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| **Memo to:** Bronwyn Cooke, City of Cambridge |  | **Date:** Aug. 2, 2016  (Updated March 31, 2017) |
| **From:** Jim Leahy, Ben Butterworth, Matthew Fitzgerald, DNV GL |  |  |
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| **Copied to:** Betty Seto, DNV GL, Manisha Bewtra MAPC |  |  |
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| **Re:** Technical Memorandum - Community-wide GHG Inventory and Forecasting Methodologies | | |

This Technical Memorandum summarizes the inventory and forecasting methodologies used for the City of Cambridge Community-wide GHG Inventory. The inventory and forecasting methodologies are described in detail in this document. A summary of the methodologies is also provided in Section 3 of the final report (provided as a separate document). Each section below is structured similarly to the report so that the content can be incorporated directly into the final inventory and forecast report.

# Inventory and Forecasting Methodology

## Understanding a Greenhouse Gas Emissions Inventory

Greenhouse gas emissions inventories are developed to help government leaders and corporate managers understand how greenhouse gas (GHG) emissions are associated with various activities in their community or business. For cities, GHG emissions are generally compiled at both the community scale and at the government operations scale. Emissions associated with government operations including fuel use from fleet vehicles and energy use in city government buildings, are included as part of the community-wide inventory.

The report presents the GHG emissions from the Cambridge community as a whole. The community-wide inventory follows the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) which was developed by the World Resources Institute, C40 Cities, and ICLEI Local Governments for Sustainability and is required by The Global Covenant of Mayors for Climate and Energy (Global Covenant)[[1]](#footnote-2), of which Cambridge is a member.

## Global Protocol for Community-Scale Greenhouse Gas Emission Inventories

The GPC was designed to provide guidance to local governments across the globe on developing effective community GHG emissions inventories. It establishes the reporting requirements for all community GHG emissions inventories and provides detailed accounting guidance for quantifying GHG emissions associated with a range of emission sources and activities. The GPC also provides several optional reporting frameworks to help local governments customize their community GHG emissions inventory reports based on the data that is available, local goals and capacity.

Using this protocol will advance the City’s efforts to reduce and manage climate change impacts and will assist the City in fulfilling the commitments it has made to the Global Covenant. The inventory provides the necessary foundation to advance and enable Cambridge’s work towards reaching GHG reduction targets, developing targeted strategies to reduce emissions, engaging specific sectors to promote emissions reductions, and tracking the community’s progress towards meeting their goals.

## Emission Sectors and Sources

The Cambridge community-wide inventory accounts for emissions from the following sources, as required by the GPC:

* Stationary energy use from residents, businesses and other activities
* On-road and off-road transportation
* Solid waste and wastewater disposal and treatment

As part of this process, the City assessed the possibility of including emissions from product use, industrial processes, and land-use; however, to the limited data for these activities, they were not included. Agriculture, forestry are other sources of 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.

Table 1 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 |
| Commercial | Energy use in commercial, government and institutional buildings as well as losses from distribution systems |
| Manufacturing and Construction | Energy use in industrial facilities, and processes as well as losses from distribution systems and construction equipment |
| Energy Industries | Stationary combustion of fuel in various equipment, such as boilers and generators. | Various – may include natural gas, propane, and diesel |
| Transportation | Transportation | All on-road vehicles  Railways  Off-road vehicles/equipment | Gasoline  Diesel  Electricity |
| Waste | Solid Waste | Landfills  Incineration of waste generated in the city | Landfill gas (methane) |
| Wastewater | Process and fugitive emissions from treating wastewater | Not applicable |

## Geographic Boundary

Cambridge has undertaken this community-wide greenhouse gas inventory primarily to advance the City’s efforts towards managing and mitigating climate change. The inventory will also assist in developing strategies in the future to reduce emissions. The ability to influence and support actions however, are limited by social, economic and physical boundaries. It’s important that the boundaries for the emissions inventory and action plans are well defined. The GPC requires the cities identify a geographic area for the inventory that most appropriately serves the purpose of the inventory. As a result, the City has chosen to utilize the administrative boundary of the City of Cambridge as the geographic boundary for this community-wide inventory.

Establishing a community-wide inventory that is focused on the emissions occurring within the administrative boundary enables Cambridge to develop emissions forecasts that directly relate to the future of the City, and our goals for reducing city-wide emissions. As outlined in the GPC, establishing this geographic boundary does not exclude emissions related to city activities that occur outside the City limits (e.g. electricity generation or landfilled waste emissions).

## Baseline Year and Forecast Years

The calendar year 2012 was chosen as the baseline year for this inventory based on availability and quality of data. One of the main benefits of selecting 2012 as the community-wide inventory year is that it also coincides with the City’s 2012 Municipal Operations Inventory. Timing municipal operations and community inventories to occur on the same years will enable improved coordination between municipal-level and community-level emission reduction goals.

For the forecast years, we chose to use 2030, 2040 and 2050 to align the City’s Net Zero Action Plan, and Climate Protection Action Committee’s (CPAC) Roadmap for the City’s role in the global response to climate change. Between 2015 and 2040 the city will undertake a series of actions identified in the Net Zero Action Plan that are anticipated to result in a 70% emissions reduction from the buildings sector. The CPAC roadmap also provides a framework for actions to reduce emissions 80% by 2050. In addition, the 2050 goals align with the State’s commitment to reduce emissions reductions 80% by 2050 according to the Global Warming Solutions Act of 2008.

Aligning the emissions forecast years with these time horizons may also result in the added benefit of placing Cambridge’s greenhouse gas inventory and reduction goals on the same timeline other goals outlined in the forthcoming Envision Cambridge plan relating to housing, mobility, climate and the environment.

## Quantifying Greenhouse Gas Emissions

All emissions in this inventory are quantified using calculation-based methodologies, which calculate emissions using activity data from each reporting sector identified in the GPC and emission factors. To calculate emissions accordingly, the basic equation is:

Activity Data (units) x Emission Factor (MT CO2e / unit) = Emissions (MT CO2e).

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 CO2 per kWh of electricity). The emission factors and the assumptions and methodologies used in composing this inventory are described below. Key activity data are listed in the inventory results section of the report (Chapter 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.[[2]](#footnote-3) 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 is primarily a Scope 2 emissions source.

**Data Summary**

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 Cambridge has a single electricity provider, Eversource, to transmit and distribute electricity. As such, Eversource was the primary source for gathering electricity consumption data in the city. Real consumption data was used to determine the electricity consumption (kWh/year) from each building sector.

When coordinating with Eversource to acquire the sector level consumption data for future inventories, the city will need to confirm that the information associated with Special Ledger Accounts is reviewed. These Special Ledge Accounts are maintained separately from the general population account data and are associated with customers who require that their account information be kept private. These types of accounts exist for both electricity and natural gas customers. Electricity use associated with these accounts was reviewed, but determined to not be useful for the 2012 community-wide inventory. Only natural gas consumption data was used for this inventory (see Section 1.6.2 for further discussion on use of Ledger Account information for emissions from natural gas).

**GPC Quantification Method Used**

In accordance with Section 6.5 of the GPC, the location-based method was used for the inventory. Reported emissions from all grid-supplied electricity consumed within the city’s boundaries were reported as Scope 2 emissions. BASIC/BASIC+ reporting avoids double counting by excluding Scope 1 emissions from electricity generation supplied to the grid.

The grid-based average emission factor is necessary due to the imprecise available supply balance of electricity generated and consumed within the city boundaries. The emissions factor used for grid supplied electricity is provided in Table 2 and is based on data from ISO New England[[3]](#footnote-4). In addition, methane (CH4) emissions as well as nitrous oxide (N2O) emissions from grid supplied energy also need to be taken into account to determine the total CO2 equivalent (CO2e) emissions factor. The CH4 and N2O emissions rates were gathered from the U.S. Environmental Protection Agency’s eGRID 2012 data. The emissions rates for these gases according to eGRID 2012 are 72.84 lb/GWh for CH4 and 10.71 lb/GWh for N2O. Based on these emissions rates, the total CO2e for electricity emissions was determined to be 0.00328 MT/kWh. While “islandable” microgrids are present within the city boundaries, no usage or emissions specific to these systems were defined for the baseline 2012 calendar year.

Table 2: ISO New England 2012 Electricity System Emissions Rate

|  |  |  |
| --- | --- | --- |
| Regional Transmission Organization | CO2 Emission Factor  (lbs CO2 / MWh) | CO2 Emission Factor  (MT CO2 / kWh) |
| ISO New England | 719 | 0.00033 |

### Stationary Energy – Natural Gas

The primary uses for natural gas in the City of Cambridge are for space heating, water heating equipment, and co-generation stations. The emissions from the co-generation units are attributed to fuel burned for heat, steam and electricity generation. The emissions from these sources are defined as Scope 1 emissions, although emissions from the Veolia Kendall cogeneration facility are excluded from the inventory because the emissions from energy generators greater than 25 MW in capacity are included in the ISO New England emissions factors for electricity. Energy generation supplied to the grid is also not included in Basic/Basic + reporting according to the GPC.

As previously noted, Eversource maintains a list of Ledger Accounts for both electricity and natural gas customers. These accounts are associated with customers who request that their information be kept private and that typically use a large amount of energy although that is not always the case. For the 2012 community-wide inventory, we reviewed the Ledger Account list to confirm that emissions and natural gas consumption associated with these customers match the information reported to the U.S. EPA’s Large Facilities Database and are accounted for in the inventory. For future community-wide inventories the city should request that Eversource confirm the total consumption associated with these Ledger Accounts and whether or not these accounts are in the general customer database used for the inventory.

