City of Bath, ME

2022 Community GHG Emissions Inventory and Pathways Reduction Analysis Methodology Report

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Introduction

The City of Bath has updated their community greenhouse gas (GHG) inventory using the ICLEI ClearPath Community Track, designed for GHG accounting on the local level, for the 2022 inventory year to determine where they stand in relation to their climate goals. As part of the planning process, the City has also completed an analysis of the specific pathways and targets necessary to reduce GHG emissions associated with City operations and the broader community.

This report provides an overview of the data sources and methodologies used in the 2022 completed prior to the Resilient Bath Climate Action Plan, including updates and corrections to provide the basis for a forecast and reduction analysis develop the high-impact strategies and actions detailed in the *Resilient Bath Climate Action Plan*.

Methodologies reported here for the 2022 inventory reflect those with the "Bath 2022 Inventory – Updated" inventory records in the ICLEI ClearPath tool.

- An export of the ClearPath "Updated_2022_ClearPath_detailedRpt.xlsx" contains all input and output values for each calculation performed in the inventory, as well as notes describing updates made to records.

GHG Inventory Methodology & Data Sources

The community GHG inventory follows the methods and emissions factors provided in the ICLEI ClearPath Community Track, in alignment with the reporting conventions defined by the U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. The ClearPath inventory uses 100-year horizon Global Warming Potential values from the Intergovernmental Panel on Climate Change (IPCC) 5th Assessment Report.

Residential Energy

Electricity

Data Sources: Central Maine Power

Activity Data: Measured annual electricity use aggregated at the residential sector was sourced from Central Maine Power.

Emissions Factors: Emissions factors for purchased electricity follow best practice guidance to utilize a 'location-based' assessment of GHG emissions to establish the physical reality of the impact of grid energy consumption. A complete accounting of GHGs from combustion generation resources needs to include factors for CO_2, CH_4, and N_2O. These were sourced from U.S. EPA eGRID and were entered into the ClearPath tool factor sets.

Metric	Value	Unit	Source
Residential Electricity Use	31,327	MWh	Central Maine Power

CO_2 Emissions Factor	536.4	lbs / MWh	EPA eGRID 2022, NEWE Subregion
CH_4 Emissions Factor	63	lbs / GWh	
N_2O Emissions Factor	8	lbs / GWh	

Methodology:

- Add EPA eGRID emissions factors to the Factor Sets in ClearPath.
- Obtain residential electricity consumption from Central Maine Power.
- Input electricity use into ClearPath using the "Emissions from Grid Electricity" calculator.
- Select the EPA eGRID 2022 NEWE emissions factors in the ClearPath calculator.
- The ClearPath tool will multiply electricity consumption by eGRID emissions factors to output emissions.

Note: Data input into the ClearPath software was checked against notes and raw data that was attached to records in the original 2022 inventory. Initial review found that data inputs matched the values provided by Central Maine Power. Further review of results led to a determination that the quantity of energy represented by the records was unrealistically small and 2018 data was checked for reference. This review led to the realization that data reported by Central Maine Power was low by an order of magnitude, or a single decimal point. To correct for this, records for electricity use in the Residential, Commercial, and Industrial sectors were increased by 10x.

Future engagement with Central Maine Power should include checks to ensure correct units. Where possible, it may be advantageous to also seek electricity use data at monthly intervals instead of annual totals.

Natural Gas

Data Sources: Maine Natural Gas

Activity Data: Measured annual natural gas use aggregated at the residential sector was sourced from Maine Natural Gas.

Emissions Factors: Emissions factors for natural gas follow ClearPath defaults.

Metric	Value	Unit	Source
Residential Natural Gas Use	244,013	Therms	Maine Natural Gas
CO_2 Emissions Factor	53.02	Kg / MMBtu	ICLEI ClearPath Defaults
CH_4 Emissions Factor	0.005	Kg / MMBtu	
N_2O Emissions Factor	1×10^{-4}	Kg / MMBtu	

Methodology:

- Obtain residential natural gas consumption from Maine Natural Gas.
- Input natural gas use into ClearPath using the "Emissions from Stationary Fuel Combustion" calculator and select Natural Gas as the fuel type.
- The ClearPath tool will multiply natural gas consumption by national default emissions factors to output emissions.

Fuel Oil

Data Sources: City of Bath Assessor's Database; U.S. Census Bureau American Community Survey; U.S. Energy Information Administration

Activity Data: Residential fuel oil consumption in Bath was estimated from the average statewide rate of oil use per household applied to the number of oil-heated homes in Bath, sourced from the city's Assessor's Database. The statewide rate of household fuel use was estimated from the number of oil-heated homes in Maine, sourced from the U.S. Census ACS, and statewide residential fuel oil consumption, sourced from the U.S. EIA.

Emissions Factors: Emissions factors for fuel oil follow ClearPath defaults.

Metric	Value	Unit	Source
Homes in Maine with Oil Heating (2021)	345,180	#	U.S. Census ACS 5-Year Estimates Table B25040
Maine Residential Oil Consumption (2021)	28.1	trillion Btu	U.S. EIA Maine State Profile and Energy Estimates Table CT4
Statewide Oil Use per Household	81.4068	MMBtu / Household	Calculated from Above
Homes in Bath with Oil Heating	2,348	#	City of Bath Assessor's Database
Bath Residential Oil Use	191,143	MMBtu	Calculated from Above
CO_2 Emissions Factor	73.96	kg / MMBtu	ICLEI ClearPath Defaults
CH_4 Emissions Factor	0.01087	kg / MMBtu	
N_2O Emissions Factor	7.2464×10^{-4}	kg / MMBtu	

Methodology:

- Obtain the total number of homes heated with oil in Maine from the U.S. Census ACS 5-Year Estimates Table B25040.
- Obtain statewide residential fuel oil energy consumption from the EIA State Profile and Energy Estimates Table CT4.
- Divide statewide residential fuel oil consumption by the number of oil-heated homes to calculate fuel oil use per household.
- Obtain the number of homes heated with oil in Bath from the city's Assessor's Database.
- Apply the statewide rate of oil use per household to the number of oil-heated homes in Bath to estimate residential fuel oil consumption in Bath.
- Input fuel oil use into ClearPath using the "Emissions from Stationary Fuel Combustion" calculator and select Distillate Fuel Oil No. 2 as the fuel type.
- The ClearPath tool will multiply fuel oil consumption by national default emissions factors to output emissions.

