COMMUNITY-WIDE GREENHOUSE GAS INVENTORY

Methodology for 2020-2024 Inventories

CITY OF CAMBRIDGE

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1. INTRODUCTION

The City of Cambridge has long recognized the scientific consensus that climate change is a real and urgent global challenge driven by excessive anthropogenic greenhouse gas (GHG) emissions. These emissions pose direct risks to the health, environment, and economic vitality of Cambridge and its residents. In response, and as a critical step toward protecting the community from the impacts of climate change, the City has committed to achieving carbon neutrality by 2050.

Greenhouse gas emissions inventories play a central role in advancing this commitment by quantifying emissions generated by activities within the community. These inventories provide government leaders and residents with a clear understanding of where emissions originate, enabling informed decision-making and targeted climate action. Compiled at the community scale and organized by emissions scopes, the City's Community-wide greenhouse gas inventory establishes a benchmark for tracking progress over time and informs strategies to reduce emissions across key sectors of the local economy.

This inventory update quantifies Community-wide greenhouse gas emissions for the 2020 through 2024 calendar years and serves as an update to the City's 2019 inventory, which was completed in 2022. The report documents the methodology used to calculate emissions, including any updates or refinements from previous inventories. It also presents emissions results for each year from 2020 through 2024, both individually and in comparison to the 2019 and 2012 inventories, providing context for understanding emissions trends over time.

Global Protocol for Community-Scale Greenhouse Gas Inventories

The City of Cambridge Community-wide inventories are developed in accordance with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), a standardized framework developed by the World Resources Institute, C40 Cities, and ICLEI – Local Governments for Sustainability. Use of the GPC ensures consistency with international best practices for Community-wide greenhouse gas accounting.

The GPC establishes core reporting requirements and offers detailed accounting guidance for quantifying emissions from a wide range of sources and activities. In addition, the GPC includes optional reporting frameworks that allow communities to tailor their inventories based on data availability, local priorities, and technical capacity, while maintaining methodological consistency and comparability across jurisdictions.

Adherence to the GPC is also required for compliance with the Global Covenant of Mayors for Climate and Energy (GCoM), a global network of cities committed to reducing greenhouse gas emissions and addressing climate change through local action. As a member of GCoM, the City of Cambridge follows the GPC to ensure transparent, accurate, and comparable reporting of community-wide emissions.

Emissions, Scope, Sectors, and Sources

The GPC requires cities to report emissions using two complementary accounting approaches: the Scopes framework and the city-induced framework. Together, these approaches provide a comprehensive understanding of emissions generated within the community boundary and those driven by activities occurring in the City.

Under the Scopes framework, emissions are categorized based on where they physically occur and how they are associated with city activities.

- **Scope 1:** Includes direct greenhouse gas emissions from sources located within the city boundary.
- **Scope 2:** Includes indirect emissions resulting from the consumption of grid-supplied electricity, heat, steam, or cooling within the city boundary.
- **Scope 3:** Includes other indirect emissions that occur outside the city boundary as a result of activities taking place within the city.

The city-induced framework organizes emissions by sector and reporting level and is used by the GPC to define minimum reporting requirements. The City of Cambridge inventories follow the GPC BASIC/BASIC+ reporting framework and, consistent with previous community-wide inventories, accounts for all Scope 1 and Scope 2 emissions as well as select Scope 3 emissions. The 2020 through 2024 inventories include emissions from the following sectors and sub-sectors:

Stationary Energy (Scopes 1, 2, and select Scope 3)

- Residential buildings
- Commercial and institutional buildings and facilities
- Manufacturing industries and construction
- Energy production facilities
- Fugitive emissions from oil and natural gas systems
- Off-road vehicles and equipment

Transportation (Scopes 1, 2, and select Scope 3)

- On-road vehicles
- Railways

Waste (Scope 3)

- Solid waste disposal generated in the city
- Biological treatment of waste generated in the city
- Incineration and open burning of waste generated in the city
- Wastewater generated in the city

This structure ensures consistency with international greenhouse gas accounting standards while supporting clear tracking of emissions trends and progress toward the City of Cambridges climate goals. The tables below provide a description of the emissions sources and how they align with the City-Induced Reporting Framework.

Table 1. Sectors and Emissions Sources in the City of Cambridge Inventories by Energy Type and Scope

Sector	Subsector	Emissions Source	Energy Types	Scope
Stationary Energy	Residential Buildings	Electricity Use in Residential Buildings	Electricity	2
		Electricity Transmission and Distribution Losses	Electricity	3
		District Heating	Steam	2
		District Cooling	Chilled Water	2
		On-Site Combustion I\in Residential Buildings	Natural Gas, Fuel Oil	1
		Fugitive Emissions from Natural Gas Systems	Natural Gas	1
	Commercial & Institutional Buildings & Manufacturing Industries	Electricity Use in Commercial, Industrial, and Manufacturing Buildings	Electricity	2
		Electricity T&D Losses	Electricity	3
		District Heating	Steam	2
		District Cooling	Chilled Water	2
		On-Site Combustion \in Commercial, Industrial, and Manufacturing Buildings	Natural Gas, Fuel Oil	1
		Fugitive Emissions from Natural Gas Systems	Natural Gas	1
		Off-Road Equipment Such as for Lawn Care and Manufacturing	Various Fuels	1
	Energy Industries	Stationary Combustion of Fuel in Various Equipment, Such as Boilers and Generators.	Various Fuels	1
	Construction	Off-Road Equipment for Construction	Various Fuels	1
Transportation	On-road	Mobile Combustion of Fuels in On-Road Vehicles	Gasoline, Diesel, CNG, Hybrid	1
		Electricity- Consumption in On-Road Vehicles	Electricity	2
		Electricity T&D Losses	Electricity	3
	Rail (MBTA)	Mobile Combustion of Fuels Commuter and Light Rail	Diesel	1
		Electricity - Consumption in Commuter and Light Rail	Electricity	2
		Electricity T&D Losses	Electricity	3
Waste	Solid Waste Disposal	Methane Commitment - Disposal of Solid Waste at Landfills	Methane	3
	Biological Treatment of Waste	Direct Emissions from Biological Treatment of Waste	N/A	3
	Incineration and Open Burning	Incineration of Waste	N/A	3
	Wastewater Treatment and Discharge	Process and Fugitive Emissions from Treating Wastewater	N/A	3

Table 2. Sub-sectors included in the Community-wide Inventory by City-Induced Framework Reporting Requirements

Sector	Subsector	Emissions Source	Scope 1	Scope 2	Scope 3
Stationary Energy	Residential Buildings	Natural Gas / Fuel Oil Use	X		
		Electricity Use		X	
		Electricity T&D Losses			X
		District Heating and Cooling		X	
		Fugitive Emissions from Natural Gas Systems	X		
	Commercial & Institutional Buildings & Manufacturing Industries	Natural Gas / Fuel Oil Use	X		
		Electricity Use		X	
		Electricity T&D Losses			X
		District Heating and Cooling		X	
		Fugitive Emissions from Natural Gas Systems	X		
		Off-Road Equipment Such as For Lawn Care and Manufacturing	X	X	
	Energy Industries	Stationary Combustion of Fuel in Various Equipment, Such as Boilers and Generators.	X		
	Construction	Off-Road Equipment for Construction	X	X	
Transportation	On-road	Mobile Combustion of Fuels in On-Road Vehicles	X		
		Electricity- Consumption in On-Road Vehicles		X	
		Electricity T&D Losses			X
	Rail (MBTA)	Mobile Combustion of Fuels Commuter and Light Rail	X		
		Electricity - Consumption in Commuter and Light Rail		X	
		Electricity T&D Losses			X
Waste	Solid Waste Disposal	Methane Commitment - Disposal of Solid Waste at Landfills			X
	Biological Treatment of Waste	Direct Emissions from Biological Treatment of Waste			X
	Incineration and Open Burning	Incineration of Waste			X
	Wastewater Treatment and Discharge	Process and Fugitive Emissions from Treating Wastewater			X

X = Emission Sources in Inventory

= Sources Required for BASIC and BASIC+ reporting

= Sources Required for BASIC+ reporting

= Sources in Other Scope 3

= Non-applicable emissions

Quantifying Greenhouse Gas Emissions

All emissions in this inventory are quantified using formula-based calculations that combine activity data with appropriate emission factors, consistent with the GPC. In general, emissions are calculated using the following relationship:

$$Acticity\ Data\ (unit) \times Emissions\ Factor\ \left(\frac{MTCO2e}{unit}\right) = Emissions\ (MTCO2e)$$

Activity data represent measurable quantities associated with emissions-generating activities, such as consumption by fuel type, metered electricity use, vehicle miles traveled, or tons of waste generated. Emission factors convert these activity data into greenhouse gas emissions and are typically expressed as emissions per unit of activity.

The inventory accounts for three greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Emissions are reported in metric tons of carbon dioxide equivalent (MT CO_2e), which allows the relative climate impacts of different gases to be compared using global warming potential (GWP) values. The GWP values applied for the 2020‑2024 inventories are sourced from the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6): 1 for CO_2, 27.9 for CH_4, and 273 for N_2O.

2. STATIONARY ENERGY

This section documents the methodology used to quantify emissions from the stationary energy sector. The stationary energy sector represents a significant share of Community-wide emissions and includes emissions associated with the consumption of electricity, natural gas, fuel oil, on-site energy generation from large stationary facilities, and off-road equipment within the city boundary.

2.1 ELECTRICITY

Electricity-related emissions arise from the generation of electricity supplied to the city and consumed by residential, commercial, institutional, and municipal end uses. Emissions are estimated based on electricity consumption reported by the serving utility and municipal data sources, with emissions factors applied to reflect the carbon intensity of electricity consumed within the City.

Electricity Data Sources

Grid-supplied electricity is used throughout the City of Cambridge to serve residential, commercial, industrial, and municipal buildings, as well as city infrastructure systems. The City is served by a single electric utility provider, Eversource, which is responsible for the transmission and distribution of electricity within the community boundary. Electricity consumption data were obtained from multiple complementary sources to support a comprehensive and detailed representation of energy use in the City. Primary sources included aggregated citywide electricity data reported through the Mass Save program[1] , electricity consumption data provided directly by Eversource, and building-level reporting submitted under the City's BEUDO. [2] Electricity consumption data were reported in kilowatt-hours (kWh). Together, these sources provide coverage across residential, commercial, industrial, and municipal customers while maintaining customer confidentiality.

[1] Mass Saves Usage and EE Program Activity Dashboards/Municipal Usage and Participation Trends. Retrieved from: Home page - VAP Public View Site

[2] Cambridge Building Energy Use Disclosure Ordinance (BEUDO) Data 2015-2024. Retrieved from: Cambridge Building Energy Use Disclosure Ordinance (BEUDO) Data 2015-2024 | Open Data Portal | City of Cambridge

Mass Save provides a high-level, sector-based view of electricity consumption data within the City . This dataset includes total annual electricity consumption, reported in kilowatt-hours by customer classes, providing distinct reporting for residential and commercial and industrial (C&I) sectors.

Eversource provided percent of electricity consumption data by customer segments and sub-segments that align with North American Industry Classification System (NAICS) based classifications. To address Eversource confidentiality and data concentration requirements, segments and sub-segments were evaluated against two rules: (1) each sub-segment was required to include at least 15 customers in a given year, and (2) no single customer could account for more than 15 percent of a sub-segment's total monthly electricity usage in any reported month. Sub-segments that did not meet these criteria were aggregated into their broader segment, and if an entire segment failed to meet the minimum thresholds, it was aggregated at the sector level. The sub-segment data provided additional contextual information on electricity consumption patterns across different building and customer types within the city. The percent of electricity consumption from each sub-segment was applied to the Mass Saves total Commercial and Industrial electricity reported.

Building-level property type information was obtained through the City of Cambridge's BEUDO reporting requirements, which require large buildings to annually report energy and water use to the City. Buildings subject to reporting yearly energy use under BEUDO include non-residential buildings 25,000 square feet or larger, residential buildings with 50 or more dwelling units, and municipal buildings 10,000 square feet or larger. Because these buildings provide standardized, building-level data, BEUDO reporting offers a detailed and reliable source of information for understanding energy consumption from the City's largest energy-using properties.

Electricity consumption information associated with the City's Community Choice Aggregation (CCA) programs was provided by Peregrine Energy Group, the program administrator. Peregrine supplied program-level electricity consumption data, reported in kilowatt-hours and disaggregated by customer type and CCA option. From 2020 through 2023, the Standard Green and 100% Green Plus program options were available, and beginning in 2024, the Economy Green (Basic) option was included.

Electricity transmission and distribution (T&D) losses were accounted for using a Massachusetts specific grid loss factor calculated in accordance with guidance from the U.S. Energy Information Administration (EIA). T&D losses represent electricity that is generated and enters the grid but is lost as heat during transmission and distribution before reaching end users. The T&D loss percentage was determined by dividing estimated electricity losses by total electricity disposition minus direct use as seen in the equation below. Total disposition represents the full amount of electricity supplied to the system, including electricity delivered to end users, system losses, and other disposition categories reported by the utility. Direct use refers to electricity generated and consumed onsite that does not enter the transmission and distribution system.

$$\frac{Total\ Dispositions - Direct\ Use}{Estimated\ Losses} = Massachussetts\ Specific\ Grid\ Loss\ Factor\ (\%)$$

All data used to calculate the loss factor were sourced from the EIA's Massachusetts Electricity -Profile,[3] Table 10, *Supply and Disposition of Electricity*, and were applied to electricity consumption totals to ensure emissions associated with electricity delivery were fully represented

[3] EIA's Massachusetts Electricity Profile data. Retrieved from: Massachusetts Electricity Profile 2024 - U.S. Energy Information Administration (EIA)

in the inventory. The distribution loss factor for each inventory year and data used to calculate it is provided in the table below.

Table 3. Calculating Massachusetts- specific annual grid loss factor

Inventory Year	Total Disposition (MWh)	Direct Use (MWh)	Estimated Losses (MWh)	Annual Grid Loss Factor (%)
2020	53,381,804	662,356	2,785,234	5.28%
2021	54,237,623	724,915	2,389,885	4.47%
2022	54,487,601	838,517	2,757,769	5.14%
2023	53,274,131	793,542	2,214,888	4.22%
2024	52,980,728	864,995	2,305,849	4.42%

Calculating Building Emissions from Electricity Use

To calculate emissions for electricity, Mass Save program data were used to understand total citywide electricity and natural gas consumption for the reporting year, aggregated into two primary categories: Residential and Commercial & Industrial. However, the Mass Save Commercial & Industrial category includes certain residential building typologies, such as large multifamily buildings billed under commercial rate structures.

To properly categorize emissions, sub-segment level consumption data from Eversource was used. Sub-segment shares derived from Eversource data were applied proportionally to the total Mass Save consumption figures to produce refined sector level estimates. The Eversource subsegment data also enabled identification of residential properties charged commercial electricity or natural gas rates, reported as the "Residential Property Manager" sub-segment. For inventory purposes, these properties were reassigned from the Commercial & Industrial sector to the Residential sector, differing from their treatment in the Mass Save dataset.

A third layer of information was incorporated through reporting submitted under BEUDO. Building-level property type data from BEUDO were integrated into each inventory sector and reported separately to support tracking of emissions and performance trends for covered BEUDO buildings. BEUDO reporting also provided additional detail for buildings included in certain Eversource sub-segments. As a result, some energy consumption previously classified within the Commercial and Industrial sector, specifically consumption associated with residential college and university housing and residential municipal property types, were reclassified into the Residential sector to better reflect actual building use.

The following figure shows how data from each source are incorporated into the final inventory sectors including categories that were reclassified from their original designation in the Mass Save data to better align with the inventory's sector definitions.

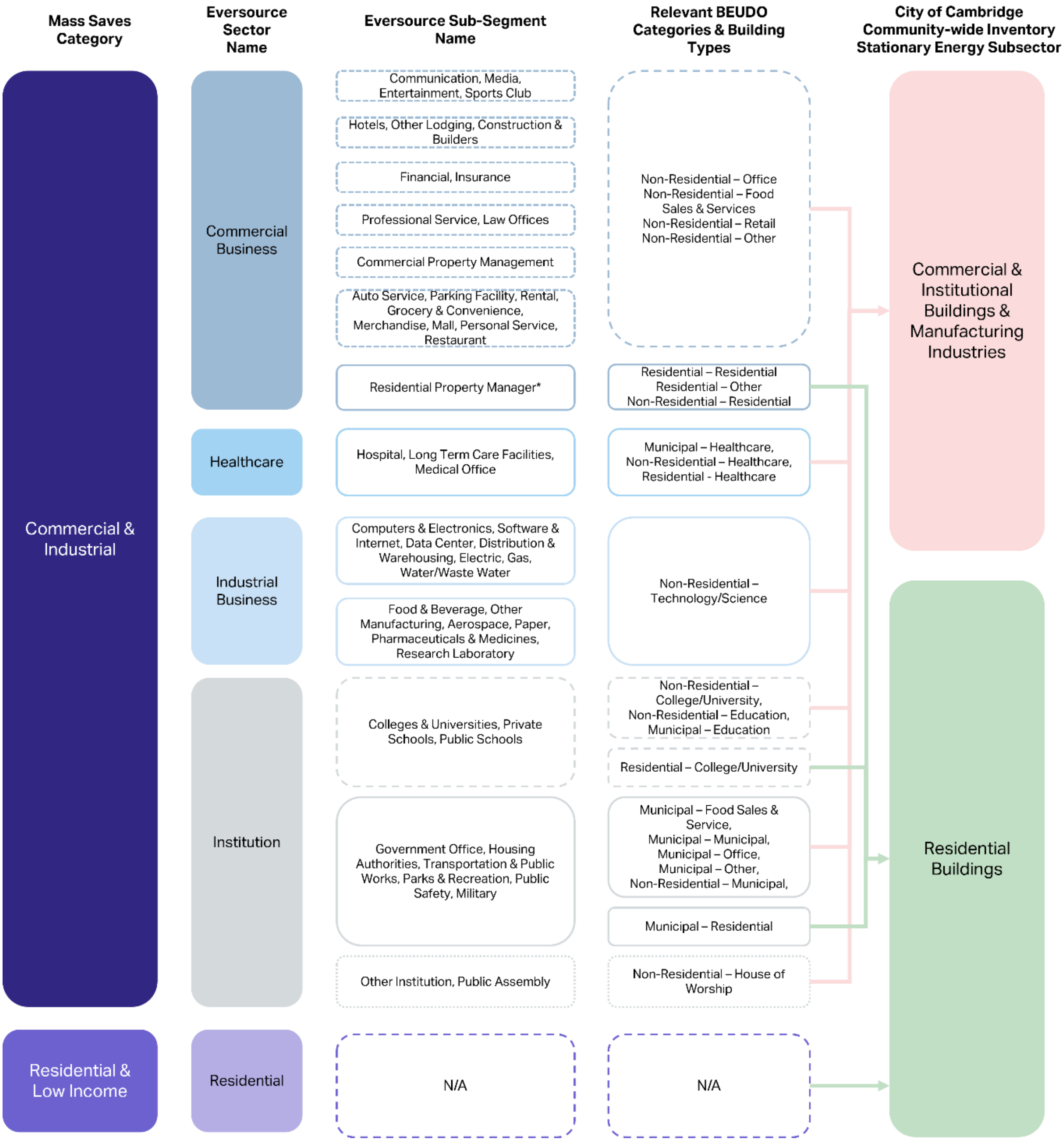

Figure 1. Mapping of Electricity and Natural Gas Data Sources to Inventory Subsectors

Electricity consumption data, after being properly categorized by inventory sector, were integrated with CCA programs data to calculate electricity-related emissions. Program-level electricity consumption, reported in kilowatt-hours and disaggregated by customer type and CCA option, was obtained directly from Peregrine Energy Group, the City of Cambridge's CCA program administrator. From 2020 through 2023, Cambridge customers participated in two CCA options, "Standard Green" and "100% Green Plus, both of which supplied electricity with a lower emissions profile than the regional default grid mix. In 2024, a third option, "Economy Green (Basic Option)", was introduced, expanding available lower emissions electricity supply choices.