The approaches to estimating the emissions from natural gas consumption in the buildings sectors and by the co-generation plants are summarized separately below because of the different approaches used for each.

**Data Summary**

***Building Sector***

Grid-supplied natural gas is provided throughout the city and is primarily used by the residential, commercial, and industrial sectors for heat and hot water production. The City of Cambridge also has a single provider for natural gas, Eversource. As such, Eversource was the primary source of information for natural gas consumption in the city. Metered data was used as the source of the annual therm consumption for each building sector.

In addition to the Building Sector natural gas usage, the GPC also requires the losses from distribution systems be accounted for. Based on an assessment of several studies that have been done on the subject of gas leakage from the distribution system network in and around the Boston, we determined that an average leakage rate of 0.6% was appropriate for the inventory (see [PNAS Article](http://www.pnas.org/content/112/7/1941.full.pdf)). According to the Harvard study Methane emission and Natural Gas delivery data reported to both the US Environmental Protection Agency and Massachusetts GHG Reporting Programs show loss rates of 0.4–1.6% among individual distribution companies in Massachusetts in 2012 and 2013, with an average of 0.6%, weighted by delivered natural gas volumes (Kathryn McKain, 2015).

***Co-generation Systems***

As mentioned, there are four large electricity and steam generation facilities located in Cambridge that were assessed as part of this inventory: The Kendall Cogeneration Station, the MIT Central Utilities Plant, the Harvard University Blackstone Plant, and the Biogen IDEC plant.

Consumption and emissions data for these facilities were gathered from publicly available reports provided on the U.S. EPA’s Greenhouse Gas Reporting Program website ([https://ghgdata.epa.gov/ghgp/main.do#](https://ghgdata.epa.gov/ghgp/main.do)). These facilities are required to report biogenic CO2 emissions and CO2 emissions excluding biogenic CO2 separately.

The Kendall Cogeneration Station is a 256MW steam and electricity energy plant. The primary gas turbine produces electricity and high pressure steam. This steam is recycled to power secondary steam turbines to generate additional power. For the 2012 emissions inventory, all emissions are allocated to Cambridge. In 2013, a pipeline was completed for the remaining low pressure steam waste to be integrated into Veolia's district energy system in Boston. For future inventories, it is suggested that the natural gas consumption associated with this plant be split between Cambridge and Boston based on the amount of steam provided to each city.

Harvard University manages the Blackstone Steam Plant. This plant uses four dual-fuel boilers operating primarily on natural gas. They have a service area covering a substantial portion of Harvard's campuses extending from Harvard Yard, the Law School and Divinity School in the North campus, along the River Houses, across the river to the Harvard Kennedy School, and Athletics and One Western Avenue in Allston. The boilers generate up to 5.7MW of electricity through it’s back-pressure turbine system. While steam is used on properties in Boston, the CHP plant is located within Cambridge’s boundaries, and therefore has been included in whole to this inventory. A CHP unit was added to the Blackstone plant in 2013 with an 8 MW turbine generator. While not included in the 2012 inventory, the additional capacity was included in City’s emissions forecast.

MIT’s Central Utilities Plant is a 21-megawatt natural gas turbine used to produce both electric and thermal energy for the campus. The heat recovery steam generator captures waste heat from turbine exhaust, and the captured steam is used for heating and cooling (via chillers driven by steam turbines). Emissions from this plant that were reported to the U.S. EPA were included in the 2012 inventory.

The BioGen IDEC facility is a 5.3MW natural gas turbine with a heat recovery steam generator (HRSG). This system operates in parallel with the electric utility. Emissions from this plant that were reported to the U.S. EPA were also included in the 2012 inventory.

Data used for the year 2012 in the ISO NE electricity emission factor includes units that are least 25 MW in capacity.[[4]](#footnote-5) To avoid double counting, the Kendall Co-generation Station should only be included in the Scope 1 territorial emissions. Only the emissions from the other three plants were included for GPC Basic reporting.

**GPC Quantification Method Used**

***Buildings Sector***

In accordance with Section 6.3 of the GPC, real consumption data for each fuel type, disaggregated by sector was used for the inventory. Reported emissions from the usage of natural gas within the city’s boundaries were reported as Scope 1 emissions.

Because Eversource-specific emission factors for natural gas emissions were not available, a universal emission factor provided by the Climate Registry[[5]](#footnote-6) was used to calculate natural gas emissions. The emissions factor used for natural gas consumption is provided in Table 3.

In addition, methane (CH4) emissions associated with distribution systems leakage also needs to be taken into account in the inventory. The total CO2 equivalent (CO2e) emissions factor for fugitive emissions from natural gas leakage was determined based on:

* Volume of natural gas per heat energy (m3 gas / therm gas)
* A density value of natural gas of 0.7 kg/m3 based on values provided in the GHG Protocol stationary combustion tool.
* The IPCC Tier 1 default for the mass fraction of methane in delivered natural gas (93.4%).
* A carbon dioxide content of 1.0% in the delivered natural gas.

The overall emissions factor was then calculated to be 0.04628 MT CO2e/leaked therm.

**Table 3: Natural Gas Consumption Emissions Rate**

|  |  |  |
| --- | --- | --- |
| Type of Emission | CO2 Emission Factor  (kg CO2 / MMBtu) | CO2 Emission Factor  (MT CO2 / Therm) |
| Natural Gas Consumption | 53.06 | 0.0053 |

\*Note CH4 or N2O are not included because these emissions are considered to be de minimis

***Co-generation Systems***

In accordance with Section 6.3 of the GPC, the community-wide inventory for the City of Cambridge used the Real-consumption data, disaggregated by sub-sector approach.The emissions associated with these facilities are taken directly from the EPA reports which are submitted by large facilities and use standard emissions calculation methodologies. Facilities generally have some flexibility in choosing which calculation method to use and their methods may change from year to year as long as the still meet the requirements of the U.S. EPA’s Greenhouse Gas Reporting Program.

### Stationary Energy – Fuel Oil

The baseline for energy-use in Cambridge for the residential, commercial and industrial sectors in Massachusetts communities includes fuel oil consumption as well. While electricity and natural gas heating are limited to specific municipal suppliers, fuel oil is supplied by many different private companies. Because customer data cannot be collected from each supplier, consumption must be estimated using community-specific assumptions. Any limited fuel oil usage by the Kendall Station, Blackstone plant, and MIT CUP is accounted for in the U.S. EPA Greenhouse Gas Reporting Systems reports.

**Data Summary**

For the Cambridge community-wide inventory, residential oil usage data was based on the number of housing units in Cambridge by type, and a percentage of units determined to be heated with fuel oil from the “American Community Survey (ACS) 2010-2014 5-Year Community Estimate.” The property types identified were:

1. Single-Family, Detached
2. Single-Family, Attached
3. Multi-Family, 2-4 Units (Sum of 2-Family and 3-4 Units categories)
4. Multi-Family, 5+ Units (Sum of 5-19 Units, 20-49 Units, and 50+ Units categories)
5. Other

Residential fuel oil combustion emissions were totaled using state average use and expenditure by fuel type and applied to Cambridge housing data. Massachusetts has a lower concentration of single family homes and a higher concentration of two- to four-unit apartments. To account for this when comparing an average Massachusetts home with an average New England home (averaged across all housing units), a weighted New England Average Consumption based on the percentage breakdown of housing unit types in Massachusetts was used.

For the Commercial sector, fuel oil use estimates were based on the total number of employees, establishments by Primary Building Activity (PBA), and the average expected energy use per employee for each PBA. The Executive Office of Labor and Workforce Development (EOWLD) ES-292 Employment and Wages Survey lists the number of employees and establishments by industry, sorted by North American Industry Classification System (NAICS) codes.[[6]](#footnote-7) The EIA 2012 Commercial building Energy Survey (CBECS) analyzes energy use and consumption data based on Primary Building Activity (PBA).

The crosswalk provided in Table 4 (generated by EIA) roughly correlates the PBA codes used in CBECS with standard three-digit NAICS codes between 400 and 1000.

Table 4: NAICS code crosswalk table for identifying Primary Building Activity

|  |  |
| --- | --- |
| PBA | NAICS Code (3-digit) |
| Education | 611 |
| Food Sales | 445 ­ |
| Food Service | 722 |
| Inpatient Health Care | 622 |
| Outpatient Health Care | 621 |
| Lodging | 623, 721 |
| Retail (non-mall) | 441, 442, 443, 444, 451, 452, 453, 532 |
| Retail (mall) | 446, 448 |
| Office | 454, 486, 511, 516, 517, 518, 519, 521, 522, 523, 524, 525, 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/ Storage | 423, 424, 493 |
| Other | 562, 927 |

Certain data required alternate collection methods due to a lack of direct employee data. PBA’s with incomplete data used one of two options for estimating the missing data for the purposes of this baseline:

* Option 1: Compare average fuel oil use to average natural gas use in the same building types, using Office buildings as a baseline. For example, if a PBA that uses natural gas uses 50% more natural gas than an Office building, assume that if the same PBA used fuel oil, it would use 50% more fuel oil than an Office building. This is the preferred method, as it yields a more conservative estimate.
* Option 2: Find average fuel oil consumption for an average New England building (across all PBAs) and divide

For the industrial sector, data was collected similarly to Commercial data. The total number of employees and establishments by PBA, and the average expected energy use per employee for each PBA. EOWLD ES-202 Survey lists the number of employees and establishments by industry, sorted by NAICS codes.[[7]](#footnote-8) This sector encompasses NAICS codes between 311 and 339 as shown in Table 5. Industrial energy uses between 100 and 200 (such as power generation and utility operations) were not incorporated in this methodology. The EIA 2012 Manufacturing Energy Consumption Survey (MECS) analyzes energy use and consumption data based on Primary Building Activity (PBA).