Note: While utilities supply buildings with electricity and natural gas, other fuels – such as fuel oil and propane – are supplied by a myriad of companies, limiting access to usage data. Non-utility fuel use may be estimated based on the square footage of households (for residential usage) or non-residential building area (for non-residential usage) and energy consumption intensities provided by EIA intensities. This estimation methodology provides a general picture of the scale of transition needed; however, it does not provide a measured value of actual fuel usage. Any detection of changes from this source will be a function of how many properties are using the fuel, not actual measures of consumption. Any efficiency measures such as weatherization to oil heated structures will not be detectable in future inventories unless paired with fuel switching that reduces the count of properties using the fuel. Bath Assessors' processes should be updated to comprehensively capture and continuously update fuels used across properties within the City capture any fuel switching.

Propane

Data Sources: City of Bath Assessor's Database; U.S. Census Bureau American Community Survey; U.S. Energy Information Administration

Activity Data: Residential propane consumption in Bath was estimated from the average statewide rate of propane use per household applied to the number of propane-heated homes in Bath, sourced from the city's Assessor's Database. The statewide rate of household fuel use was estimated from the number of propane-heated homes in Maine, sourced from the U.S. Census ACS, and statewide residential propane consumption, sourced from the U.S. EIA.

Emissions Factors: Emissions factors for propane follow ClearPath defaults.

Metric	Value	Unit	Source
Homes in Maine with Propane Heating (2021)	68,174	#	U.S. Census ACS 5-Year Estimates Table B25040
Maine Residential Propane Consumption (2021)	6.7	trillion Btu	U.S. EIA Maine State Profile and Energy Estimates Table CT4
Statewide Propane Use per Household	98.2779	MMBtu / Household	Calculated from Above
Homes in Bath with Propane Heating	32	#	City of Bath Assessor's Database
Bath Residential Propane Use	3,144	MMBtu	Calculated from Above
CO_2 Emissions Factor	62.98	Kg / MMBtu	ICLEI ClearPath Defaults
CH_4 Emissions Factor	0.01087	Kg / MMBtu	
N_2O Emissions Factor	0.001087	Kg / MMBtu	

Methodology:

- Obtain the total number of homes heated with propane in Maine from the U.S. Census ACS 5-Year Estimates Table B25040.

- Obtain statewide residential propane consumption from the EIA State Profile and Energy Estimates Table CT4.
- Divide statewide residential propane consumption by the number of propane-heated homes to calculate propane use per household.
- Obtain the number of homes heated with propane in Bath from the city's Assessor's Database.
- Apply the statewide rate of propane use per household to the number of propane-heated homes in Bath to estimate residential propane consumption in Bath.
- Input propane use into ClearPath using the "Emissions from Stationary Fuel Combustion" calculator and select LPG as the fuel type.
- The ClearPath tool will multiply propane consumption by national default emissions factors to output emissions.

Note: All notes included above for Residential Fuel Oil use as it relates to the estimation method used for this inventory are applicable to this section.

Wood

Data Sources: City of Bath Assessor's Database; U.S. Census Bureau American Community Survey; U.S. Energy Information Administration

Activity Data: Residential wood consumption in Bath was estimated from the average statewide rate of wood use per household applied to the number of wood-heated homes in Bath, sourced from the city's Assessor's Database. The statewide rate of household wood use was estimated from the number of wood-heated homes in Maine, sourced from the U.S. Census ACS, and statewide residential wood consumption, sourced from the U.S. EIA.

Emissions Factors: Emissions factors for propane follow ClearPath defaults.

Metric	Value	Unit	Source
Homes in Maine with Wood Heating (2021)	51,807	#	U.S. Census ACS 5-Year Estimates Table B25040
Maine Residential Wood Consumption (2021)	16.1	trillion Btu	U.S. EIA Maine State Profile and Energy Estimates Table CT4
Statewide Wood Use per Household	310.7688	MMBtu / Household	Calculated from Above
Homes in Bath with Wood Heating	3	#	City of Bath Assessor's Database
Bath Residential Wood Use	932	MMBtu	Calculated from Above
CO_2 Emissions Factor	0	Kg / MMBtu	ICLEI ClearPath Defaults
CH_4 Emissions Factor	0.316	Kg / MMBtu	
N_2O Emissions Factor	0.0042	Kg / MMBtu	

Methodology:

- Obtain the total number of homes heated with wood in Maine from the U.S. Census ACS 5-Year Estimates Table B25040.
- Obtain statewide residential wood consumption from the EIA State Profile and Energy Estimates Table CT4.
- Divide statewide residential wood consumption by the number of wood-heated homes to calculate wood use per household.
- Obtain the number of homes heated with wood in Bath from the city's Assessor's Database.
- Apply the statewide rate of wood use per household to the number of wood-heated homes in Bath to estimate residential wood consumption in Bath.
- Input wood use into ClearPath using the "Emissions from Stationary Fuel Combustion" calculator and select Wood as the fuel type.
- The ClearPath tool will multiply wood consumption by national default emissions factors to output emissions.

Note: All notes included above for Residential Fuel Oil use as it relates to the estimation method used for this inventory are applicable to this section.

Carbon dioxide emissions from wood burning are set to 0 in ClearPath as they are biogenic and not counted towards the inventory total.

Commercial Energy

Electricity

Data Sources: Central Maine Power

Activity Data: Measured annual electricity use aggregated at the commercial sector was sourced from Central Maine Power.

Emissions Factors: Emissions factors for purchased electricity follow best practice guidance to utilize a 'location-based' assessment of GHG emissions to establish the physical reality of the impact of grid energy consumption. A complete accounting of GHGs from combustion generation resources needs to include factors for CO_2, CH_4, and N_2O. These were sourced from U.S. EPA eGRID and were entered into the ClearPath tool factor sets.

