities:

1. Passenger vehicles: Passenger vehicles include motorcycles, passenger cars, and light-duty passenger trucks. Due to vehicle population labelling inconsistencies between the MDEP and FHWA, this group also includes light-duty commercial trucks (which only make up 4% of York County vehicles and likely contribute a negligible amount of emissions due to lower milage than passenger vehicles). Passenger vehicles account for 69.9% of the York County vehicle population. Therefore, passenger vehicle emissions can be calculated as follows:

$$Passenger\ vehicle\ emissions\ (MT\ CO_2e) = Community\ ORT\ emissions\ \times 0.699$$

2. Commercial vehicles: this subsector includes single-unit short haul and long haul trucks and combination short haul and long haul trucks. Due to vehicle population labeling inconsistencies between the MDEP and FHWA, this group also includes motorhomes (which only make up 0.4%

of York County vehicles and likely contribute a negligible number of emissions). Commercial vehicles make up 28.6% of the York County vehicle population and commercial vehicle emissions can be calculated as follows:

$$Commercial\ vehicle\ emissions\ (MT\ CO_2e) = Community\ ORT\ emissions\ \times 0.286$$

3. Public Transit: this subsector includes intercity buses, transit buses, and school buses. Public transit buses are 1.5% of the York County Vehicle population. Public Transit vehicle emissions can be calculated as follows:

$$Public\ Transit\ vehicle\ emissions\ (MT\ CO_2e) = Community\ ORT\ emissions\ \times 0.015$$

4. Vehicle populations for other years, regions, and communities can be found on the MDEP Vehicle Emissions and Greenhouse Gas Data portal.
5. Record transportation emissions. If not using the ICLEI Clearpath Platform, simply complete steps 1 to 4 to calculate passenger vehicle, commercial vehicle, and public transit emissions in MT CO_2e. If you are using the ClearPath platform, you must enter CO_2, N_2O, and CH_4 emissions separately into the calculators as described below:
    a. If using the ICLEI ClearPath Platform: Use the "On-Road Transportation" calculator under the Transportation and Mobile Sources tab to separately enter passenger and commercial (which they refer to as "freight") emissions.
        i. Choose Calculation Method: Direct Entry
        ii. Choose Travel Type: Passenger or Freight (i.e. Commercial)
        iii. ClearPath requires you enter CO_2, N_2O, and CH_4 emissions separately. To calculate based on passenger emissions in MTCO_2e:

$$CO_2\ emissions\ =\ Emissions\ (MT\ CO_2e)\ \times 0.9966$$

$$N_2O\ emissions\ =\ Emissions\ (MT\ CO_2e)\ \times 0.0022$$

$$CH_4\ emissions\ =\ Emissions\ (MT\ CO_2e)\ \times 0.0012$$

    b. If using the ICLEI ClearPath Platform: Use the "Emissions from Public Transit" calculator under the Transportation and Mobile Sources tab to enter public transit emissions.
        i. Choose *Is this a Direct Entry Record*: Yes
        ii. ClearPath requires you enter CO_2, N_2O, and CH_4 emissions separately. To calculate based on passenger emissions in MTCO_2e:

$$CO_2\ emissions\ =\ Emissions\ (MTCO_2e)\ \times 0.9966$$

$$N_2O\ emissions\ =\ Emissions\ (MTCO_2e)\ \times 0.0022$$

$$CH_4\ emissions\ =\ Emissions\ (MTCO_2e)\ \times 0.0012$$

6. One important caveat is that this methodology is unable to separate out scope 1 (emissions that occur within the community boundary) and scope 3 (emissions that occur outside of the municipal boundary) transportation emissions. If your municipality is recording emission scopes, we recommend you estimate 33% of emissions as scope 1 and 66% of emissions as scope 3.

On-road transportation data quality

The activity-based VMT emissions methodology employed to calculate ORT emissions for York County is a valid and useful way to estimate on-road transportation GHG emissions in Maine communities. Because the Streetlight Data analysis can be performed for an entire region, we can better evaluate where vehicles are travelling, how to allocate VMTs appropriately, and what emissions factors and other contextual data are most appropriate, simple, and available. While this methodology is a significant improvement over other methodologies, limitations remain. Streetlight Data are a subscription service that may not be available to Maine's regional planning organizations in future years. Currently, the Streetlight Data service area does not cover the entire state of Maine. One limitation of this methodology is that the use of county and national vehicle information means that the emissions estimate does not reflect the actions a municipality might take to increase electric vehicle (EV) adoption by their residents or workforce. However, while municipalities can and should pursue EV adoption, changes to fuel efficiency and EV infrastructure are primarily guided by state and national actions and markets. Thus, we expect that the variations in EV activity between York County communities are currently minimal. This may change as larger, more urbanized communities advance ahead of rural communities in EV adoption in future years. The incorporation of local EV activity should continue to be considered in future ORT emissions estimates.

Recommendations for methodology improvement

There will be a significant opportunity to refine the on-road transportation emissions methodology as data availability improves and as Streetlight Data develops new analysis tools, such as analyses that break out passenger, public transit, and commercial trips. Planned increases in data frequency and data granularity (i.e. vehicle class and age) for MDEP vehicle population data will improve the accuracy of the emissions estimates, particularly as EVs become more popular.