Table 5: Industrial NAICS Codes

|  |  |  |  |
| --- | --- | --- | --- |
| NAICS\_3 | Industry | NAICS\_3 | Industry |
| 311 | Food | 326 | Plastics and Rubber Products |
| 312 | Beverage and Tobacco Products | 327 | Nonmetallic Mineral Products |
| 313 | Textile Mills | 331 | Primary Metals |
| 314 | Textile Product Mills | 332 | Fabricated Metal Products |
| 315 | Apparel | 333 | Machinery |
| 316 | Leather and Allied Products | 334 | Computer and Electronic Products |
| 321 | Wood Products | 335 | Electrical Equip., Appliances, and Components |
| 322 | Paper | 336 | Transportation Equipment |
| 323 | Printing and Related Support | 337 | Furniture and Related Products |
| 324 | Petroleum and Coal Products | 339 | Miscellaneous |
| 325 | Chemicals |  |  |

As previously mentioned, fuel oil consumption from the Kendall Cogeneration Station, Blackstone plant, and MIT CUP are reported directly from the EPA Greenhouse Gas Reporting Program submittals and therefore were not estimated here.

**GPC Quantification Method Used**

In accordance with Section 6.3 of the GPC, the emissions from these Stationary Energy sources are calculated by multiplying activity data by the corresponding emission factors for each fuel. Estimated energy consumption by fuel type, applicable consumption rates, and the total quantity of energy consumption overall are used to obtain a percentage that can be used to approximate how much of each fuel type is used by each sector in the community.

As detailed above, a collection of representative consumption surveys, modelled energy consumption, and regional fuel consumption data was used to properly characterize the City of Cambridge emissions. Being that there is likely a higher number of employees per square foot in Cambridge than industry averages, oil consumption emissions are likely overestimated in this inventory.

### Stationary Energy – Off-Road Vehicles and Equipment

Mobile machinery emissions that occur off public roadways are also included in this inventory. The off-road mobile activities are categorized according to the area where they occur. For the purposes of the GPC, only activities in the city (Scope 1) emissions are included.

**Data Summary**

The off-road data is derived from a publicly available U.S. EPA emission modeling system called the Motor Vehicle Emission Simulator (MOVES). MOVES estimates emissions for mobile non-road sources at the national and county level for criteria air pollutants, greenhouse gases, and air toxics. Proportional emissions data were extracted from the county-level data based on the ratio of landscaped area in Cambridge versus the total landscaped area in Middlesex County determined by a GIS geospatial analysis.

The MOVES2014 modeling tool multiplies equipment population, average load factor expressed as an average fraction of available power, available power in horsepower, hours of use per year, and emission factors with deterioration and/or new standards. Emissions are then temporally and geographically allocated using appropriate allocation factors. This produces emissions estimates attributable to many non-road activities but does not include aircraft, commercial marine vessels, or rail, which are the primary non-road transportation sources contributing to GHG emissions.

Construction related fuel emissions were estimated using the work-in-place (WIP) method and fuel factor from the "GHG and Criteria Air Pollutants Emissions Inventory for the Port Authority of New York and New Jersey", CY 2011. The WIP method uses an established emissions rate estimate per dollar of construction value (i.e. the dollar amounts for construction contracts). The total annual cost of construction in Cambridge was determined using the "Cambridge Open Data, Commercial and Multifamily Building Permits, Building Cost of Construction."

Table 6 summarizes the methodologies used for each of the off-road emission sources.

Table 6: Off-road Emissions Sources and Methodologies

|  |  |  |
| --- | --- | --- |
| Off-Road Mobile Emission Source | Proportionality Multiplier Source | Category |
| Commercial Activity | Retail Jobs Ratio | Commercial |
| Industrial Activity | Manufacturing Jobs Ratio | Industrial |
| Lawn and Garden | Percentage of Permeable Surface Area | Commercial |
| Construction | PA of NY WIP Method | Commercial |

**GPC** **Quantification Method Used**

In accordance with Section 6.3 and 7.7 of the GPC, the community-wide inventory used the modeling tool MOVES2014a data, disaggregated by sub-sector. Construction data will be using industry market-based calculation.

Emissions factor modeling parameters in MOVES2014a were developed and used to produce emissions factors and emissions output was restricted to the Middlesex County geographic bounds, the smallest subdivision possible in the model.

### Transportation – On-Road

**Data Summary**

The Massachusetts Vehicle Census (MAVC) is a catalog of information about vehicle registered in the Commonwealth from 2009 to 2014. The Vehicle Census combines information from vehicle registrations, inspection records, mileage ratings, and other sources to document the ownership and mileage history of each vehicle. The MAVC was mined for passenger and commercial vehicles garaged in Cambridge from vehicle inspections during quarter 2 of 2012. The data includes cars garaged in Cambridge including commercial vehicle fleets and rental cars available in Cambridge.

The MAVC provided the data on the number of vehicles in Cambridge, average vehicle miles travelled (VMT), average fuel efficiency of vehicles and fuel consumption of vehicles broken down by both fuel type and passenger vs. commercial vehicles. Fuel types included gasoline, diesel, flex fuel, hybrid, and electric. See Table 7 for summary of data collected.

Table 7: Detailed Attributes Reported for On-road Vehicles Garaged in Cambridge

|  |  |
| --- | --- |
| Attribute | Details |
| Count | Total vehicles based town vehicle is registered in |
| Average Miles per Day | Average daily mileage for vehicles with a valid inspection record |
| Average VMT per Day | Average daily mileage for vehicles with a valid inspection record multiplied by the vehicle count |
| Average VMT per Year | Average daily mileage for vehicles with a valid inspection record multiplied by the vehicle count and by 366 (2012 was a leap year) |
| Average VMT by Vehicle per Year | Average annual mileage divided by the count of vehicles with a valid inspection record |
| Average Fuel Efficiency (mpg) | Average fuel economy for vehicles with valid mileage estimates, weighted by average daily mileage. Calculated as total estimated fuel consumption (gal\_per\_day) for vehicles with valid mileage estimates and fuel economy ratings, divided by total daily miles for same vehicles. |
| Fuel Consumption per Year | Average VMT per year divided by the average fuel efficiency |

***2010 Comparison with ACS Vehicle Availability Data***

To further explore the accuracy of the dataset, MAVC was compared to the American Community Survey (ACS) vehicle availability data by census tract and Cambridge residential parking permit data from the City of Cambridge’s Department of Traffic, Parking, and Transportation. In 2015, MAPC conducted an analysis that compared the MAVC to ACS Vehicle Availability[[8]](#footnote-9). The ACS vehicle availability question was asked of occupied housing units. The data shows the number of passenger cars, vans, and pickup or panel trucks of one-ton capacity or less kept at home and available for the use of household members. Vehicles rented or leased for one month or more, company vehicles, and police and government vehicles were included if kept at home and used for non-business purposes. Dismantled or immobile vehicles were excluded. Vehicles kept at home but used only for business purposes also were excluded[[9]](#footnote-10).

MAPC found that the MAVC total vehicle estimate and the ACS vehicle availability estimate for the City of Cambridge were not statistically significantly different from one another. The difference between the estimates was 193 vehicles, which was less than a 1% difference from one another. See Table 8 below.

Table 8: Cambridge MVAC and ACS Summary Comparison (Quarter 2, 2010)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| MAVC Total Vehicles | ACS Vehicle Availability | ACS Margin of Error | Difference (ACS - MAVC) | Percent Difference |
| 41,641 | 41,448 | 1,081 | -193 | -0.46% |

MAPC also examined differences at the census tract level. Seventy-two percent of census tracts (23 of 32 census tracts) had similar estimates for both the ACS and MAVC total vehicle estimates. Of the nine census tracts that had different estimates, the ACS estimate was greater than the total vehicle MAVC estimate in six census tracts and less than the total vehicle MAVC estimate in three census tracts. See Figure 1 below.

Figure 1: MVAC Total Vehicle and ACS Vehicle Availability Comparison by Census Tract