Metric	Value	Unit	Source
Commercial Electricity Use	20,788	MWh	Central Maine Power
CO_2 Emissions Factor	536.4	lbs / MWh	EPA eGRID 2022, NEWE Subregion
CH_4 Emissions Factor	63	lbs / GWh	
N_2O Emissions Factor	8	lbs / GWh	

Methodology:

- Add EPA eGRID emissions factors to the Factor Sets in ClearPath.
- Obtain commercial electricity consumption from Central Maine Power.

- Input electricity use into ClearPath using the "Emissions from Grid Electricity" calculator.
- Select the EPA eGRID 2022 NEWE emissions factors in the ClearPath calculator.
- The ClearPath tool will multiply electricity consumption by eGRID emissions factors to output emissions.

Note: All notes included above for Residential Electricity use as it relates to the correction of input data for this inventory are applicable to this section.

Natural Gas

Tracking natural gas use in commercial buildings within Bath faces some challenges with the presence of large industrial users which are aggregated along with all other commercial accounts when reported from Maine Natural Gas. Unfortunately, this makes it difficult to differentiate between gas used for space heating, water heating, and cooking within non-industrial uses from what is utilized at Bath Iron Works and other firms supporting the shipyard.

Bath Iron Works total GHG footprint is available via Maine Department of Environmental Protection[1], however it is undifferentiated by source energy. In this situation, utility data sharing aggregation rules prevent clear tracking of domestic end uses within non-industrial commercial facilities. To correct for this, natural gas energy use was estimated using consistent methods as is applied to estimating residential fuel-oil and propane use. One important distinction in the method provided here is the use of energy intensity values that are matched to the building types in the Bath Assessors database using NREL Comstock as opposed to coarse energy intensities published in the EIA Commercial Building Energy Consumption Survey. This provides a more refined estimate for Bath in terms of understanding what share of emissions need to be addressed through commercial building focused strategies. Unfortunately, it will be difficult to detect a measured impact of strategies focused on commercial buildings, which may need to be estimated from individual projects in the short term.

Data Sources: City of Bath Assessor's Database; NREL ComStock End Use Savings Shapes

Activity Data: Natural gas used for heating in commercial buildings was estimated using the Bath's Assessor's Database and the NREL ComStock public datasets, highly granular models of the U.S. building stock categorized by building type.

Emissions Factors: Emissions factors for natural gas follow ClearPath defaults.

Metric	Value	Unit	Source
Medium Offices with Natural Gas Heating	205,955	Square Feet	City of Bath Assessor's Database
Primary Schools with Natural Gas Heating	168,714	Square Feet	
Retail Standalone with Natural Gas Heating	220,970	Square Feet	

[1] https://www.maine.gov/dep/ftp/AIR/DATA/GHG_SUMMARIES/

Small Hotels with Natural Gas Heating	118,301	Square Feet	
Warehouses with Natural Gas Heating	16,155	Square Feet	
Multifamily with Natural Gas Heating	356,396	Square Feet	
Natural Gas Use Intensity for Medium Offices	7.4	kWh / Square Feet	End Use Load Profiles TMY3 2021.1 Release, NREL ComStock
Natural Gas Use Intensity for Primary Schools	15.4	kWh / Square Feet	
Natural Gas Use Intensity for Retail Standalone	13.8	kWh / Square Feet	
Natural Gas Use Intensity for Small Hotels	35.8	kWh / Square Feet	
Natural Gas Use Intensity for Warehouses	1.5	kWh / Square Feet	
Natural Gas Use Intensity for Multifamily	14.0	kWh / Square Feet	
Commercial Natural Gas Use	390,552	Therms	Calculated from Above
CO_2 Emissions Factor	53.02	Kg / MMBtu	ICLEI ClearPath Defaults
CH_4 Emissions Factor	0.005	Kg / MMBtu	
N_2O Emissions Factor	1×10^{-4}	Kg / MMBtu	

Methodology:

- Obtain the total area of commercial buildings heated with natural gas in Bath by building type from the City's Assessor's Database.
- Determine the energy consumption intensity of commercial buildings heated with natural gas by building type using the NREL ComStock End Use Savings Shapes dataset filtered to Maine and the respective building types.
- Multiply the total heating energy per square foot by commercial building area per respective building type to calculate fuel usage.
- Input natural gas use into ClearPath using the "Emissions from Stationary Fuel Combustion" calculator, selecting Natural Gas as the fuel type.
- The ClearPath tool will multiply natural gas consumption by national default emissions factors to output emissions.

Note: An unfortunate complication for tracking natural gas usage in Bath is the presence of a single large customer using fuels in a productive capacity at Bath Iron Works with the inability to distinguish that usage from consumptive usage for the heating of buildings, domestic hot water, and cooking; all of which have viable options for decarbonization with today's technology. Thankfully this situation does not impact residential usage, but it does complicate getting a clear understanding of utility gas within non-residential structures in Bath. It is recommended that the city continue to engage with Maine Natural Gas to exclude Bath Iron Works from future reports on aggregate gas consumption in order to better track progress in this area.

Alternatively, some directed survey efforts focused on downtown businesses or other voluntary disclosure could fill gaps in knowledge. While improved information would be useful to know, the current situation should not be an impediment to action as individual building owners can still make proactive decisions to decarbonize their properties. It is worth noting that the situation in Bath is not unique and the need for modernizing utility privacy rules to advance climate action are recognized in other places, particularly within the State of California.[2]

Fuel Oil

Data Sources: City of Bath Assessor's Database; NREL ComStock End Use Savings Shapes

Activity Data: Fuel oil used for heating in commercial buildings was estimated using the Bath's Assessor's Database and the NREL ComStock public datasets, highly granular models of the U.S. building stock categorized by building type

Emissions Factors: Emissions factors for fuel oil follow ClearPath defaults.