To avoid double counting, the electricity from electric vehicle (EV) Charging in the transportation sector has been subtracted from the Building Sector totals for each inventory year. Refer to the

Transportation sector of this report for more information on how electricity consumption from EVs was calculated.

The table below shows the total community electricity consumption before and after re-allocation of inventory sectors, separation of CCA consumption, and adjustment of EV Charging for each inventory year:

Table 4. Subsector Electricity Consumption prior-to and after subsector reallocation

Data Source	Annual Community-wide Electricity Consumption (MWh/year)				
	2020	2021	2022	2023	2024
Mass Saves Reported (prior to re-allocation)	**1,635,945**	**1,913,814**	**1,580,116**	**1,618,424**	**1,585,887**
Residential	234,922	215,999	239,073	235,381	215,999
Commercial & Industrial	1,401,023	1,369,888	1,341,043	1,383,043	1,369,888
Community-wide Inventory (after re-allocation)	**1,634,814**	**1,912,142**	**1,577,852**	**1,614,791**	**1,580,950**
IOU* Residential	186,818	217,247	184,123	180,205	156,327
CCA** Residential	151,116	139,900	156,870	158,279	161,029
Residential EV Charging Adjustment	-889	-1,321	-1,793	-2,837	-3,847
IOU* Non-Residential***	1,122,104	1,361,516	989,179	1,018,449	1,063,724
CCA** Non-Residential***	175,907	195,150	249,944	261,491	204,808
Non-Residential EV Charging Adjustment	-241	-351	-470	-796	-1,089

** Investor-Owned Utility (IOU) refers to electricity consumption billed at the standard utility rate and supplied directly by Eversource.*
*** Community Choice Aggregation (CCA) represents electricity supplied through the City of Cambridge's Community Choice Aggregation program options.*
**** Non-Residential includes Commercial, Institutional, and Manufacturing buildings, and incorporates electricity consumption associated with Energy Industries facilities.*

Electricity Emission Factors

Electricity-related greenhouse gas emissions were calculated by multiplying annual electricity consumption by regionally appropriate grid emission factors. Consistent with best practices for community-wide inventories, emission factors were selected to reflect the characteristics of the electricity grid and community choice aggregation options serving the City of Cambridge in each inventory year.

Electricity emission factors for standard Eversource electricity supply were sourced from the U.S. Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID) [4] for the New England ISO Grid.

Electricity supplied through Community Choice Aggregation (CCA) programs was assigned program-specific emission factors to more accurately reflect the renewable energy attributes of these offerings. Applying program-specific factors improves the accuracy of the inventory and allows the emissions impacts of CCA participation and clean electricity procurement strategies to be represented in the inventories. Across the city of Cambridge the CCA offered 2 programs throughout 2020 through 2023 and added a third program in 2024. The renewable energy content for each offering was as follows:

[4] U.S. Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID) Retrieved from: Detailed Data | US EPA

Table 5. CCA program offerings and renewable energy content

CCA Program	Renewable Energy Content in a CCA Program				
	2020	2021	2022	2023	2024
Standard Green	28%	30%	49%	50%	50%
100% Green Plus	100%	100%	100%	100%	100%
Residential Economy Green	N/A	N/A	N/A	N/A	24%

Emission factors for electricity supplied CCA programs were calculated as weighted averages based on the renewable energy content of each program option publicly reported and the share of total electricity consumption served provided by the program administrator. CCA-specific emission factors were informed by the Massachusetts Department of Environmental Protection (MassDEP) Greenhouse Gas Reporting Program Summary for Retail Sellers of Electricity[5] for each inventory year. The weighted average CCA emissions factors declined between 2020 and 2024 as each Cambridge CCA supply option increased its renewable energy content over time, as shown in Table 6, and further decrease in 2024 with the introduction of the Economy Green option.

Table 6. Annual Electricity Emission Factors Used

Electricity Emission Factors	Annual Electricity Emission Factors Used (lbs. of CO2e/MWh)				
	2020	2021	2022	2023	2024
NEWE E-Grid	533	544	541	543	543
Residential Weighted CCA	420	422	298	320	296
Non-Residential Weighted CCA	432	438	309	335	324

Electricity Transmission and Distribution Losses

All data used to calculate the electricity T&D loss factor were sourced from the EIA's *Massachusetts Electricity Profile*, Table 10, *Supply and Disposition of Electricity,*[6] and were applied to electricity consumption totals to ensure emissions associated with electricity delivery were fully represented in the inventory. To calculate emissions the total electricity consumed was multiplied the grid loss factor and multiplied by a weighted average electricity emission factor by building subsector including all electricity programs (investor-owned utilities and community choice aggregators). The grid loss factor for each inventory year is provided below.

Table 7. Annual Grid Loss Factor

Inventory Year	Annual Grid Loss Factor (%)	Residential – Weighted Average Electricity Emission Factors (lbs. of CO2e/MWh)	C & I Buildings, Manufacturing Industries – Weighted Average Electricity Emission Factors (lbs. of CO2e/MWh)
2020	5.28%	483	519
2021	4.47%	596	531
2022	5.14%	429	494
2023	4.22%	439	501
2024	4.42%	418	508

[5] Massachusetts GHG Emissions Report for Retail Sellers of Electricity. Retrieved from Massachusetts Greenhouse Gas (GHG) Reporting Program Data | Mass.gov

[6] EIA's Massachusetts Electricity Profile data. Retrieved from: Massachusetts Electricity Profile 2024 - U.S. Energy Information Administration (EIA)

Differences in calculation methodology from 2019 Inventory

The electricity emissions methodology for this inventory differs from the 2019 Community-wide Greenhouse Gas Inventory in several ways intended to improve data resolution and alignment with local programs. Most notably, this inventory incorporates Community Choice Aggregation (CCA) program data and Building Energy Use Disclosure Ordinance (BEUDO) reporting, which were not integrated in the 2019 inventory. The inclusion of these datasets enables more accurate sector-level electricity consumption estimates and allows emissions reductions associated with lower-carbon electricity supply options to be explicitly reflected.

In addition, the treatment of electricity T&D losses has been updated. The previous inventories applied a single grid loss factor of 9.13 percent, based on 2014 data, uniformly across all inventory years. For the current inventory, Massachusetts-specific T&D loss factors were calculated for each inventory year using updated U.S. Energy Information Administration data.[7] This has also been updated in the previous inventories (2012 through 2019) to improve temporal accuracy and ensures that electricity emissions calculations reflect year-specific grid conditions.

2.2 NATURAL GAS

Natural gas is used throughout the City of Cambridge to serve residential, commercial, industrial, and municipal buildings, as well as certain city infrastructure systems. Natural gas emissions in the stationary energy sector primarily occur from the on-site combustion of natural gas in buildings for space heating, domestic hot water, cooking, and other end uses. These emissions are generated directly within the community at residential, commercial, and institutional buildings and are reported as Scope 1 stationary combustion emissions in the Community-wide greenhouse gas inventory. The City of Cambridge is served by a single electric and natural gas utility provider, Eversource, which is responsible for the transmission and distribution of natural gas within the community boundary.

Natural Gas Data Sources

Natural gas consumption data were obtained from multiple complementary sources to support comprehensive coverage across all relevant building types and customer classes. Primary data sources included aggregated citywide data reported through the Mass Save program[8], natural gas sub-segment patterns provided directly by Eversource, and building-level reporting submitted under BEUDO.[9] Natural gas consumption data were reported in therms and reflect usage from residential, commercial, industrial, and municipal customers within the City of Cambridge.

Mass Save provides a high-level, sector-based view of natural gas consumption data within the City. This dataset includes total annual natural gas consumption, reported in therms by customer classes, providing distinct reporting for residential and commercial and industrial (C&I) sectors.

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[7] EIA's Massachusetts Electricity Profile data. Retrieved from: Massachusetts Electricity Profile 2024 - U.S. Energy Information Administration (EIA)

[8] Mass Saves Usage and EE Program Activity Dashboards/Municipal Usage and Participation Trends. Retrieved from: Home page - VAP Public View Site

[9] Cambridge Building Energy Use Disclosure Ordinance (BEUDO) Data 2015-2024. Retrieved from: Cambridge Building Energy Use Disclosure Ordinance (BEUDO) Data 2015-2024 | Open Data Portal | City of Cambridge

Eversource provided natural gas consumption data by customer segments and sub-segments mapped to NAICS-based classifications. These data sets were reported in accordance with standard utility confidentiality requirements, including minimum customer count and usage concentration thresholds, and were provided only in aggregate form. To address Eversource confidentiality and data concentration requirements, segments and sub-segments were evaluated against two rules: (1) each sub-segment was required to include at least 15 customers in a given year, and (2) no single customer could account for more than 15 percent of a sub-segment's total monthly energy usage in any reported month. Sub-segments that did not meet these criteria were aggregated into their broader segment, and if an entire segment failed to meet the minimum thresholds, it was aggregated at the sector level. The percent of natural gas consumption from each sub-segment was applied to the Mass Saves total Commercial and Industrial natural gas reported.

Building-level property type information was obtained through BEUDO reporting, which requires large buildings to annually report energy and water use to the City. Covered properties include non-residential buildings 25,000 square feet or larger, residential buildings with 50 or more dwelling units, and municipal buildings 10,000 square feet or larger. Because these buildings provide standardized, building-level data, BEUDO reporting offers a detailed and reliable source of information for understanding energy consumption from the City's largest energy-using properties. BEUDO data provide supplemental information on natural gas consumption for covered buildings and were used to support sector-specific reporting and tracking of energy use associated with disclosed properties. BEUDO data were reported separately within each inventory sector to allow continued monitoring of natural gas consumption trends among BEUDO buildings.

Fugitive methane emissions associated with natural gas transmission and distribution were estimated using loss rates reported in the peer-reviewed study by Sargent et al. (2021), "Majority of U.S. urban natural gas emissions unaccounted for in inventories"[10]. This study estimates that approximately 2.5 percent, with an uncertainty of ±0.5 percent, of natural gas entering urban distribution systems is lost during transmission and distribution due to leaks and system losses.

Calculating Emissions from Natural Gas Combustion

Natural gas consumption data, reported in therms, were obtained at a higher level of detail than in previous inventories through the integration of multiple complementary data sources. These included Mass Save program data, consumption data provided directly by Eversource, and reporting submitted under BEUDO. This multi-layered approach enabled improved sectoral accuracy while maintaining customer confidentiality. As described in the electricity data sources section and summarized in Figure 1, these datasets were integrated to refine sector assignments and ensure consistent treatment across inventory years, including the reallocation of natural gas consumption from residential buildings billed under commercial rate structures to the appropriate Residential sector.

In addition to building-level natural gas consumption, fuel use associated with large stationary energy generation facilities was evaluated. For facilities that serve both Boston and Cambridge, including the Vicinity Kendall Green plant and the Harvard University (Cambridge‑Allston‑Blackstone) district energy system, on-site natural gas combustion is excluded from the Stationary Energy sector. For these facilities, any thermal energy delivered to Cambridge buildings is reported as Scope 2 emissions; additional detail is provided in the District Energy section of this report. Although these facilities appear in the Mass Save Commercial and Industrial dataset and within the

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[10] "Majority of U.S. urban natural gas emissions unaccounted for in inventories" by Sargent et al. (2021), Retrieved from: Majority of US urban natural gas emissions unaccounted for in inventories | PNAS

industrial segment of Eversource utility data, their Scope 1 natural gas consumption has been excluded to accurately reflect their operational role beyond the City of Cambridge and to avoid double counting.

In contrast, for cogeneration facilities that exclusively serve Cambridge buildings, including the MIT Central Utility Plant and the Biogen Inc. cogeneration plant, on-site natural gas combustion is included as Scope 1 stationary emissions. Although buildings served by these auto-producer facilities may report thermal energy consumption through BEUDO for disclosure purposes, in the Community-wide greenhouse gas inventory this energy use is accounted for through the underlying natural gas consumption at the plant as Scope 1 stationary emissions. Additional detail on how data and emissions from cogeneration facilities are incorporated into the inventory is provided in the Energy Industries section of this report.

The table below presents total building-sector natural gas consumption before and after sectoral reallocation and removal of the appropriate co-generation plants for each inventory year.

Table 8. Annual Sub-Sector Natural Gas Consumption

Subsector	Annual Building Natural Gas Consumption (therms)				
	2020	2021	2022	2023	2024
Mass Saves Reported (Prior to Re-Allocation)	**210,685,401**	**230,513,413**	**250,446,032**	**270,198,031**	**270,544,623**
Residential	18,121,996	17,980,524	17,575,217	16,210,031	16,082,477
Commercial & Industrial*	192,563,405	212,532,889	232,870,815	253,988,000	254,462,146
Community-wide Inventory (After Re-Allocation)	**64,129,329**	**94,626,122**	**114,751,173**	**110,397,521**	**110,744,113**
Residential	24,301,613	24,111,255	25,656,704	22,556,449	32,216,078
Non-Residential**	39,827,716	70,514,867	89,094,469	87,841,072	78,528,034

** This includes co-generation plants natural gas consumption which generates steam and electricity across multiple jurisdictions.*
***Non-Residential includes Commercial, Institutional, and Manufacturing buildings. Co-generation plants that do not solely serve Cambridge have been removed and are reported separately as their own sub sector, refer to District Energy and Energy Industries sections of this report for more details.*

Fugitive Emissions from Natural Gas Distribution Losses

Fugitive methane emissions associated with natural gas transmission and distribution were estimated using loss rates reported in the peer-reviewed study by Sargent et al. (2021), "Majority of U.S. urban natural gas emissions unaccounted for in inventories."[11] This study estimates that approximately 2.5 percent, with an uncertainty of ±0.5 percent, of natural gas entering urban distribution systems is lost during transmission and distribution due to leaks and system losses.

For this inventory, the estimated loss rate was applied to total community natural gas consumption to calculate the volume of natural gas lost prior to end use. The resulting natural gas losses were then converted to emissions using standard natural gas combustion emission factors, with methane emissions reflected as fugitive emissions.

Differences in calculation methodology from 2019 Inventory

This inventory updates the methodology of emissions quantification from cogeneration facilities relative to the 2019 community-wide greenhouse gas inventory to better align with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). In 2019, cogeneration plants were reported in the Energy Industries sector as centralized energy generation. Under the

[11] "Majority of U.S. urban natural gas emissions unaccounted for in inventories" by Sargent et al. (2021), Retrieved from: Majority of US urban natural gas emissions unaccounted for in inventories | PNAS

GPC, cogeneration and combined heat and power facilities that primarily generate electricity and thermal energy for on-site or directly connected end uses are classified as auto-producers, and the GPC recommends that emissions from these facilities be reported in the relevant building sectors when the energy produced is consumed within the community boundary. Consistent with this guidance, the MIT Central Utility Plant and the Biogen Inc. cogeneration plant are treated as auto-producers in this inventory; because both facilities exclusively serve Cambridge buildings, their on-site natural gas combustion is reported as Scope 1 stationary emissions rather than Energy Industries.

In the 2019 inventory, fugitive emissions from natural gas distribution were calculated using an incorrect interpretation of results from a Boston-area natural gas leakage study "Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts"[12] by McKain et al., 2014. The previous inventory applied a loss rate of 0.6 percent, whereas the study findings indicated a substantially higher loss rate of approximately 2.7 percent, with an uncertainty of ±0.6 percent. For the current and previous inventories, the natural gas distribution loss rate has been updated to 2.5 percent, consistent with the MAPC recommended regional loss factor and aligned with a more recent peer-reviewed study by Sargent et al. (2021), "Majority of U.S. urban natural gas emissions unaccounted for in inventories."[13] This update significantly improves the accuracy of fugitive methane emissions estimates associated with natural gas use in Cambridge and has been retroactively applied to the previous inventories.

In addition, the new inventories incorporate building-level information reported under the BEUDO, which was not included in the previous inventories. BEUDO data provided additional insight into building property types and energy use characteristics, enabling improved sector alignment and more accurate classification of natural gas consumption, particularly for residential buildings billed under commercial rate structures.

2.3 DISTRICT HEATING AND COOLING

District Heating and Cooling Data Sources

District heating and cooling activity data were sourced from BEUDO reporting, which includes reported steam and chilled water consumption for large buildings in Cambridge. These data were reviewed and screened by building owner to distinguish buildings connected to district energy systems that serve areas beyond the City of Cambridge such as the Vicinity Kendall Green and Harvard Blackstone plants. This screening was necessary to identify district energy systems whose associated emissions should be attributed to imported energy rather than on-site stationary fuel combustion.

Calculating Emission from District Heating and Cooling

District heating and cooling emissions are reported as Scope 2 stationary energy emissions, consistent with the GPC which classifies district steam and chilled water as indirect emissions occurring at the point of energy generation but attributable to end users within the community

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

[13] "Majority of U.S. urban natural gas emissions unaccounted for in inventories." by Sargent et al., 2021., Majority of US urban natural gas emissions unaccounted for in inventories | PNAS

boundary. District energy is included only for systems that serve customers both inside and outside Cambridge, where emissions from the plant are not fully attributable to Cambridge alone.

This approach allows the inventory to capture buildings in Cambridge that consume steam from the Vicinity Kendall Green Energy plant, while avoiding the attribution of emissions associated with thermal energy delivered to buildings outside the city boundary. For the Harvard University (Cambridge-Allston-Blackstone) district energy system, only thermal energy consumed by Cambridge buildings is included, and thermal energy delivered to buildings in Boston is explicitly excluded. By screening BEUDO data for buildings by location and ownership, the methodology ensures that only district heating and cooling consumption occurring within Cambridge contributes to reported emissions.