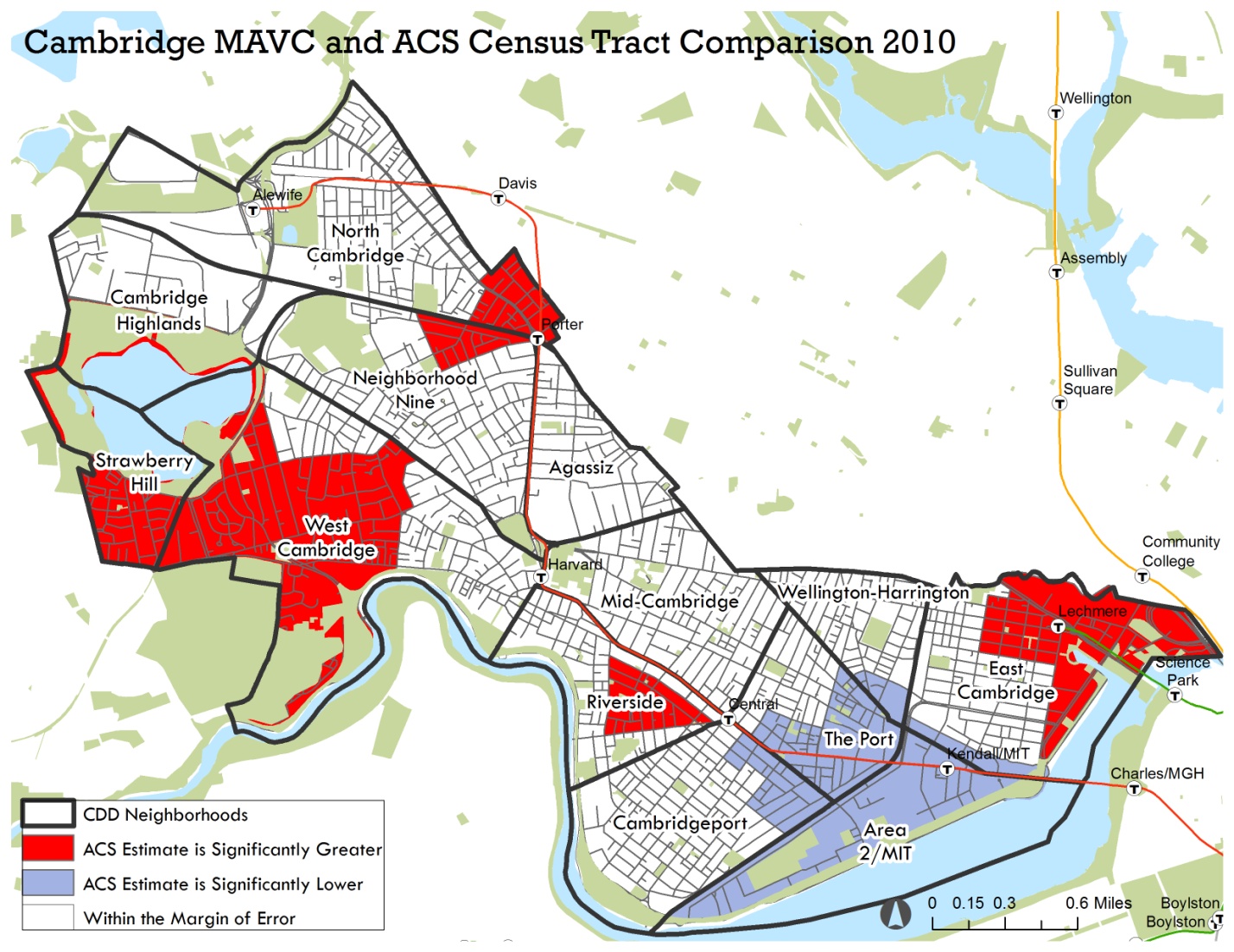


Table 9 shows the differences between the MAVC and ACS estimates. The difference between these two estimates for these nine census tracts is 522 vehicles.

Table 9: Cambridge MVAC Total Vehicle and ACS Vehicle Availability Comparison by Census Tract (Quarter 2, 2010)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Census Tract | MAVC Total Vehicles | ACS Vehicle Availability | ACS Margin of Error | Difference (ACS-MAVC) | Percent Difference |
| 25017352101 | 353 | 815 | 137 | 462 | 130.9% |
| 25017353500 | 1,025 | 1,326 | 173 | 301 | 29.4% |
| 25017354300 | 1,503 | 1,844 | 206 | 341 | 22.7% |
| 25017354700 | 1,187 | 1,414 | 150 | 227 | 19.2% |
| 25017352102 | 1,259 | 1,488 | 198 | 229 | 18.1% |
| 25017354200 | 1,986 | 2,261 | 205 | 275 | 13.9% |
| 25017352400 | 696 | 543 | 113 | -153 | -22.0% |
| 25017353101 | 755 | 545 | 125 | -210 | -27.8% |
| 25017353102 | 1,231 | 280 | 88 | -951 | -77.3% |
| **Total** | **9,994** | **10,516** | **480.6** | **522** | **5.2%** |

It is possible that the ACS underestimates university vehicles as the ACS’s survey universe is occupied housing units. There is also potential for more double counting in the ACS because the question asks about vehicle availability while the MAVC draws from registered vehicles.

***2010 Comparison with Cambridge Resident Parking Permit Data***

MAVC passenger vehicle estimate data was also compared to residential parking permit data provided by the City of Cambridge. The MAVC passenger vehicles data was compared to the permit data because commercial vehicles would likely not be included in the permit data. It was found that MAVC passenger vehicle estimate was approximately 7% higher than the Cambridge residential parking permit data, a difference of approximately 3,000 vehicles. See Table 10 below.

Table 10: Cambridge MAVC Passenger Vehicle and Cambridge Parking Permit Comparison (2012)

|  |  |  |  |
| --- | --- | --- | --- |
| MAVC Passenger Vehicles | Resident Permits | Difference (Passenger MAVC - Permit) | Passenger MAVC Percent Difference |
| 41,483 | 38,521 | 2,962 | 7.1% |

***Electric Vehicle Charging Data***

Scope 2 electricity emissions associated with the on-road transportation sector were also quantified. MAPC contacted ChargePoint, an electric vehicle (EV) charging network company. In 2012, the City of Cambridge worked with ChargePoint to install 25 EV charging stations[[10]](#footnote-11). ChargePoint provided the number of EV charging ports in 2012 and their total electric fuel use for the year.

Table 11: EV Charging Ports and Electric Fuel Use in Cambridge (2012)

|  |  |  |
| --- | --- | --- |
| Total ChargePoint Ports | Electric Fuel (MWh) | Average Fuel Use per Station (MWh) |
| 25 | 14.47 | 0.5788 |

**GPC Quantification Method Used**

In accordance with Section 7.3 of the GPC, the resident activity method was used to quantify on-road transportation emissions in Cambridge. This method quantifies emissions from transportation activity undertaken by city residents and businesses that garage their vehicle in the city.

There are several methodologies recommended by the GPC for calculating on-road transportation emissions. There are a few key benefits of the resident activity method. The MAVC data used for the resident activity methodology is free and will be available to the City on an annual basis, ensuring that this methodology can be replicated in future years. Some commonly used methodologies such as the in-boundary and origin-destination methodologies for calculating on-road transportation emissions require costly modeling that can be difficult to replicate from year to year. Secondly, the resident activity methodology is a good approach when double counting with other cities in the region is a concern. 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.

**Emissions Factor Used**

Diesel and gasoline emission factors are from TCR and electricity emission factor is from ISO New England as provided in Table 12.

Table 12: Public Transit Emission Factors

|  |  |  |  |
| --- | --- | --- | --- |
| Fuel Type | Emission Factor | Emission Factor Units | Source |
| Gasoline | 0.01032 | MT CO2e / gallon | TCR |
| Diesel | 0.01033 | MT CO2 / gallon | TCR |
| Electricity | 0.000353802 | MT CO2 / kWh | ISO New England |

### Transportation – On-Road Bus

**Data Summary**

As of the writing of this report, the MBTA is not able to distinguish between electricity used for trains and trackless trolleys and that used for buildings. Based on conversations with MBTA representatives, an estimated 60% of their total system-wide electricity consumption is used to power these vehicles, and the remaining 40% powers buildings. When the City of Boston conducted their GHG inventory, they also applied the 60% estimate to the total MBTA system-wide electricity usage to arrive at an estimate of electricity used for trains and trackless trolleys. Boston then estimated that 61% of the MBTA’s rapid transit system is contained within the City of Boston, presumably by track mileage. They applied this percentage of the transit system contained within the City of Boston to proportion of MBTA system-wide electricity consumption allocated to transit to arrive at Boston’s share of electricity consumption associated with MBTA trains and trackless trolleys. A similar approach was used for Cambridge.

***Heavy Rail, Light Rail, Trackless Trolley***

The City of Cambridge is served by three modes of public transit that are powered by electricity - heavy rail (the red line), light rail (the green E line), and trackless trolleys (bus routes 71, 72, 73, and 77A). The MBTA has one primary account for its electricity usage. As mentioned, they estimate that 60% of their electricity use is for operating their transit system and 40% is for powering buildings.[[11]](#footnote-12) For the Cambridge Community-wide Inventory, the system-wide electricity use was multiplied by 60% to arrive at an estimate of electricity used for the three electricity-dependent transit modes.

Primarily because of the trackless trolley system, MAPC did not estimate the proportion of electricity used in Cambridge based purely on route or track mileage. Instead, the transit electricity usage was broken down by transit mode based on annual vehicle miles travelled for each mode. In calendar year 2012, of the total VMT for modes that use electricity, 78.4% was from heavy rail (red, blue, orange lines), 19.4% was from light rail (green lines), and 2.2% was for trackless trolley lines. MAPC applied these percentages to the system-wide estimate of electricity used for the transit system to arrive at system-wide estimates for each mode.[[12]](#footnote-13)

MAPC then estimated the percentage of electricity use for each mode that should be allotted to Cambridge. For heavy rail, this estimate was based only on the percentage of the system’s heavy rail track that lies within the boundaries of Cambridge (10.7% or 4.2 of 39.1 system miles). For light rail and trackless trolley, the Cambridge percentage was based on an estimate of annual vehicle miles traveled. Route miles and VMT estimates used in these calculations are provided in Table 13.

Light Rail VMT was estimated based on the schedules published in the 2014 edition of the MBTA’s Blue Book. MAPC estimated a weekday, Saturday, and Sunday frequency by line, then calculated an estimate of the annual number of trips by line using the following formula:

Annual count = (weekday \* 254) + (Saturday \* 54) + (Sunday \* 58)[[13]](#footnote-14)

This frequency was then multiplied by total route length of the corresponding line to arrive at annual VMT by line. The length of the E line contained within the city of Cambridge was multiplied by number of annual E line trips to arrive at an E line VMT estimate for the City. The percentage of VMT within the City of Cambridge was multiplied by the light rail electricity estimate for 2012 to arrive at an estimate for Cambridge’s contribution.