Metric	Value	Unit	Source
Medium Offices with Oil Heating	732,695	Square Feet	City of Bath Assessor's Database
Primary Schools with Oil Heating	339,919	Square Feet	
Retail Standalone with Oil Heating	265,578	Square Feet	
Secondary Schools with Oil Heating	6,876	Square Feet	
Small Hotels with Oil Heating	6,248	Square Feet	
Warehouses with Oil Heating	27,887	Square Feet	
Multifamily with Oil Heating	356,111	Square Feet	
Oil Use Intensity for Medium Offices	6.6	kWh / Square Feet	End Use Load Profiles TMY3 2021.1 Release, NREL ComStock
Oil Use Intensity for Primary Schools	11.3	kWh / Square Feet	
Oil Use Intensity for Retail Standalone	10.7	kWh / Square Feet	
Oil Use Intensity for Secondary Schools	19.2	kWh / Square Feet	
Oil Use Intensity for Small Hotels	17.0	kWh / Square Feet	
Oil Use Intensity for Warehouses	1.8	kWh / Square Feet	

[2] Data Access for a Decarbonized Grid: Policy Solutions to Improve Energy Data Access and Drive the Clean and Resilient Grid of the Future, Berkeley Law (2021).

Oil Use Intensity for Multifamily	12.9	kWh / Square Feet	
Commercial Fuel Oil Use	40,212	MMBtu	Calculated from Above
CO_2 Emissions Factor	73.96	Kg / MMBtu	ICLEI ClearPath Defaults
CH_4 Emissions Factor	0.01087	Kg / MMBtu	
N_2O Emissions Factor	7.2464×10^{-4}	Kg / MMBtu	

Methodology:

- Obtain the total area of commercial buildings heated with fuel oil in Bath by building type from the City's Assessor's Database.
- Determine the energy consumption intensity of commercial buildings heated with fuel oil by building type using the NREL ComStock End Use Savings Shapes dataset filtered to Maine and the respective building types.
- Multiply the total heating energy per square foot by commercial building area per respective building type to calculate fuel usage.
- Input fuel oil use into ClearPath using the "Emissions from Stationary Fuel Combustion" calculator, selecting Distillate Fuel Oil No. 2 as the fuel type.
- The ClearPath tool will multiply fuel oil consumption by national default emissions factors to output emissions.

Note: For consistency with the treatment of natural gas energy intensity, fuel oil intensity for commercial facilities were updated to use the ComStock model as well. This change created a significant reduction in estimated fuel oil consumption in commercial facilities than was previously estimated using reference values from the EIA Commercial Building Energy Consumption Survey.

Industrial Energy

Electricity

Data Sources: Central Maine Power

Activity Data: Measured annual electricity use aggregated at the industrial sector was sourced from Central Maine Power.

Emissions Factors: Emissions factors for purchased electricity follow best practice guidance to utilize a 'location-based' assessment of GHG emissions to establish the physical reality of the impact of grid energy consumption. A complete accounting of GHGs from combustion generation resources needs to include factors for CO_2, CH_4, and N_2O. These were sourced from U.S. EPA eGRID and were entered into the ClearPath tool factor sets.

Metric	Value	Unit	Source
Industrial Electricity Use	80,221	MWh	Central Maine Power
CO_2 Emissions Factor	536.4	lbs / MWh	EPA eGRID 2022, NEWE Subregion
CH_4 Emissions Factor	63	lbs / GWh	

N_2O Emissions Factor	8	lbs / GWh	

Methodology:

- Add EPA eGRID emissions factors to the Factor Sets in ClearPath.
- Obtain industrial electricity consumption from Central Maine Power.
- Input electricity use into ClearPath using the "Emissions from Grid Electricity" calculator.
- Select the EPA eGRID 2022 NEWE emissions factors in the ClearPath calculator.
- The ClearPath tool will multiply electricity consumption by eGRID emissions factors to output emissions.

Note: All notes included above for Residential Electricity use as it relates to the correction of input data for this inventory are applicable to this section.

Bath Iron Works – Bath Facility

Data Sources: Maine Department of Environmental Protection (DEP)

Emissions Data: Every facility that is licensed by Maine DEP to emit criteria air pollutants at or above the limits established in DEP Rules, Chapter 137, "Emission Statements" is required to submit an annual air emissions inventory. Maine DEP provides annual summaries of these criteria air pollutant and greenhouse gas emissions inventories for each facility. These reports include facility-level emissions by criteria air pollutant and GHG; activity data and fuel source information are not included.

CO_2 emitted from the Bath Iron Works (Bath Facility) in 2021 were obtained from the Maine DEP emissions inventory database, and were entered directly into ClearPath

The Bath Iron Works Harding Facility was also listed in the database, but is excluded from the City of Bath's GHG inventory as this facility is located in Brunswick, ME.

Metric	Value	Unit	Source
CO_2 Emissions	15,330	Metric tons	Maine DEP Air Emissions Inventory Data: GHG Summaries

Methodology:

- Obtain annual CO_2 emissions for the Bath Iron Works – Bath Facility from the Maine DEP Air Emissions Inventory Database.
- Select the "Emissions from Stationary Fuel Combustion" calculator in ClearPath.
- Select "Yes" under the "Were emissions calculated externally from ClearPath" question and input CO_2 emissions.

Transportation & Mobile Sources

Resident Vehicles – Gasoline & Diesel

Data Sources: Maine Department of Transportation;

Activity Data: Annual VMT per vehicle type in Bath was sourced from Maine Department of Transportation. Vehicle counts distributed by vehicle class, fuel type, and age for Bath was obtained from the Maine DEP Vehicle Emissions and Greenhouse Gas Data. The allocation between gasoline and diesel vehicles per vehicle type, sourced from MDEP, was applied to the VMT per vehicle type, sourced from MDOT, to determine VMT by vehicle and fuel type.

Emissions Factors: National fuel efficiencies and emissions factors for gasoline and diesel use per vehicle type follow ClearPath defaults.