Differences in calculation methodology from 2019 Inventory

The treatment of district heating and cooling has been refined from the 2019 inventory to better align with GPC boundary definitions and to take advantage of available, higher-resolution BEUDO data. In the 2019 inventory, emissions from district energy systems were estimated using more limited datasets and emissions from the Vicinity Kendall Green Energy plant were excluded entirely, meaning that steam consumption by Cambridge buildings connected to this system was not captured. For the Harvard University (Cambridge-Allston-Blackstone) district energy system the 2019 inventory did not allow for differentiation between thermal energy consumed within Cambridge and energy delivered to buildings outside the city boundary. In this inventory, the use of BEUDO data enables building-level identification of steam and chilled water consumption, making it possible to include steam consumed by Cambridge buildings served by the Vicinity plant and Harvard University (Cambridge-Allston-Blackstone) district energy system while explicitly excluding thermal energy delivered to buildings outside of the City. The availability of this improved dataset supports methodological improvements that enhance geographic accuracy.

2.4 FUEL OIL

Fuel oil consumption within the City of Cambridge was estimated using a combination of federal, state, and local datasets due to the absence of centralized utility reporting for fuel oil deliveries. Unlike electricity and natural gas, fuel oil is supplied by numerous private vendors, making direct collection of customer-level consumption data infeasible. As a result, fuel oil use was estimated using building characteristics, employment data, and nationally and regionally representative fuel consumption datasets. Key data sources included the U.S. Energy Information Administration (EIA), the Massachusetts Executive Office of Labor and Workforce Development (EOLWD), the American Community Survey (ACS), and fuel oil disclosures reported under BEUDO.

Fuel Oil Data Sources

Fuel oil is used within the City of Cambridge primarily for space heating in residential, commercial, institutional, and industrial buildings. Unlike electricity and natural gas, which are supplied by a single regulated utility, fuel oil is delivered by numerous private vendors. As a result, no centralized utility records of fuel oil consumption are available for the community. Fuel oil consumption data for this inventory were therefore derived from a combination of federal, state, and regional datasets that provide information on building characteristics, fuel usage patterns, and economic activity relevant to the Cambridge community.

Building-level fuel oil consumption data reported through the City of Cambridge's BEUDO were also used as a supplemental source. BEUDO data provide annual fuel oil consumption by reported property type for non-residential buildings 25,000 square feet or larger, residential buildings with

50 or more dwelling units, and municipal buildings 10,000 square feet or larger. This was used to support sector-specific reporting and tracking.

Residential Fuel Oil Data Sources

Residential fuel oil data were informed by multiple national and local datasets. Data on housing units by building type were obtained from the American Community Survey (ACS) 5-Year Estimates, specifically the Housing Tenure by Units in Structure table (B25032)[14], using the five-year estimates for the City of Cambridge. Information on the percentage of households using fuel oil for space heating was sourced from ACS-based regional datasets[15] available through the Metropolitan Area Planning Council (MAPC) DataCommon, which reports household fuel use by housing type. Data on Massachusetts average fuel oil consumption is from EIA 2020 RECS Dashboard[16], filtered to Massachusetts and Fuel oil consumption per household using fuel oil data.

Commercial and Institutional Fuel Oil Data Sources

Fuel oil data for commercial and institutional buildings were informed by employment and establishment data from the Massachusetts Executive Office of Labor and Workforce Development (EOLWD) Employment and Wages (ES-202) dataset.[17] This dataset provides average monthly employment and counts of employer establishments by three-digit NAICS codes. NAICS classifications were matched to commercial "Primary Building Activities" as defined by the U.S. Energy Information Administration.

Fuel oil consumption characteristics, including fuel oil consumption per employer establishment, for commercial buildings were sourced from the U.S. EIA's 2018 Commercial Buildings Energy Consumption Survey (CBECS) and shown in the table below. Fuel oil consumption per building was obtained from CBECS Table C34[18], U.S. Commercial Building Fuel Oil Consumption and Expenditures. For building activity types where fuel oil data were not reported in CBECS, comparative consumption data from CBECS Table C34, U.S. Commercial Building Natural Gas Consumption and Expenditures, were used to inform relative fuel oil usage. Information on the percentage of commercial and institutional buildings using fuel oil for heating was sourced from DNV GL's Massachusetts Commercial and Industrial Market Characterization On-site Assessments and Market Share and Sales Trends Study.[19]

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[14] American Community Survey (ACS) 5-Year Estimates, specifically the Housing Tenure by Units in Structure table (B25032). Retrieved from: MAPC DataCommon

[15] ACS data for Housing Tenure by Fuel Type. Retrieved from MAPC DataCommon

[16] Energy Information Administration (EIA) 2020 Residential Energy Consumption Survey (RECS) Dashboard Retrieved from: Residential Energy Consumption Survey Dashboard

[17] Massachusetts Executive office of Labor and Workforce Development (EOLWD) Employment and Wages (ES-202). Retrieved from: Labor Market Information | Mass.gov

[18] Commercial Buildings Energy Consumption Survey (CBECS) Table C34 Retrieved from: Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS) Data

[19] DNV GL's MA C&I Market Characterization On-site Assessments and Market Share and Sales Trends Study, 2016. Retrieved from: Microsoft Word - Vol I_MA CI Onsite Assessments Final Report

Table 9. Fuel oil consumption per building was obtained from CBECS Table C34[20]

Primary Building Activity (PBA)	Fuel Oil Consumption Per Employer Establishment (Gallons/ Employer Establishment / Year)
Education	6,322
Food Sales	909
Food Service	1,280
Health Care Inpatient	7,315
Health Care Outpatient	222
Lodging	1,421
Mercantile Retail (other than mall)	1,022
Mercantile Enclosed and Strip Malls	2,719
Office	824
Public Assembly	1,095
Public Order And Safety	1,475
Religious Worship	1,388
Service	692
Warehouse And Storage	651
Other	1,839

Industrial Fuel Oil Data Sources

Industrial fuel oil data were informed by a combination of economic activity and national energy consumption datasets. Employment and establishment data by primary industrial activity were obtained from the Massachusetts EOLWD ES-202 dataset,[21] with NAICS codes matched to EIA-defined industrial activity categories.

Fuel oil consumption per employee by industrial activity was sourced from the U.S. Energy Information Administration's Manufacturing Energy Consumption Survey (MECS), Table 6.1,[22] Consumption Ratios of Fuel. Data for the Northeast region were used where available; for activities without regional data, national-level values were applied. Additional supporting data on total energy consumption and fuel end uses by industrial activity were obtained from MECS Table 1.1[23], First Use of Energy for All Purposes, and MECS Table 5.4,[24] End Uses of Fuel Consumption. Distillate fuel oil and diesel fuel data were combined, with the analysis assuming distillate fuel oil represents the full amount of this combined category.

Estimating Emissions from Fuel Oil in Residential Buildings

Residential fuel oil consumption was estimated based on the number of housing units in the City of Cambridge by building type and the share of units using fuel oil for space heating. Housing unit

[20] Commercial Buildings Energy Consumption Survey (CBECS) Table C34 Retrieved from: Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS) Data

[21] Massachusetts Executive office of Labor and Workforce Development (EOLWD) Employment and Wages (ES-202). Retrieved from: Labor Market Information | Mass.gov

[22] .Energy Information Administration (EIA) 2018 Manufacturing Energy Consumption Survey (MCES) Table 6.1: Consumption Ratios of Fuel. Retrieved from: U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

[23] U.S. Energy Information Administration (EIA) 2018 Manufacturing Energy Consumption Survey (MCES) Table 1.1: First Use of Energy for all Purposes (Fuel and Nonfuel). Retrieved from: U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

[24] Energy Information Administration (EIA) 2018 Manufacturing Energy Consumption Survey (MCES) Table 5.4: End Uses of Fuel Consumption. Retrieved from: U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

counts were obtained from the ACS 5-Year Estimates, disaggregated by units-in-structure categories. The residential building types included in the analysis were:

- Single-family, detached
- Single-family, attached
- Multi-family, 2-4 units (combined total of 2-family and 3-4-unit structures)
- Multi-family, 5 or more units (combined total of 5–19 units, 20–49 units, and 50+ units)
- Other residential structures

The percentage of housing units heated with fuel oil was derived from ACS data. Residential fuel oil combustion emissions were calculated using data on Massachusetts average fuel oil consumption is from EIA 2020 RECS Dashboard[25], filtered to Massachusetts and Fuel oil consumption per household using fuel oil data.

Estimating Emissions from Fuel Oil in Commercial and Industrial Buildings

Fuel oil consumption for commercial buildings was estimated using employment-based activity data and building energy use characteristics. Employment and establishment counts by industry were obtained from the Massachusetts Executive Office of Labor and Workforce Development Employment and Wages (ES-202) survey, which reports data by NAICS code. NAICS codes were mapped to commercial Primary Building Activities (PBAs) consistent with classifications used by the U.S. Energy Information Administration. The table below maps the NAICS Codes the EIA PBAs.

Table 10. Commercial Buildings EIA Primary Building Activities and NAICS Codes crosswalk

EIA Primary Building Activity	NAICS Codes
Education	611
Food Sales	445
Food Service	722
Inpatient Health Care	621
Outpatient Health Care	622
Lodging	623, 721
Retail (Non-Mall)	441, 442, 443, 444, 451,452, 453, 532
Retail (Mall)	446, 448
Office	425, 454, 486, 511, 517, 518, 519, 521, 522, 523, 524, 525, 531, 542, 551, 561, 624, 921, 923, 924, 925, 926, 928
Public Assembly	481, 482, 485, 487, 512, 515, 711, 712, 713
Public Order/Safety	922
Religious Worship	813
Service	447, 483, 484, 488, 491, 492, 811, 812
Warehouse/Service	423, 424, 493
Other	562, 927

Average fuel oil consumption by primary building activity was informed by data from the U.S. EIA's 2018 CBECS survey. Fuel oil use estimates incorporated the total number of employees and establishments associated with each PBA and the expected energy use per employee for each building activity category. This approach allowed fuel oil consumption to be estimated across a wide range of commercial building types while maintaining consistency with nationally representative energy use data.

[25] Energy Information Administration (EIA) 2020 Residential Energy Consumption Survey (RECS) Dashboard Retrieved from: Residential Energy Consumption Survey Dashboard

Fuel oil consumption for industrial buildings was estimated using a similar approach to that used for the commercial sector, with data sources tailored to industrial activities. Employment and establishment data were obtained from the EOLWD ES-202 survey and mapped to industrial primary building activities using NAICS codes. This analysis included industrial sectors corresponding to NAICS codes 311 through 339, as shown in the table below.

Table 11. Industrial Buildings EIA Primary Building Activities and NAICS Codes crosswalk

EIA Primary Building Activity	NAICS Codes
Food	311
Chemicals	325
Machinery	333
Computer and Electronic Products	334
Miscellaneous	339

Industrial energy consumption data were informed by the U.S. Energy Information Administration's Manufacturing Energy Consumption Survey (MECS), which provides fuel consumption data by manufacturing activity. Fuel oil use was estimated using average energy consumption per employee for each industrial PBA. Industrial energy uses categorized between codes 100 and 200, such as power generation and utility operations, were excluded from this analysis to avoid overlap with the Energy Industries sector.

Differences in calculation methodology from 2019 Inventory

Previously the inventories used a single estimate of the percentage of residential buildings using fuel oil for space heating derived from the U.S. Census Bureau's ACS 2010-2014 5-Year Estimates. This approach applied a fixed value across all inventory years and did not reflect changes in residential heating fuel use over time.

For the current inventory, the percentage of residential buildings heated with fuel oil is sourced from the ACS 5-Year Estimates corresponding to each specific inventory year. This update improves temporal accuracy and better reflects year-to-year changes in residential fuel use patterns in Cambridge. To ensure consistency in trend analysis, this revised approach has been applied retroactively to prior inventory years where data were available (2012 through 2019), updating historical fuel oil estimates using year-specific ACS data as shown in the table below.

Table 12. Percent of Housing Units Using Fuel Oil for Heating by Housing Tenure (ACS 5-Year Estimates)

Inventory Year	Percent of Homes in Community Using Fuel Oil as Heating Fuel (%)
2012	11.60%
2013	9.88%
2014	9.20%
2015	8.36%
2016	7.79%
2017	6.90%
2018	6.13%
2019	5.34%
2020	4.95%
2021	4.45%
2022	4.18%
2023	3.94%
2024	3.94%

2.5 ENERGY INDUSTRIES

Four major electricity and steam generation facilities located within the City of Cambridge were evaluated as part of this inventory: the Kendall Co-Generation Station (Vicinity), the Massachusetts Institute of Technology (MIT) Central Utilities Plant, the Harvard University Blackstone Plant, and the Biogen Inc. cogeneration plant. After further review of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), emissions from these facilities are no longer reported as a standalone *Energy Industries* subsector in the community-wide inventory. Instead, emissions are attributed to the sectors in which energy is ultimately consumed, consistent with GPC BASIC and BASIC+ accounting guidance. Emissions from these plants fall into one of two categories described below.

Category 1: Facilities that Produce Energy Direct On-Site for Dedicated Local Use (Auto-Producers)

If electricity or thermal energy generated at a facility is consumed directly by buildings within the City of Cambridge, such as cogeneration facilities serving a university campus or large institutional user, those facilities are classified as *auto-producers* under the GPC. In these cases, the natural gas consumption and associated emissions required to generate electricity and heat are captured within the *Stationary Energy – Buildings* sector. Reporting these emissions separately under an Energy Industries subsector would duplicate emissions that are already included in the Eversource totals.

Consistent with this guidance, the MIT Central Utilities Plant and the Biogen Inc. cogeneration plant are treated as auto-producers in this inventory. Because these facilities exclusively serve Cambridge buildings, their electricity and natural gas consumption is included in Eversource totals and reported as Scope 1 stationary emissions in the Buildings sector. These facilities are not reported separately under Energy Industries.

Category 2: Facilities that Serve Multiple Jurisdictions or Export Energy Beyond Cambridge

If electricity or thermal energy generated at a facility is delivered to the regional grid or serves buildings beyond the City of Cambridge boundary, emissions from the generating facility are not reported as Scope 1 under GPC BASIC or BASIC+ guidelines. Instead, only the portion of energy consumed within the City of Cambridge is captured as Scope 2 emissions.

Consistent with this approach, steam and district energy consumption in Cambridge from facilities serving multiple jurisdictions is reported directly in the Buildings sector as Scope 2 emissions. Steam consumption is sourced from BEUDO data and calculated using the BEUDO steam emissions factor. To avoid double counting, the natural gas used to generate this thermal energy is removed from Eversource natural gas totals.

For the Harvard University Blackstone Plant, steam and chilled water consumed by connected buildings located within Cambridge is sourced from BEUDO data and reported as Scope 2 district steam emissions, while thermal energy delivered to buildings in Boston is excluded. Natural gas use associated with this plant reported to EPA's Greenhouse Gas Reporting Program (GHGRP) is subtracted from Eversource totals.

For the Vicinity Kendall Co-Generation Station, steam consumed by Cambridge buildings is sourced from BEUDO data and reported as Scope 2 district steam emissions. Natural gas use for this facility that is reported to EPA's Greenhouse Gas Reporting Program (GHGRP) is also removed from

Eversource totals, as it is either used to produce steam already captured as Scope 2 emissions or to generate electricity that is exported to the regional grid.

Through this approach, emissions are consistently attributed to the point of energy consumption rather than generation. This methodology aligns with the GPC's emphasis on end-use accounting, avoids both under- and double counting, and ensures that community-wide emissions reflect only energy consumed within the Cambridge boundary.

Table 13. Total direct emissions from power generation facilities, for informational purposes only

Power Facility in Cambridge	Total Direct Emissions (MT CO2e)				
	2020	2021	2022	2023	2024*
BIOGEN INC	27,101	29,388	29,755	28,268	28,268
MIT Central Utility Plant	111,369	131,848	168,494	163,804	163,804
The President and Fellows of Harvard University (Cambridge Allston Blackstone)	73,613	76,533	76,378	79,476	79,476
Kendall Green Energy	718,051	659,907	677,634	788,060	788,060

** 2024 FLIGHT EPA data is not yet available; therefore emissions estimated from reported for 2023 are used in the 2024 inventory*

Differences in calculation methodology from 2019 Inventory

The treatment of the Energy Industries sector has changed in this inventory update relative to the 2019 Community-wide greenhouse gas inventory. In the 2019 inventory, electricity and steam generation facilities located within Cambridge, excluding the Vicinity Kendall Green plant, were reported as a standalone Energy Industries subsector to provide visibility into emissions from on-site power and thermal generation. Beginning with the 2020 inventory year, the Energy Industries subsector is no longer reported independently. This change reflects a methodological refinement based on closer alignment with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) and the availability of improved building-level data from BEUDO.

The introduction of BEUDO data enables a more accurate allocation of energy and emissions based on where electricity and thermal energy are ultimately consumed. With this improved data resolution, emissions from cogeneration and district energy facilities can be consistently attributed to the Buildings sector as either Scope 1 stationary emissions for auto-producer facilities or Scope 2 emissions for purchased steam and district energy from multi-jurisdictional systems. As a result, reporting emissions separately under an Energy Industries subsector is no longer necessary and would risk double counting emissions already captured through building-level natural gas, electricity, and steam consumption.

The methodology applied in the 2019 and earlier inventories has not been retroactively revised. Instead, this update represents a forward-looking methodological improvement applied to the current inventory and subsequent years. Differences between the 2019 inventory and inventories from 2020 onward reflect improved data availability and improvement with GPC-aligned accounting, rather than changes in underlying energy systems or facility operations.

2.6 OFF-ROAD (VARIOUS FUEL-TYPES)

The Off-Road sector includes greenhouse gas emissions from fuel combustion in non-road equipment and vehicles that operate within Cambridge but are not registered for on-road use. This includes equipment such as construction machinery, industrial equipment, landscaping and maintenance equipment, airport ground support equipment, and other off-road engines powered by gasoline, diesel, or other fuels. Emissions in this sector primarily occur from fuel combustion during operation and are reported as direct (Scope 1) emissions within the community boundary.

Off-Road Vehicles and Equipment Data Sources

Emissions from off-road equipment and vehicles operating within the City of Cambridge were informed by data from the U.S. Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) version 4.0 NONROAD model.[26] MOVES is a publicly available EPA emissions modeling system that estimates emissions from mobile non-road sources at the county level for greenhouse gases, criteria air pollutants, and air toxics. County-level MOVES emissions outputs were accessed through the MAPC DataCommon platform and served as the primary emissions dataset for the off-road sector.

