BOSTON GREENHOUSE GAS INVENTORY METHODOLOGY

2023 Edition

This document summarizes the methodologies used for the City of Boston Community-wide and Local Government Operations GHG Inventories. This document is an update to the 2018 edition.

UNDERSTANDING A GREENHOUSE GAS EMISSIONS INVENTORY

Cities compile greenhouse gas emissions inventories to understand how greenhouse gas (GHG) emissions are associated with various activities in their community. City inventories are generally compiled at both the community scale and at the government operations scale. Emissions associated with government operations (fuel use from fleet vehicles and energy use in city government buildings), are included as part of the community-wide inventory.

In 2017, Mayor Martin J. Walsh set the goal of reaching carbon neutrality by 2050. To stabilize the global climate, the world needs to drastically curb greenhouse gas emissions. In Boston, a majority of greenhouse gasses come from burning oil, gasoline, natural gas, and coal. These gasses accumulate in the atmosphere and contribute to global climate change, which affects all facets of society. More than half the world's population lives in cities, like Boston, which can play a leadership role in tackling the climate challenge. The community-wide inventory helps us track how our emissions stack up against our goals, and the local government operations inventory helps the City to lead by example.

MUNICIPAL INVENTORY METHODOLOGY

The Local Government Operations inventory methodology for calculating GHG emissions is based on the ICLEI greenhouse gas reporting protocol for local government operations, developed by ICLEI and the National Association of Clean Air Agencies. The protocol categorizes emissions as direct (Scope 1) or indirect (Scope 2). Direct emissions come from the burning of natural gas, fuel oil, gasoline, diesel fuel, and other fuels in the City's facilities, vehicles, and other equipment. Indirect emissions come from the burning of fuels in facilities owned and operated by others to produce electricity, and steam that the City uses. Emissions that are not under the operational control of the City government, or involve leased properties, are excluded. Emissions from the Boston Housing Authority, the

Massachusetts Water Resources Authority (MWRA), and the Boston Planning and Development Agency (BPDA) are not included in the inventory. Those from the Boston Public Health Commission (BPHC), and the Boston Water and Sewer Commission (BWSC) are.

Another significant methodology change since the 2019 inventory methodology involves steam accounting. Previously, all emissions associated with steam brought into the City from the Kendall cogeneration plant were associated with the electricity generated by the cogeneration process, with no emissions associated with the steam generated, treated as a byproduct. The emissions factor has since been updated to account for emissions associated with steam production by allocating a portion of the plant's emissions to steam production using the efficiency method. The methodology change is further detailed later in this document.

COMMUNITY INVENTORY PROTOCOL

This methodology describes how the City of Boston compiles GHG emissions from the entire Boston community. The community-wide inventory follows the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), developed by the World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability. Applying this inventory method is in fulfillment of Boston's obligations as a member of The Global Covenant of Mayors for Climate and Energy (Global Covenant).

GLOBAL PROTOCOL FOR COMMUNITY-SCALE GREENHOUSE GAS EMISSION INVENTORIES

The City began issuing annual reports on Boston's community-wide GHG emissions in 2007 for the 2005 calendar year, as well as emissions from local government operations. In 2015, Mayor Walsh signed on to what is now known as the Global Covenant of Mayors (GCoM), which required the city to follow the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). The City of Boston adopted the GPC in 2015 and updated data for prior years (2005-2014) to the new methodology.

GREENHOUSE GAS EMISSIONS REPORTING IN BOSTON

Boston's GHG inventories are reported in CO_2 equivalents (or CO_2e) which is a unit of measurement that accounts for the global warming potential (GWP) of different greenhouse gasses. Boston's GHG inventory includes carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), and uses Global Warming Potentials (GWPs) from the latest version of the International Panel on Climate Change (IPCC) Guidelines (currently 5AR). The formula used to determine the CO_2e from a given energy use is Activity Data x Emissions Factor^{1+2+3} = GHG Emissions from the activity.

Boston currently is choosing to report at the GCP BASIC level, which covers scope 1 and scope 2 emissions from stationary and transportation sources, as well as scope 1 and scope 3 emissions from waste.

Scope 1: GHG emissions from sources located within the city boundary
Scope 2: GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam, and cooling within the city boundary
Scope 3: All other emissions that occur outside the city boundary as a result of activities taking place within the city boundary

Boston's community-wide GHG inventories are overseen by the Climate and Environmental Planning Division within the City of Boston Environment Department; the local government operations inventories are overseen by the Municipal Energy Unit. However, these inventories are the product of close cooperation and collaboration with colleagues in many City departments, several departments of the Commonwealth of Massachusetts, Boston's energy utilities, and various local institutions.

Please direct comments or questions about the inventories to Alison Brizius, Director of Climate and Environmental Planning, at alison.brizius@boston.gov. Suggestions for improving the accuracy or completeness of the inventory are welcome.