Trackless Trolley VMT was estimated based on General Transit Feed Specification (GTFS) schedule data from March 2012.[[14]](#footnote-15) MAPC created a relational database to connect the calendar table to the trip table by the service ID, which is a unique identifier for days that have the same schedule. Trip counts were then determined by line and service, then selected the maximum number of trips for each line for a Wednesdays, Saturdays, and Sundays. MAPC came up with an annual estimate for number of trips by line using the formula above. This frequency was multiplied by the total mileage of each route and the route length contained within the City of Cambridge to arrive at a percentage of trackless trolley VMT within the City. This percentage was then multiplied by the system-wide estimate of trackless trolley electricity use to arrive at an estimate for Cambridge’s use.

***Commuter Rail***

To estimate the amount of diesel fuel consumed by the Commuter rail within the City of Cambridge, the total system-wide diesel fuel consumption in calendar year 2012 was multiplied by the percentage of the commuter rail track system contained within Cambridge. We counted both revenue and non-revenue commuter rail diesel consumption.

***Bus***

We estimated diesel and CNG consumption by busses within Cambridge by applying the percentage of revenue bus VMT within the City to the system-wide diesel and CNG consumption by busses from calendar year 2012.[[15]](#footnote-16) We estimated bus VMT using GTFS data following the same method as for trackless trolley VMT.

Table 13: MBTA Routes Miles Estimates

|  |  |  |  |
| --- | --- | --- | --- |
| Transit Type | Cambridge Route Miles | System Miles | Cambridge pct |
| Red line (heavy rail) | 4.2 | 39.1 | 10.7% |
| E line (light rail) | 0.4 | 22.8 | 1.8% |
| Fitchburg line (commuter rail) | 3.4 | 438.5 | 0.8% |
| **Transit Type** | **Cambridge VMT** | **System VMT** | **Cambridge pct** |
| Trackless trolley | 898,588.8 | 1,601,904.0 | 56.1% |
| Bus | 1,439,501.7 | 40,933,536.6 | 3.5% |

**GPC Quantification Method**

Trackless trolley and bus emissions were calculated in accordance with Section 7.3 of the GPC. Heavy rail, light rail, and commuter rail emissions were quantified in accordance with Section 7.4 of the GPC.

**Emissions Factor Used**

Diesel and CNG emission factors are from TCR and electricity emission factor is from ISO New England as provided in Table 14.

Table 14: Public Transit Emission Factors

|  |  |  |  |
| --- | --- | --- | --- |
| Fuel Type | Emission Factor | Emission Factor Units | Source |
| Diesel | 0.01033 | MT CO2e / gallon | TCR |
| CNG | 0.05306 | MT CO2 / MMBTU | TCR |
| Electricity | 0.000353802 | MT CO2 / kWh | ISO New England |

### Waste – Solid Waste Disposal

For the City of Cambridge, solid waste consists mainly of Municipal Solid Waste (MSW), but is collected by various entities. About 30% of the MSW is collected as part of the municipal curbside pick-up programs. The other 70% is collected by private haulers that work for larger multi-family complexes or commercial facilities. To calculate the emissions associated with solid waste, information is needed on the amount of solid waste collected from residents and businesses as part of the curbside pickup, as well as the amount of solid waste collected by private haulers. Information on where the MSW is disposed of is also needed.

The main source of information for MSW generated was city waste collection and disposal records provided by the City Department of Public Works. Public Works maintains detailed records on the tonnage of MSW collected by individual trucks serving the city. They also maintain statistics on waste from other municipal operations such as tree stump removal, pavement and street cleaning operations, and catch basin debris. This is considered “Mixed Waste.” The total amount of MSW collected by municipal services is the Curbside Pickup plus the Mixed Waste. Public Works also collects detailed information on the curbside recycling programs as well; however, because no emissions are generated from disposal of recycled materials, they are not included in the totals.

In 2012, the contractor for municipal services was Waste Management Inc., however there was a period of time during that year in which curbside pickup was performed by Republic Services, Inc. The recorded tonnage collected by each of these companies was used to generate the annual tonnage collected by municipal services.

The amount of MSW collected by private haulers was much more difficult to obtain. In the absence of this information, MSW production estimates based on square footage of commercial properties needed to be used to estimate the amount of MSW collected. There is very limited industry data available on the amount of waste produced by commercial properties on a square footage basis, so for this assessment, a commercial facilities waste generation factor developed by the County of Los Angeles Department of Regional Planning[[16]](#footnote-17)of 0.005 lbs/sf/day was used. The total square footage of commercial properties was estimated based on the known approximate total square feet of buildings in Cambridge (~127,000,000 sf), and the total square footage of buildings over 50,000, which are covered by the Building Energy Use Disclosure Ordinance reported data and are unlikely to be serviced by DPW (73,541,605 sf). The amount of waste that is estimated to be handled by haulers was calculated to be 67,107 short tons per year.

On average, ~65% of MSW in Massachusetts is diverted to combustion facilities. This data is based on the Massachusetts Department of Environmental Protection (MA DEP) 2014 Solid Waste Update. Cambridge-specific data on percent of waste landfilled vs. combusted was not available. In Massachusetts, the incinerated waste is used to produce electricity. Emissions generated as a result of incineration out of city boundaries is considered Scope 3 emissions. According to the GPC waste to generate energy is considered a stationary energy source, but because this is a stationary energy source outside the city boundary it was not included in the inventory. Some portion of emissions from waste to energy are allocated to Cambridge through the regional electricity emissions factor.

**GPC Quantification Method Used**

GHG gas emissions associated with solid waste disposal are carbon dioxide (), methane (), and nitrous oxide (). For waste sent to landfill, methane emissions were calculated using equations 8.1, 8.3, and 8.4 of the Global GHG Protocol as well as emission factors from Table 8.5. Equation 8.3 is used to calculate total methane (CH4) emissions. This is known as the Methane Commitment Model. Alternatively, a First Order of Decay method can be used but requires historical waste disposal data and this information was not available for years prior to 2012.

In general, waste disposal amounts that were provided by the Cambridge Department of Public Works. were summed, and then multiplied by emission factors in the Global GHG Protocol to determine total emissions from landfill disposed waste.

GHG emissions from incineration of MSW are calculated using equation 8.6, 8.7 & 8.8 of the Global GHG Protocol as well as emission factors from Tables 8.4, 8.5, and 8.6. In general, the mass of incinerated waste in total and each fraction of matter type i (paper, textiles, food, etc.) are used to determine the emissions. The quantities for CO2, CH4 and NO2 are summed, and then multiplied by the mass to calculate the total emissions from incinerated waste.

**Emissions Factors Used**

For waste sent to landfill, equations 8.1, 8.3 and 8.4 require the user to input values for each variable based on the characteristics of the waste and landfill. For equation 8.1, Degradable organic carbon (DOC) is calculated based on the proportion of certain types of waste (e.g. food, paper, wood, etc.) in the waste stream. For this inventory, we used DPW Waste Categories from the report “What’s in Weekly Household Trash”, to determine the characteristics. Because the categories in the DPW report don’t match consistently with the GPC categories, the following assumptions were made:

1. All waste categorized as "Organics (primarily food waste" in the DPW report was placed in the "Food Waste" category for Equation 8.1. None of the "Organics (primarily food waste" in the DPW report was placed in the "Garden Waste and Plant Debris" category for Equation 8.1
2. All waste categorized as "Items That Could Be Recycled Curbside" and "Other Trash" in the DPW report was placed in the "Paper" category for Equation 8.1.
3. All waste categorized as "Construction & Demolition Debris" in the DPW report was placed in the "Wood" category for Equation 8.1
4. All waste categorized as "Household Hazardous Waste" in the DPW report was placed in the "Industrial Waste" category for Equation 8.1.

Equation 8.3 calculates the CH4 emissions based on the mass of solid waste sent to landfill (MSW), the methane generation potential (Lo), the fraction of methane recovered from the landfill(frec), and the oxidation factor (OX). For this inventory, the Fraction of Methane Recovered in Landfill was assumed to be 0.0 because it could not be determined which landfills Cambridge waste was sent to, and an Oxidation Factor of 0.1 was selected because we could say that in all likelihood, the landfills Cambridge sends waste to are managed. These are in accordance with GPC values. The methane generation potential (Lo) is calculated as part of equation 8.4.

The methane generation potential is calculated based on a methane correction factor (MCF), the DOC calculated as part of equation 8.1, the fraction of DOC degraded (DOCf) and the fraction of methane in landfill gas. In accordance with the GPC, the following values were used:

1. A value of 1.00 was input for Methane Correction Factor (MCF) since landfills waste is sent to are actively managed.
2. A default value of 0.6 was input for Fraction of Degradable Organic Carbon Degraded (DOCf).
3. A default value 0.5 was input for Fraction of Methane in Landfill Gas (F).

The default fraction of 16/12 was also used as the input for Stoichiometric Ratio Between Methane and Carbon.

### Waste – Wastewater

Wastewater in the City is generated by residents, businesses and industrial processes. All wastewater produced in the city is directed to the Deer Island Treatment Plant in Winthrop, MA. The Massachusetts Water Resource Authority (MWRA) operates the Deer Island facility and will be the main source of data used to calculate the GHG emissions from wastewater generation in Cambridge.

For Deer Island, no methane is released from the treatment process. The facility used 97.3% of its methane in 2012 for heating the digester tanks according to MWRA records. The excess is diverted to a co-generation system where it is used to heat buildings and generate electricity via steam turbine generators. This saves the MWRA approximately $15 million dollars annually in fuel oil costs. Any emissions associated with this process is considered scope 3 and there is no guidance at this time on accounting for the combustion of methane for heat outside the city boundary.

There are N2O emissions from the wastewater treatment plant that must be accounted for. This N2O in this case is primarily from treated effluent being discharged into the ocean. To determine the amount of N2O emissions, the total population of Cambridge served by the Deer Island Treatment Plant is needed as well as the per capita protein consumption value. For this inventory a value of 34.7 kg/person/day was used based on guidance from the U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 -2014.