Metric	Value	Unit	Source
Gasoline Passenger Vehicles	26,002,291	VMT	Estimated from Maine Department of Transportation and Maine Department of Environmental Protection data.
Gasoline Light Trucks	7,291,334	VMT	
Gasoline Heavy Trucks	1,738,404	VMT	
Gasoline Motorcycles	923,566	VMT	
Diesel Passenger Vehicles	248,375	VMT	
Diesel Light Trucks	91,990	VMT	
Diesel Heavy Trucks	578,537	VMT	

Methodology:

- Obtain VMT by vehicle type in Bath from Maine Department of Transportation.
- Obtain vehicle counts in Bath by vehicle class and fuel type from the Maine DEP Vehicle Emissions and Greenhouse Gas Data.
- Divide the number of diesel passenger vehicles by the total number of passenger vehicles to determine the share of diesel passenger vehicles in Bath.
- Apply the share of diesel passenger vehicles to the total VMT for passenger vehicles to estimate diesel passenger vehicle VMT.
- Subtract diesel passenger vehicle VMT from total passenger vehicle VMT to determine gasoline passenger vehicle VMT.
- Repeat this process for motorcycles, light trucks, and heavy trucks.
- For each vehicle class and fuel type combination, create a record in ClearPath using the “On-Road Transportation” calculator.
- Select “VMT & MPG” as the Calculation Method, “In-Boundary” as the VMT Location, and “Passenger” as the Travel Type.
- Input VMT for each vehicle type and fuel type combination record, and enter “100%” under the respective Percent Vehicle Type field.
- The ClearPath tool will multiply fuel consumption and VMT by national default emissions factors per vehicle type to output emissions.

Notes: Emissions from on-road transportation in Bath's GHG inventories to date have been based on measures of total VMT occurring within the city limits derived from simple traffic counts on major roads. While this is an overall good and repeatable measure of traffic activity, it does not indicate much about the transportation demands of Bath residents and workforce. Alternative data sources such as those derived from cell phone and vehicle location data can provide a clearer picture of what Bath resident's individual contributions are; however, those alternatives are currently expensive. Over time options may continue to improve and possibly studies from the State of Maine or Mid-Coast Council of Governments could refine inventory estimates in this sector.

Evolving data availability is a factor that all communities working on climate action must work with. The City of Bath should not shy away from continued improvements in data collection and shifting to improved methodologies even if they lead to inconsistencies with the baselines from which targets were set. As field of local government climate action continues to evolve, it is likely that messaging and updating targets in the future may re-orient in terms of our distance from zero emissions rather than how far we've come from an uncertain starting point.

Solid Waste

Landfilled Waste

Data Sources: Bath Public Works

Activity Data: Tons of municipal solid waste collection sent to landfill from Bath was sourced from the City's Public Works department. The 2011 Maine Residential Waste Characterization Study was used to allocate total tons of landfilled waste by material type.

Emissions Factors: Emissions factors for landfilled waste per material type follow ClearPath defaults.

Metric	Value	Unit	Source
Waste Collected in Bath Sent to the Landfill	4,840	Tons	City of Bath Department of Public Works
Mixed MSW Emissions Factor	0.0648	MT CH_4 / Wet Short Ton	ICLEI ClearPath Defaults
Newspaper Emissions Factors	0.042	MT CH_4 / Wet Short Ton	
Office Paper Emissions Factor	0.1556	MT CH_4 / Wet Short Ton	
Corrugated Cardboard Emissions Factor	0.1048	MT CH_4 / Wet Short Ton	
Food Scraps Emissions Factors	0.0648	MT CH_4 / Wet Short Ton	
Leaves Emissions Factor	0.026	MT CH_4 / Wet Short Ton	

Branches Emissions Factor	0.058	MT CH_4 / Wet Short Ton	
Dimensional Lumber Emissions Factor	0.0068	MT CH_4 / Wet Short Ton	

Methodology:

- Obtain total landfilled waste from the City's Department of Public Works.
- Add the 2011 Maine Residential Waste Characterization to the Factor Sets in ClearPath.
- Input tons of landfilled waste into ClearPath using the "Landfilled Waste" calculator.
- Select the ME Solid Waste Characterization factor set in the ClearPath calculator.
- Select the "Worst-Case Collection" as the Landfill Methane Collection Scenario, "Moderate" as the Landfill Moisture Content, and "Inside the Jurisdiction" as the Disposal Location.
- The ClearPath tool will multiply tons of landfilled waste by default emissions factors per material type to output emissions.

Composted Waste

Data Sources: Bath Public Works

Activity Data: Tons of municipal solid waste collection sent to compost was sourced from the City's Public Works department.

Emissions Factors: Emissions factors for composted waste per material type follow ClearPath defaults.

Metric	Value	Unit	Source
Green Waste Collected in Bath Sent to Compost	95	Tons	City of Bath Public Works Department
CH_4 Emissions Factor	0.0044	MT CH_4 / Ton	ICLEI ClearPath Defaults
N_2O Emissions Factor	6.7×10^{-5}	MT N_2O / Ton	

Methodology:

- Input tons of composted green waste into ClearPath using the "Biologic Treatment of Solid Waste (Composting)" calculator – selecting "Green Waste" as the waste type and "Generated and Disposed In-Boundary" as the disposal location.
- The ClearPath tool will multiply tons of composted green waste by default emissions factors to output emissions.

Landfill Gas Flared

Data Sources: Bath Public Works

Activity Data: Volume of landfill gas flared was sourced from the City's Public Works department.

Emissions Factors: Emissions factors for flaring of landfill gas follow ClearPath defaults.

Metric	Value	Unit	Source
Landfilled Gas Flared	8,030,000	Cubic Feet / Year	City of Bath Public Works Department
Fraction of CH_4 in Landfill Gas	0.50	Decimal	ICLEI ClearPath Defaults
Destruction Efficiency	0.99	Decimal	
CH_4 Emissions Factor	9.3673×10^{-8}	MT CH_4 / Scf	

Methodology:

- Input the volume of flared landfill gas into ClearPath using the "Emissions from Flaring of Landfill Gas" calculator.
- Keep the ClearPath defaults of the fraction of CH4 in Landfill Gas and the Destruction Efficiency as is.
- The ClearPath tool will multiply the volume of flared gas by default emissions factors to output emissions.

Water & Wastewater

Water Treatment – Electricity Use

Data Sources: Bath Water District

Activity Data: Electricity used for the extraction, treatment, and distribution of potable water for residents and businesses of Bath was sourced from the Bath Water District.

Emissions Factors: Emissions factors for purchased electricity follow best practice guidance to utilize a 'location-based' assessment of GHG emissions to establish the physical reality of the impact of grid energy consumption. A complete accounting of GHGs from combustion generation resources needs to include factors for CO_2, CH_4, and N_2O. These were sourced from U.S. EPA eGRID and were entered into the ClearPath tool factor sets.