EMISSIONS SCOPE, SECTORS AND SOURCES

The goal of the community inventory is to include GHG emissions associated with all activities—residential, commercial/industrial, institutional, transportation-related—within the administrative boundary of the City of Boston. The Boston community-wide inventory accounts for Scope 1 and 2 emissions from the following sources:

- Stationary energy use from residents, businesses and other activities, including municipal buildings.
- On-road and off-road transportation, including municipal vehicle fleet fuel use.
- Solid waste and wastewater disposal and treatment.

Within Scope 2 emissions, the inventory does not currently include emissions from airplane travel at Logan Airport.

Regarding Scope 3 emissions, the City assessed the possibility of including emissions from the complete life cycle of consumer products used within Boston, industrial processes, or land use; however, due to the limited data for these activities, they were not included. Agriculture and forestry are other sources of Scope 3 emissions that can also be accounted

for using the GPC, but these were also not included due to limited activity in each of these areas in the City.

The table below summarizes the sectors, emissions sources, and energy types included in the community-wide GHG inventory.

Table 1: Sectors and Emissions in the GHG Inventory

SECTOR	SUB-SECTOR	EMISSIONS SOURCES	ENERGY TYPES
Stationary Energy	Residential	Energy use in residential buildings as well as losses from distribution systems	Electricity; Natural Gas; Petroleum products; Steam
	Industrial, Commercial, and Institutional	Energy use in commercial, government and institutional buildings as well as losses from distribution systems	
	Energy Industries	Stationary combustion of fuel in various equipment, such as boilers and generators	Various - may include natural gas, propane, and diesel
	Natural gas infrastructure	Emissions within the city boundary from natural gas distribution systems	Natural Gas
Transportation	Transportation	All on-road vehicles Fleet vehicles (municipal, MBTA, Massport...) Railways Off-road vehicles and equipment (aviation excluded)	Gasoline; Diesel; Electricity; Propane; Biodiesel
Waste	Wastewater	Process and fugitive emissions from treating wastewater	Anaerobic digester gas (methane, nitrous oxide)

BASELINE YEAR AND FORECAST YEARS

The community inventory is based on the calendar year. The calendar year 2005 was chosen as the baseline year for this inventory based on availability and quality of data when we released our first inventory in 2007. The inventory currently compares yearly emissions against our interim 2020 goal of reducing emissions by 25% from our 2005 baseline. We

also have a 2050 goal to achieve carbon neutrality. This is in alignment with the City of Boston's commitment to the Paris Climate Agreement.

Although our inventory is primarily based on the calendar year, some parts are based on the fiscal year:

- Data provided by the Massachusetts Water Resources Authority (MWRA) were based on the fiscal year through 2011, but calendar year data has been provided since 2012.
- Data provided by the Massachusetts Bay Transportation Authority are based on the fiscal year.
- The GHG inventory for Boston's municipal operations is based on the City's fiscal year, July 1 to June 30.

QUANTIFYING GREENHOUSE GAS EMISSIONS

All emissions in this inventory are calculation-based methodologies, meaning that they are not measured, but calculated using activity data from each reporting sector identified in the GPC and emission factors. The community inventory mixes top-down and bottom-up inventory methods and includes estimates based on models. For this reason, no more than two significant digits should be used when citing these results. The inventory's unit of measurement is metric tons of carbon dioxide equivalent (CO2e).

To calculate emissions, the basic equation is:

Activity Data (units) x Emission Factor ($mtCO_2e$ / unit) = Emissions ($mtCO_2e$)

Activity data refer to the relevant measurement of energy use or other GHG-generating processes such as fuel consumption by fuel type, metered annual electricity consumption, and annual vehicle miles traveled. Known emission factors are used to convert energy usage or other activity data into associated quantities of emissions. Emissions factors are usually expressed in terms of emissions per unit of activity data (e.g. metric tons of CO_2 per kWh of electricity). The emission factors and the assumptions and methodologies used in composing this inventory are described below.

Emissions factors

The municipal and community GHG inventories use the annual electricity emissions factors calculated by ISO-New England, the regional transmission organization. The ISO-NE electricity emissions factor is usually several percent lower than the factor used by the Commonwealth of Massachusetts for the statewide GHG emissions inventory, which is based primarily on power plants located in Massachusetts. Both factors can vary from year to year according to the actual fuel mix used to produce electricity. All other emissions