**GPC Quantification Method Used**

For the Cambridge Community-wide Inventory, only N2O emissions need to be considered (Equation 8.11). Key variables used to complete this equation can be found in the U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sink (1990-2014) [[17]](#footnote-18) including:

* Annual per capita protein consumption: 34.7 kg/person/yr
* Factor to adjust for non-consumed protein: 1.40 (for countries with garbage disposals)
* Fraction of nitrogen in protein: 0.16
* Factor for industrial and commercial co-discharged protein to sewer system: 1.25
* Nitrogen removed from sludge: 0.0 kg/year (default value)
* Emissions factor for N2O from discharged wastewater: 0.005 kg N2O-N/kg N2O (default value)
* Conversion of kg N2O-N into kg of N2O: 1.57

Seem like the part about subtracting electricity from buildings and re-allocating to transportation (for the 2 EVs in the MAVC is not covered here.

## Forecasting Methodology

### “Business as Usual” Emissions Forecast

The emissions forecast represents a “business-as-usual” (BAU) calculation of how GHG emissions would grow in the absence of policies aimed at reducing GHG emissions. Conducting an emissions forecast is an essential step in developing strategies to reduce GHG emissions, because one must compare future potential reductions in emissions with projected emissions levels to determine whether a specific target level of reduction will be achieved by a particular year.

The 2012 Cambridge Community-wide Inventory was used as the baseline for emissions forecasting. Forecasts years of 2030, 2040 and 2050 were selected based on other city goals and initiatives underway. The 2030 forecast time horizon aligns with the time horizons of both the Cambridge Climate Vulnerability Assessment goals and Envision Cambridge. The 2050 forecast time horizon aligns both with the time horizon of the city’s commitment and the State’s goal of an 80% reduction in GHG emissions by 2050. The 2040 forecast time horizon will serve as an interim year to assist the City in measuring progress between the 2030 and 2050 targets. Figure 2 summarizes the BAU forecast for the City out to the selected forecast years of 2030, 2040 and 2050.

Figure 2: Forecasted Business-as-usual Emissions for 2030, 2040, 2050

To predict BAU growth in emissions, the compound annual growth rate in select demographics were used as proxies for the growth rate in corresponding emissions inventory subsectors. For example, the annual growth rate in Cambridge’s population from 2012 to 2030 was used as the anticipated BAU emissions growth rate in the “Residential Buildings” subsector. Population, jobs and household forecasts from MAPC’s Boston Region Long Range Transportation Plan Projections (BRLRTPP) were used to project Cambridge community-scale emissions by subsector.

Table 15 summarizes the base year (2012) and forecast years (2030, 2040, 2050) demographic data used as inputs to determine annual BAU growth rates for the emissions forecast.

Table 15: Emissions Forecast Demographic Growth Rates

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sector | Year | Data | Annual Growth Rate: 2012 🡪 Forecast Year | Data Source |
| Population | 2012 | 1172 | N/A | US Census Bureau |
| 2030 | 118,625 | 0.62% | BRLRTPP, MAPC, 2014 |
| 2040 | 123,804 | 0.55% | BRLRTPP, MAPC, 2014 |
| 2050 | 130,787 | 0.55% | BRLRTPP, MAPC, 2014 |
| Jobs | 2010 | 105,746 | N/A | BRLRTPP, MAPC, 2014 |
| 2012 | 108,084 | N/A | Calculated |
| 2030 | 118,726 | 0.52% | BRLRTPP, MAPC, 2014 |
| 2040 | 123,389 | 0.47% | BRLRTPP, MAPC, 2014 |
| 2050 | 129,365 | 0.47% | Calculated |
| Households | 2010 | 44,032 | N/A | US Census Bureau |
| 2012 | 44,652 | N/A | Calculated |
| 2030 | 49,640 | 0.59% | BRLRTPP, MAPC, 2014 |
| 2040 | 51,886 | 0.54% | BRLRTPP, MAPC, 2014 |
| 2050 | 54,744 | 0.54% | Calculated |

For the co-generation plants, the growth rates consider the following:

* In 2015 the MIT Central Utilities Plant Second Century Plant Expansion plan was developed, with the in-service date of the first of two new CHP units in 2018 followed by the 2nd unit in 2019. The plant is projected to meet all the Institute’s energy needs by 2020.
* In 2013 a combustion turbine CHP unit was added to the Harvard Blackstone plant, with a nominal 7.5MW turbine generator and a new Heat Recovery Steam Generator (HRSG).

These forecast emissions projections for the co-generation plants account for the rated capacity of the equipment and expected operations, and do not reflect downstream restrictions that would limit actual emissions such as demand reduction. Displacement of heating emissions was not calculated due to an indeterminate proportion of steam being integrated into new and existing buildings in Boston and Cambridge. All projections should be updated as data becomes available.

Table 16 summarizes the BAU growth rates used to forecast future emissions in each subsector and the demographic proxy the growth rates are derived from.

Table 16: Emissions Forecast Annual Growth Rates Used to Project Emissions by Subsector

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sector | Subsector | Annual Growth Rate Proxy Used | Annual BAU Growth Rate | | |
| 2012-2030 | 2012-2040 | 2012  -2050 |
| Stationary Energy | Residential Buildings | Population | 0.62% | 0.55% | 0.55% |
| Commercial & Institutional Buildings and Facilities | Jobs | 0.52% | 0.52% | 0.47% |
| Manufacturing Industries and Construction | Population & Jobs | 0.57% | 0.51% | 0.51% |
| Energy Industries\* | Installed Capacity | 1.99% | 1.27% | 0.94% |
| Transportation | On-road | Households | 0.59% | 0.54% | 0.54% |
| Rail | Households | 0.59% | 0.54% | 0.54% |
| Waste | Solid Waste Disposal | Population & Jobs | 0.57% | 0.51% | 0.51% |
| Incineration and Open Burning | Population & Jobs | 0.57% | 0.51% | 0.51% |
| Wastewater Treatment and Discharge | Population & Jobs | 0.57% | 0.51% | 0.51% |
| All Subsectors Weighted Average Growth Rate | | | 0.77% | 0.61% | 0.56% |

\*Energy industry growth based on planned or installed capacities after 2012

Table 17 summarizes the 2012 baseline emissions, annual growth rates used to project BAU emissions growth and projected BAU emissions by subsector.

Table 17: 2012 Baseline Inventory and “Business as Usual” Emissions Forecast by Subsector

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sector** | **Subsector** | **2012** | **2030** | | **2040** | | **2050** | |
| **(MTCO2e)** | **Annual growth rate:  2012-->2030** | **(MTCO2e)** | **Annual growth rate:  2012-->2040** | **(MTCO2e)** | **Annual growth rate:  2012-->2050** | **(MTCO2e)** |
| **Stationary Energy** | Residential Buildings | 205,495 | 0.62% | 229,598 | 0.55% | 239,622 | 0.55% | 253,138 |
| Commercial & Institutional Buildings and Facilities | 756,703 | 0.52% | 831,211 | 0.47% | 863,857 | 0.47% | 905,698 |
| Manufacturing Industries and Construction | 38,234 | 0.57% | 42,358 | 0.51% | 44,114 | 0.51% | 46,426 |
| Energy Industries | 194,907 | 1.99% | 277,809 | 1.27% | 277,809 | 0.94% | 277,809 |
| **Transportation** | On-road | 153,993 | 0.59% | 171,194 | 0.54% | 178,940 | 0.54% | 188,798 |
| Rail | 8,945 | 0.59% | 9,945 | 0.54% | 10,395 | 0.54% | 10,967 |
| **Waste** | Solid Waste Disposal | 92,051 | 0.57% | 101,977 | 0.51% | 106,206 | 0.51% | 111,772 |
| Incineration and Open Burning | 2,145 | 0.57% | 2,377 | 0.51% | 2,475 | 0.51% | 2,605 |
| Wastewater Treatment and Discharge | 2,146 | 0.57% | 2,377 | 0.51% | 2,476 | 0.51% | 2,606 |
| **TOTAL** | | 1,462,236 | 0.51% | 1,677,284 | 0.61% | 1,734,681 | 0.56% | 1,809,067 |

### Incorporating the Impact of State Policies into the Business-as-usual Forecast

The above BAU emissions forecast presented in Table 17 represents the expected growth in emissions in Cambridge absent of both state and local policies aimed at reducing GHG emissions. State policies such as the California Clean Car Standards (which Massachusetts law requires the Commonwealth to adopt) and the Massachusetts Renewable Energy Portfolio Standard (RPS) have the potential to significantly reduce future emissions in Cambridge. It is important to incorporate these state policies into the emissions forecast so the City has an accurate estimate of what portion of their CAP emissions reduction target will be satisfied by state action and what portion will need to be satisfied by local policies and actions.

#### California Low Emission Vehicle Program:

**Description of Policy:** Massachusetts adopted the California motor vehicle standard in early 2006 and updated its rules in December 2012 to reflect California’s 2012 revisions.[[18]](#footnote-19) In 2002, the California legislature enacted Assembly Bill (AB) 1493 (aka “the Pavley Bill”), which directs the Air Resources Board to adopt standards that will achieve "the maximum feasible and cost-effective reduction of greenhouse gas emissions from motor vehicles," taking into account environmental, social, technological, and economic factors. In September 2009, the Air Resources Board adopted amendments to the “Pavley” regulations to reduce GHG emissions in new passenger vehicles from 2009 through 2016. The Pavley Bill is considered to be the national model for vehicle emissions standards. In January of 2012, the Air Resources Board approved a new emissions-control program for model years 2017 through 2025 referred to as the Advanced Clean Cars (ACC) program. The ACC program combines the control of smog, soot and global warming gases and requirement for greater numbers of zero-emission vehicles into a single package of standards.