Marine Vessels - Data Details

Scope: Scope 1 and Scope 3

Activity Data Quality: MEDIUM

Emission Factor Quality: MEDIUM

Marine Vessels

This subsector includes emissions associated with marine freight and passenger vessels. Freight carrying vessels may include ships, barges, tugboats, towboats, fishing vessels, patrol boats, and industrial boats. Passenger carrying vessels may include ferries, cruise ships, and recreational boats. This source is only likely to be significant if an operating port exists within the community. Standardized methods for conducting a GHG emissions inventory for marine vessels do not exist. The simplest method is to base emissions on fuel loaded on to watercraft at the point of departure (i.e. the municipal harbor). This method provides a reasonable estimate for our small coastal communities. However, it excludes any fuel used that is already loaded onto the vessels outside of the municipal boundary, and it excludes fuel that is loaded at standard gas stations.

Data collection methodology

Estimate emissions from marine vessels according to the following steps:

1. Determine whether your community has any fueling facilities at local harbors or marinas.
2. For each port, harbor, or marine authority, obtain total real fuel sales estimates of fuel loaded onto marine vessels.
3. Convert gallons of fuel used to emissions in MT CO_2e.
    a. If using ICLEI ClearPath platform: Use the "Water Transportation" Calculator under the Transportation and Mobile Sources tab to enter emissions for each fuel type (i.e., Gasoline and Diesel).
        i. Choose *Location Type*: Within Jurisdiction
        ii. Chose *Fuel Type:* Gasoline or Diesel
        iii. Input fuel quantity
    b. If not using the ICLEI ClearPath Platform: Convert the gallons of fuel used to emissions in MT CO_2e using the EPA Emissions Factors for Greenhouse Gas Inventories Document.

Marine vessel data quality

The Marine vessel fuel use data provides a very basic representation of emissions from marine vessel travel. It does not include fuel delivered to marine vessels at regular gas stations. This method also does not include any emissions from larger freight or passenger vessels that are traveling within the municipal jurisdiction but fueling in other locations, such as cruise ships.

Recommendations for methodology improvement

For most communities, marine vessel emissions are only a very small part of the community-wide GHG inventory. Therefore, it may not make sense to put effort into more extensive marine vessel emissions estimates. However, communities with a large port (for industry or ferry service) may choose to work with port agencies to conduct a more thorough estimate of marine emissions.

7. Waste

The management of solid waste and wastewater results in GHG emissions through the decay of waste with biologic constituents or burning of waste. Community-wide GHG inventories include all emissions from the disposal and treatment of waste generated within the municipal boundary, whether treated inside or outside of the municipal boundary. They also include the treatment of waste generated outside the community but imported into and processed at a facility within the municipality. For most Maine communities, solid waste is generated inside the municipal boundary but treated at one or more facilities outside of the municipal boundary. Wastewater is typically treated within the municipality. Waste types and waste collect methods vary by community. Not all communities will have to calculate emissions for all subsectors. Instead, emissions should be calculated only for those subsectors used by the community or that are occurring within the community.

Waste sectors included in the Southern Maine GHG inventory protocol

SECTOR	SUBSECTOR	EMISSIONS SOURCES	ENERGY TYPE
WASTE	MSW - Landfilling	Landfill gas (CH_4) emissions resulting from all trash generated by residential and commercial activity in the community and sent to landfill	Landfill Gas
	MSW - Incineration	GHG emissions resulting from the incineration of all trash generated by residential and commercial activity in the community that is sent to an incineration plant	Incineration Emissions
	Wastewater	Process and fugitive emissions from treating wastewater from all residential and commercial activities	Aerobic and Anaerobic Digestion

Municipal Solid Waste - Data Details

Scope:

- Disposed outside community = Scope 3
- Disposed within community = Scope 1

Activity Data Quality: MEDIUM

Emission Factor Quality: LOW

Municipal Solid Waste

Communities dispose of municipal solid waste (MSW) by some combination of landfilling, incineration, composing, recycling, and anaerobic digestion. You will need to collect information on the amount of waste generated by residents and business in your community as well as the ways that waste is disposed. The protocol includes methodologies for calculating emissions from landfilling and incineration.

Composting and anaerobic digestion are both material management options for yard trimmings, food scraps, and mixed organics. When these biodegradable materials are placed into a landfill, a fraction of their carbon is converted into CH_4 emissions. In composting, the vast majority of these CH_4 emissions are avoided. In anaerobic digestion, biogas consisting of both CO_2 and CH_4 is generated. The biogas may then be used as alternative to natural gas as an energy source. Both composting and anaerobic digestion have other benefits, such as reducing chemical fertilizer use that have downstream emission effects.

While both composting and anaerobic digestion produce GHGs, their net overall effect is to reduce emissions that would otherwise occur through landfilling. While these avoided emissions can be calculated, they are beyond the scope of this inventory. Similarly, avoided emissions from recycling are beyond the scope of this inventory. More information on this can be found in the ICLEI Recycling and Composting Emissions Protocol.

You should track what quantity of solid waste is being recycled, composted, or anaerobically digested and report this in their inventory report, and set goals for reducing and diverting waste through composting and recycling.

To determine what methodologies your community should estimate emissions from MSW, ask someone knowledgeable in your community (ex. Director of Public Works) the following questions:

1. What is the total tonnage of MSW generated during the inventory year? What is the total tonnage for MSW sent to landfill, incineration, recycling, composting, and anaerobic digestion?
    a. Any reported yard waste collected should be added to either compost or anaerobic digestion depending on the method of disposal.