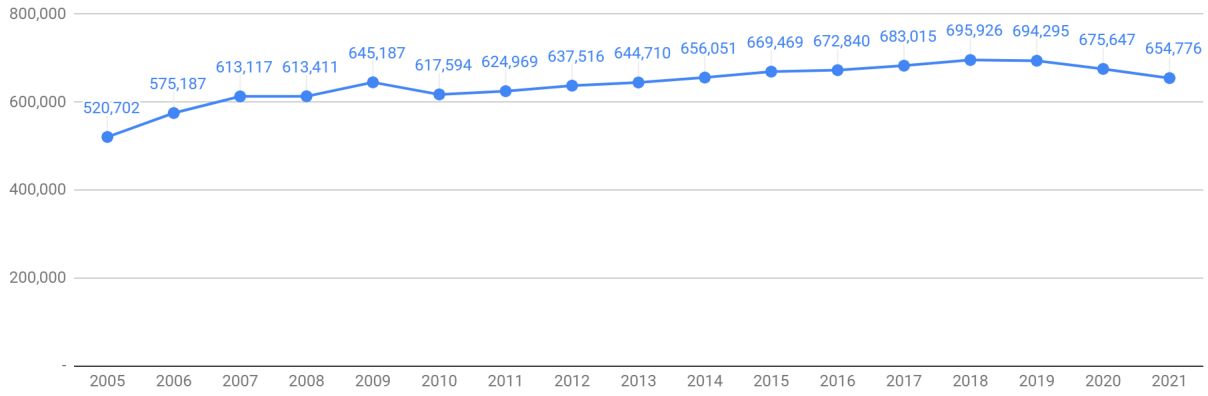
factors—except steam's —come from GHG inventory tools released by ICLEI - Local Governments for Sustainability and the National Association of Clean Air Agencies and the U.S. EPA's "Emissions Factors for Greenhouse Gas Inventories" reports.[1]

City Information

Population

Boston population estimates are drawn from U.S. Census Bureau data, namely the 2010 Decennial Census for 2010 and the 1-year American Community Surveys for the 2005-2009 and 2011-2016 period.

Figure 1: Boston Population, 2005-2021[2]

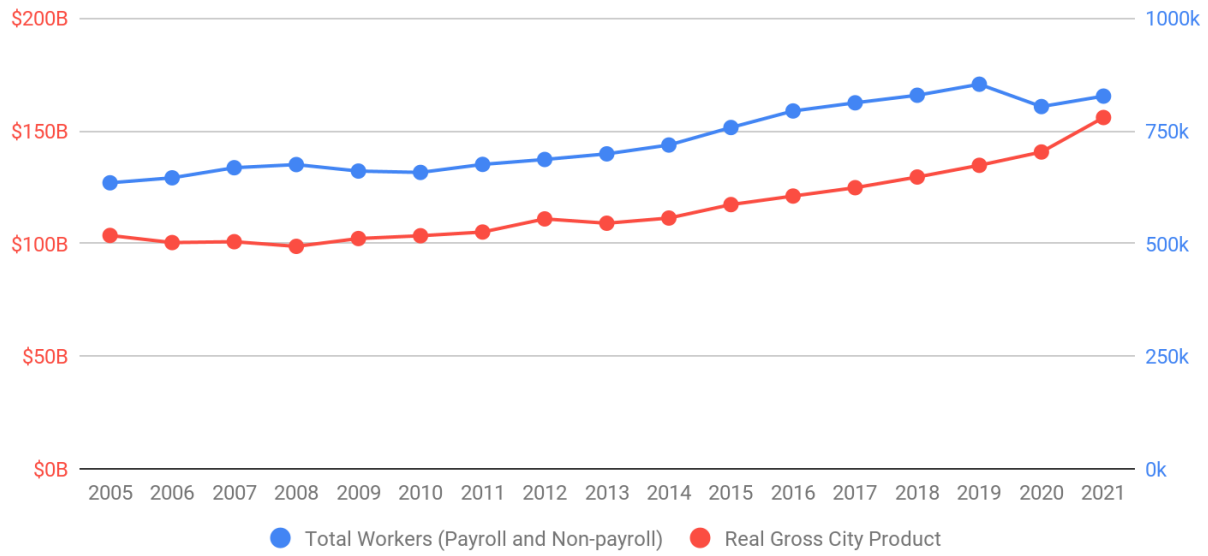


Economy

Each year, the Boston Planning and Development Agency's Research department compiles and publishes the *Boston's Economy* report. This includes estimates of Boston's real Gross City Product and total payroll and non-payroll jobs.

Figure 2: Boston's Economy, 2005-2021[3]