**Methodology for Quantifying Impact of Policy:** The California Air Resources Board maintains the EMFAC Web Database, an online database containing historical and forecasted data on state-level vehicle emission rates through calendar year 2050. The EMFAC model accounts for efficiency improvements and penetration rates of electric vehicles in accordance with the ACC program and Federal CAFE standards. Since Massachusetts has adopted the ACC program, the EMFAC database was used to calculate forecasted vehicle emission rates for Cambridge. EMFAC provides annual VMT and total gallons of fuel consumed by vehicle class and fuel type. Using this data, it is possible to calculate projected MPG for both gasoline and diesel vehicles and the projected percent of total VMT attributable to gasoline, diesel and electric vehicles. Table 18 below summarizes the impact of the ACC program in terms of vehicle efficiency, percent of total Cambridge VMT by fuel type and emissions avoided compared to the BAU scenario by fuel type.

Table 18: 2030-2050 Vehicle Efficiency Improvements, Percent of Total VMT by Fuel Type and Emissions Avoided in Cambridge from Vehicle Efficiency Programs and Projected EV Market Growth

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vehicle Category | Data Description | 2012 | 2030 | 2040 | 2050 |
| Gasoline | Average MPG | 18.8 | 33.8 | 38.0 | 39.0 |
| Diesel | Average MPG | 7.4 | 8.4 | 8.4 | 8.4 |
| Electric | Average kWh/Mile | 0.33 | 0.33 | 0.33 | 0.33 |
| Gasoline | Percent of Total VMT | 98.6% | 91.8% | 90.1% | 89.9% |
| Diesel | Percent of Total VMT | 1.4% | 1.4% | 1.4% | 1.4% |
| Electric | Percent of Total VMT | 0.02% | 6.82% | 8.55% | 8.76% |
| Emissions Avoided from CAFE + Advanced Clean Car program (MT CO2e) | | N/A | 64,211 | 78,273 | 84,735 |
| Emissions Avoided from Projected EV Market Growth | | N/A | 4,530 | 5,427 | 6,161 |
| **Total Emissions Avoided from Vehicle Efficiency Standards + EV Market Growth** | | **N/A** | **68,742** | **83,700** | **90,896** |

Average MPG for gasoline and diesel vehicle was pulled directly from EMFAC. Average kWh/mile for electric vehicles is estimated using FuelEconomy.Gov data on the current efficiency of the top three selling electric vehicles (Nissan Leaf, Chevrolet Volt, Toyota Prius plug-in)[[19]](#footnote-20). EMFAC estimates the percent of California statewide VMT from EVs for each year through 2050. Due to a lack of Cambridge-specific data on the future percent of citywide VMT from EVs, the EMFAC forecasted percentage of California statewide VMT from EVs was used as a proxy for Cambridge. It was assumed that a future increase in the percentage of total Cambridge VMT from EVs would lead to a decrease in the percent of VMT from gasoline vehicles but have no impact on the percent of VMT from diesel vehicles. Emissions avoided (compared to the BAU scenario) from gasoline and diesel vehicles are the result of future efficiency improvements in these vehicle types. Emissions avoided (compared to BAU scenario) from electric vehicles are the result of gasoline vehicles being replaced by less carbon-intensive electric vehicles.

#### **Massachusetts Renewable Energy Portfolio Standard (RPS)**

**Description of Policy:** The Massachusetts Renewable Energy Portfolio Standard (RPS) is a statutory obligation that suppliers (both regulated distribution utilities and competitive suppliers) obtain a percentage of electricity from qualifying units for their retail customers. The RPS began with an obligation of 1% in 2003, and then increased by 0.5% annually until it reached 4% in 2009. In 2009, as a part of the Green Communities Act of 2008, the RPS was broken into RPS Class I (New Resources) and RPS Class II (Existing Resource) and the Class I annual obligation was set to increase by 1% annually. Each class has different supplier compliance percentages, as well as different qualifying generation units used to meet the compliance percentage. This established growth target for Class I renewables puts Massachusetts on pace to achieve the State target of at least 15% of total electricity sold from Class I renewables in 2020. This target of 15% of all electricity sold from Class I renewables by 2020 is in addition to the percent or electricity sold from Class II renewables, which was set to be 6.03% in 2016[[20]](#footnote-21).

**Methodology for Quantifying Impact of Policy:** This analysis estimated future percent decrease for the electricity factor of grid electricity in Cambridge based on a percent increase in the percent of renewables electricity suppliers in the State are required by law to provide. The percent of electricity sold in 2012 supplied by Class I renewables (7.0%)[[21]](#footnote-22) and the percent supplied by Class II renewables (7.1%)[[22]](#footnote-23) was summed to establish a baseline of 14.1% of electricity sold supplied from either Class I or Class II renewables. Class I renewables were assumed to increase 1% per year in accordance with RPS policy. Class II renewables were assumed to hold constant at the 2016 percent of total electricity sold (6.03%). Table 19 summarizes the projected increase in the percent of renewable electricity supplied by renewable energy for forecast years 2030, 2040 and 2050 and the resulting emissions avoided compared to the BAU scenario.

Table 19: 2030-2050 Increase in Percent of Electricity Sales from Renewables and Emissions Avoided in Cambridge Resulting from RPS

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Percent of Total Electricity Sold in State from Renewables | | | % Reduction in Electricity Emission Factor from 2012 Baseline | Emissions Avoided  (MT CO2e) |
| Class I Renewables | Class II Renewables | Class I + Class II Renewables |
| 2012 | 7.0% | 7.1% | 14.10% | N/A | N/A |
| 2030 | 25.0% | 6.03% | 31.03% | 19.7% | 108,477 |
| 2040 | 35.0% | 6.03% | 41.03% | 31.4% | 179,488 |
| 2050 | 45.0% | 6.03% | 51.03% | 43.0% | 258,459 |

#### Business-as-usual Forecast with State Policies

Table 20 summarizes the projected BAU emissions in Cambridge absent of state policies (top row), emissions reduction impact of state policies (middle rows) and the remaining BAU emissions (bottom row).

Table 20: 2030-2050 Business-as-usual Emissions Factoring in State Policies

|  |  |  |  |
| --- | --- | --- | --- |
| Description | 2030 | 2040 | 2050 |
| BAU Emissions (MT CO2e) | 1,677,284 | 1,734,681 | 1,809,067 |
| Emissions Reduction from Vehicle Efficiency Standards + EV Market Growth (MT CO2e) | -68,742 | -83,700 | -90,896 |
| Emissions Reduction from RPS (MT CO2e) | -108,477 | -179,488 | -258,459 |
| Remaining BAU Emissions w/ State Policies (MT CO2e) | 1,500,065 | 1,471,493 | 1,459,712 |

Figure 3 provides a visualization of the City’s BAU emissions with and without State policies.

Figure 3: Forecasted Emissions for BAU and State Measures Only Scenarios for 2030, 2040 & 2050

Once the City has established emission reduction targets, any emissions remaining after the BAU emissions and State policies are accounted for, will be the projections to focus on (i.e. what other actions can the city take to further reduce emissions beyond these projections?). There are other State policies that exist that will affect emissions reductions in the future. These may further decrease the gap between existing actions and the city’s goals, but for this forecast we could only account for those State policies whose impacts were readily quantifiable.

### Incorporating the Impact of City Policies into the Business-as-usual Forecast

In addition to State policies, it is important to consider the impact of Cambridge policies in driving future emissions reductions. Table 21 provides a listing of the city policies and initiatives taken into account in the forecast of the impact of city policies on emissions.

Table 21: List and Description of City Measures Quantified

|  |  |
| --- | --- |
| **City Measure** | **Description of Measure** |
| 1. Reduction in Municipal Operations Emissions | Cambridge has adopted a target of reducing municipal operations emissions 30% below 2008 levels by 2020. |
| 2. Net Zero Emissions from New & Existing Buildings | Cambridge has adopted a policy requiring all new buildings in the community to be Zero Net Emissions (ZNE) by 2030 and all existing buildings in the community to be ZNE by 2050. |
| 3. Solar Installations in Cambridge | Cambridge has adopted a target of 60 MW of installed solar capacity in the community by 2020 and 160 MW of installed solar capacity in the community by 2040. |
| 4. Reduce Vehicle Miles Travelled by Vehicles Registered in Cambridge | Cambridge has adopted a target of reducing community VMT 5% below 2010 levels by 2020. |
| 5. Reduce Vehicle Ownership Per Household Rate | Cambridge has adopted a target of reducing community vehicle ownership per household 15% below 1990 levels by 2020. |
| 6. Reduce Residential Waste Collected by the City Trash Service | Cambridge has adopted a target of reducing residential waste collected by the City trash service 30% below 2008 levels by 2020 and 80% below 2008 levels by 2050. |

#### City Measure 1: Reduction in Municipal Operations Emissions

**Description of Measure:** Cambridge has adopted a target of reducing municipal operations emissions 30% below 2008 levels by 2020.

**Methodology for Quantifying Measure:** Cambridge’s municipal operations emissions for 2008 of 28,486 MT CO2e were pulled from the “City of Cambridge Municipal Greenhouse Gas Inventory 2008-2012.” A 30% reduction below this 2008 level by 2020 would represent in avoided emissions totaling 2,821 MT CO2e. Since Cambridge does not have a target for reduction in municipal operations emissions for a target year beyond 2020, it was assumed that this avoided emissions level of 2,821 MT CO2e would plateau in 2020 and remain constant for forecast years 2030, 2040 and 2050.