Disposal Method	Tons Generated in Inventory Year	Percentage of total MSW
Landfill		%
Incineration		%
Recycling		%
Composter		%
Anaerobic Digestion		%

2. Does your MSW collect services cover all residents, school buildings and businesses?
    a. If Yes:
        i. No additional data needs to be collected.
    b. If No: Our public schools are serviced separately from MSW.
        i. You may choose to estimate emissions from public schools separately if waste data are available from your school system. If you are unable to include public school waste data, make sure to note this in your inventory.
    c. If No: Our Businesses are served by private waste haulers.
        i. You may exclude commercial solid waste from this category since it will be a small portion of overall GHG emissions. There is currently no estimation methodology for waste dispose by private haulers. Make sure to note this exclusion in your inventory.
3. Is there a facility in your community that landfills or incinerates MSW for other communities?
    a. If Yes: Determine the total tons of MSW imported from other communities during the inventory year. Account for this MSW separately in your inventory.

Landfilling – Data collection methodology

If your community disposes of solid waste at a landfill outside of the community, you must calculate emissions for that waste. Landfill emissions of CH_4 occur as organic materials decompose. These emissions continue for several decades after waste disposal. For this protocol, we used the *Methane Commitment method* to estimate CH_4 emissions from landfill solid waste disposal. This method assigns landfill emissions based on waste disposed in a given year, regardless of when the emissions actually occur. Emissions are calculated according to the following steps:

1. Determine the quantity (mass in short tons) of waste generated by the community that is sent to a landfill.
2. Estimate emissions from landfilled MSW.
    a. If using ICLEI ClearPath Platform: Use the “Waste Generation” calculator under the Solid Waste tab. Enter emissions separately for 1) community waste exported, 2) community waste landfilled within the community, and 3) outside waste imported and landfilled within the community.
        i. Choose *Is this a previously calculated value?*: No
        ii. Enter total waste generated
        iii. Choose *Landfill Methane Collection Scenario*: Typical
        iv. Choose *Landfill Moisture Content*: National Average

   v. Choose *Waste Type to Calculate Emissions For*: Mixed MSW (unless you have waste characterization data for the MSW)
   vi. Choose *Disposal Location*: Outside the Jurisdiction (EXCEPT if the landfill is within your community)

b. If not using ICLEI ClearPath: You will need to calculate CH_4 emissions using the *methane commitment model* described in 2014 Global Protocol for Community-Scale Greenhouse Gas Inventories Equations 8.1, 8.3 and 8.4.
   i. 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. Maine's MSW waste composition was estimated most recently in a 2011 study.
   ii. Equation 8.4 uses the DOC estimate derived from Equation 8.1 to calculate the overall CH_4 generation potential of the waste sent to landfill.
   iii. Equation 8.3 uses the total mass of waste sent to landfill, the CH_4 generation potential of waste calculated in Equation 8.4 to calculate the overall CH_4 commitment for solid waste sent to landfill.

Incinerating outside the community – Data collection methodology

If your community disposes of solid waste at an incineration plant inside or outside of the community, you must calculate those emissions. Incineration plants are often also waste-to-energy plants, generating steam and/or electricity from the combustion of solid waste. Solid waste that is incinerated produces CH_4, N_2O, and CO_2 as well as biologic CO_2. This biologic CO_2, produced through the burning of vegetation, woody products, and aquatic materials, should be reported separate from fossil fuel CO_2 as biogenic CO_2, or not reported at all.

The majority of southern Maine communities that dispose of MSW through incineration do so at the EcoMaine Waste-to-Energy plant in South Portland, Maine. As a large emitting facility, EcoMaine is required to report GHG emissions data to the EPA. The EPA's Greenhouse Gas Reporting Program (GHGRP) collects GHG data from large emitting facilities, suppliers of fossil fuels and industrial gases that result in GHG emissions when used, and facilities that inject carbon dioxide underground. The EPA's Facility Level information on Greenhouse gases Tool (FLIGHT) provides information about GHG emissions from these facilities. To calculated MSW incineration emissions from MSW sent to EcoMaine or another large waste-to-energy plant, follow these steps:

1. Determine the quantity (mass in short tons) of waste generated by the community that is sent to an incineration plant.
2. Determine the quantity (mass in short tons) of waste incinerated annually by the WTE plant.
   a. For EcoMaine, annual mass of combusted MSW can be found in the annual reports available on the EcoMaine website.
      i. In 2019, EcoMaine combusted 172,695 tons of MSW.
3. Determine the annual GHG emissions of the WTE plant using the Facility Level information on Greenhouse gases Tool (FLIGHT).

   a. Use FLIGHT's map to navigate to the WTE plant (EcoMaine is located at 64 Blueberry Road in Portland).
   b. Select the year of the inventory in "Data Year".
   c. Click "Review reported data".
      a. Find and save the Gas Emission Details for CO_2, biologic CO_2, CH_4, and N_2O the *Fuel Emissions Details.*
4. Calculate your community's emissions for each gas (CO_2, biologic CO_2, CH_4, and N_2O) using the following formula:

$$GHG\ Emissions\ = \frac{Mass\ of\ community\ MSW}{Total\ MSW\ Processed\ by\ WTE\ plant} \times Total\ Emissions\ of\ GHG\ Reported$$