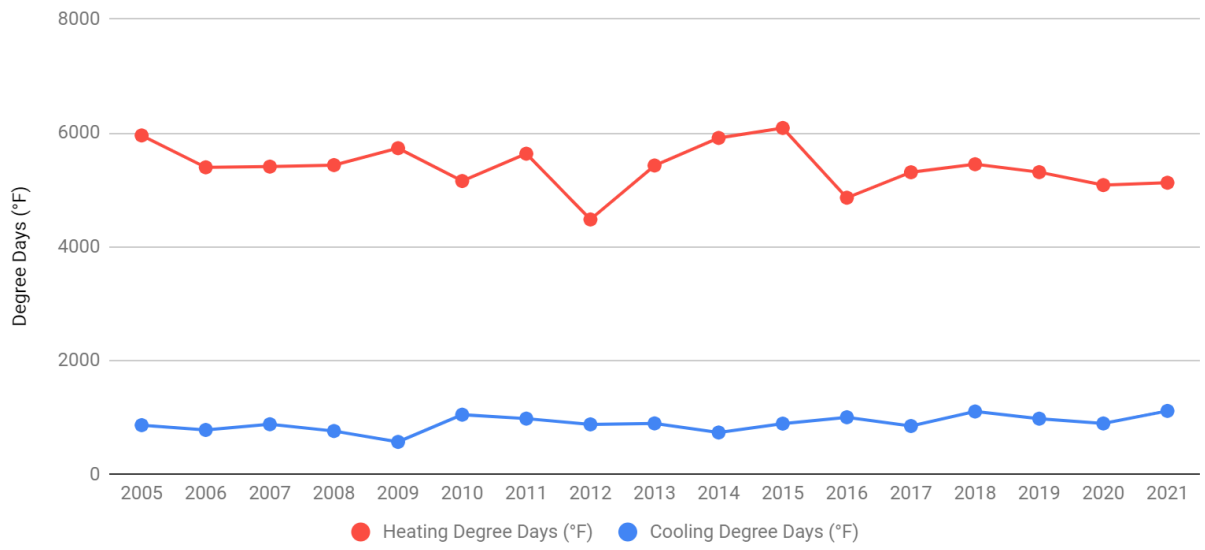
[1] U.S. Environmental Protection Agency, Emission Factors for Greenhouse Gas Inventories, 13 April 2023, https://www.epa.gov/system/files/documents/2023-03/ghg_emission_factors_hub.pdf
[2] U.S. Census Bureau, American FactFinder, Community Facts: Boston city, Massachusetts, 13 April 2023, https://data.census.gov/table?q=Boston+city,+Massachusetts+population&tid=DECENNIALPL2020.P1
[3] Boston Planning and Development Agency, *Boston's Economy* 2022, 13 April 2023 http://www.bostonplans.org/getattachment/b7be231d-c72c-4f87-9c21-e84dcf26c361



Climate

Heating and cooling buildings can be a driver of greenhouse gas emissions. The U.S. National Oceanic and Atmospheric Administration (NOAA) provides climate data. This includes degree days, a quantitative index that reflects demand for energy to heat or cool houses and businesses. To calculate degree days, NOAA adds up the differences between average daily temperatures and 65 °F, the base temperature. When outside temperatures are colder than 65°F, this adds to annual heating degree days. In the same way, when average outdoor temperatures are hotter than 65 °F, the number of cooling degree days goes up. Degree days are used to estimate heating usage in the winters and air conditioning usage in the summers.

Figure 3: Heating Degree Days and Cooling Degree Days, 2005-2021[4]



Stationary Energy – Electricity

Electricity generation in Massachusetts is made up of a mix of natural gas, nuclear, coal, hydroelectric, and other renewable generators, and accounts for about 21% of Massachusetts's total GHG emissions. Much of the electricity used in the Commonwealth is imported from power plants located in other states and in Canada. On a city level, electricity consumption contributes primarily to Scope 2 emissions.

Grid-supplied electricity is provided throughout the city and powers the residential, commercial, and industrial sectors, in addition to city infrastructure and transport systems. The City of Boston has a single electricity provider, Eversource, to transmit and distribute electricity. Each year, Eversource reports total aggregate electricity consumption (in kWh) from each building sector (residential and institutional, commercial & industrial).

Emissions from grid-supplied electricity consumed with Boston's boundaries are reported as Scope 2 emissions. Electricity generation within the City's boundaries are currently excluded to avoid double counting, in accordance with standard procedure for BASIC reporting. On-site electricity generation is already included in the inventory through stationary energy use data, which is assumed to reflect the built environment's net energy needs.

[4] Downloaded from NOAA, Global Summary of the Year Station Details: Boston, MA, 13 April 2023, https://www.ncdc.noaa.gov/cdo-web/datasets/GSOY/stations/GHCND:USW00014739/detail

The emissions factor used for grid supplied electricity is provided in Table 2 and is based on data from annual emissions reports from ISO New England.

Table 2: ISO New England 2005 and 2021 Electricity System Emissions Rate

YEAR	2005	2021
CO_2 Emission Factor (lbs CO2 / MWh)	919	658
CO_2 Emission Factor (MT CO2 / kWh)	0.00042	0.000298

Stationary Energy – Natural Gas

The primary uses for natural gas are for space heating, water heating and equipment. The emissions from these sources are defined as Scope 1 emissions.

Data on natural gas consumption in Boston are provided by National Grid and Eversource. National Grid services most of the city while Eversource services part of the Hyde Park neighborhood. National Grid reported natural gas sales in two categories according to account type—residential and commercial/industrial. National Grid charges large residential sites—that is, buildings with more than four units that are not separately metered—a commercial rate. Because these buildings are classified as commercial by the utility, there is no way to identify them as residential; consequently, they are included in the commercial/industrial category. (This is true only for natural gas, not for electricity). Natural gas used by Veolia steam plants, the MBTA and Massport, is subtracted from the National Grid commercial sector data to prevent double counting. Emissions from the usage of natural gas within the city's boundaries were reported as Scope 1 emissions.

Inventory emissions related to natural gas include leaks from the natural gas distribution system in Boston. The emissions factor currently in use is the default emissions factor for natural gas distribution losses set forth by the International Panel on Climate Change (IPCC) in 2006.