Supporting activity data used to contextualize off-road emissions were obtained from multiple federal, state, and regional sources. Employment data were sourced from the U.S. Census Bureau's ACS 5-Year Estimates[27] and the Massachusetts Employment and Wages (ES-202) dataset.[28] Data on developed open space were obtained from MAPC DataCommon using estimates derived from the National Land Cover Database,[29] and information on commercial development activity was sourced from the MAPC MassBuilds database.[30] Together, these datasets provide the underlying activity indicators used alongside MOVES emissions data to represent off-road emissions within the City of Cambridge.

Off Road Vehicles and Equipment Emissions

The NONROAD component of MOVES captures emissions from a wide range of equipment types, including construction equipment, landscaping equipment, agricultural equipment, industrial machinery, and other non-highway mobile sources operating on various fuel types.

For this Community-wide inventory, county-level MOVES NONROAD emissions estimates served as the foundation for quantifying off-road emissions. These county-level emissions were then allocated to the City of Cambridge using proportional scaling based on locally relevant activity indicators. The activity indicators used to perform this allocation were derived by comparing city-level data to county-level totals for the following variables: total employment, manufacturing employment, square footage of developed open space, and square footage of commercial development under construction. These indicators were selected to reflect the primary drivers of off-road equipment activity, such as construction, industrial operations, and grounds maintenance.

Differences in calculation methodology from 2019 Inventory

While off-road emissions were estimated for earlier inventories, including 2012, they were not calculated or reported for the 2019 inventory year. Off-road emissions for 2019 were calculated retroactively using the same data sources, modelling assumptions, and estimation methodology applied consistently across the 2020 through 2024 inventory years. This update ensures

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[26] U.S. Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES) version 4.0 NONROAD model data. Retrieved from: MAPC DataCommon

[27] ACS 5-year estimates "Industry by Occupation for the Civilian Employed Population 16 Years and Over" (Table S2405). Retrieved from: S2405 - Census Bureau Search

[28] Massachusetts Executive office of Labor and Workforce Development (EOLWD) Employment and Wages (ES-202). Retrieved from: Labor Market Information | Mass.gov

[29] MAPC Estimated square footage of landscaped area by county and by municipality. Retrieved from: MAPC DataCommon

[30] MAPC Mass Builds database commercial development area. Retrieved from: MassBuilds

methodological consistency across inventory years and allows for improved comparability of emissions trends over time.

2.7 STATIONARY ENERGY SECTOR SUMMARY

Buildings and energy production emissions are generated through the consumption of fuel and electricity in residential and commercial buildings, manufacturing industries, the energy industry within the City's boundaries, and off-road equipment. Commercial & Institutional Buildings & Manufacturing Industries generated the greatest share of emissions within the Buildings and Energy Production sector for inventory years 2020 through 2024, representing between 68 to 75 percent of total emissions. This is followed by residential buildings at 18 to 26 percent. This is primarily due to Cambridge's high density of education, research, and commercial activity. Construction emissions from off-road equipment account for the remaining 5 to 8 percent of Stationary Energy emissions. The table below provides a breakdown of the City's Stationary Energy emissions by sub-sector for years 2020 through 2024.

Table 14. Stationary Energy Subsector Emissions Summary

Subsector	Emissions (MT CO2e)				
	2020	2021	2022	2023	2024
Residential Buildings	255,659	259,231	255,202	234,553	291,174
Commercial & Institutional Buildings & Manufacturing Industries	677,555	957,691	990,678	990,344	926,454
Construction	61,693	68,068	73,836	89,051	97,241
TOTAL Stationary Energy Emissions	**994,907**	**1,284,990**	**1,319,716**	**1,313,949**	**1,314,869**

Comparison with previous inventories

Total stationary energy emissions increased from approximately 1.09 million metric tons of CO_2e in 2012 to 1.30 million metric tons of CO_2e in 2019, followed by a modest increase to approximately 1.31 million metric tons of CO_2e in 2024.

Residential building emissions declined between 2019 and 2024, decreasing from approximately 303,295 MT CO_2e to 291,174 MT CO_2e, and falling below 2012 levels. This reversal suggests reduced residential energy emissions, potentially driven by efficiency improvements, fuel switching, or lower-carbon electricity supply. Emissions from Commercial and Institutional Buildings and Manufacturing Industries increased partially as a result of methodology update by integrating BEUDO data from the Harvard Blackstone plant and reporting emissions from the MIT Central Utilities Plant and the Biogen Inc. cogeneration plant within the building sectors rather than energy industries sector.

Construction emissions declined modestly from 2019 to 2024 due to slightly decreased development in Cambridge in 2024 compared to 2019.

Table 15. Stationary Energy Subsector Emissions Comparison with previous years

Subsector	Stationary Energy Emissions (MT CO2e)		
	2012 (Updated)	2019 (Updated)	2024
Residential Buildings	287,768	303,294	291,174
Commercial & Institutional Buildings & Manufacturing Industries	582,956	685,266	926,454
Energy Industries	194,907	179,682	N/A
Construction	25,164	131,156	97,241
TOTAL Stationary Energy Emissions	**1,090,795**	**1,299,398**	**1,314,869**

3. TRANSPORTATION

Transportation emissions are a combination of on-road vehicle activity and off-road rail activity. On-road vehicle activity includes personal, commercial, and municipal/state vehicles registered in the City of Cambridge, as well as public transportation that occurs on roadways within the geographic boundary of the city, such as buses and trackless trolleys. Rail travel incorporates the portion of public transportation that occurs within the city boundary but off roadways. In Cambridge, this includes the MBTA Fitchburg Line (commuter heavy rail), Red Line (subway heavy rail), and Green Line E Branch (light rail).

3.1 TRANSPORTATION SECTOR DATA SOURCES

Vehicle Miles Traveled

Emissions from on-road personal, commercial, and municipal/state vehicles are estimated using information from the Massachusetts Vehicle Census (MVC) and Massachusetts Vehicle Census Summary Statistics (MAVC). These data sources included vehicle miles traveled (VMT) by vehicle class and fuel type.

Table 16. VMT Data Sources

Data Name	Data Owner	Data Source	Data Use
Massachusetts Vehicle Census (MVC)	Massachusetts Department of Transportation (MassDOT)	https://geodot-massdot.hub.arcgis.com/pages/vehicle-census	Resident VMT
Massachusetts Vehicle Census Summary Statistics (MAVC)	Metropolitan Area Planning Council (MAPC)	https://datacommon.mapc.org/browser/datasets/483	Resident VMT
Replica	Replica	https://studio.replicahq.com	Geographic VMT
Archived GTFS Data	Massachusetts Bay Transportation Authority (MBTA)	https://cdn.mbta.com/archive/archived_feeds.txt	Public Transportation VMT
Cambridge City Boundary	City of Cambridge	https://www.cambridgema.gov/GIS/gisdatadictionary/Boundary/BOUNDARY_CityBoundary	Public Transportation VMT
MBTA Vehicle Inventory	The MBTA Vehicle Inventory Page	https://roster.transithistory.org/	Public Transportation Fuel Type
Traffic Volume Trends	Federal Highway Administration	https://highways.dot.gov/newsroom/us-driving-last-year-was-lowest-two-decades-new-data-show	2020 VMT Factor

Transportation Emissions Factors

VMT was combined with emission rates identified from the California Air Resources Board (CARB) EMission FACtor (EMFAC) model, which estimates the official emissions inventories of on-road mobile sources. Off-road emissions for electric vehicle charging were identified from the Massachusetts Department of Environmental Protection (MassDEP). Off-road emissions for rail were identified from MAPC's Fuel Consumption and Route Distance data for the MBTA.

Table 17. Emissions Data Sources

Data Name	Data Owner	Data Source	Data Use
EMission FACtor (EMFAC) Model	California Air Resources Board (CARB)	https://arb.ca.gov/emfac/emissions-inventory/	On-Road Emissions Rates
Massachusetts Greenhouse Gas (GHG) Reporting Program Data	Massachusetts Department of Environmental Protection (MassDEP)	https://www.mass.gov/lists/massachusetts-greenhouse-gas-ghg-reporting-program-data	Electric Vehicle Charging Emissions Rates
MBTA Fuel Consumption and Route Distance	MAPC	https://datacommon.mapc.org/browser/datasets/409	Rail Fuel Efficiency Rates
MOR-EV Emissions Rates	MOR-EV	https://mor-ev.org/statistics	Electric Vehicle Fuel Efficiency Rates
eGRID (Emissions & Generation Resource Integrated Database)	Environmental Protection Agency (EPA)	https://www.epa.gov/egrid	Electricity Emissions Factors

To report emissions in terms of MT CO2e, conversion factors were used to determine the amount of CO_2 that would have an equivalent atmospheric effect to one unit of CH_4 and N_2O.
The Intergovernmental Panel on Climate Change (IPCC) conversion factors are used in this inventory. The 100-year time horizon was used to align with calculations from the 2019 inventory.[31]

3.2 ESTIMATING TRANSPORTATION EMISSIONS

The process for estimating emissions is laid out in the GPC. It follows the ASIF framework, where each letter represents one input to the calculation: Activity, mode Share, Intensity, and Fuel.

The following sections describe the approach and data sources used in the calculation of on-road and off-road transportation emissions. Also discussed are alternative approaches that were either considered but not selected or not recommended for this estimate.

On-Road Emissions: Passenger, Commercial, and Municipal/State Vehicles

There are four different methodologies for calculating on-road emissions, as defined by the GPC. See Figure 2 for brief descriptions of the methodologies, which include Fuel Sales, Induced Activity, Geographic, and Resident Activity. The 'resident activity' method, which is a bottom-up approach,

[31] The 100-year Global Warming Potential (GWP), as defined by the IPCC, is a metric measuring the total radiative forcing (heat-trapping ability) of 1 kilogram of a greenhouse gas relative to 1 kilogram of CO_2 over a 100-year timeframe. It allows comparison of different gases' climate impacts. The 100-year timeframe is a standard reference period and was used in the 2019 inventory.

was used to estimate on-road car emissions in both the 2012 and 2019 inventories. This section describes why this methodology was selected and how it was calculated.

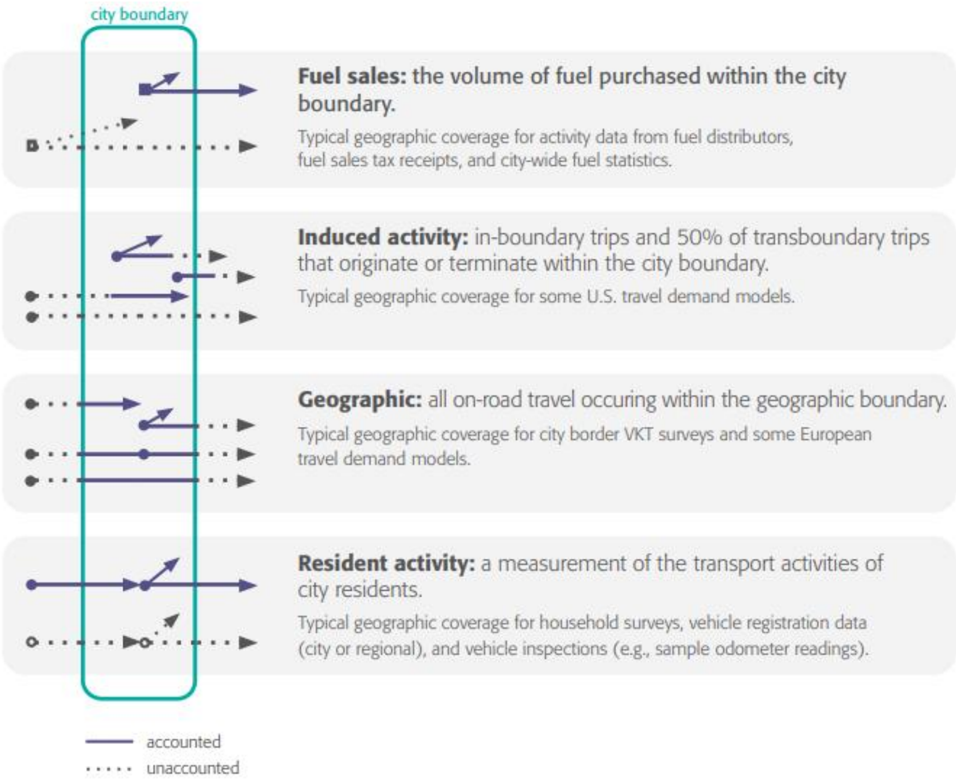

Figure 2: GPC Transportation Methodologies.[32]

The 'resident activity' approach estimates emissions from transportation activities carried out by City residents and businesses that garage their vehicles in the city.[33] One of the benefits of the 'residential activity' method is that the data is readily available to the City. In addition, this method is a good approach when trying to avoid double counting emissions with other cities in the region. If each city only quantifies the impact of vehicles registered in their city, the complications that arise from allocating cross-boundary trips to multiple jurisdictions can be avoided.

In 2012, the Massachusetts Vehicle Census (MVC) was used to estimate emissions from vehicles registered in Cambridge. The MVC captures odometer readings for vehicles registered in the state and each municipality within. In 2019, the MVC had not been updated (including only data from 2009 to 2014) and instead data from the Massachusetts RMV was used to determine raw vehicle counts by vehicle type. In 2024, the MVC was updated and published with data from 2020 to 2024. Statewide legislation for vehicle reporting indicates that this dataset will continue to be updated annually by MassDOT and will support this and future inventory assessments. It is the primary data source for this analysis.

The MVC provides multiple data breakdowns for annual VMT, including fuel class (fossil fuel, hybrid, plug-in hybrid, battery electric), vehicle use (passenger, commercial, municipal, state), and weight class (light duty, medium/heavy duty). Additional breakdowns such as vehicle type (e.g., passenger,

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[32] Image source: https://ghgprotocol.org/sites/default/files/ghgp/standards/GHGP_GPC_0.pdf

[33] Note that this methodology includes all the transport activities completed by city residents, regardless of location. It does not capture trips to/from Cambridge by non-residents nor does it capture pass-through trips, but is meant to be representative of normal activity in Cambridge.

truck, bus, ambulance, motorcycle) and vehicle age (1 year, 2-5 years, 5-10 years, 10+ years) were not used.

The MVC does not differentiate between fossil fuels, so the Massachusetts Vehicle Census Summary Statistics (MAVC) from the MAPC was used as a supplemental source to determine the percentage of diesel, gasoline, and compressed natural gas (CNG) vehicles. The MAVC only included data from 2020-2022 so linear trends were forecasted to identify fossil fuel vehicle splits in other analysis years.

Annual VMT was converted to emissions using factors identified from the CARB EMFAC model. EMFAC estimates the official emissions inventories of on-road mobile sources. Although this is an out-of-state inventory it is recommended as a source for emissions factors for the following reasons:

1. **Applicability**. In March 2023, Massachusetts adopted the California vehicle emissions standards and compliance requirements set forth in the CARB Advanced Clean Cars II regulation.[34] Additionally, the Massachusetts LEV Program requires all new passenger cars and light-duty trucks, medium-duty vehicles, and heavy-duty vehicles and engines sold and registered in Massachusetts to meet California motor vehicle emissions standards.[35] The resident activity methodology is based on registered vehicles, so with the alignment of standards the emissions rates identified in CARB are applicable to those in Massachusetts.
2. **Detail and Quality.** The EMFAC model provides running exhaust emissions (RUNEX) rates for all GHG pollutants: Carbon Dioxide (CO_2), Nitrous Oxide (N_2O) and Methane (CH_4). Rates are calculated by year, vehicle category (e.g., passenger car, light-duty truck, medium-heavy duty delivery truck), and fuel type (gasoline, diesel, plug-in hybrid, natural gas, electricity, fuel cell). This detail was not available in Massachusetts state nor national datasets.
3. **Updated Data.** In the 2019 inventory, on-road emissions were calculated using fuel efficiencies from the National Highway Transportation Safety Administration's (NHTSA) Corporate Average Fuel Economy (CAFE) standards. In this approach fuel economies (distance traveled per fuel consumed, e.g. miles per gallon) from 2012 were projected to 2019 following the CAFE standards. Thus, the factors were projections of minimum standards and not derived from on-road mobile sources. Additionally, the factors were calculated by pollutant and fuel type but not vehicle class. This reduces the granularity of the data as the emissions estimates did not account for differences in fuel efficiency between personal cars and heavy-duty trucks. Recent federal changes have also removed the penalties associated with non-compliance to CAFE standards, therefore the standards cannot be relied on for continued alignment with typical on-road fuel efficiencies.

An example formula of how VMT was converted to emissions using the EMFAC on-road emissions factors (EF) is provided below:

- For each analysis year and combination of vehicle type v (e.g., passenger), vehicle class c (e.g., light-duty), and fuel type f (e.g., gasoline), let:
  - $\mathrm{VMT}_{v,c,f}$ = annual vehicle miles traveled
  - $EF_{v,c,f}^{\mathrm{CO_2}}$ = $\mathrm{CO_2}$ emission factor (g $\mathrm{CO_2}$ / mi)
  - $EF_{v,c,f}^{\mathrm{CH_4}}$ = $\mathrm{CH_4}$ emission factor (g $\mathrm{CH_4}$ / mi)
  - $EF_{v,c,f}^{\mathrm{N_2O}}$ = $\mathrm{N_2O}$ emission factor (g $\mathrm{N_2O}$ / mi)

[34] https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/states-have-adopted-californias-vehicle-regulations

[35] https://afdc.energy.gov/laws/10537

- Calculate mass emission by GHG (converting grams to metric tons);
    - $\mathrm{CO}_{2\,v,c,f} = \mathrm{VMT}_{v,c,f} \times EF_{v,c,f}^{\mathrm{CO}_2} \times 0.000001$
    - $\mathrm{CH}_{4\,v,c,f} = \mathrm{VMT}_{v,c,f} \times EF_{v,c,f}^{\mathrm{CH}_4} \times 0.000001$
    - $\mathrm{N}_2\mathrm{O}_{v,c,f} = \mathrm{VMT}_{v,c,f} \times EF_{v,c,f}^{\mathrm{N}_2\mathrm{O}} \times 0.000001$
- Calculate CO_2-equivalent emissions by multiplying emissions by their 100-Year global warming potential (GWP):
    - $\mathrm{GWP}_{\mathrm{CO}_2} = 1$
    - $\mathrm{GWP}_{\mathrm{CH}_4} = 27.9$
    - $\mathrm{GWP}_{\mathrm{N}_2\mathrm{O}} = 273$
    - $\mathrm{CO}_2\mathrm{e}_{v,c,f} = \left(\mathrm{CO}_{2\,v,c,f} \times \mathrm{GWP}_{\mathrm{CO}_2}\right) + \left(\mathrm{CH}_{4\,v,c,f} \times \mathrm{GWP}_{\mathrm{CH}_4}\right) + \left(\mathrm{N}_2\mathrm{O}_{v,c,f} \times \mathrm{GWP}_{\mathrm{N}_2\mathrm{O}}\right)$
- Aggregate to obtain CO_2-equivalent emissions across all vehicle types v, vehicle classes c, and fuel types f:
    - Total Annual $\mathrm{CO}_2\mathrm{e} = \sum_v \sum_c \sum_f \mathrm{CO}_2\,\mathrm{e}_{v,c,f}$

An example calculation of emissions using the above formula for passenger light-duty gasoline vehicles in 2024 is provided below:

VMT = 272,861,312 miles

$\mathrm{EF}^{\mathrm{CO}_2} = 352.86\ \mathrm{g\ CO_2\ /\ mi}$
$\mathrm{EF}^{\mathrm{CH}_4} = 0.0086\ \mathrm{g\ CH_4\ /\ mi}$
$\mathrm{EF}^{\mathrm{N}_2\mathrm{O}} = 0.0087\ \mathrm{g\ N_2O\ /\ mi}$

$\mathrm{GWP}_{\mathrm{CO}_2} = 1$
$\mathrm{GWP}_{\mathrm{CH}_4} = 27.9$
$\mathrm{GWP}_{\mathrm{N}_2\mathrm{O}} = 273$

$\mathrm{CO}_2 = 272{,}861{,}312 \times 352.86 \times 0.000001$
$= 96{,}281\ \mathrm{MT\ CO_2}$
$\mathrm{CH}_4 = 272{,}861{,}312 \times 0.0086 \times 0.000001$
$= 2.3\ \mathrm{MT\ CH_4}$
$\mathrm{N}_2\mathrm{O} = 272{,}861{,}312 \times 0.0087 \times 0.000001$
$= 2.4\ \mathrm{MT\ N_2O}$

$\mathrm{CO}_2\mathrm{e} = (96{,}281 \text{ x } 1) + (2.3 * 27.9) + (2.4 \text{ x } 273)$

$= 96{,}993\ \mathrm{MT\ CO_2e}$

On-Road Emissions: Public Transit

In addition to passenger, commercial, and municipal/state vehicles on the road, the City of Cambridge is also served by bus and trackless trolleys operated by the Massachusetts Bay Transit Authority (MBTA).