5. If using the ClearPath Platform:
   a. Use the "Combustion of Solid Waste Generated by the Community" calculator under the Solid Waste tab to enter your emissions.
      i. Select *Input Method*: Direct Entry
      ii. Insert *Percent of Total Combusted MSW Generated In-Boundary*: 100
      iii. Enter your data for previously calculated CO_2 biologic CO_2, CH_4 and N_2O
      iv. Select *Is Electricity Generated from Waste?*: Yes
      v. Select *Waste Generation and Disposal Location*: Out of Boundary
6. If not using the ClearPath Platform:
   a. You must convert your GHG emissions for CH_4 and N_2O into MT CO_2e using the global warming potentials:

$$Emissions\ (MT\ CO2e)\ =\ Emissions\ (MT)\ \times\ GWP$$

Global warming potential from the IPCC 5th assessment report

Global warming potentials	GWP
CH_4	28
N_2O	265

Municipal Solid Waste Data Quality

Because municipalities are responsible for transfer stations and residential waste options, they often have good records of residential MSW. However, it is often unclear how much of the commercial and industrial waste streams are captured in municipal MSW. Some communities allow commercial waste to be dropped off at their transfer stations. However, many businesses either choose or are required to pay for their waste to be picked up by private haulers, and there is currently no way to estimate this amount of waste. Additionally, there has been no recent study of MSW characteristics in Maine communities, leading to uncertainties in the emission factors for landfilling and incineration.

Recommendations for Methodology improvement

Reducing the amount of waste landfilled is the best way to reduce GHG emissions from solid waste. But with no way to track the amount of waste being generated and landfilled by commercial and industrial entities, it is difficult to set community-wide waste reduction goals and strategies. Individual communities could potentially survey businesses to try and get a clearer picture of commercial waste volumes. However, state-wide research and reporting could potentially be more valuable in helping southern Maine communities understand the role solid waste plays in their community-wide emissions. Better understanding of the make-up of Maine waste streams will help improve emission estimates and also help us better track municipal, regional, and state waste diversion, compost, and recycling efforts.

Wastewater - Data Details

Scope:

- Treated outside community = Scope 3
- Treated within community = Scope 1

Activity Data Quality: MEDIUM

Emission Factor Quality: LOW

Wastewater

Wastewater from Maine residents and commercial facilities is treated either at wastewater treatment plants or through private septic systems. The majority of southern Maine communities operate local or regional wastewater treatment plants. These plants can treat wastewater aerobically or anaerobically. Anaerobic treatment produces CH_4, while both processes produce N_2O. Wastewater treatment also produces biologic CO_2, which is not included in the GHG inventory. Wastewater can come from both domestic and industrial sources. Industrial wastewater may be treated on-site or released into domestic sewer systems.

In general, wastewater treatment may employ one or more operation types that can result in the emissions of GHGs. In Maine, these are typically:

1. **Septic Tanks:** These typically contain stagnant and unaerated tanks where treatment occurs through settling and biological activity.
2. **Lagoons:** These are shallow earthen basins where a combination of physical, chemical, and biological treatment processes are employed. While less common, lagoons are used by some Maine municipalities for centralized wastewater treatment.
3. **Conventional Treatment:** A centralized system other than a lagoon that degrades the dissolved organics in wastewater under aerobic conditions. These systems may sometimes employ anaerobic digestion for solids processing.
4. **Conventional Treatment with Nitrification or Denitrification**: These are centralized aerobic systems with additional treatment to either oxidize nitrogenous wastes to oxidized forms of nitrogen or the removal of nitrogen by a subsequent anoxic step that reduces the oxidized forms to elemental nitrogen gas. These systems are far less common in Maine.
5. **Anaerobic Digestion**: Organic solids from any of the above treatment processes may be further treated in enclosed, anaerobic tanks where microorganisms degrade these organics to produce a biogas. The biogas may then be captured and burned in devices to generate renewable energy. There are only a few anaerobic digesters in Maine.

To determine which wastewater emissions sources must be accounted for in your community, ask someone knowledgeable about your community's wastewater (e.g., Sewer Department) the following questions:

Wastewater treatment questions	**If yes: Complete this analysis**	**If No:**	**Data Needed**
Is some of the community served by septic systems?	Fugitive Emissions from Septic Tanks	No calculation needed	Population served (# of people)
Does the wastewater treatment plant (WWTP) have a lagoon system?	Process Emissions from Wastewater Treatment Lagoons **And** Process Emissions from Effluent Discharge to Rivers and Estuaries	See next row for WWTP without Lagoon Systems	Population Served **And** Percent of flow that comes from industrial sources
Only for WWTP without Lagoon Systems: Does the WWTP practice Nitrification or Denitrification?	Process Emissions from Wastewater Treatment Plants <u>with</u> Nitrification or Denitrification **And** Process Emissions from Effluent Discharge to Rivers and Estuaries	Complete these analyses: Process Emissions from Wastewater Treatment Plants <u>without</u> Nitrification or Denitrification **And** Process Emissions from Effluent Discharge to Rivers and Estuaries	Population Served **And** Percent of flow that comes from industrial sources
Does the WWTP practice Anaerobic Digestion?	Emissions from Combustion of Digester Gas	No calculation needed	Population served **And** Energy recovery process

Emissions should be calculated for municipal wastewater 1) generated within and treated within the community (Scope 1), 2) generated within and treated outside the community (Scope 3), and 3) generated outside and imported to be treated within the community (Scope 1).