Metric	Value	Unit	Source
Electricity Use for Potable Water	900	MWh	Bath Water District
CO_2 Emissions Factor	536.4	lbs / MWh	EPA eGRID 2022, NEWE Subregion
CH_4 Emissions Factor	63	lbs / GWh	
N_2O Emissions Factor	8	lbs / GWh	

Methodology:

- Add EPA eGRID emissions factors to the Factor Sets in ClearPath.

- Obtain electricity used for potable water treatment and delivery from the Bath Water District.
- Input electricity use into ClearPath using the "Emissions from the Supply of Potable Water" calculator.
- Select the EPA eGRID 2022 NEWE emissions factors in the ClearPath calculator.
- The ClearPath tool will multiply electricity consumption by eGRID emissions factors to output emissions.

Wastewater Treatment – Electricity & Natural Gas Use

Data Sources: Bath Wastewater Division

Activity Data: Electricity and natural gas used at the wastewater facility was sourced from the Bath Wastewater Division.

Emissions Factors: Emissions factors for purchased electricity follow best practice guidance to utilize a 'location-based' assessment of GHG emissions to establish the physical reality of the impact of grid energy consumption. A complete accounting of GHGs from combustion generation resources needs to include factors for CO_2, CH_4, and N_2O. These were sourced from U.S. EPA eGRID and were entered into the ClearPath tool factor sets.

Emissions factors for natural gas follow ClearPath defaults.

Metric	Value	Unit	Source
Electricity Use at the Wastewater Facility	1,215	MWh	Bath Wastewater Division
Natural Gas Use at the Wastewater Facility	1,064	MMBtu	
Electricity CO_2 Emissions Factor	536.4	lbs / MWh	EPA eGRID 2022, NEWE Subregion
Electricity CH_4 Emissions Factor	63	lbs / GWh	
Electricity N_2O Emissions Factor	8	lbs / GWh	
Natural Gas CO_2 Emissions Factor	0.05302	MT / MMBtu	ICLEI ClearPath Defaults
Natural Gas CH_4 Emissions Factor	5×10^{-6}	MT / MMBtu	
Natural Gas N_2O Emissions Factor	1×10^{-7}	MT / MMBtu	

Methodology:

- Add EPA eGRID emissions factors to the Factor Sets in ClearPath.
- Obtain electricity and natural gas used at the wastewater treatment facility from the Bath Wastewater Division.

- Input electricity and natural gas use into ClearPath using the "Emissions from Wastewater Treatment Energy Use" calculator.
- Select the EPA eGRID 2022 NEWE emissions factors in the ClearPath calculator.
- The ClearPath tool will multiply electricity and natural gas consumption by eGRID and national default emissions factors to output electricity and natural gas-based emissions, respectively.

Wastewater Treatment – Process Emissions

Data Sources: Bath Wastewater Division

Activity Data: The population served by the City's wastewater treatment facility was sourced from the Bath Wastewater Division.

Emissions Factors: The process N_2O emissions factor for the population served by a wastewater treatment facility follow ClearPath defaults.

Metric	Value	Unit	Source
Population Served by the Wastewater Treatment Facility	8,788	People	Bath Wastewater Division
Industrial Commercial Discharge Multiplier	1.26	Unitless	U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions.
N_2O Emissions Factor for Wastewater Treatment	3.2	Grams / Person	ICLEI ClearPath Defaults

Methodology:

- Input the population served by the wastewater treatment facility into ClearPath using the "Process N2O Emissions from Wastewater Treatment" calculator – selecting "No" for the inclusion of nitrification/denitrification as a step in the treatment process.
- Input 1.26 as the Industrial Commercial Discharge Multiplier per the U.S. Community Protocol for GHG Emissions.
- The ClearPath tool will multiply population served by the wastewater treatment facility by default emissions factors to output emissions.

Upstream Impacts of Activities

Grid Loss

Data Sources: Central Maine Power

Activity Data: Measured annual electricity use aggregated at the residential, commercial, and industrial sectors was sourced from Central Maine Power.

Emissions Factors: Emissions factors for purchased electricity follow best practice guidance to utilize a 'location-based' assessment of GHG emissions to establish the physical reality of the impact of grid energy consumption. A complete accounting of GHGs from combustion generation resources needs to include factors for CO_2, CH_4, and N_2O. These were sourced from U.S. EPA eGRID and were entered into the ClearPath tool factor sets.

Metric	Value	Unit	Source
Residential Electricity Use	31,327	MWh	Central Maine Power
Commercial Electricity Use	20,788	MWh	
Industrial Electricity Use	80,221	MWh	
Grid Loss Factor	0.051	Decimal	EPA eGRID 2022, NEWE Subregion
CO_2 Emissions Factor	536.4	lbs / MWh	
CH_4 Emissions Factor	63	lbs / GWh	
N_2O Emissions Factor	8	lbs / GWh	

Methodology:

- Add EPA eGRID emissions factors to the Factor Sets in ClearPath.
- Obtain residential, commercial, and industrial electricity consumption from Central Maine Power.
- Input electricity use into ClearPath using the "Emissions from Electric Power Transmission and Distribution Losses" calculator.
- Select the EPA eGRID 2022 NEWE emissions factors in the ClearPath calculator.
- Input 0.051 as the Grid Loss Factor per the EPA eGRID 2022 NEWE Subregion.
- The ClearPath tool will multiply electricity loss by eGRID emissions factors to output emissions.

Pathways Analysis

BAU Forecast

The business-as-usual forecast is designed here to incorporate likely changes that will influence the background rate of emissions and set the conditions for how reduction strategies may perform over time. Overall, the approach to developing the forecast is to apply growth projections for

population and jobs to indicators of emissions generating activities derived from the 2022 baseline inventory.