Table 3: Natural Gas Distribution Fugitive Emissions Rate

TYPE OF EMISSION	CO_2 EMISSION FACTOR ($kg\ CO_2 / m^3$)	CO_2E EMISSION FACTOR ($mtCO_2e/m^3$)
Fugitive Emissions from Natural Gas Distribution	0.000051	0.000031

Stationary Energy – Steam

Emissions from the use of steam within Boston are reported in the GPC as Scope 1 stationary emissions. There are three steam generation facilities located in Boston and Cambridge – the Kneeland Steam Plant, the Scotia Steam Plant and the Kendall Cogeneration Station. These facilities supply steam to residential and commercial buildings in Boston, primarily in the Downtown area, with two distribution systems dubbed the main loop and the Longfellow loop. Vicinity Energy provides data on delivered steam by category (residential, commercial, medical, governmental, and educational). Prior to 2013, then-owner Veolia included mixed-use hotel/residential buildings entirely in the residential category; starting in 2013, the hotel portion was included in the commercial category. Boston also has other district steam distribution systems, including the Longwood Medical Area Total Energy Plant (MATEP), a natural gas-fired cogeneration facility.

In the City's prior methodology, because steam products associated with non-Vicinity systems are fully produced and consumed within Boston, their emissions were reflected in citywide stationary natural gas energy use, whereas a dedicated steam emissions factor had previously been assigned to the steam from Vicinity because its production takes place in part outside the Boston boundary at the Kendall cogeneration facility. The Vicinity emissions factor assigned no emissions to steam generated by the Kendall cogeneration plant, with the steam generated being regarded as a byproduct to electricity production; emissions were driven instead by the use of fuel oil and natural gas at the Kneeland and Scotia plants to supplement additional steam production to meet demand not met by Kendall.

In 2020, the City adopted the Building Emissions Reduction and Disclosure Ordinance (BERDO), for which building-level emissions must be calculated using a consistent methodology across all energy production systems. Steam in particular would need to be assigned an emissions factor in a consistent manner across all steam production facilities, including Vicinity, MATEP or any other campus facilities. Following extensive stakeholder engagement through the BERDO regulations development process, the City adopted the efficiency method from the GHG Protocol.[5] Pursuant to the efficiency method, steam emissions provided by Vicinity Energy are assigned to the main loop and the Longfellow loop based on the respective amount of energy needed to produce the steam distributed in the two distribution systems. The corresponding emissions factor is then applied to the steam that is distributed through each system.

[5] GHG Protocol, "Allocation of GHG Emissions from a Combined heat and Power (CHP) plant," accessed August 8, 2023 at https://ghgprotocol.org/calculation-tools-and-guidance

Using data provided by Vicinity Energy, the efficiency method was applied to the steam emissions factor for the 2018-2021 period, resulting in revised emissions factors shown below in Table 4. The previously published 2018 and 2019 inventories were updated using the revised emission factors. Due to insufficient pre-2018 data, the City will continue to use the previous method of emissions allocation for steam for the 2005-2018 inventories.

Table 4: Steam CO_2e Emission Factors

YEAR	PRIOR METHOD	REVISED - MAIN LOOP		REVISED - LONGFELLOW LOOP	
	(lbs CO_2e / klb)	(lbs CO_2e / klb)	($mtCO_2e$/klb)	(lbs CO_2e / klb)	($mtCO_2e$/klb)
2018	111.25	132.93	0.0603	106.08	0.0481
2019	84.4	120.12	0.0545	107.76	0.0488
2020	90.0	124.38	0.0564	110.75	0.0502
2021	N/A	131.45	0.0596	108.68	0.0493

Stationary Energy – Fuel Oil

While electricity, steam and natural gas heating are limited to known municipal suppliers, fuel oil is supplied by many different private companies. Since customer data cannot be collected from each supplier, fuel oil consumption is estimated for the community inventory. Fuel oil usage by Veolia steam plants is captured in its emissions factor.

Residential estimate

We estimate residential fuel oil use by multiplying the average fuel oil use per household by the number of households using fuel oil in Boston. The U.S. Census Bureau provides an estimate of the number of households that use heating oil in Boston through its annual American Community Survey. The household consumption data come from Mass Energy Consumers Alliance (Mass Energy), a non-profit energy organization with 15,000 residential customers in eastern Massachusetts, 3,000 of whom are in Boston. The Mass Energy data are reported by heating season, so we take the average of consecutive seasons as representative of a calendar year. Mass Energy estimates that their members use 30-50 fewer gallons of fuel oil than average Massachusetts residents. Because of this, we added 40 gallons to Mass Energy's calculated total gallons per household.