Calculations for each of these emissions sources are too complicated to detail in full here. For communities using the ClearPath platform, the steps needed to complete these calculations are detailed below. For other communities, the calculations required are referenced from the *U.S. Community*

Protocol for Accounting and Reporting Greenhouse Gas emissions, Appendix F: Wastewater and Water Emission Activities and Sources.

Fugitive Emissions from Septic Tanks – Data collection methodology

Almost all Maine communities have households served by septic systems. These systems result in the anaerobic production of CH_4. In many communities, the only available data on septic systems is the number of systems in the community. This number can be used to estimate the population served by septic systems and the resulting fugitive CH_4 emissions according to the following steps:

1. Obtain the number of properties served by septic systems in your community.
2. Obtain the community population and number of households for the inventory year from the US Census.
3. Calculate the average household size by dividing the population by the number of households.
4. Multiply the average household size by the number of properties with septic systems to calculate the population served by septic systems in your community.

$$Population\ served\ by\ septic\ Ssstems = \frac{Population}{\#\ of\ Households} \times \#\ of\ septic\ systems$$

5. Convert population served to emissions in MT CO_2e.
   a. If using the ClearPath platform: Use the “Fugitive Emissions from Septic Systems” calculator under the Water and Wastewater tab.
      i. Chose *Calculation Type*: Population Based
      ii. Insert *Population Served*
   b. If not using the ClearPath Platform: Use the following formula from the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas emissions: *Equation WW.11(alt) Alternate Methane Emissions from Septic Systems (page 52)*

Process N_2O Emissions from Wastewater Treatment Lagoons – Data collection methodology

Emissions of N_2O occur due to wastewater treatment processes in wastewater treatment lagoons. In many communities, municipalities keep track of the number of sewer connections. This number can be used to estimate the population served by Lagoon System and the resulting N_2O emissions according to the following steps:

1. Obtain the number of sewer connections in your community. If wastewater is imported into your community from other municipalities, obtain the number of imported sewer connections as well. We make the simplifying assumption that all sewer connections are to residential properties.
2. Obtain the community population and number of households for the inventory year from the US Census.
3. Calculate the average household size by dividing the population by the number of households.
4. Multiply the average household size by the number of sewer connections to calculate the population served by the Lagoon System.

$$Population\ served\ by\ lagoon\ system = \frac{Population}{\#\ of\ Households} \times \#\ of\ sewer\ connections$$

5. Convert population served to emissions in MT CO_2e.
    a. If using the ClearPath platform: Use the "Process Emissions from Wastewater Treatment Lagoons" calculator under the Water and Wastewater tab. Separately use the calculator for wastewater generated in the community and wastewater imported into the community.
        i. Chose *Calculation Type*: Population Based.
        ii. Insert *Population Served.*
        iii. Insert the *Industrial Discharge Multiplier*: If the lagoons receive industrial discharges, include a multiplier to account for this additional Biochemical Oxygen Demand (BOD_5; a measure of the dissolved oxygen required by microorganisms to oxidize or decompose the organic matter in wastewater) load. The default value from the Community Protocol is 1.25 or you can use a known industrial discharge percentage supplied by the sewer department.
        iv. Choose the *Wastewater Generation and Treatment Location*: in or out of boundary.
    b. If not using the ClearPath Platform: Use the following formula from the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas emissions: *Equation WW.6.(alt) Alternate Methane Emissions from Lagoons (Page 39)*.

Process Emissions from Wastewater Treatment Plants with Nitrification or Denitrification – Data collection methodology

The process for estimating emissions from a WWTP without wastewater treatment lagoons is similar to the methodology for lagoon systems. The number of sewer connections can be used to estimate the population served by a WWTP with Nitrification or Denitrification and the resulting N_2O emissions according to the following steps:

1. Obtain the number of sewer connections in your community. If wastewater is imported into your community from other municipalities, obtain the number of imported sewer connections as well. We make the simplifying assumption that all sewer connections are to residential properties.
2. Obtain the community population and number of households for the inventory year from the US Census.
3. Calculate the average household size by dividing the population by the number of households.
4. Multiply the average household size by the number of sewer connections to calculate the population served by the WWTP.

$$Population\ served\ by\ WWTP = \frac{Population}{\#\ of\ Households} \times \#\ of\ sewer\ connections$$

5. Convert population served to emissions in MT CO_2e.
    a. If using the ClearPath platform: Use the "Process N2O Emissions from Wastewater Treatment" calculator under the Water and Wastewater tab to separately enter wastewater generated by the community and wastewater imported into the community for treatment.
        i. Select *Nitrification/Denitrification as a step in the treatment process?*: Yes
        ii. Insert *Population Served.*

iii. Insert the *Industrial Discharge Multiplier*: If the WWTP receive industrial discharges, include a multiplier to account for this additional BOD_5 load. Enter a factor to account for commercial and industrial discharges to the system. The default assumption is a 25% increase from these sources. Enter "1.25" if you are unaware of the specific contribution from these sources. If you know there are no industrial and commercial discharges received at this facility, enter "1".
iv. Choose the *Wastewater Generation and Treatment Location*: in boundary or out of boundary.

b. If not using the ClearPath platform: Use the following formula from the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas emissions: *Equation WW.7 N_2O Process Emission from Wastewater Treatment Plants (or aeration basin) that Uses Nitrification or Denitrification (page 41).*

Process Emissions from Wastewater Treatment Plants without Nitrification or Denitrification – Data collection methodology

If your community has a WWTP that doesn't practice Nitrification or Denitrification, follow the steps outlined in the "Process Emissions from Wastewater Treatment Plants with Nitrification or Denitrification" section, but instead select: *Nitrification/Denitrification as a step in the treatment process?*: NO.