Bus and trackless trolley activity was tabulated from General Transit Feed Specification (GTFS) archived service schedules. A Python script was developed for this project to count the number of buses run per day and per year.[36] These routes were clipped to the City of Cambridge boundary using GIS and aggregated to identify the total distance traveled per year by MBTA buses within the City of Cambridge.

[36] The script processes all archived GTFS schedules for the analysis year. For each schedule, it uses shape data to identify routes operating on each service day and classifies them by mode (e.g., bus, commuter rail). Route shapes are geocoded to calculate route distances, which are then multiplied by daily trip counts to estimate daily vehicle miles traveled (VMT) by route. These values are aggregated across schedules to produce annual VMT by mode.

The on-road routes that operate in the City of Cambridge are listed in

Table 18 by their average length in miles. Note that the routes in operation change throughout the analysis period – the 747 route is now operated as CT2 and the trackless trolley routes were discontinued on March 12, 2022 but the service for Routes 71 and 73 were maintained with buses.

Table 18: On-Road MBTA Routes in the City of Cambridge by Average Length (mi) and Year

Mode	Route	Average Length (mi) within the City of Cambridge					
		2019	2020	2021	2022	2023	2024
Bus	1	2.21	2.05	2.01	2.01	2.01	2.00
	47	1.11	1.09	1.09	1.09	1.09	1.10
	62	0.60	0.62	0.67	0.67	0.67	0.67
	64	1.64	1.67	1.87	1.87	1.87	1.87
	66	0.63	0.63	0.63	0.63	0.63	0.60
	67	0.60	0.62	0.66	0.67	0.67	0.67
	68	2.19	2.19	2.19	2.19	2.19	2.19
	69	2.52	2.55	2.52	2.62	2.60	2.58
	70 / 70A	1.15	1.15	1.15	1.15	1.15	1.15
	74	2.76	2.59	2.61	2.62	2.62	2.62
	75	2.93	2.58	2.58	2.56	2.56	2.57
	76	0.60	0.62	0.67	0.67	0.67	0.67
	77	2.31	2.34	2.32	2.37	2.39	2.39
	78	2.86	2.86	2.87	2.88	2.88	2.89
	79	0.72	0.75	0.75	-	-	-
	80	0.36	0.36	0.36	0.33	0.32	0.32
	83	2.13	2.13	2.11	2.10	2.11	2.11
	84	0.60	0.62	-	-	-	-
	85	1.19	1.19	1.19	1.19	1.19	1.19
	86	1.49	1.49	1.49	1.49	1.49	1.42
	87	0.36	0.36	0.36	0.33	0.32	0.32
	88	0.36	0.36	0.36	0.33	0.32	0.32
	91	0.86	0.84	0.84	0.84	0.84	0.83
	96	1.34	1.36	1.40	1.42	1.42	1.43
	325	0.15	0.15	-	-	-	-
	350	0.72	0.75	0.72	0.75	0.75	0.75
	351	0.44	0.47	-	-	-	-
	352	0.15	0.15	-	-	-	-
	725	2.58	-	-	-	-	-
	747 / CT2	2.64	2.65	2.65	2.65	2.65	2.64
Trackless Trolley / Bus	71	1.69	1.71	1.88	1.98	1.99	1.99
	73	1.93	1.95	2.12	2.24	2.25	2.25
Trackless Trolley	72	2.22	2.14	-	-	-	-

This approach more accurately captures VMT from on-road public transport than the 2019 inventory. The previous inventory used GTFS for bus activity, but only identified typical weekday, Saturday, and Sunday trips then multiplied them to factor up to yearly values. The updated methodology directly quantifies the miles traveled by transit modes within city boundaries, removing the need for relative calculations and yearly factors.

These public transit modes use a combination of diesel, CNG, and diesel-hybrid fuels to operate. The trackless trolleys operate on electricity. The breakdown of buses by fuel type was identified from the

MBTA Vehicle Inventory Page. Emission rates from EMFAC, described above for on-road passenger, commercial, and municipal/state vehicles, were used for on-road public transport vehicles.

Off-Road Emissions: Public Transit

A variety of off-road public transportation modes serve the City of Cambridge: commuter heavy rail, subway heavy rail, and light rail. The commuter rail includes the Newburyport, Haverhill, Lowell, and Fitchburg Lines. The subway includes the MBTA Red Line. The light rail includes the MBTA Green Lines (D, and E).

The on-road routes that operate in the City of Cambridge are listed in Table 19 by their average length in miles. Note that the Green Line at Lechmere was closed for starting in 2020 and into 2022 as the GLX was constructed.

Table 19: Off-Road MBTA Routes in the City of Cambridge by Average Length (mi) and Year

Mode	Route	Average Length (mi) within the City of Cambridge					
		2019	2020	2021	2022	2023	2024
Subway	Red	4.52	4.47	4.49	4.43	4.46	4.34
Light Rail	Green-D	0.40	0.40	-	0.65	0.67	0.67
	Green-E	0.40	0.40	-	0.57	0.68	0.69
Commuter Rail	CR-Fitchburg	2.43	2.43	2.43	2.43	2.43	2.43
	CR-Haverhill	0.31	0.31	0.31	0.31	0.31	0.31
	CR-Lowell	0.32	0.32	0.32	0.32	0.32	0.32
	CR-Newburyport	0.31	0.31	0.31	0.31	0.31	0.31

The same methodology as the on-road public transport was used to identify total distance traveled per year by MBTA rail within the City of Cambridge. This geographic approach is preferred to the 2019 inventory methodology, which used the proportion of miles in Cambridge relative to the system network, as it directly quantifies the miles traveled by transit modes within city boundaries.

The commuter rail engines use diesel fuel to operate. The subway and light rail operate on electricity.

Emissions were calculated from VMT using MBTA Fuel Consumption and Route Distance data available from MAPC's DataCommon. Electricity use (kWh) per mile was calculated for the years available (2017, 2021, 2022) and linear trends were forecasted to identify rates in other analysis years.

Off-Road Emissions: Electric Vehicle Charging

Indirect electricity emissions (Scope 2) associated with the on-road transportation sub-sector were also quantified. For on-road vehicles, Scope 2 emissions come from electric vehicle charging within the City of Cambridge boundaries. Data on annual electricity consumption for privately owned chargers was estimated from annual average electricity consumption by passenger, commercial, and municipal/state vehicles. Data from ChargePoint, a provider of public electric vehicle charging stations, was provided and added to calculated electrical consumption values to quantify electricity consumption from chargers owned by the City of Cambridge.

As the MVC data includes vehicles registered in the City of Cambridge, it was assumed that passenger vehicles charge at residential locations and commercial and municipal/state vehicles charge at commercial, institutional, or industrial buildings. Electricity emissions factors from eGRID were used to convert electricity use (kWh) into emissions (CO_2, CH_4, N_2O).

As was noted in the 2019 inventory, as the share of electric vehicles grows and charging stations proliferate around the City, the acquisition of data must improve to ensure the integrity of future GHG emissions inventories.[37]

Alternate Approaches

The 'geographic approach' is another bottom-up approach that aims to quantify emissions occurring solely within the Cambridge city boundary, regardless of origin, destination or trip maker residency. In Cambridge, where there exists through traffic from a large proportion of commuters into Boston, this captures transportation activity from non-residents which is not part of the 'resident activity' methodology.

This approach was not available for the previous inventory but was suggested as the preferred methodology. The 2019 Inventory indicated that the four-step travel demand model from the Boston Region Metropolitan Planning Organization's (MPO) Central Transportation Planning Staff (CTPS) should be used to quantify VMT and emissions occurring within Cambridge. This would enable consistency with regional mode share inputs and emissions estimates for federal reporting. However, the travel demand model is developed on a sample set[38] (the MVC captures all registered vehicles), lacks detail needed for estimation (e.g., fuel type, fuel efficiency), have does not include a freight component to capture heavy-duty vehicle emissions.[39]

The MPO model was not available for this inventory as well. To review the 'geographic approach,' a simulated trip results were accessible using Replica's activity-based travel demand model. Replica is data platform that provides a trip-based travel demand model using anonymized mobility data to estimate origin-destination patterns.[40] Replica provides detailed, trip-by-trip travel patterns (as opposed to zone-by-zone patterns or averages), improving accuracy for VMT and associated emissions within the geographic boundaries of Cambridge.

Network link volumes from the Replica platform were queried and downloaded as spreadsheets for assessment. This data includes trips at the network link level, including detail on link distance (length per street segment) and trip mode (auto, auto passenger, commercial medium, commercial heavy, on-demand auto (taxi/rideshare)). The network was clipped to the City of Cambridge boundary, then added up per vehicle mode per link to calculate total VMT on all roads within Cambridge.

As with the 'resident activity' method, emissions for the 'geographic approach' were calculated using factors from EMFAC.

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[37] As noted in the 2019 inventory, improving access to high-resolution charging data should be prioritized. Data acquisition could include formal data-sharing agreements with charging network operators and major fleet owners to obtain location-specific charging activity and electricity consumption data. This may enable development of factors to distinguish between residential, workplace, and public charging and thereby allow electric vehicle emissions to be more accurately attributed.

[38] The CTPS four-step travel demand model does not simulate all vehicles or trips directly, but instead operates on a modeled sample of households, persons, and trips that is scaled up to represent regional travel behavior.

[39] TDM23.1.0 Users Guide. *Boston Region MPO*. https://ctpsstaff.github.io/tdm23_users_guide/1.0/.

[40] Replica. https://documentation.replicahq.com/docs/network-link-volumes. Access provided through enterprise subscription service.

This 2019 inventory also estimated the 'fuel sales' approach, which is a top-down approach, as a back-up alternative approach. In theory, fuel sales treats sold fuel as a proxy for transportation activity, however, changes in the quantity of fuel sold in Cambridge may be dependent on where commuters fill up cars and not reflective of changes in Cambridge's transportation sector. Additionally, sufficient data on fuel sales was not available for this analysis.

The 'induced activity' approach assesses emissions from intra-Cambridge trips and 50 percent of transboundary trips that originate or terminate within the city boundary (see Figure 2). This can be calculated from the Replica origin-destination data but was not evaluated in previous inventories and thus not assessed here to minimize additional comparisons.

3.3 TRANSPORTATION SECTOR RESULTS

Vehicle Miles Traveled

Total VMT in the City of Cambridge grew slightly (+1.8 percent) between 2020 and 2024. By 2024, approximately 357 million miles are traveled by on-road vehicles, with an additional 0.6 million miles traveled by off-road vehicles (public transit rail). This aligns with nationally observed trends, where vehicle travel is rebounding from pandemic-era lows to reach new record levels.[41]

On-road gasoline passenger vehicles are the significant majority of VMT within the City. In 2024, gasoline vehicles traveled 80 percent of all miles and passenger vehicles traveled 92 percent of all miles.

Non-fossil fuel vehicles saw an incredible amount of growth between 2020 and 2024. There is increased travel in more fuel efficient Hybrid, Plug-In Hybrid, and Electric Vehicles – up from 8 percent of all VMT in 2020 to 18 percent of all VMT in 2024. However, their overall VMT is still only 4.3 percent of the total private on-road VMT (Passenger and Commercial vehicles) in Cambridge. This indicates that most emissions reductions (see below) come from improvements in the fuel efficiency of gasoline powered vehicles.

Table 20. Annual Vehicle Miles Traveled (VMT) by Fuel Type

Vehicle Type	Annual Vehicle Miles Traveled (VMT)				
	2020	2021	2022	2023	2024
On-Road	**350,992,193**	**344,467,816**	**359,529,583**	**353,003,752**	**357,302,782**
Gasoline	313,578,652	303,840,142	310,745,190	295,450,845	289,209,916
Diesel	7,718,100	6,520,089	6,451,613	5,208,600	4,578,135
Hybrid	22,594,480	24,582,900	29,665,117	34,595,981	40,160,215
Plug-in Hybrid	2,873,630	3,859,735	5,308,525	6,670,898	8,162,047
CNG	166,988	179,611	210,431	209,093	220,992
Electricity	4,060,343	5,485,339	7,148,706	10,868,336	14,971,478
Rail	**678,001**	**652,310**	**668,669**	**578,377**	**608,543**
Diesel	32,657	29,319	38,864	39,608	41,856
Electricity	645,344	622,991	629,805	538,769	566,687
TOTAL	**351,670,193**	**345,120,126**	**360,198,252**	**353,582,129**	**357,911,325**

[41] Annual VMT in the United states tracked by the Federal Highway Administration (https://afdc.energy.gov/data/10315) show that VMT is increasing year by year since the pandemic.

Table 21. Annual Vehicle Miles Traveled (VMT) by Vehicle Type

Vehicle Type	Annual Vehicle Miles Traveled (VMT)				
	2020	2021	2022	2023	2024
On-Road	**350,992,193**	**344,467,816**	**359,529,583**	**353,003,752**	**357,302,782**
Passenger	325,657,618	321,655,602	332,918,358	328,582,602	334,540,193
Commercial	20,683,275	17,940,962	21,718,545	19,478,987	17,535,470
Municipal / State	3,370,320	3,518,027	3,545,539	3,651,764	3,863,284
Bus	1,030,552	1,108,452	1,298,662	1,290,399	1,363,835
Trackless Trolley	250,428	244,774	48,479	0	0
Rail	**678,001**	**652,310**	**668,669**	**578,377**	**608,543**
Commuter Rail	32,657	29,319	38,864	39,608	41,856
Subway	630,429	622,991	574,116	417,209	445,000
Light Rail	14,915	0	55,689	121,560	121,687
TOTAL	**351,670,193**	**345,120,126**	**360,198,252**	**353,582,129**	**357,911,325**

Transportation Emissions

As shown in Table 22 and Table 23, this GHG inventory estimates that the Transportation sector in the City of Cambridge emitted 127,615 MT CO2e in 2024 using the 'resident activity' methodology. Private on-road transportation (Passenger and Commercial vehicles) represents the greatest source of emissions for the transportation sector in Cambridge. It is estimated that private transportation is the source of 126,438 MT CO2e, or 95.3 percent of total transportation emissions.

Table 22. CO2e Emissions (MT CO2e) by Fuel Type

Vehicle Type	CO_2e Emissions (MT CO_2e)				
	2020	2021	2022	2023	2024
On-Road	**140,209**	**133,761**	**137,058**	**130,029**	**126,438**
Gasoline	128,481	122,270	124,812	117,520	113,078
Diesel	6,077	5,196	5,031	4,002	3,499
Hybrid	4,009	4,344	5,205	6,039	6,822
Plug-in Hybrid	475	641	876	1,087	1,303
CNG	374	388	450	441	464
Electricity	793	922	683	940	1,273
Rail	**1,350**	**1,288**	**1,334**	**1,131**	**1,177**
Diesel	47	39	52	51	54
Electricity	1,303	1,249	1,282	1,080	1,123
TOTAL	**141,559**	**135,049**	**138,392**	**131,160**	**127,615**

Table 23. CO2e Emissions (MT CO2e) by Vehicle Type

Vehicle Type	CO_2e Emissions (MT CO_2e)				
	2020	2021	2022	2023	2024
On-Road	**140,209**	**133,761**	**137,058**	**130,029**	**126,438**
Passenger	114,557	111,119	112,500	107,819	106,204
Commercial	20,406	17,304	19,534	17,519	15,430
Municipal / State	3,479	3,578	3,436	3,422	3,480
Bus	1,261	1,270	1,489	1,268	1,323
Trackless Trolley	506	491	99	0	0
Rail	**1,350**	**1,288**	**1,334**	**1,131**	**1,177**
Commuter Rail	47	39	52	51	54
Subway	1,273	1,249	1,169	836	882
Light Rail	30	0	113	244	241
TOTAL	**141,559**	**135,049**	**138,392**	**131,160**	**127,615**

Emissions from transportation decrease between 2020 and 2024. As noted above, this reduction is due to the change in vehicle fuel type, shifting more towards Hybrid, Hybrid-Plug-In, and Electric Vehicles. As shown above, these modes still have emissions but relative to Gasoline and Diesel vehicles they have significantly fewer emissions.

The average emission rate by fuel type can be calculated by dividing the values in Table 22 by those in Table 21. All fuel types have a negative trend, indicating improved fuel efficiency from 2020 to 2024. See Figure 2.