Commercial and institutional estimate

We estimate Boston's commercial and institutional (C/I) fuel oil consumption by taking a proportion of total Massachusetts C/I consumption of fuel oil. The annual state number is

reported in the State Energy Data System of the U.S. Energy Information Administration.[6] The Boston proportion 0.175 is equal to the C/I square footage in Boston (Boston Assessing Database) divided by the corresponding figure for the state (Metropolitan Area Planning Council). (An analogous calculation based on employment would give a Boston factor of 0.170.) We are going to continue to use this proportion for the next several years on the presumption that new Boston construction is unlikely to use heating oil as a source. This methodology was used to revise the C/I fuel oil figures back to 2005.

Transportation – On-Road Vehicles

The City of Boston relies on a baseline vehicle-miles-traveled estimate and annual fuel sales data to estimate GHGs from cars and trucks.

Vehicle-Miles-Traveled

The inventory relies on VMT estimates based on linear extrapolations from the Boston Metropolitan Planning Organization's Central Transportation Planning Staff (CTPS). CTPS maintains and refines a computer of eastern Massachusetts to estimate the number of miles traveled by all vehicles, except private fleet vehicles, on a high-traffic mid-week day in Boston in 2016. To calculate annual VMTs, CTPS recommends multiplying the daily VMT estimate by an annualization factor of 340, taking into account weekend, holiday and summer traffic patterns.

Inventories released prior to 2016 relied on 2005 and 2012 baseline estimates from CTPS for VMTs that included passenger vehicles and transit, but excluded freight. As such, transit emissions, reported separately using real fuel consumption data supplied by MBTA, were double-counted, and emissions from freight traffic was not reported. The updated 2016 baseline supplied by CTPS included freight and passenger vehicle VMTs, and excludes transit VMTs. To extrapolate the updated 2016 baseline, we use the year-to-year relative change in the annual VMT estimate for the Boston Metropolitan Statistical Area from the U.S. Federal Highway Administration Highway Statistics Series.[7] The inventory will incorporate updated results from the CTPS model when available, and adjust intermediate years as appropriate.

Previously, we relied on estimates and linear extrapolations from the Commonwealth's Central Transportation Planning Staff (CTPS), which used their computer model of eastern Massachusetts to estimate the number of miles traveled by all vehicles, except transit

[6] U.S. Energy Information Administration, State Profile and Energy Estimates: Massachusetts, 13 April 2023, http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/com/use_com_MA.html&sid=MA

[7] U.S. Department of Transportation Federal Highway Administration, Highway Statistics Series,13 April 2023, https://www.fhwa.dot.gov/policyinformation/statistics.cfm

vehicles, on a high-traffic mid-week day in Boston in 2000 and 2010. To calculate annual VMTs, CTPS recommended a multiplier of 340, taking into account the weekend, holiday, and summer traffic patterns. The new method, described above, reflects year-to-year changes that the model, which is updated infrequently, can fail to capture.

Vehicle fuel consumption estimate

Fleet vehicles

The CTPS model's VMT estimate does not include public or private vehicle fleets, which must therefore be reported separately. Total diesel and gasoline use by public and private vehicle fleets is subtracted from total state fuel sales to avoid a double-count. Those vehicle fleets include:

- Municipal vehicle fleets: Boston Public Schools, Boston Police Department, Boston Fire Department, Department of Public Works, Parks & Recreation, Boston Water and Sewer Commission…
- MBTA: buses, THE RIDE paratransit program.
- Massport fleet: Massport Shuttle Bus, Massport Express Bus, Massport Honda fleet vehicles.

MBTA and Massport vehicle fleets also include other vehicle categories that operate off-road; their fuel use is reported in the "Transportation – Off-road transportation" section.

Fuel sales-based estimate

The U.S. Federal Highway Administration publishes annual statewide diesel and motor gasoline sales.[8] In order to estimate fuel consumption with Boston's geographic boundaries, we apply the best available VMT share estimate for different vehicle fuel types, drawn from ICLEI's 2009 Clean Air and Climate Protection (CACP) software. The CACP software translated VMTs into annual GHG emissions by using the national fleet mix to determine the distribution of vehicle types and assigning to these vehicle types a representative fuel mileage. The relative VMT shares are the following:

- Gasoline:
    - Passenger cars: 61% of total VMTs, or 65% of gas VMTs
    - Light duty vehicles: 32% of total VMTs, or 35% of gas VMTs
- Diesel:
    - Heavy duty vehicles: 5% of total VMTs, or 77% of diesel VMTs
    - Light duty vehicles: 1% of total VMTs, or 19% of diesel VMTs
    - Passenger cars: 0.3% of total VMTs, or 4% of diesel VMTs

The relative proportions of gas VMTs and diesel VMTs are applied to estimated total Boston diesel sales and gas sales to estimate total diesel and gas fuel consumption by vehicle type.

[8] See Table MF-21: Motor-fuel use from U.S. Department of Transportation Federal Highway Administration, Highway Statistics Series, 13 April 2023, https://www.fhwa.dot.gov/policyinformation/statistics.cfm

Finally, we apply the emissions factors for different vehicle types from the EPA Emissions Factors for "Greenhouse Gas Inventories" reports to generate total greenhouse gas emissions.