Process Emissions from Effluent Discharge to Rivers and Estuaries – Data collection methodology

Effluent discharge is treated wastewater that flows out from a treatment facility into waterways, lakes, or the ocean. Conventional WWTPs are not able to remove all of the nitrogen content in wastewater. When nitrogen containing effluent reaches a natural watershed, indirect N_2O emissions occur through side reactions. All communities with lagoon systems or conventional WWTPs with/without nitrification must also calculate process emissions from Effluent discharge. This may be calculated using the number of sewer connections as estimated in the previous sections. Calculate the emissions from effluent discharge for internal, exported, and imported wastewater (whichever apply).

1. Calculate the population served based on the number of sewer connections as detailed in the earlier sections.
2. Convert population served to emissions in MT CO_2e.
    a. If using the ClearPath Platform: Use the "Process N2O From Effluent Discharge To Rivers And Estuaries" calculator under the Water and Wastewater tab.
        i. Select *Do You have daily N load data from your effluent discharge?:* No
        ii. Insert *Population Served*
        iii. Insert the *Industrial Discharge Multiplier*: If the WWTP receive industrial discharges, include a multiplier to account for this additional BOD_5 load. Enter a factor to account for commercial and industrial discharges to the system. The default assumption is a 25% increase from these sources, enter "1.25" if you are unaware of the specific contribution from these sources. If you know there are no industrial and commercial discharges received at this facility, enter "1".
        iv. Select *Is your facility predominantly an Aerobic or Anaerobic system?*: Yes or No
        v. Select *Does your facility employ Nitrification/Denitrification?*: Yes or No

    vi. Choose the *Wastewater Generation and Treatment Location*: In boundary or out of boundary

  b. If not using the ClearPath Platform: Use the following formula from the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas emissions: *Equation WW.12(alt) N2O Emission from Effluent Conversion when only Population Served by Wastewater Treatment Plant is Known (Page 56).*

Emissions from Combustion of Digester Gas – Data collection methodology

For those WWTPs with anaerobic digestion, emissions must be calculated for the combustion of the digester gas. Again, an estimate of the population served can be used to calculate emissions from digester gas combustion according to the following steps:

1. Calculate the population served based on the number of sewer connections as detailed in the earlier sections.
2. Convert population served to emissions in MT CO_2e.
   a. If using the ClearPath Platform: Use the "Emissions From The Combustion Of Digester Gas" calculator under the Water and Wastewater tab.
      i. Select *Calculation Type:* Population Based
      ii. Insert *Population Served*
      iii. Chose *Is Energy Recovered From Combustion?:* Yes or No
      iv. Choose the *Wastewater Generation and Treatment Location*: In boundary or out of boundary
   b. If not using the ClearPath Platform: Use the following formulas from the U.S. Community Protocol for Accounting and Reporting Greenhouse Gas emissions: *Equation WW.1. (alt) Emissions from Devices Designed to Combust Anaerobic Digester Gas (page 24)* **AND** *WW.2.(alt) Method for N2O Emissions from Combustion when only Population Served by System is Known (page 28).*

Wastewater Data Quality

Because municipalities are responsible for wastewater treatment, municipal staff usually have good records of wastewater treatment at centralized plants. Records of septic systems may be less accurate or complete. Using the number of sewer connections to estimate wastewater treatment emissions is a relatively coarse and inaccurate method for calculating emissions, but more accurate methods would require additional and potentially unavailable data on the wastewater treatment process.

Recommendations for Methodology Improvement

Safe and effective wastewater treatment is vital for the public health of the community and ecosystems. Strategies for reducing emissions from wastewater treatment will likely be focused on reducing energy use (i.e. the electricity captured in the industrial electricity use subsector) rather than through reductions in overall wastewater volume. Additionally, wastewater treatment emissions make up a very small portion of a community's overall GHG inventory. Thus, it seems unlikely that efforts to make significant improvement on the wastewater treatment methodology (i.e. calculating emissions based on BOD5 load and facility-specific factors) will substantially improve the quality and usefulness of the community-wide GHG inventory for southern Maine communities.

8. Additional Indicators

The process of calculating and inventorying GHG emissions from community-wide activities is a vital step for communities to understand the sources of their emissions and identify priority actions for reducing emissions. But due to the need to sometimes rely on statewide, national, or modelled data for GHG inventories, it can be hard to quantify the impact of specific mitigation efforts to the emission values calculated in the inventory. This is especially true for those efforts that have an indirect impact on emissions, such as educating residents and businesses about renewable energy or community building and environmental justice initiatives. To help your community develop mitigation initiatives and set clear goals, we recommend collecting an additional set of *indicators* that can accompany your GHG inventory.

Additional indicators cannot currently be recorded in the ClearPath platform. We suggest tracking additional indicators in a separate excel file or another worksheet. Your community should summarize both the GHG inventory and the additional indicators in a community-wide GHG inventory report to provide a clearer picture of your community's emissions and progress on municipal and community actions to reduce them.

Stationary Energy

Indicators for stationary energy can provide a clearer picture of community efforts to increase energy efficiency and reduce reliance on fossil fuels in homes and businesses.

1. Heat pump and weatherization rebates

Communities can track how many times heat pump and weatherization rebates have been used in their community. This data may be obtained from Efficiency Maine.