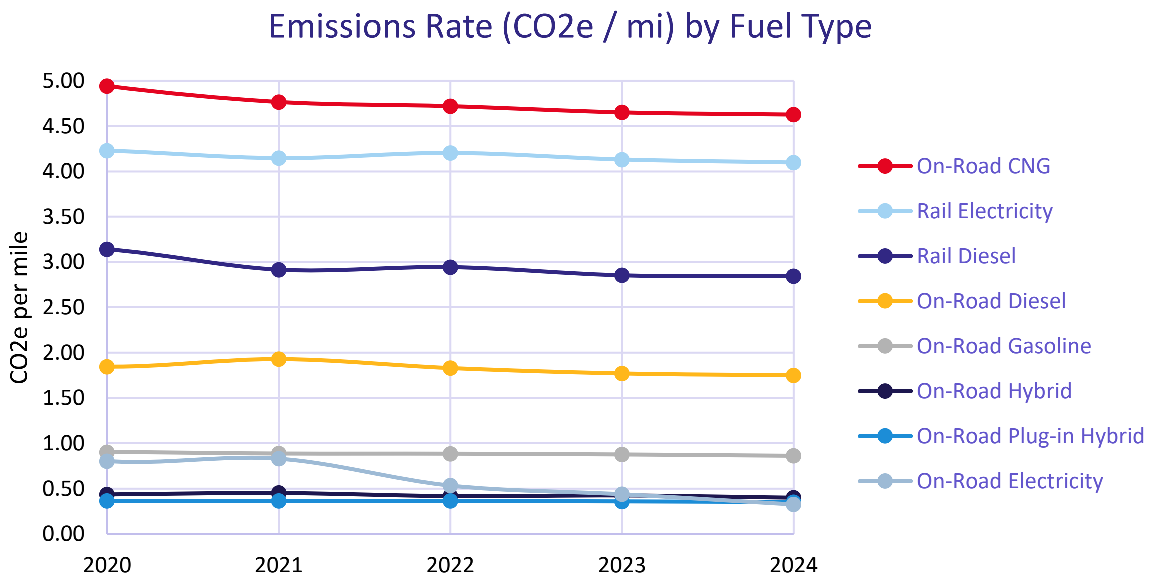

Figure 3. Emission Rate (CO2e / mi) by Fuel Type

Comparison to Geographic Approach

Using the 'geographic approach', the estimate for total transportation emissions in the City of Cambridge is 123,917 MT CO2e in 2024. Private on-road transportation (Passenger and Commercial vehicles) represents the greatest source of emissions for the transportation sector, with 93.4 percent of the emissions.

The total emissions are 2.9 percent lower than those estimated using the 'resident activity' method. Although this is only a slight change between methodologies the 'resident activity' approach is recommended for the following reasons:

- Proper capturing of Commercial vehicles. As shown in Table 24, Replica undercounts the Commercial trips within Cambridge (-25.5 percent VMT). The Replica model has limited commercial datasets and does not appear to accurately capture truck movements, which has significant implications for emissions.
- Proper capturing of Municipal, and State vehicles. Replica only has three vehicle classes: Private Auto, For-Hire Vehicle (Taxi, Uber, Lyft), Commercial. The MVC also includes Municipal and State vehicles.
- Proper capturing of Hybrid, Plug-In Hybrid, and Electric Vehicles. The share of fossil fuel vehicles in Replica (93 percent) is higher than that in the MVC (82 percent), the latter of which is a direct measurement of vehicles registered in Cambridge. Although the geographic method includes trips from external users, the significant differences in fuel type indicate that Replica may not be properly capturing trips with alternative fuels.

Table 24. Comparison of VMT and Emissions by Methodology - 2024

Vehicle Type	Annual Vehicle Miles Traveled (VMT) in 2024			CO_2e Emissions ($MT\ CO_2e$) in 2024		
	Resident Activity	Geographic	Difference	Resident Activity	Geographic	Difference
On-Road	**357,302,782**	**333,227,459**	**-6.7%**	**126,438**	**122,740**	**-2.9%**
Passenger	334,540,193	318,805,388	-4.7%	106,204	109,270	2.9%
Commercial	17,535,470	13,058,236	-25.5%	15,430	12,147	-21.3%
Municipal / State *	3,863,284	0	-100.0%	3,480	0	-100.0%
Bus	1,363,835	1,363,835	-	1,323	1,323	-
Trackless Trolley	0	0	-	0	0	-
Rail	**608,543**	**608,543**	**-**	**1,177**	**1,177**	**-**
Commuter Rail	41,856	41,856	-	54	54	-
Subway	445,000	445,000	-	882	882	-
Light Rail	121,687	121,687	-	241	241	-
TOTAL	**357,911,325**	**333,836,002**	**-6.7%**	**127,615**	**123,917**	**-2.9%**

** Municipal / State vehicles are not separated identified in Replica and therefore were unable to be calculated as a distinct mode in the Geographic methodology. Vehicles are assumed to be distributed into Passenger and Commercial categories.*

Table 25. Comparison of VMT and Emissions by Methodology - 2024

Vehicle Type	Annual Vehicle Miles Traveled (VMT) in 2024			CO_2e Emissions ($MT\ CO_2e$) in 2024		
	Resident Activity	Geographic	Difference	Resident Activity	Geographic	Difference
On-Road	**357,302,782**	**333,227,459**	**-6.7%**	**126,438**	**122,740**	**-2.9%**
Gasoline	289,209,916	303,882,105	5.1%	113,078	112,966	-0.1%
Diesel	4,578,135	7,190,627	57.1%	3,499	5,457	56.0%
Hybrid	40,160,215	17,012,039	-57.6%	6,822	3,128	-54.2%
Plug-in Hybrid	8,162,047	2,406,998	-70.5%	1,303	384	-70.5%
CNG	220,992	220,992	-	464	464	-
Electricity	14,971,478	2,514,698	-83.2%	1,273	342	-73.2%
Rail	**608,543**	**608,543**	**-**	**1,177**	**1,177**	**-**
Diesel	41,856	41,856	-	54	54	-
Electricity	566,687	566,687	-	1,123	1,123	-
TOTAL	**357,911,325**	**333,836,002**	**-6.7%**	**127,615**	**123,917**	**-2.9%**

Comparison with 2019 emissions inventory

The 'resident activity' methodology used to calculate the 2020 to 2024 VMT and emissions was followed to evaluate 2019 for comparison against the previous inventory.

Relative to the previous inventory there was a 12 percent reduction in Passenger and Commercial VMT. This change is attributed to the updated methodology, which uses the MVC instead of data from the Massachusetts RMV. Changes include a lack of FlexFuel category – although it appears that these vehicles were grouped under the Diesel fuel type – an increase in Electric Vehicles, and a rebalancing of Gasoline and Hybrid Vehicles. This occurred for both Passenger and Commercial vehicles.

The significant increase in On-Road Public Transit trips reflects more complete accounting of bus and trolley operations in the updated methodology, not necessarily an expansion in service.

Table 26. Comparison of Annual Vehicle Miles Traveled (VMT) between 2019 and Current Inventory

Mode	2019 Previous	2019 Updated	% Change
Passenger and Commercial Vehicles	**397,415,937**	**346,582,945**	**-12%**
Gasoline	363,294,303	316,842,615	-13%
Diesel	5,378,373	10,741,144	+100%
FlexFuel	6,156,578	0	-100%
Gasoline (Hybrid)	21,254,747	16,444,816	-11%
Electric	1,331,936	2,554,370	+92%
On-Road Public Transit	**1,356,362**	**1,432,051**	**+6%**
Bus	1,014,196	**1,106,545**	+9%
Trackless Trolley	342,166	325,506	-5%
Rail Public Transit	*not calculated*	**756,499**	**-**
Subway (Red Line)	*not calculated*	671,894	-
Light Rail (Green Line)	*not calculated*	42,738	-
Commuter Rail	*not calculated*	41,866	-

Despite the reduction in VMT there is a 2.3 percent increase in emissions between the 2019 inventory and the updated methodology. This is attributed to the new methodology, which better captures emission rates by directly converting VMT to emissions (CO_2, CH_4, N_2O) – as opposed to the 2019 inventory that used VMT to estimate fuel consumption and then convert fuel rates to emissions. The EMFAC emissions rates include emissions factors for vehicle type (e.g., passenger, commercial) and vehicle class (e.g., light duty, medium/heavy duty) that were not previously available. This granularity improves the estimation, as it is not appropriate to use the same emissions rate for both Passenger Light Duty Diesel and Commercial Heavy Duty Diesel.

Table 27. Comparison of CO2e Emissions (MT CO2e) between 2019 and Current Inventory

Category	Subcategory	CO2e Emissions (MT CO2e)		
		2019 Previous	2019 Updated	% Change
Public Transportation	MBTA Buses	485	1,577	+225.1%
	Trackless Trolley	851	662	-22.3%
	Commuter Rail	1,105	61	-94.5%
	Subway	6,216	1,365	-78.0%
	Light Rail	258	87	-66.3%
	All Public Transport	8,915	3,751	-57.9%
Private Transportation	All On-Road Private	132,580	140,950	+6.3%
Total Transportation		**141,495**	**144,701**	**+2.3%**

3.4 TRANSPORTATION SECTOR SUMMARY

Total VMT in the City of Cambridge grew slightly (+1.8 percent) while total emissions decreased (-9.8 percent) between 2020 and 2024. Although there was increased vehicle activity, the reduction in emissions can be attributed to two factors.

First, there was a large growth in Hybrid, Plug-In Hybrid, and Electric Vehicles. These vehicles are more fuel efficient than Gasoline, Diesel, and CNG vehicles and emit fewer or no on-road emissions (emissions are generated by the grid, not at the tailpipe). Note that their overall VMT is still only 4.3 percent of the total private on-road VMT in Cambridge, so emissions are mostly a factor of gasoline vehicle use.

Second, and more significantly, were improvements in the fuel efficiency of gasoline-powered vehicles. GHG emissions rates per mile decreased from 0.00037015 to 0.00035547 between 2020 and 2024 for gasoline-powered vehicles. Although this percent change is small, private on-road transportation represents the greatest source of vehicle miles in Cambridge and improved fuel efficiency for these vehicles results in large reductions in on-road emissions totals.

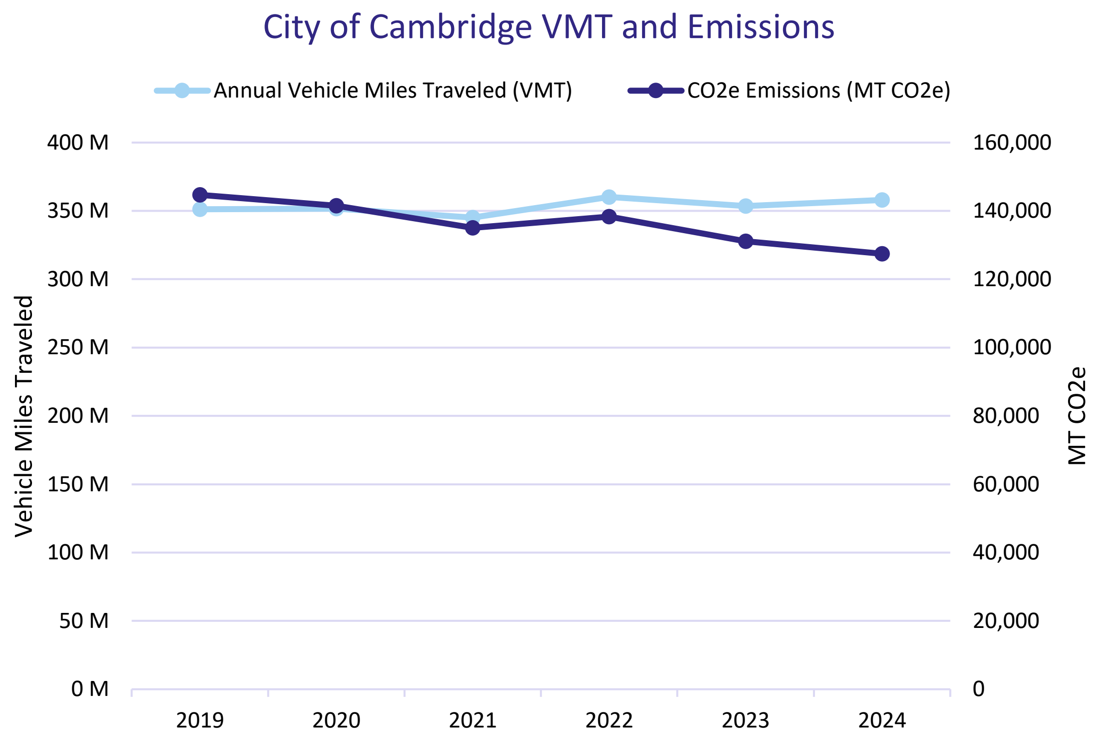

Figure 4. City of Cambridge VMT and Emissions Summary

4. WASTE

Waste-sector emissions are generated from solid waste disposal at landfills, the biological treatment of organic waste (such as composting and anaerobic digestion), waste incineration, and wastewater treatment processes. For the City of Cambridge's Community-wide GHG inventory, all Waste-sector emissions are categorized as Scope 3, because both waste and wastewater are managed outside the inventory boundary (i.e., beyond the City of Cambridge).

4.1 WASTE SECTOR DATA SOURCES

Municipal solid waste (MSW) information for the City of Cambridge was compiled from a combination of City-provided records, waste characterization studies, and publicly available datasets. Primary data for municipal curbside collection was provided by the Cambridge Department of Public Works (DPW) and includes annual tonnages from refuse collection, the City's curbside organics (food waste) program, and yard waste collection.

Solid waste collected by private haulers serving commercial properties was estimated using annual Labor Force and Unemployment data from the Massachusetts EOLWD.[42] Employment figures were converted to waste tonnage using industry-specific waste generation factors (tons per employee per year) developed by CalRecycle.[43] For multi-family residential properties not served by the municipal curbside program, private hauler waste quantities were estimated using a per-capita annual waste

[42] Massachusetts Department of Unemployment Assistance, Economic Research Department. Labor Force and Unemployment Data. Retrieved from: Labor Market Information | Mass.gov

[43] CalRecycle. Disposal and Diversion Rates for Business Groups. Retrieved from: Disposal and Diversion Rates for Business Groups

generation rate derived from municipal curbside collection data and the proportion of the City's population served by that program. Data on the total number of households in Cambridge and the share served by the municipal trash program were sourced from MassDEP's Municipal Solid Waste & Recycling dataset[44] and the American Community Survey 1-Year Estimates (Table DP02).[45]

The City of Cambridge 2022 Waste Characterization Study[46] was used to inform the composition of MSW disposed of via landfill and incineration. Cambridge DPW provided data on the percentage of collected waste sent to landfill versus incineration, indicating that approximately 65 percent of waste was landfilled and 35 percent was incinerated. Cambridge DPW also supplied information indicating that food waste collected by the City is processed through anaerobic digestion, while yard waste is managed through composting.

Information on landfill operations, including methane recovery practices, was obtained from the U.S. Environmental Protection Agency's Facility Level Information on GreenHouse Gases Tool (FLIGHT) database.[47]

Data on privately managed organic waste collection (composting) programs was collected through direct outreach to private service providers operating within the City of Cambridge, as well as large university campuses with established organic waste management programs.

All wastewater generated within the City of Cambridge is treated at the Deer Island Wastewater Treatment Plant in Winthrop, Massachusetts, operated by the Massachusetts Water Resources Authority (MWRA). MWRA data was used as the primary source for calculating emissions associated with wastewater generation in Cambridge.

4.2 SOLID WASTE DISPOSAL (LANDFILL & INCINERATION)

Municipal solid waste (MSW) generated in the City of Cambridge is primarily disposed of outside the state and managed through a combination of landfill disposal and waste-to-energy incineration. Approximately 65 percent of collected MSW is landfilled, while 35 percent is incinerated to produce energy. An estimated 57 percent of Cambridge households participate in the City's municipal curbside collection programs, with the remaining 43 percent (primarily larger multi-family residential properties) served by private haulers. All commercial solid waste generated within the City is collected exclusively by private haulers.

Quantification of Solid Waste Disposed via Landfill and Incineration

To calculate emissions associated with landfill disposal and incineration, this inventory requires activity data representing the total quantity of solid waste collected within the City boundary, including waste collected through municipal curbside programs and by private haulers. In addition to total quantities, information on the disposal method and destination of solid waste is also

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[44] MassDEP Recycling & Solid Waste Data for Massachusetts Cities & Towns. Retrieved from: Recycling & Solid Waste Data for Massachusetts Cities & Towns | Mass.gov

[45] American Community Survey 1-Year Estimates (Table DP02), number of households in Cambridge. Retrieved from: DP02 - Census Bureau Tables

[46] City of Cambridge 2022 Waste Characterization Study. Provided by Cambridge DPW and publicly available: wastecharacterizationfinal2022.pdf

[47] EPA's Facility Level Information on GreenHouse gases Tool (FLIGHT). Retrieved from: EPA Facility Level GHG Emissions Data

required. Municipal curbside data were obtained from waste collection and disposal records provided by the Cambridge Department of Public Works (DPW), which maintains detailed records of MSW tonnage collected by individual collection vehicles serving the City. DPW also tracks waste streams associated with other municipal operations, including recycling, yard waste, food waste, mattresses, scrap metal, electronics, and textiles. While DPW collects detailed data for the municipal recycling program, recycling tonnage is excluded from total MSW quantities for the purposes of this inventory, as the disposal of recycled materials is associated with negligible direct emissions.

Detailed solid waste tonnage data for waste collected by private haulers were not available and were therefore estimated for the purposes of this analysis. Residential solid waste collected by private haulers was estimated by prorating municipal curbside collection data based on the proportion of households served by the municipal program, as summarized in the equation and table below.

$$\frac{(\boldsymbol{Mass\ of\ Solid\ Waste\ Collected\ by\ Municipal\ Curbside\ Program})}{(\boldsymbol{Total\ Number\ of\ Households\ Served\ by\ Municipal\ Trash\ Program})} \times (\boldsymbol{Number\ of\ Households\ Served\ by\ Private\ Haulers})$$

Table 28. Yearly Data for Estimation of Residential Solid Waste Collected by Private Haulers

Inventory Year	Total Number of Households[48]	Households Served by Municipal Trash Program[49]	Households Served by Private Haulers	Residential Solid Waste Collected by Municipal Trash Program[50] (Short Tons)	Estimated Residential Solid Waste Collected by Private Haulers (Short Tons)
2020	49,564	32,500	17,064	14,923	7,835
2021	50,152	32,500	17,652	13,881	7,539
2022	48,801	32,500	16,301	13,069	6,555
2023	47,160	32,724	14,436	12,604	5,560
2024	49,165	32,771	16,394	12,631	6,319

The commercial waste collected by private haulers was estimated using the Labor Force and Unemployment Data for the City of Cambridge from EOLWD's website[51] using the following steps.