Fuel economy

The U.S. Federal Highway Administration publishes annual fuel economy estimates for each state. Average fuel economy within Boston is estimated using data from the Massachusetts Vehicle Census for the 2009-2014 period, and is estimated for other years using a factor of 1.015 (percent change per year out to 2040 per the U.S. Energy Information Administration's table of light-duty fuel economy).[9]

Transportation – Transit

The MBTA provides data on its annual system-wide usage of gasoline, diesel, electricity, natural gas, steam and fuel oil. Starting in 2008, the MBTA was able to separate natural gas usage for vehicles and buildings. We used the 2008 system-wide natural gas usage by vehicles (that is, CNG) as an estimate for 2005 to 2007. Natural gas usage by buildings is included in the commercial/industrial sector number. Starting in 2012, we have introduced two adjustments to the MBTA's data, both of which have been applied all the way back to 2005.

The MBTA's system electricity data include usage for both transit vehicles and buildings. According to the MBTA, this breaks down to about 60 percent for trains and 40 percent for buildings. To prevent double-counting, the electricity use for MBTA is subtracted out of the total commercial/industrial electricity consumption data reported by Eversource.

We have further reduced the electricity, gasoline, diesel, and CNG numbers to reflect estimates of the proportion of activity, as determined by the MBTA, that takes place within Boston's geographic boundaries.

- The MBTA estimates 64% of Boston's rapid transit system lies within Boston. We applied this factor to the vehicle portion of MBTA's electricity consumption (approximately 60% of overall electricity use).
- The MBTA estimates 48.4% of bus VMTs occur within Boston boundaries, taking into account bus routes and frequency of service. We applied this factor to the MBTA's system-wide diesel, CNG, and gasoline consumption.
- The Charlestown ferry line is the only one that operates entirely within Boston's boundaries.

[9] U.S. Energy Information Administration, Annual Energy Outlook 2023, Transportation: Energy Efficient Indicators: Light-Duty Stock, 13 April 2023, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2018&region=0-0&cases=ref2018&start=2016&end=2050&f=A&linechart=~ref2018-d121317a.33-7-AEO2018&map=&ctype=linechart&chartindexed=0&sourcekey=0

Transportation – Off-Road Vehicles and Equipment

Off-road vehicle emissions are categorized in the inventory according to the owner of the equipment. This primarily concerns MBTA, MWRA and Massport. For the purposes of the GPC, only activities occurring within Boston's boundaries (Scope 1) emissions are included.

The MBTA reports gasoline and diesel use by non-revenue generating vehicles, or service fleet vehicles, for the commuter rail.

MWRA reports vehicle consumption data for gasoline and diesel based on fuel receipts and DITP emissions reports. MWRA indicates that 38% of reported vehicle fuel is solely used on-site at Deer Island.

Massport reports energy use data for ground support equipment, Massport Fire Rescue and agricultural equipment.

Waste – Solid Waste Disposal

Emissions traditionally associated with waste are included within Boston's stationary emissions for the purposes of the community inventory. As far as we have been able to determine, almost all waste collected in Boston, both residential and commercial, is burned in power plants that use the waste to produce electricity. The GHG emissions generated in this process are included in ISO-New England's calculation of the GHG emissions factor for electricity. To include a separate GHG figure for waste would, therefore, be double-counting.

The City of Boston remains committed to reducing solid waste in Boston, and is currently undertaking the *Zero Waste Boston* planning initiative.[10] The City also publishes its figures on waste collection in its City Score reports.[11]

Waste – Wastewater

The Massachusetts Water Resources Authority (MWRA) and the Boston Water and Sewer Commission (BWSC) both provide service for Boston. The water and sewer category here includes only the MWRA; see the municipal inventory for separate BWSC emissions, which are incorporated into the industrial, commercial and **institutional** category of the community inventory.

[10] City of Boston, *Zero Waste Boston*, 13 April 2023, https://www.boston.gov/departments/environment/zero-waste-boston
[11] City of Boston, *City Score*, 13 April 2023, http://www.cityofboston.gov/bar/

The MWRA provides water and sewer services to 2.5 million people and more than 5,500 businesses in 61 communities in eastern and central Massachusetts. At our request, the MWRA allocated to Boston its pro rata share of the total annual energy used based on measurements of actual water and sewer flows.

The MWRA data may entail some double-counting related to electricity and natural gas consumption. Boston accounts for about one-third of MWRA system usage. A few MWRA buildings outside of the Deer Island complex are likely included in the industrial, commercial and institutional energy consumption data reported by National Grid and Eversource. However, given the MWRA electricity and natural gas use is likely negligible, the inventory does not seek to remove any double-counting consistent with a conservative approach.

OTHER ANALYSES

As indicated earlier, the inventory does not include emissions from airplane travel at Logan Airport. An order-of-magnitude calculation conducted in 2018 based on average airline travel by U.S. residents suggests that the inclusion of emissions from airplane travel by Boston residents would add on the order of one million tons of CO2e to the annual inventory.