2. Number of solar panels installed

Tracking the number of solar panels installed by residents and businesses can help communities track the development of renewable energy in their community. Municipal staff should work with their local code enforcement or state electrical permitting department to collect this data.

3. Electricity use per household

Tracking the electricity use per household can help communities track their efforts to improve energy efficiency. This can be calculated using the consumption and number of meter data from the residential electricity subsector.

4. Household energy burden

Efforts to expand renewable energy adoption must be paired with actions to increase the access and affordability of energy services to low-income residents. Municipalities can track the impact of initiatives to support accessible renewable energy by measuring the energy burden (percentage of household income devoted to energy expenditures) of average and low-income households. Rough estimates of local energy burden may be obtained from the U.S. Department of Energy's Low-income Energy Affordability Tool.

5. Summary of regulations supporting clean energy adoption

Communities can examine the way that their ordinances and regulations encourage (or are a barrier to) clean energy and energy efficiency. Has the municipality adopted a renewable energy ordinance? Does the zoning ordinance address and allow/permit solar and wind systems? Do development codes require energy efficiency or limit the heating fuel type for different buildings? Examining ordinances can help municipalities identify regulatory tools they could employ to reduce emissions from stationary energy use.

Transportation

Indicators for transportation can help communities track efforts to increase electric vehicle adoption, walk/bike-ability, and use of public transit.

1. Number of EVs and Hybrids in local vehicle population

Community efforts to increase the number or residents or businesses driving EVs can be tracked by looking at the number of EVs and hybrids registered in the municipality. This data can be found at the MDEP Vehicle Population and Greenhouse Gas Data portal.

2. Number of public EV charging stations

Documenting the number of public EV charging stations can help communities understand their accessibility to EV drivers. This data may be obtained through municipal records or via public websites like PlugShare.

3. Number of private EV charging stations

Documenting the number of private EV charging stations can help communities track the development of EV infrastructure in their communities. Municipalities that manage their own electrical permitting can create a specific EV charging station permit or can modify their existing electrical permit to track the number of residential and commercial private EV charging stations installed.

4. Public transit ridership and number of routes
Understanding the utilization of public transit (via number of rides or number of routes) will help communities to measure alternative transportation initiatives that reduce passenger car vehicle emissions. This data may be obtained through local public transit agencies.

5. Average commutes
Determining the average commute of residents and local employees can help municipalities track initiatives to improve workforce and affordable housing. This data may be obtained through a local survey, a Streetlight Data analysis, or can be roughly estimated using the American Community Survey data.

6. Summary of regulations supporting electric vehicle infrastructure
Municipalities can support EV adoption by guiding and regulating the development of EV charging stations through land use and other ordinances. Examining ordinances and permitting/inspection processes can help municipalities identify regulatory tools they could employ to reduce emissions from transportation by increasing the infrastructure that supports vehicle electrification.

Waste
Municipal solid waste disposal and wastewater treatment only account for 2% of Maine's GHG emissions. However, reducing, reusing, and recycling waste are vital strategies for reducing or avoiding emissions from the consumption of goods and foods. Indicators for waste management can help municipalities track efforts to reduce consumption and increase waste diversion.

1. Number of residents composting at home
Home compost doesn't make it into the waste streams measured by municipalities but is important for reducing food waste in landfills. Municipalities could survey residents to understand the popularity of home composting to identify strategies for increasing composting in the community.

2. Number of residents and businesses using curbside composting
Curbside composting offers an alternative to home composting for residents, apartment dwellers, and businesses. Municipalities can work with local composting companies to determine the volume of compost or number of residential and business customers participating in curbside composting programs.

3. Re-use economy statistics
Reuse, rather than disposal, reduces the production of new products (and the associated emissions) and keeps goods out of the waste stream. Municipalities can track re-use by looking at statistics such as: number of items donated to local community swap shop; number of re-use businesses in the community; sales of local re-use businesses; number of yard sales and more.

4. Business waste management practices
Many Maine municipalities either do not accept or do not separately track waste from local businesses. Municipalities could survey businesses about their waste management practices to identify ways to divert waste from landfills or incineration.

9. GHG Inventory Checklist

Use this checklist to identify and track which emissions calculations you need to complete for your municipality's community-wide GHG inventory (* means complete only if applicable).

Stationary Energy	Electricity	Residential	☐ Usage
			☐ T&D Losses
		Commercial	☐ Usage
			☐ T&D Losses
		Industrial	☐ Usage
			☐ T&D Losses
	Natural Gas	Residential*	☐ Usage
			☐ T&D Losses
		Commercial and Industrial combined*	☐ Usage
			☐ T&D Losses
	Discrete Fuel Use	Residential	☐ Usage
		Commercial and Industrial combined	☐ Usage
		Large Emitting Facilities*	☐ Usage
Transportation	On-Road Transportation	Passenger Vehicles	☐ Usage
		Commercial Vehicles	☐ Usage
		Public Transit	☐ Usage
	Marine vessels	All*	☐ Usage
Waste	Municipal Solid Waste	Landfilling*	☐ Usage – landfilled outside community
			☐ Usage – landfilled inside community (internal)
			☐ Usage – Landfilled inside community (imported)
		Incineration*	☐ Usage – incinerated outside community
			☐ Usage – incinerated inside community (internal)
			☐ Usage – incinerated inside community (imported)
	Wastewater	Septic Tanks*	☐ Usage
		WWTPs with lagoon systems*	☐ Process emissions from usage
			☐ Fugitive emissions from effluent discharge
		Conventional WWTP with nitrification/denitrification*	☐ Process emissions from usage
			☐ Fugitive emissions from effluent discharge
		Conventional WWTP without nitrification/denitrification*	☐ Process emissions from usage
			☐ Fugitive emissions from effluent discharge
		Anaerobic Digestion*	☐ Usage