Population, Jobs, and VMT Projections

Several factors related to GHG generation rates will change over a nearly 30-year planning horizon. Detailed projections over that period would involve significant speculation, but with some relatively simple inputs, the overall magnitude of expected changes can be anticipated. Key inputs to the BAU projection include the following:

- Population follows the Maine City and Town Population Projections through 2040.[3]
- Jobs follow the statewide employment projections detailed in the Maine.gov Workforce Outlook.[4]

Existing Activity Growth

The baseline rate of activity per capita, job, or VMT for each inventory item was developed from the City's 2022 GHG inventory (Table 1). The activity per year for each inventory item was then calculated from this baseline activity rate and the respective population or VMT projections from 2023 to 2050. The table below details each inventory item and the associated basis of growth.

Table 1. Business-As-Usual Growth Factors Applied to Each Inventory Item

Sector	Sub-Sector	Source	BAU Growth Factor
Buildings	Residential Buildings	Electricity	Population-Based
		Natural Gas	Population-Based
		Fuel Oil	Population-Based
		Propane	Population-Based
		Wood	Population-Based
	Commercial Buildings	Electricity	Job-Based
		Natural Gas	Job-Based
		Fuel Oil	Job-Based
	Industrial Buildings	Electricity	No Growth
		Natural Gas	No Growth
Transportation	Passenger Vehicles	Gasoline	Population-Based
		Diesel	Population-Based
	Light Trucks	Gasoline	Population-Based
		Diesel	Population-Based
	Heavy Trucks	Gasoline	Population-Based
		Diesel	Population-Based
	Motorcycles	Gasoline	Population-Based
	Shuttle Bus	Gasoline	No Growth

[3] Maine City and Town Population Projections 2040, Maine Department of Administrative and Financial Services (2023).
[4] Workforce Outlook: Employment and Job Openings in Maine in 2022 and Projected 2032, Maine.gov Center for Workforce Research and Information (2023).

	Trolley	Gasoline	No Growth
Solid Waste	MSW Collection	Waste Landfilled	Population-Based
		Waste Composted	Population-Based
		Landfilled Gas Flared	No Growth
Water & Wastewater	Wastewater Treatment Facilities	Electricity	Population-Based
		Natural Gas	Population-Based
		Fugitive N2O	Population-Based
	Water Treatment Facilities	Electricity	Population-Based
Upstream Impacts	Residential Grid Loss	Electricity	Population-Based
	Commercial Grid Loss	Electricity	Job-Based
	Industrial Grid Loss	Electricity	No Growth

Changes in Emissions Intensity

The baseline rate of emissions per unit of activity for each inventory item was derived from the City's 2022 GHG inventory. The 2022 baseline emissions intensities for all non-electricity-sourced inventory items were held constant through 2050.

A significant variable in GHG reduction outcomes is the emissions intensity of grid electricity. While there are state policies in place to impact the carbon intensity of the grid, these policies also play out in an interconnected region that determines the actual mix of generation sources used. Future scenarios of grid carbon intensity are complex and uncertain.

Scenarios developed by the National Renewable Energy Lab Cambium project provide the most realistic estimates of how change will occur to this variable, incorporating likely influences of state and federal policy, technology change, and transmissions constraints. The City's BAU forecast follows the grid carbon intensity values projected by the NREL Cambium Model under the 95% decarbonization by 2050 scenario – assuming that further progressive policies at the state and federal level will result in near-zero emissions intensities by 2050.[5]

Projected Emissions

Emissions of each inventory item were projected from 2023 to 2050 based on the projected changes in the levels of GHG-generating activities and, where relevant, changes to the emissions intensities per year for each year.

GHG Reduction Pathways

Reduction pathways are inherently a simplification of reality and are intended to be representative of the magnitude of change necessary to produce different outcomes for GHG reduction scenarios. It is likely that many of the assumptions underpinning these calculations will change in short order and that should be kept in mind for interpretation of the results and considerations for how rapidly

[5] Cambium 2023 Scenario Viewer, National Renewable Energy Laboratory.

changing technologies and policy landscapes at the state and federal levels will change the trajectory of sources of GHGs in Bath.

Building & Energy

Electrification of Residential Buildings

Residential building emissions reductions were based on the impact of electrifying buildings with natural gas, fuel oil, and propane heating and applying high efficiency retrofits. Calculations are based on the differences in Energy Utilization Index (EUI) values between the base-case buildings and the EUI values for the same buildings operating with the upgraded measure packages detailed in the NREL ResStock End Use Savings Shapes datasets.[6] Changes in EUIs were calculated to determine the electricity rebound that would occur when fossil fuels were removed.

The mix of energy conservation measures for households is assumed to be split between standard weatherization (EUSS Package 1) and standard weatherization + high-efficiency electrification (EUSS Package 9) as detailed in Table 2. This split allows for deep reductions in GHGs through full decarbonization of a targeted share of homes each year while utilizing weatherization retrofits to reduce energy use and associated GHGs in the interim.

Table 2. Implementation Schedule for Residential Building Retrofits

Retrofit	2030	2040	2050
No Action	80%	20%	0%
Standard Weatherization (EUSS Package 1)	0%	0%	0%
Standard Weatherization + High-Efficiency Electrification (EUSS Package 9)	20%	80%	100%

Methodology:

- Obtain energy consumption intensities of single-family residential buildings by heating type per the ResStock baseline dataset filtered to Maine.
- Obtain energy consumption intensities of single-family residential buildings by heating type per the ResStock *Standard Weatherization* Package 1 filtered to Maine.
- Obtain energy consumption intensities of single-family residential buildings by heating type per the ResStock *Standard Weatherization + High -Efficiency Electrification* Package 9 filtered to Maine.
- Determine the percent changes in the energy use intensities (EUIs) of natural gas, fuel oil, propane, and electricity heated buildings (respectively) between the baseline and the two ResStock scenarios.
- Create implementation schedules for existing residential buildings detailing the percent of respective units upgraded to Package 1 and Package 9 by each target year (2030, 2040, and 2050).
- Apply the ResStock scenario-specific percent reductions in natural gas, fuel oil, and propane consumption and the percent rebound of electricity to the City's projected energy

[6] End Use Savings Shapes (EUSS) TMY3 2022.1 Release, NREL ResStock.

usages of existing residential buildings for each target year per the respective implementation schedules.
- Convert the projected reductions in fuel consumption of existing residential buildings to $MTCO_2e$ to determine the respective GHG emissions savings.