1. "Select Area Type" drop-down: Select "City or Town"
2. "Select Specific Geographic Area" drop-down: Select your community
3. "Select a Year" drop-down: Select your inventory year
4. "Select the Time Period" drop-down: Select "Annual Report"
5. "Select the Ownership" drop-down: Select "All ownership types"
6. "Select an Industry or Industry Sector" drop-down: Select "Total, All Industries"
7. "Select the Category" option: Select "Category and all sub-categories"
8. Select the link to "Download and save the data as a Comma Separated Value (CSV) File"

To avoid double counting, this inventory was developed using only three-digit NAICS codes, although the source datasets contained multiple levels of NAICS classification. To ensure consistent

[48] American Community Survey 1-Year Estimates (Table DP02), number of households in Cambridge. Retrieved from: DP02 - Census Bureau Tables

[49] MassDEP Recycling & Solid Waste Data for Massachusetts Cities & Towns data provided by Cambridge DPW. Retrieved from: Recycling & Solid Waste Data for Massachusetts Cities & Towns | Mass.gov

[50] Provided by Cambridge Department of Public Works (DPW)

[51] Massachusetts Department of Unemployment Assistance, Economic Research Department. Labor Force and Unemployment Data. Retrieved from: Labor Market Information | Mass.gov

and relevant industry groupings, NAICS codes and titles were mapped to the “principal business activities” (PBAs) defined by the EIA. Employment data were aggregated by PBA and limited to those activity categories applicable to the City of Cambridge.

This approach produced annual estimates of average monthly employment within the City for each reporting year, organized into a set of simplified industry groupings, as summarized in the table below. Each PBA was also matched with an industry-specific disposal rate (tons per employee per year).

Table 29. Yearly Data for Estimation of Commercial and Industrial Solid Waste Collected by Private Haulers

Principal Business Activity (PBA)	NAICS codes	Cal-Recycle Business Group	Cal-Recycle Disposal Rate (tons / employee)	Average Monthly Employees per year				
				2020	2021	2022	2023	2024
Commercial and Institutional				**125,319**	**131,457**	**133,435**	**133,974**	**133,878**
Education	611 – Educational services	Education	0.38	30,178	30,454	30,755	31,373	32,080
Food Sales	445-Food And Beverage Stores	Retail Trade - Food & Beverage Stores	0.94	1,712	1,620	1,623	1,657	1,733
Food Service	722 – Food Services And Drinking Places	Restaurants	1.57	4,636	5,119	6,642	7,111	7,158
Healthcare Inpatient	622 – Hospitals	Medical & Health	0.57	4,288	4,906	4,827	4,867	4,552
Healthcare Outpatient	621 – Ambulatory Health Care Services	Medical & Health	0.57	2,502	2,664	2,725	2,726	2,648
Lodging	623 – Nursing And Residential Care Facilities 721 – Accommodation	Hotels & Lodging	1.40	3,929	3,966	4,211	4,274	4,503
Retail (Mall)	446 – Health And Personal Care Stores 448 – Clothing And Clothing Accessories Stores 451 – Sports, Hobby, Music Instrument, Book Stores 452 – General Merchandise Stores 453 – Miscellaneous Store Retailers	Retail Trade – All Other	1.74	939	1,017	-	-	-
Retail (non-Mall)	441 – Motor Vehicle And Parts Dealers 442 – Furniture And Home Furnishings Stores 443 – Electronics And Appliance Stores 444 – Building Material And Garden Supply Stores 532 – Rental And Leasing Services	Retail Trade – All Other	1.74	1,475	1,481	180	112	104
Office	425 – Electronic Markets And Agents And Brokers 511 – Publishing Industries, Except Internet 517 – Telecommunications 518 – Data Processing, Hosting And Related Services 519 – Other Information Services 522 – Credit Intermediation And Related Activities 523 – Securities, Commodity Contracts, Investments 524 – Insurance Carriers And Related Activities 525 – Funds, Trusts, And Other Financial Vehicles 531 – Real Estate 541 – Professional And Technical Services 551 – Management Of Companies And Enterprises 561 – Administrative And Support Services 624 – Social Assistance 926 – Administration Of Economic Programs 999 – Unclassified	AVERAGE of Services - Management, Administrative, Support & Social AND Services - Professional, Technical, & Financial	1.11	69,584	73,495	74,642	75,246	74,961

Principal Business Activity (PBA)	NAICS codes	Cal-Recycle Business Group	Cal-Recycle Disposal Rate (tons / employee)	Average Monthly Employees per year				
				2020	2021	2022	2023	2024
Public Assembly	487 – Scenic And Sightseeing Transportation 512 – Motion Picture And Sound Recording Industries 711 – Performing Arts And Spectator Sports 712 – Museums, Historical Sites, Zoos, And Parks 713 – Amusements, Gambling, And Recreation	Arts, Entertainment, & Recreation	1.94	817	920	1,284	1,519	1,524
Service	447 – Gasoline Stations 484 – Truck Transportation 485 – Transit And Ground Passenger Transportation 491 – Postal Service 811 – Repair And Maintenance 812 – Personal And Laundry Services	AVERAGE of Services - Management, Administrative, Support & Social AND Services - Professional, Technical, & Financial AND Services - Repair & Personal	1.02	2020	2021	2022	2023	2024
Warehouse and Storage	423 – Merchant Wholesalers, Durable Goods 424 – Merchant Wholesalers, Nondurable Goods	Durable Wholesale & Trucking	0.57	3,494	3,814	4,557	3,097	2,634
Manufacturing Industries				**2,426**	**2,738**	**877**	**916**	**972**
Food	311 – Food manufacturing	Manufacturing - Food & Nondurable Wholesale	1.23	675	640	648	706	733
Printing and Related Support	323 – Printing and related support activities	Manufacturing - Food & Nondurable Wholesale	1.23	28	17	10	9	-
Chemicals	325 – Chemical manufacturing	Manufacturing - Food & Nondurable Wholesale	1.23	1,583	1,536	-	-	-
Machinery	333 – Machinery manufacturing	Manufacturing - All Other	0.44	33	30	-	31	34
Computer and Electronic Products	334 – Computer and electronic product manufacturing	Manufacturing -Electronic Equipment	0.31	60	80	111	113	125
Miscellaneous	339 – Miscellaneous manufacturing	Manufacturing - All Other	0.44	47	-	108	57	80

Total municipal solid waste disposal associated with commercial, institutional, and manufacturing properties and collected by private haulers was calculated by applying industry-specific disposal rates (tons per employee per year) to the corresponding employment estimates and summing the resulting waste quantities across all industries

Data from the City of Cambridge's municipal curbside collection programs were combined with estimated waste quantities collected by private haulers to develop a comprehensive estimate of total municipal solid waste generated within the City boundary for each inventory year.

Table 30. Mass of solid waste generated by collection type

Waste Collection Type	Mass of Waste Collected - Excluding Separated Organic Waste (short tons)				
	2020	2021	2022	2023	2024
Municipally Collected - Residential	14,923	13,881	13,069	12,604	12,631
Private Hauler - Residential	7,835	7,539	6,555	5,560	6,319
Private Hauler – Commercial and Industrial	118,966	125,194	124,530	125,887	125,863
TOTAL Solid Waste	**141,724**	**146,615**	**144,154**	**144,051**	**144,813**

Total MSW was then allocated between landfill disposal and waste-to-energy incineration using the disposal distribution provided by the Cambridge Department of Public Works, with 65 percent assigned to landfill disposal and 35 percent to incineration.

Table 31. Mass of solid waste generated by waste disposal type

Waste Disposal Type	Mass of Waste Collected - Excluding Separated Organic Waste (short tons)				
	2020	2021	2022	2023	2024
Landfilled	92,120	95,300	93,700	93,633	94,128
Incinerated	49,603	51,315	50,454	50,418	50,685
TOTAL Solid Waste	**141,724**	**146,615**	**144,154**	**144,051**	**144,813**

Calculating Emissions from Landfilled Waste

Emissions from waste disposed of in landfills were calculated using the GPC Equation 8.3, which applies a methane commitment approach. Under this method, the total quantity of waste landfilled in a given inventory year is used to estimate the full amount of methane that will be generated over the lifetime of that waste, independent of the year in which emissions physically occur.

Equation 8.3 **Methane commitment estimate for solid waste sent to landfill**

$$CH_4 \text{ emissions} = MSW_x \times L_0 \times (1 - f_{rec}) \times (1 - OX)$$

Description			Value
CH_4 emissions	=	Total CH_4 emissions in metric tonnes	Computed
MSW_x	=	Mass of solid waste sent to landfill in inventory year, measured in metric tonnes	User input
L_0	=	Methane generation potential	Equation 8.4 Methane generation potential
f_{rec}	=	Fraction of methane recovered at the landfill (flared or energy recovery)	User input
OX	=	Oxidation factor	0.1 for well-managed landfills; 0 for unmanaged landfills

Source: Adapted from Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories

Figure 5. GPC Equation 8.3

The methane generation potential (L_0) used in the landfill methane commitment calculation (GPC Equation 8.3) was calculated using GPC Equation 8.4, which estimates the amount of degradable organic carbon (DOC) contained in the waste disposed during each inventory year. This calculation incorporates waste-specific parameters that reflect the fraction of organic material capable of anaerobic decomposition and subsequent methane generation.

Equation 8.4 Methane generation potential, L_0

$$L_0 = MCF \times DOC \times DOC_F \times F \times 16/12$$

Description			Value
L_0	=	Methane generation potential	Computed
MCF	=	Methane correction factor based on type of landfill site for the year of deposition (managed, unmanaged, etc., fraction)	Managed = 1.0 Unmanaged (≥5 m deep) = 0.8 Unmanaged (<5 m deep) = 0.4 Uncategorized = 0.6
DOC	=	Degradable organic carbon in year of deposition, fraction (tonnes C/tonnes waste)	Equation 8.1
DOC_F	=	Fraction of DOC that is ultimately degraded (reflects the fact that some organic carbon does not degrade)	Assumed equal to 0.6
F	=	Fraction of methane in landfill gas	Default range 0.4-0.6 (usually taken to be 0.5)
16/12	=	Stoichiometric ratio between methane and carbon	

Source: IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)

Figure 6. GPC Equation 8.4

Waste composition inputs required for this calculation were sourced from the City of Cambridge 2022 Waste Characterization Study[52], which provides detailed information on the material breakdown of municipal solid waste streams disposed of via landfill and incineration. The study was used to determine the relative proportions of biodegradable waste components, such as food waste, paper, and yard waste, within the total landfilled waste stream and used to determine the City of Cambridge estimates for the amount of DOC contained in the yearly waste disposed per GPC equation 8.1.

Equation 8.1 Degradable organic carbon (DOC)[52]

$$DOC = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) + (0.15 \times F)$$

A	=	Fraction of solid waste that is food
B	=	Fraction of solid waste that is garden waste and other plant debris
C	=	Fraction of solid waste that is paper
D	=	Fraction of solid waste that is wood
E	=	Fraction of solid waste that is textiles
F	=	Fraction of solid waste that is industrial waste

Figure 7. GPC Equation 8.1

[52] City of Cambridge 2022 Waste Characterization Study. Provided by Cambridge DPW and publicly available: wastecharacterizationfinal2022.pdf

The fraction of methane recovered at landfill facilities (f_{rec}) used in the methane commitment calculation (GPC Equation 8.3) was estimated using reported landfill gas recovery data from both in-state and out-of-state landfills. Methane recovery data were sourced from the U.S. Environmental Protection Agency's Facility Level Information on Greenhouse Gases Tool (FLIGHT) database, which provides annual, facility-specific reporting of methane generation and recovery at large landfill sites. For each inventory year, reported methane recovery rates from applicable landfill facilities were reviewed and aggregated to develop a representative recovery fraction. This aggregated value reflects the proportion of landfill gas captured through collection systems and either flared or utilized for energy generation, rather than emitted directly to the atmosphere.

Calculating Emissions from Incinerated Waste

Emissions associated with the incineration of municipal solid waste were calculated in accordance with the GPC using Equations 8.6, 8.7, and 8.8. These equations quantify emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), respectively, resulting from waste combustion. Equation 8.6 estimates non-biogenic CO_2 emissions from the oxidation of fossil carbon contained in the waste stream, while Equations 8.7 and 8.8 estimate CH_4 and N_2O emissions generated during the incineration process.

For GPC Equation 8.6, the fraction of waste by material type (WF) was derived from the City of Cambridge 2022 Waste Characterization Study, which provides locally specific data on the composition of municipal solid waste disposed of via incineration. Default values for dry matter content (dm) and the fraction of carbon in dry matter (CF) were sourced from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 2, Table 2.4. Default values for the fraction of fossil carbon in total carbon (FCF) were obtained from 2006 IPCC Guidelines, Volume 5, Chapter 2, Table 2.5.

An oxidation factor (OF) of 100 percent was assumed, consistent with GPC and IPCC guidance for controlled waste-to-energy incineration facilities, reflecting near-complete oxidation of carbon during combustion.

Equation 8.6 Non-biogenic CO_2 emissions from the incineration of waste

$$CO_2 \text{ Emissions} = m \times \textstyle\sum_i (WF_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times (44/12)$$

Description			Value
CO_2 emissions	=	Total CO_2 emissions from incineration of solid waste in tonnes	Computed
m	=	Mass of waste incinerated, in tonnes	User input
WF_i	=	Fraction of waste consisting of type i matter	User input[54]
dm_i	=	Dry matter content in the type i matter	User input (default values provided in Table 8.4 below)
CF_i	=	Fraction of carbon in the dry matter of type i matter	
FCF_i	=	Fraction of fossil carbon in the total carbon component of type i matter	
OF_i	=	Oxidation fraction or factor	
i	=	Matter type of the Solid Waste incinerated such as paper/cardboard, textile, food waste, etc.	

Note: $\sum_i WF_i = 1$

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Figure 8. GPC Equation 8.6

Methane and nitrous oxide emissions from incineration were calculated using GPC Equations 8.7 and 8.8. For these equations, the fraction of waste by material type (WF) was derived from the City of Cambridge 2022 Waste Characterization Study[53] and applied to the total mass of waste incinerated in each inventory year to calculate the quantity of incinerated waste by material type (IW). Methane emissions from the incineration process were estimated using an aggregate methane emission factor representative of continuous incineration using stoker technology, with an emission factor of 0.2 grams of CH_4 per ton of waste incinerated, consistent with GPC and IPCC default values. Nitrous oxide emissions from the incineration process were estimated using an aggregate N_2O emission factor representative of continuous and semi-continuous incineration systems, with an emission factor of 50 grams of N_2O per ton of waste incinerated.

Equation 8.7 CH_4 emissions from the incineration of waste

$$CH_4\ \text{Emissions} = \sum(IW_i \times EF_i) \times 10^{-6}$$

Description			Value
CH_4 Emissions	=	CH_4 emissions in inventory year, tonnes	Computed
IW_i	=	Amount of solid waste of type i incinerated or open-burned, tonnes	User Input
EF_i	=	Aggregate CH_4 emission factor, g CH_4/ton of waste type i	User Input (default values provided in Table 8.5 below)
10^{-6}	=	Converting factor from gCH_4 to t CH_4	
i	=	Category or type of waste incinerated/open-burned, specified as follows: MSW municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)	User input

Figure 9. GPC equation 8.7

Equation 8.8 N_2O emissions from the incineration of waste

$$N_2O\ \text{Emissions} = \sum(IW_i \times EF_i) \times 10^{-6}$$

Description			Value
N_2O Emissions	=	N_2O emissions in inventory year, in tonnes	Computed
IW_i	=	Amount of solid waste of type i incinerated or open-burned, in tonnes	User Input
EF_i	=	Aggregate N_2O emission factor, g CH_4/ton of waste type i	User Input (default values provided in Table 8.6 below)
i	=	Category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)	User input

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, chapter 5: Incineration and Open Burning of Waste

Figure 10. GPC equation 8.8

[53] City of Cambridge 2022 Waste Characterization Study. Provided by Cambridge DPW and publicly available: wastecharacterizationfinal2022.pdf

Differences in calculation methodology from 2019 Inventory

The methodology used to estimate solid waste-related emissions for the 2020-2024 inventories differs from the original 2019 inventory in three key respects: the treatment of landfill methane recovery, the assumed split between landfill disposal and incineration, and the waste categories included in the calculations. These updates reflect improved data availability and more current information on waste management practices for the City of Cambridge.

For the 2020-2024 inventories, landfill methane recovery was incorporated into the emissions using an average of relevant in-state and out of state landfill methane recovery data. The original 2019 inventory assumed no methane recovery. To ensure consistency across years, 2019 landfill emissions were recalculated using the updated methane recovery assumption.

The assumed allocation of waste disposal pathways was updated for the 2020-2024 inventories based on data provided by the Cambridge Department of Public Works. Total municipal solid waste was allocated using a 65 percent landfill and 35 percent incineration split, different from the 40 percent landfill and 60 percent incineration split used in the 2019 inventory.

In addition, solid waste calculations for the updated inventory were revised to reflect the material-specific results of the City of Cambridge Waste Characterization Study. As part of this update, several waste categories that were not explicitly included in the original 2019 inventory were incorporated into the revised calculations, including diapers and pet waste; plastics; metal; glass; rubber and leather; and other materials. These expanded material categories were integrated into the waste composition used for landfill and incineration emissions calculations to improve completeness and methodological consistency. To support comparability across all inventory years, the 2019 inventory was recalculated using the expanded waste categories and updated characterization data.

4.3 BIOLOGICAL TREATMENT

Biological treatment of waste includes the management of organic materials, such as food scraps and yard waste, through composting and anaerobic digestion. The City of Cambridge, through its Department of Public Works (DPW), provides curbside collection of organic waste from residential properties. Food waste collected through the City's curbside organics program is sent to an anaerobic digestion facility located in Charlestown, Massachusetts. For all inventory years covered by this report, 100 percent of municipally collected food waste was managed through anaerobic digestion, with no food waste sent to composting facilities. Cambridge DPW also conducts separate curbside collection of yard waste including leaves, grass clippings, and brush. All municipally collected yard waste was sent to composting facilities, with no yard waste directed to anaerobic digestion.

In addition to municipally collected organic waste, organic materials are also managed through private collection programs serving residential and commercial properties, as well as institution-managed programs, including composting operations run by large educational campuses within the City. Data for organic waste collected through private haulers and campus-operated programs were obtained through direct outreach to service providers and review of publicly available reports and disclosures from participating organizations.

Table 32. Mass of separated organic waste by collection type

Waste Collection Type	Mass of Separated Organic Waste Collected (short tons)				
	2020	2021	2022	2023	2024
Municipally Collected – Food Waste	381	969	1,884	2,189	2,275
Municipally Collected – Yard Waste	2,014	1,978	1,566	1,905	1,740
Private Collection programs	2,367	1,672	1,745	1,870	1,928
TOTAL Organic Waste	**4,888**	**4,619**	**5,195**	**5,964**	**5,943**

Table 33. Mass of separated organic waste by waste disposal type

Waste Disposal Type	Mass of Separated Organic Waste Collected(short tons)				
	2020	2021	2022	2023	2024
Composting	4,487	3,597	3,217	3,678	3,554
Anaerobic Digestion	401	1,022	1,978	2,286	2,389
TOTAL Organic Waste	**4,888**	**4,619**	**5,195**	**5,964**	**5,943**

Emissions associated with the biological treatment of organic waste were calculated in accordance with GPC Equation 8.5. Default biological treatment emission factors from GPC Table 8.3 were applied, using the "wet waste" emission factors for both composting and anaerobic digestion at biogas facilities, consistent with the characteristics of the organic waste streams managed by the City. In addition, assumptions regarding methane recovery were incorporated into the analysis to reflect differences in treatment technologies. Methane recovery was assumed to be 0 percent for composting facilities, reflecting aerobic treatment conditions with no landfill gas collection, and 100 percent for anaerobic digestion facilities, reflecting full capture and management of biogas generated during the digestion process. These assumptions were applied consistently across all inventory years for the calculation of emissions from organic waste managed through biological treatment pathways.