10. Sources and References

GHG Inventory Protocols

- ClearPath Platform, ICLEI – Local Governments for Sustainability. https://clearpath.icleiusa.org/
- U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions, ICLEI – Local Governments for Sustainability, July 2019. https://icleiusa.org/us-community-protocol/
- Greenhouse Gas Inventories for Massachusetts Cities & Towns, Metropolitan Area Planning Council, April 10, 2020. https://www.mapc.org/wp-content/uploads/2020/03/04102020_MAPC-Step-by-Step-GHG-Inventory-Guide.pdf
- Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories, Greenhouse Gas Protocol, 2014. https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
- Local Government Operations Protocol For the quantification and reporting of greenhouse gas emissions inventories. ICLEI – Local Governments for Sustainability, May 2010. https://icleiusa.org/ghg-protocols/
- Estimating On-Road Transportation Emissions in York County, Maine, Southern Maine Planning and Development Commission. https://smpdc.org/sustainable_transportation
- Recycling and Composting emissions Protocol, ICLEI – Local Governments for Sustainability, July 2013. https://icleiusa.org/recycling-composting-emissions-protocol/

Data

Natural Gas

- Natural Gas Distributors, Maine Public Utilities Commission. https://www.maine.gov/mpuc/natural_gas/distributors.html
- Territory Map, Unitil. https://unitil.com/energy-for-residents/territory-map-1
- Our Community: Municipal Access, Unitil. https://unitil.com/our-community/municipalities
- User Guide for Natural Gas Leakage Rate Modeling Tool, Environmental Defense Fund. https://www.edf.org/sites/default/files/US-Natural-Gas-Leakage-Model-User-Guide.pdf

Discrete Fuel Use

Residential

- Explore Census Data, United States Census Bureau. https://data.census.gov/cedsci/

- Table DP04 “Selected Housing Characteristics for Maine”, United States Census Bureau. https://data.census.gov/cedsci/table?q=Maine%20DP04&tid=ACSDP1Y2019.DP04&hidePreview=false

- U.S. Energy Information Administration. https://www.eia.gov/

- Table CT4. Residential Sector Energy Consumption Estimates, 1960-2019, Maine, U.S. Energy Information Administration. https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_use/res/use_res_ME.html&sid=ME

Commercial

- Quarterly and Annual Industry Employment and Wages Interactive Viewer, Center for Workforce Research and Information, Maine Department of Labor. https://www.maine.gov/labor/cwri/qcew1.html

- 2018 Commercial Buildings Energy Consumption Survey Preliminary Results, Commercial Buildings Energy Consumption Survey (CBECS), U.S. Energy information Administration. https://www.eia.gov/consumption/commercial/

- Building Type Definitions, Commercial Builds Energy Consumption Survey (CBECS), U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/building-type-definitions.php

- Building Characteristics information, 2018 CBECS Survey Data, Commercial Builds Energy Consumption Survey (CBECS), U.S. Energy Information Administration. https://www.eia.gov/consumption/commercial/data/2018/index.php?view=characteristics

- Table C35 “Fuel oil consumption and conditional energy intensity by Census region, 2012”, Commercial Builds Energy Consumption Survey (CBECS), U.S. Energy Information Administration, May 2016. https://www.eia.gov/consumption/commercial/data/2012/c&e/pdf/c35.pdf

Industrial

- Facility Level Information on GreenHouse gases Tool (FLIGHT), U.S. Environmental Protection Agency. https://ghgdata.epa.gov/ghgp/main.do

Transportation

- Vehicle Emissions and Greenhouse Gas Data, Maine Department of Environmental Protection. https://www.maine.gov/dep/air/mobile/vehicle-data.html

Waste

- Reports and Data on Sustainable Waste Management, ecomaine. https://www.ecomaine.org/about-ecomaine/reports/

Emission Factors

- Emission Factors for Greenhouse Gas Inventories, U.S. Environmental Protection Agency, March 26, 2020. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Additional Indicators

- Efficiency Maine. https://www.efficiencymaine.com/

- Low-Income Energy Affordability Data (LEAD) Tool, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. energy.gov/eere/slsc/low-income-energy-affordability-data-lead-tool

- Vehicle Emissions and Greenhouse Gas Data, Maine Department of Environmental Protection. https://www.maine.gov/dep/air/mobile/vehicle-data.html

- PlugShare. https://www.plugshare.com/

Other

- Maine Won't Wait: A Four-Year Plan for Climate Action, Maine Climate Council, Dec. 2020. https://www.maine.gov/future/sites/maine.gov.future/files/inline-files/MaineWontWait_December2020.pdf

- Maine Renewable Portfolio Standard, Maine Public Utilities Commission. https://www.maine.gov/mpuc/electricity/RPSMain.htm

- Mass Save Data, The Massachusetts Energy Efficiency Database. https://www.masssavedata.com/Public/Home

- South Portland Energy and Water use Performance Benchmarking Ordinance, South Portland Code Sec 27-1701. https://www.southportland.org/files/8215/1301/6769/Benchmarking_Ordinance_FINAL.pdf