Electrification of Commercial Buildings

Commercial building emissions reductions were based on the impact of electrifying buildings with natural gas and fuel oil heating and applying high efficiency retrofits. Calculations are based on the differences in Energy Use Intensity (EUI) values per building type for the base-case compared to the EUI values of the same buildings operating with the upgraded measure packages detailed in the Buildings Sector Report, A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study (Figures 22, 24, and 27).[7] Changes in EUIs per building type were calculated to determine the electricity rebound that would occur when fossil fuels were removed.

While there will likely be a range of implementation levels, for simplicity of modeling and communicating reduction potentials from the sector, only the most aggressive level of building interventions was applied, which was the ECM4 package. This package includes best-in-class equipment for electrification, insulation and shell improvement to passive house standards, and best-in-class appliances and controls. Commercial building emissions reductions were based on the share of building area electrified according to the implementation schedule detailed in Table 3.

Table 3. Implementation Schedule for Commercial Building Retrofits

Sub-Sector	2030	2040	2050
Commercial Buildings	10%	80%	100%

Methodology:

- Estimate the baseline energy use intensities and the EUIs of buildings operating under the Energy Conservation Measure (ECM) package 4 upgrade (per commercial building type) as detailed in the MA Buildings Sector Report.
- Determine the percentage changes in the energy use intensities of fossil fuels and electricity between the baseline and the ECM4 upgrade.
- Create an implementation schedule for existing commercial buildings detailing the percent of building area updated to the ECM4 upgrade by each target year (2030, 2040, and 2050).
- Apply the ECM4 package percent reductions in fossil fuel consumption and the percent rebound of electricity to the City's projected energy usages of commercial buildings for each target year per the implementation schedule.
- Convert the projected reductions in fuel consumption to $MTCO_2e$ to determine GHG emissions savings.

[7] Buildings Sector Report: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study, Commonwealth of Massachusetts (2020).

Transportation

Electrification of Bath-Registered Vehicles

Emissions reductions from Bath-registered vehicles were based on the EV conversion schedules per vehicle type detailed in Table 4. These shares were primarily determined by iterating to reach desired reduction targets as increased EV adoption faces among the fewest physical barriers to scaling up quickly as compared to other actions. For comparison, it should be noted that the Massachusetts 2030 Clean Energy and Climate Plan only targets 19.2% uptake of electric passenger vehicles by 2030.[8]

Table 4. Implementation Schedule for EV Adoption

Sub-Sector	2030	2040	2050
Passenger Vehicles	10%	80%	100%
Light Trucks	10%	80%	100%
Heavy Trucks	5%	43%	80%
Motorcycles	10%	80%	100%

Solid Waste

Increased Diversion Rate

The following waste reduction rates were applied to the baseline MSW landfilled: 30% by 2030, 60% by 2040, and 90% by 2050. These reductions were made to stay in sync with a reduction in waste disposed from the baseline according to the Massachusetts Solid Waste Master Plan.[9] The value of the reduction was calculated from the difference in projected waste generation from the BAU forecast.

Additional Calculations

Additional calculations were made for the exploration of specific strategies that were not applied directly to the Pathways Analysis due to assumption constraints or overlap with existing scenarios. In the case of local solar expansion, the contribution of new generation was not applied to the pathways due to recognition of very common solar financing strategies which transfer the renewable energy attributes to a third party, which leads to double counting of those benefits.

Rooftop Solar

The City of Bath estimates that 40% of current buildings are viable for rooftop solar. The pathways analysis assumes that the City of Bath will reach 100% of this potential by 2040. The 2050 target was increased to 60% viable rooftop space, assuming that new technologies will increase the potential of current buildings.

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[8] Appendices to the Massachusetts Clean Energy and Climate Plans for 2025 and 2030: Transportation Sector Metrics, Commonwealth of Massachusetts (2022).

[9] Massachusetts 2030 Solid Waste Master Plan: Working Together Toward Zero Waste, Mass DEP (2021).

The potential of rooftop solar generation was estimated in this analysis with the use of Google Project Sunroof.[10] At the time of this analysis, the City of Bath was not modeled in Project Sunroof; as a result, the City of Lewiston, ME was used as a comparable proxy. Project Sunroof estimates an average system size of 10.2 kW and an annual production of 11,200 kWh per roof in Lewiston.

Table 5. Solar Generation Potential

	2030	2040	2050
Total Number of Buildings	3,225	3,225	3,225
% of Buildings with Viable Rooftop Space	10%	40%	60%
Solar Systems Installed	323	1,290	1,935
Average Systems per Year	40	97	65
Local Energy Produced (MWh)	3,612	14,448	21,672

Average production from this quantity of solar was compared to projected electricity use in each benchmark year as both building energy and transportation are transitioned to this energy source. Results of this analysis indicate that with rooftop solar alone, Bath could self-supply approximately 34% of the 2050 electricity demand in residential and commercial buildings. This is likely a conservative estimate as it does not include potential generation from parking canopies. It also does not incorporate any improvement in solar efficiency which is likely to improve over the time period as well.

Accessory Dwelling Units

At the time of the writing of the Resilient Bath Climate Action Plan, an update to the Bath Zoning Code was underway which is likely to support allowances for expanded housing opportunities within Bath, enabling more live-work opportunities and consequently fewer commuting miles among new residents.

Due to uncertainty around the extent of the zoning update and the number of units anticipated, this impact was not incorporated into the analysis used for the final plan, however these results may have some additional utility in further discussions around adding housing density of any kind within Bath.

Estimating current commuting miles was performed using the US Census Longitudinal Employer Household Dynamics Survey, which provides estimates of the home location for workers in Bath of 21 miles[11].

Assuming a 240 workday per year schedule, every worker that could be accommodated within Bath would avoid approximately 9,990 miles per year, in a 24 mpg vehicle that would avoid 417 gallons of

[10] Data Explorer, Google Project Sunroof (2024).

[11] U.S. Census Bureau. LEHD Origin-Destination Employment Statistics Data (2002-2021) Longitudinal-Employer Household Dynamics Program. https://onthemap.ces.census.gov/

gasoline and approximately 4 MTCO2e per year. These values could be scaled in the future depending on the number of ADU or other missing middle housing is planned for Bath.