The inventory also does not include consumption-based emissions, or emissions associated with the production, transportation, and waste disposal of all food and other goods consumed by Bostonians. We made another order-of-magnitude calculation using average consumption data from the U.S. Consumer Expenditures Survey conducted by the Bureau of Labor Statistics and emissions factors from the Berkeley Institute of the Environment, University of California, Berkeley. This calculation conducted in 2018 suggested that life-cycle emissions from consumption in Boston were on the order of five million tons CO2e.

Both of these calculations are very rough and could easily vary, up or down, by a factor of 2 or more.

Construction emissions are not disaggregated. We are investigating different methods to better document and report these emissions.

Comments and suggestions pertaining to the treatment of airplane travel, construction emissions and consumption-based emissions are welcome.

APPENDIX: DATA REVISIONS

2020-2021 data notes:

- The City revised its methodology regarding the steam emissions factor. Previously, all emissions associated with steam brought into the City from the Kendall cogeneration plant were associated with the electricity generated by the cogeneration process, with no emissions associated with the steam generated, treated as a byproduct. The emissions factor has since been updated to account for emissions associated with steam production by allocating a portion of the plant's emissions to steam production using the efficiency method. The methodology change is further detailed later in the methodology document that may be accessed on our website. The change in methodology took effect for the 2020 and 2021 inventories, and was applied to 2018 and 2019 inventories. Insufficient data is available to make the change in methodology retroactive to 2005.
- The Census Bureau did not release its standard 2020 American Community Survey 1-year estimates because of the impacts of the COVID-19 pandemic. As a result, we used the 2019 number of households with heating oil as a placeholder for the 2020 inventory. The 2021 ACS 1-year estimate was used for the 2021 inventory.
- MBTA data is largely reported based on the fiscal year rather than the calendar year.

2018-2019 data revisions:

- Revised steam emissions factors were applied to the 2018 and 2019 inventories following the adoption of the efficiency method for steam emissions allocation for the 2020 and 2021 inventories.

2016 data revisions:

- The Boston Metropolitan Planning Organization's Central Transportation Planning Staff (CTPS) released an updated model that estimates vehicle miles traveled (VMT) for passenger vehicles, freight vehicles and other transportation modes. The new model estimates VMTs in a baseline year, 2016, and a future year (2040). We then linearly interpolated between the two years to determine annual VMTs. We also linearly interpolated between the CTPS 2016 baseline year and our 2005 inventory baseline year to include both passenger vehicle and freight VMT estimates throughout our inventory period.
- We have included newly available fuel use data from the Massachusetts Bay Transportation Authority, including service vehicle fuel use, gasoline for the paratransit program THE RIDE, and additional building fuel use, allowing for more granular reporting. This data was available for FY 2009 to FY 2016. We used passenger load, derived from MBTA Bluebook reports, to estimate fuel use for the FY 2005 to FY 2008 period.

- We included additional energy consumption data not related to air travel from Massport. Previous inventories included energy use data for ground support equipment and auxiliary power units. This has been expanded to include the Massport Shuttle Bus, the Massport Express Bus, the Massport Fire Rescue, agricultural equipment and Massport fleet vehicles.
- Previous iterations of the community inventory included vehicle fuel use for Boston Public School buses. The inventory has been updated to report municipal vehicle fleet fuel use line by line, including biodiesel and propane.
- One notable correction in accounting methodology since the 2015 inventory was a double-count identified in fleet fuels. When the City began reporting vehicle fuels based on delivery point in FY15, it did not account for the fact that Boston Public Health Commission (BPHC), and Emergency Medical Services (EMS) fueled their vehicles at Department of Public Works (DPW) and Boston Fire Department (BFD) fueling stations. Fueling reports from BPHC and EMS were counted separately, even though said fuel use was already included in the DPW and BFD. This correction results in an approximately 141,000 gallon reduction between diesel and gasoline for the FY15 inventory. The correction is included in the new FY16 inventory, and all years FY05-FY14 are not impacted by this correction.

2015 data revisions:

- We discovered a few areas where we received data from dual sources that resulted in a double count of energy use. Adjustments have been made for all discovered sources and applied back to the baseline year.
- Accounting for the Deer Island Wastewater Treatment Plant and other Massachusetts Water Resources Authority (MWRA) buildings inside of Boston has been adjusted. Historically we attributed a percentage of the MWRA system-wide energy use to Boston, based on Boston's pro rata share of wastewater treated. After reevaluation of the GPC guidelines, we decided that a better method was to attribute all the energy used at Deer Island and any other facilities inside Boston to Boston at 100%, and apply a proportion reflecting just Boston's contribution to the wastewater effluent and processing emissions. Other emissions from treated wastewater are not included because it is released far into the harbor, outside of Boston.
- The Boston Metropolitan Planning Organization's Central Transportation Planning Staff (CTPS)[12] released an updated model that estimates vehicle miles traveled (VMT). This model estimates VMTs in a baseline year, 2012, and a future year (2020). They then linearly interpolate between the two years to determine annual VMTs.

[12] Central Transportation Planning Staff (CTPS). November 20, 2017, http://www.ctps.org/