Equation 8.5 Direct emissions from biologically treated solid waste

$$CH_4 \text{ Emissions} = (\Sigma_i (m_i \times F\_CH4_i) \times 10^{-3} - R)$$

$$N_2O \text{ Emissions} = (\Sigma_i (m_i \times EF\_N2O_i) \times 10^{-3})$$

Description			Value
CH_4 emissions	=	Total CH_4 emissions in tonnes	Computed
N_2O emissions	=	Total N_2O emissions in tonnes	Computed
m	=	Mass of organic waste treated by biological treatment type i, kg	User input
EF_ CH4	=	CH_4 emissions factor based upon treatment type, i	User input or default value from table 8.3 Biological treatment emission factor
EF_ N2O	=	N_2O emissions factor based upon treatment type, i	User input or default value User input or default value from table 8.3 Biological treatment emission factor
i	=	Treatment type: composting or anaerobic digestion	User input
R	=	Total tonnes of CH_4 recovered in the inventory year, if gas recovery system is in place	User input, measured at recovery point

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 4: Biological Treatment of Solid Waste

Figure 11. GPC Equation 8.5

Table 8.3 Biological treatment emission factors

Treatment type	CH_4 Emissions Factors (g CH_4/ kg waste)		N_2O Emissions Factors (g N_2O /kg waste)	
	Dry waste	Wet waste	Dry waste	Wet waste
Composting	10	4	0.6	0.3
Anaerobic digestion at biogas facilities	2	1	N/A	N/A

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Chapter 4: Biological Treatment of Solid Waste

Figure 12. GPC Table 8.3

Differences in calculation methodology from 2019 Inventory

The treatment of biologically managed organic waste in the 2020‑2024 inventories reflects several methodological updates compared to the original 2019 inventory, aimed at improving completeness and consistency with current waste management practices in the City of Cambridge. The 2019 inventory did not include emissions associated with yard waste composting, nor did it account for organic waste collected and treated through private hauler or institution-managed composting programs.

For the 2020‑2024 inventories, municipally collected yard waste was explicitly included in the biological treatment calculations. In addition, estimates of organic waste managed through private haulers and large institution-operated programs (e.g., university campuses) were incorporated based on available data from service providers, direct outreach, and publicly reported information.

To ensure comparability across inventory years, yard waste composting was back-calculated and incorporated into the 2019 inventory to reflect the updated biological treatment estimates. This back-calculation was performed using available municipal yard waste collection data and the same composting emission factors and assumptions applied to later years. A 2019 estimate of composting from private services was also added. As a result, the revised 2019 estimates reflect consistent coverage of biologically treated waste streams.

4.4 WASTEWATER

Wastewater generated within the City of Cambridge originates from residential, commercial, and industrial activities. All wastewater produced within the City is conveyed to the Deer Island Wastewater Treatment Plant in Winthrop, Massachusetts, which is operated by the Massachusetts Water Resources Authority (MWRA). The Deer Island facility employs advanced treatment technologies that result in no direct methane (CH_4) emissions to the atmosphere, as methane generated during the treatment process is captured and managed on site. For this Communitywide greenhouse gas inventory, only nitrous oxide (N_2O) emissions from wastewater treatment are included. Because these methane capture and utilization activities occur outside the City of Cambridge boundary, any associated emissions are classified as Scope 3.

Wastewater-related emissions were estimated following the methodology used by the Massachusetts Department of Environmental Protection (MassDEP) to calculate wastewater treatment emissions for Massachusetts communities, as documented in Appendix C of the Greenhouse Gas Baseline & Inventory Report. Specifically, data and calculations from the *"Wastewater"* tab of the Appendix C workbook were used to estimate nitrous oxide emissions from wastewater treatment. This approach is consistent with methodologies recommended by the GPC.

The methodology estimates indirect N_2O emissions based on the total population served by the treatment facility, annual per-capita protein consumption, and a series of adjustment and emission factors that account for human protein intake, nitrogen content, and wastewater treatment characteristics. Default parameter values were sourced from the MassDEP Greenhouse Gas Baseline & Inventory Report, Appendix C, and include the following assumptions:

- Annual per-capita protein consumption of 34.4 kg/person/year
- A non-consumed protein adjustment factor ($F_{NON-CON}$) of 1.75
- A fraction of nitrogen in protein (F_{NPR}) of 0.16
- An N_2O emission factor of 0.005 for discharged wastewater
- A conversion factor of 44/28 (1.57) to convert kilograms of N_2O-N to kilograms of N_2O
- WWTP N2O Process Emissions of 4 g N2O / cap / year

It was assumed that 100 percent of Cambridge residents are served by the Deer Island WWTP. Population data used in the wastewater emissions calculations were based on the American Community Survey 5-Year Estimates applicable to each inventory year.

Differences in calculation methodology from 2019 Inventory

The methodology used to estimate wastewater-related emissions in the 2020–2024 inventories differs from the approach applied in the 2019 inventory, reflecting updates to data sources and alignment with statewide accounting practices to increase regional accuracy.

In the 2019 inventory, wastewater emissions calculations followed GPC Equation 8.11 and relied on default parameter values sourced from the U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990–2017). For the 2020–2024 inventories, the wastewater emissions methodology was updated to follow the approach used by the Massachusetts Department of Environmental Protection (MassDEP) for estimating municipal wastewater emissions, as documented in Appendix C of the Massachusetts Greenhouse Gas Baseline & Inventory Report. While still consistent with GPC Equation 8.11 and limited to N_2O emissions, this updated approach relies on parameter values and assumptions standardized across Massachusetts communities. Notably, the MassDEP methodology incorporates revised default values for per-capita protein consumption and non-consumed protein, and does not apply a separate industrial and commercial co-discharge protein factor. This reflects a refinement in how nitrogen contributions from non-residential sources are accounted for at the statewide level.

These methodological updates improve consistency with state-level GHG accounting and local realities. Differences in reported wastewater emissions between 2019 and 2020–2024 should therefore be interpreted in the context of these updates, as changes may reflect shifts in methodology and parameter assumptions rather than changes in wastewater generation or treatment performance.

4.5 WASTE SECTOR SUMMARY

Waste-sector emissions arise solid waste disposal in landfills, the biological treatment of organic waste (including composting and anaerobic digestion), the incineration of municipal solid waste, and wastewater treatment and discharge. The table below presents emissions from each Waste sub-sector for the reported inventory years. For the City of Cambridge, all Waste sector emissions are categorized as Scope 3, since all solid waste and wastewater generated within the City are managed, treated, or disposed of outside the community inventory boundary. As a result, these emissions reflect activities that occur beyond Cambridge's jurisdiction but are attributable to waste generated by the community.

Table 34. Cambridge Waste Emissions by Sub-Sector

Sub-Sector	Emissions (MT CO2e)				
	2020	2021	2022	2023	2024
Solid Waste Disposal	24,605	22,556	21,469	20,197	20,304
Biological Treatment of Waste	788	631	565	646	624
Incineration and Open Burning	5,557	5,748	5,652	5,648	5,678
Wastewater Treatment and Discharge	1,636	1,627	1,647	1,643	1,684
TOTAL Waste Emissions (Scope 3)	**32,585**	**30,563**	**29,332**	**28,134**	**28,290**

Solid waste disposal, defined as waste sent to landfill, was the largest contributor to Waste sector emissions, accounting for approximately 72 to 76 percent of total Waste emissions across the 2020–2024 inventory years. These high emissions are driven primarily by methane generated during the anaerobic decomposition of organic materials in landfills. Of the total municipal solid waste generated by the City of Cambridge, approximately 65 percent is disposed of in landfills, while the remaining 35 percent is managed through incineration. Methane is a particularly potent greenhouse gas, with a global warming potential approximately 28 times greater than carbon dioxide over a 100-year time horizon. While many landfill facilities employ methane recovery systems that capture and either flare or utilize landfill gas for energy, residual methane emissions still represent the largest source of Waste sector emissions.

The incineration of municipal solid waste was the second-largest contributor to Waste sector emissions, representing 17 to 20 percent of total Waste emissions from 2020 through 2024. Incineration results in emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) during the combustion of waste materials. In Massachusetts, incinerated waste is processed at waste-to-energy facilities, where it is used to generate electricity. Although incineration produces direct emissions, it avoids long-term methane generation associated with landfilling. As a result, incineration can provide a relative greenhouse gas mitigation benefit when compared to landfill disposal.

Wastewater treatment and discharge accounted for 5 to 6 percent of total Waste sector emissions across the 2020–2024 inventory years. The Deer Island Wastewater Treatment Plant, which treats all wastewater generated by the City of Cambridge, releases no methane to the atmosphere, as methane produced during treatment is captured and diverted to cogeneration systems where it is used to generate electricity and provide heat. Consequently, all wastewater-related emissions reported for Cambridge consist of indirect nitrous oxide (N_2O) emissions. These emissions primarily result from nitrogen-related processes associated with treated effluent discharged into receiving waters following treatment.

Emissions from the biological treatment of waste account for only about 2 percent of total Waste sector emissions in 2020 through 2024 inventory years, reflecting the relatively low greenhouse gas intensity of composting and anaerobic digestion compared to landfill disposal. In Cambridge, these emissions arise almost entirely from methane generated during composting, primarily of yard waste and organics managed through private composting programs. By contrast, all food waste collected through the City's curbside organics program is sent to anaerobic digestion, where 100 percent of methane is assumed to be captured and managed, resulting in no direct emissions from this process. The use of anaerobic digestion provides an important climate benefit, since diverting food waste from landfill avoids substantial methane emissions that would otherwise occur in landfills.

Comparison with 2012 and 2019 Inventories

The 2012 and 2019 Community-wide GHG inventories were updated for this analysis to reflect methodological improvements and expanded data availability. These updates include the addition of yard waste managed through composting, the inclusion of waste material categories that were not previously accounted for, and the incorporation of landfill methane recovery in solid waste emissions calculations. Together, these adjustments improve the completeness and consistency of waste sector emissions estimates and enable more accurate comparisons across inventory years.

Table 35. Comparison of Previous Inventories Waste Emissions by Sub-Sector

Sub-Sector	Emissions (MT CO2e)		
	2012 - Updated	2019 - Updated	2024
Solid Waste Disposal	14,508	19,146	20,304
Biological Treatment of Waste	864	737	624
Incineration and Open Burning	8,102	10,920	5,678
Wastewater Treatment and Discharge	2,146	2,319	1,684
TOTAL Waste Emissions (Scope 3)	**25,620**	**33,122**	**28,290**

Across the updated inventories, total Scope 3 Waste sector emissions increased from 2012 to 2019 and then declined by 2024. The rise between 2012 and 2019 was driven primarily by higher estimated emissions from solid waste disposal and incineration, reflecting methodological improvements in the 2019 inventory, particularly the use of updated private hauler estimation methods that capture a larger share of commercial and multi-family waste.

By 2024, emissions from incineration and open burning declined substantially, contributing to the overall reduction in total Waste sector emissions, even as landfill-related emissions continued to increase. This shift is largely attributable to updated disposal assumptions, which allocate municipal solid waste using a 65 percent landfill and 35 percent incineration split, replacing the 40 percent landfill and 60 percent incineration split used in the 2019 inventory.

Emissions from the biological treatment of waste declined steadily across all three inventory years, reflecting expanded diversion of organic materials to composting and anaerobic digestion pathways. Wastewater treatment emissions remained relatively stable between 2012 and 2019 and declined by 2024, largely due to the incorporation of newly available, localized data and calculation methods from the Massachusetts Department of Environmental Protection (MassDEP).

5. CONCLUSION

Taken together, the results of this inventory underscore the scale and complexity of greenhouse gas emissions generated across the City of Cambridge and highlight how emissions patterns are evolving over time. The findings reinforce the central role of energy use in buildings as the dominant driver of community-wide emissions, while also revealing meaningful shifts in how different sectors contribute to the city's overall emissions profile. These trends reflect a combination of real changes in community activity, energy systems, and technology adoption, as well as improvements in data quality and reporting practices.

Summary of Community-wide GHG Emissions

This Community-wide GHG inventory update shows that, across the evaluated calendar years, the Stationary Energy sector accounted for the vast majority of emissions, representing approximately 87 to 90 percent of total emissions each year. Transportation was the second-largest contributor at 9 to 10 percent, followed by the Waste sector at approximately 2 percent. At the sub-sector level, the largest sources of emissions in the City of Cambridge were commercial, institutional, and manufacturing buildings, which comprised 58 to 67 percent of total emissions, followed by residential buildings at 16 to 22 percent and on-road vehicles at 9 to 12 percent.

Table 36. Summary of emissions 2020-2024

Sector	Subsector	Emissions (MT CO2e)					
		2020	2021	2022	2023	2024	Percent of Total (2024)
Stationary Energy	Residential Buildings	255,659	259,231	255,202	234,553	291,174	19.8%
	Commercial & Institutional Buildings & Manufacturing Industries	677,555	957,691	990,678	990,344	926,454	63.0%
	Construction	61,693	68,068	73,836	89,051	97,241	6.6%
Transportation	On-Road	140,209	133,761	137,057	130,029	126,438	8.6%
	Rail (MBTA)	1,350	1,288	1,334	1,131	1,177	0.1%
Waste	Solid Waste Disposal	24,605	22,556	21,469	20,197	20,304	1.4%
	Biological Treatment of Waste	788	631	565	646	624	0.04%
	Incineration and Open Burning	5,557	5,748	5,652	5,648	5,678	0.4%
	Wastewater Treatment and Discharge	1,636	1,627	1,647	1,643	1,684	0.1%
TOTAL Emissions		**1,169,051**	**1,450,602**	**1,487,440**	**1,473,243**	**1,470,775**	

Comparison with Previous Inventories

Updated results from the 2012, 2019, and 2024 Community-wide greenhouse gas inventories indicate meaningful shifts in both total emissions and the relative contributions of key sectors over time. Total emissions increased from approximately 1.28 million metric tons of CO_2e in 2012 to a approximately 1.48 million metric tons in 2019, and decreased modestly to 1.47 million metric tons in 2024. Although total emissions in 2024 remain above 2012 levels, the reduction since 2019 suggests progress in several emissions sources. Stationary energy continues to be the dominant contributor to emissions, but notable declines from electricity emissions occurred due to improvements in grid emissions factors, and participation in Community Choice Aggregation programs.

Transportation emissions showed consistent declines over time, with on-road vehicle emissions falling steadily from 2012 through 2024 and rail emissions remaining relatively low after a significant drop by 2019. Waste emissions displayed mixed trends, with decreases in biological treatment, incineration, and wastewater emissions balanced against increases in solid waste disposal. Overall, the 2024 inventory indicates a shift in emissions drivers since 2019, with progress in buildings and transportation countered by growth in select stationary and waste-related sources, shaping the City's current emissions profile.

Table 37. Comparison of sector emissions with previous inventory years

Sector	Emissions (MT CO2e)		
	2012 (Updated)	2019 (Updated)	2024
Stationary Energy	1,090,795	1,299,398	1,314,869
Transportation	162,938	144,701	127,616
Waste	25,620	33,122	28,290
TOTAL Emissions	**1,279,353**	**1,477,221**	**1,470,775**

Table 38. Comparison of sub-sector emissions with previous inventory years

Sector	Subsector	Emissions (MT CO2e)		
		2012 (Updated)	2019 (Updated)	2024
Stationary Energy	Residential Buildings	287,768	303,294	291,174
	Commercial & Institutional Buildings & Manufacturing Industries	582,956	685,266	926,454
	Energy Industries	194,907	179,682	N/A
	Construction	25,164	131,156	97,241
Transportation	On-Road	153,993	143,188	126,438
	Rail (MBTA)	8,945	1,513	1,177
Waste	Solid Waste Disposal	14,508	19,146	20,304
	Biological Treatment of Waste	864	737	624
	Incineration and Open Burning	8,102	10,920	5,678
	Wastewater Treatment and Discharge	2,146	2,319	1,684
TOTAL Emissions		**1,279,353**	**1,477,221**	**1,470,775**

Considerations for Future Inventories

As the City of Cambridge continues to advance its greenhouse gas accounting practices, ongoing review of data sources and methodological assumptions will be essential to ensuring that future inventories remain accurate, relevant, and responsive to changing local conditions. Emissions inventories are most effective when they reflect the best available data at the time of preparation and adapt to evolving energy systems, data availability, and community practices. The considerations outlined below highlight key areas where future updates and refinements may be warranted.

Future inventory updates should continue refining emissions factors and data sources to better reflect actual energy use and system performance. In particular, the utility-specific emissions factor for district steam should be reevaluated to incorporate more detailed, supplier-provided data. Using generalized or static assumptions may not fully capture the true emissions associated with steam production, especially as plant operations, fuel inputs, and efficiency vary over time. Access to more granular, utility-reported data would improve the accuracy of emissions estimates and better align reported emissions with actual system conditions.

Continued improvement of fuel oil data remains an opportunity, as fuel oil is supplied by numerous private vendors rather than a centralized utility. In this and prior inventories, residential fuel oil consumption has been estimated using housing unit counts by type and the share of homes heated with fuel oil from the ACS 5-Year Estimates. Commercial fuel oil use has been estimated based on employment, establishments by primary building activity, and average expected energy use assumptions. Access to customer-level fuel oil consumption data would significantly reduce uncertainty and improve sector-specific accuracy in future inventories.

Additionally, future inventories could consider how commercial Virtual Power Purchase Agreements (VPPAs) are accounted for in building emissions. As BEUDO data continues to expand and improve, it may begin to capture the impact of these agreements more directly, providing a more accurate representation of building-level electricity emissions and renewable energy procurement.

Inputs used for estimating waste-related emissions merit further refinement if better data sources become available. Employment-based waste disposal rates currently rely on CalRecycle's 2014 Waste Characterization Study. While this dataset remains a widely used reference, it is both outdated and geographically distant from Cambridge. The availability of more current and locally relevant waste generation data would improve the precision of waste-sector emissions estimates.

Collectively, these considerations provide a roadmap for strengthening future inventories and supporting informed, data-driven climate action by the City of Cambridge.