#### City Measure 2: Net Zero Emissions from New and Existing Buildings

**Description of Measure:** In June of 2015 Cambridge City Council adopted the Net Zero 25-year Action Plan. This plan focuses on energy consumption in the building sectors and aims to expand the number of buildings whose annual emissions are offset by carbon-free energy production. The strategies to achieve this include increasing energy efficiency and renewable energy production and purchasing carbon offsets when necessary in both newly constructed buildings and existing buildings.

For new construction, the plan is to use zoning ordinances and policy actions to make incremental improvements in the design of buildings resulting in all new building being net zero by 2030. As part of the Net Zero Action Plan, a series of targets have been set for building types. For example, by 2020 the goal is to have any new municipal building be net zero. This is followed by the target that new homes will be net zero in 2022, new multi-family, commercial, and institutional buildings will be net zero in 2025, and new labs will be required to be net zero in 2030. To help developers reach these targets, a variety of incentives will be utilized.

For existing buildings, the City plans to leverage incentives and regulations to encourage building owners to improve the performance of their buildings.  Building owners will be encouraged to work with the utilities to take advantage of energy efficiency incentive programs, and the city plans to continue to work with the utility to customize programs to yield greater results in the city. The city will also continue to leverage the Building Energy Use Disclosure Ordinance (BEUDO) and explore Time of Renovation or Sale Improvements. With these actions the city hopes to reach its goal to achieve significant reductions in GHG emissions from the buildings sector by 2040 and have all existing buildings in the City to a net zero standard by 2050.

**Methodology for Quantifying Measure:** To incorporate the anticipated emission reductions from the Net Zero Action Plan into the forecast, DNV GL used the Net Zero Model provided by the City to calculate annual reductions by building type. The model is set up to take the total GHG emissions from building energy use in both the commercial and residential buildings sectors and calculate the emissions reductions by year from 2015 – 2040.

Because 2015 is the starting point for the Net Zero Model and the inventory year is 2012, DNV GL reviewed the energy consumption trends in the city for the commercial sector[[23]](#footnote-24) only using information provided by Eversource for the years 2012-2014 to estimate 2015 usage. Actual consumption information for the year 2015 could not be used because of questionable data quality. The trends show an overall reduction in energy use between 2012 and 2014 of about 14%, however there is a slight increase in energy use between 2012 and 2013. The increase may be in part due to the higher number of heating degree days (HDD) for the year 2013, meaning more natural gas was consumed. However, when looking at the normalized use of natural gas on an mmbtu/HDD basis, 2014 shows an increase in mmbtu’s per HDD over the previous two years and, in fact, 2013 shows the lowest mmbtu/HDD while having the highest number of HDD.

Electricity use shows a downward trend year over year by about 3% on average. Without fully understanding the reason for the fluctuations in natural gas usage, a trend of 3% reduction in energy use was used as a conservative value to estimate the GHG emissions from the commercial and residential building sectors in 2015. For the commercial sector, this was estimated to be 945,062 MTCO2e and for residential sector it was 187,550 MTCO2e. As a result of these actions it is estimated the Cambridge will avoid approximately 261,883 MT CO2e of emissions by the year 2030 and 493,951 MTCO2e of emissions by the year 2040. See Table 22 below for a summary of emissions avoided by year and by building sector.

Table 22: Summary of Emissions Avoided from Net Zero Action Plan

|  |  |  |  |
| --- | --- | --- | --- |
| **Sector** | **2030 Emissions Avoided (MT CO2e)** | **2040 Emissions Avoided (MT CO2e)** | **2050 Emissions Avoided (MT CO2e)** |
| New Residential | 21,004 | 43,822 | 43,822 |
| Existing Residential | 48,341 | 162,432 | 162,432 |
| New Commercial | 37,718 | 84,962 | 84,962 |
| Existing Commercial | 154,821 | 202,735 | 202,735 |
| **All Sectors** | **261,883** | **493,951** | **493,951** |

#### City Measure 3: Solar Installations in Cambridge

**Description of Measure:** Cambridge has adopted a target of 60 MW of installed solar capacity in the community by 2020 and 160 MW of installed solar capacity in the community by 2040.

**Methodology for Quantifying Measure:** Table 23below summarizes the estimated emissions avoided for each forecast year resulting from City Measure 3. The interim target of 110 MW of solar capacity installed in Cambridge by 2030 was determined by taking the average of the targets for 2020 (60 MW) and 2040 (160 MW). Since there is no establish target for installed solar capacity beyond 2040, the 2040 target (160 MW) is assumed to hold constant for 2050. A Boston-specific solar capacity of 1,321,000 kWh of electricity generated per MW of installed solar capacity was provided by NREL’s PVWatts tool. Since it is difficult to project future improvements in solar potential, a conservative approach was taken assuming a constant solar potential of 1,321,000 kWh generated per installed MW of solar PV per year. Using the installed solar capacity resulting from the policy and the average solar potential, the annual solar electricity generation was calculated. Since the electricity emission factor of the electricity grid is decreasing over time (see RPS analysis above), the marginal avoided emissions from electricity generated by solar PV decreases over time. The emissions avoided from the RPS have already been accounted for under State measures. Thus, the avoided emissions calculations for City Measure 3 factor in the decreased grid electricity emission factor over time to avoid double counting the avoided emissions impact of the RPS.

Table 23: Summary of Emissions Avoided from Solar Installations in Cambridge

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **Solar Capacity Installed (MW)** | **Average Solar Potential**  **(kWh / MW / Year)** | **Electricity Generated from Solar Capacity Installed**  **(kWh / Year)** | **Grid Electricity Emission Factor**  **(MT CO2e / kWh)** | **Emissions Avoided**  **(MT CO2e)** |
| 2030 | 110 | 1,321,000 | 145,310,000 | 0.00026 | 38,315 |
| 2040 | 160 | 1,321,000 | 211,360,000 | 0.00023 | 47,651 |
| 2050 | 160 | 1,321,000 | 211,360,000 | 0.00019 | 39,570 |

#### City Measures 4 and 5: Reduce Vehicle Miles Travelled by Vehicles Registered in Cambridge & Reduce Vehicle Ownership per Household Rate

**Description of Measure:** Cambridge has adopted a target of reducing community VMT 5% below 2010 levels by 2020. Cambridge has also adopted a target of reducing community vehicle ownership per household 15% below 1990 levels by 2020.

**Methodology for Quantifying Measure:** Since City Measure 4 (reduce VMT) and City Measure 5 (reduce vehicle ownership) are closely intertwined, the avoided emissions from each measure were calculated simultaneously. Measure 4 calls for a 5% reduction in community VMT below 2010 levels by 2020 and City Measure 5 calls for a 15% reduction in vehicle ownership per household below 1990 levels by 2020. For City Measure 4, 2010 data on VMT or emissions from vehicles registered in Cambridge was not available, so 2012 data on vehicles registered in Cambridge was used as a proxy.

To estimate the additional future reduction in VMT from Measure 5 (on top of the 5% reduction in VMT associated with Measure 4), the following approach was taken. The City considers reaching the MAPC Strong Region level of 0.84 vehicles per household as the equivalent of reaching the 15% reduction in vehicle ownership per household below 1990 levels. Using this assumption, the goal of a 15% reduction in vehicle ownership per household below 1990 levels by 2020 was translated to a goal of 9.3% reduction in vehicle ownership below 2012 levels by 2020. 2012 data on vehicles registered in Cambridge per household provided by MAPC was used to translate this target. To avoid double counting with City Measure 4, the 5% VMT reduction associated with City Measure 4 by 2020 was subtracted from the 9.3% reduction in vehicle ownership goal of City Measure 5 to arrive at 4.3% additional reduction in VMT from Measure 5 by 2020. It was assumed that a 1% decrease in household car ownership in Cambridge translates to a 1% reduction in household VMT in Cambridge. The result is Measure 4 and Measure 5 achieving a combined reduction in VMT of 9.3% below 2012 levels by 2020, with Measure 4 being responsible for a 5% reduction in VMT and Measure 5 being responsible for a 4.3% reduction in VMT. Since there is not VMT reduction or vehicle ownership reduction target for a year beyond 2020, it was assumed that the 2020 VMT (9.3% below 2012 levels) would plateau in 2020 and remain constant for forecast years 2030, 2040 and 2050. As Table 24 summarizes, despite a decreasing emissions rate from 2030-2050 (improved efficiency of vehicles) the emissions avoided from the policy compared to the BAU scenario continue to increase. This is due to the increasing BAU VMT from 2030-2050 (tied to projected increases in households provided by MAPC).

Table 24: Summary of Emissions Avoided from Reduction in Vehicle Miles Travelled and Vehicle Ownership per Household

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Business as Usual VMT** | **VMT with Measure 4 + Measure 5 in Place** | **Vehicle Emissions Rate**  **(MT CO2e/VMT)** | **Emissions Avoided**  **(MT CO2e)** |
| 2012 | 362,934,702 | N/A | 0.000413 | N/A |
| 2030 | 403,476,739 | 329,101,380 | 0.000242 | 18,025 |
| 2040 | 421,732,355 | 329,101,380 | 0.000214 | 19,847 |
| 2050 | 444,964,787 | 329,101,380 | 0.000208 | 24,152 |

#### City Measure 6: Reduce Residential Waste Collected by City Trash Service

**Description of Measure:** Cambridge has adopted a target of reducing residential waste collected by the City trash service 30% below 2008 levels by 2020 and 80% below 2008 levels by 2050.

**Methodology for Quantifying Measure:** Since 2008 data on emissions associated with residential waste collected by the City trash service was not available, 2012 data was used as a proxy. Since no residential waste reduction goals for 2030 and 2040 compared to a 2008 baseline have been established, a linear increase in the percent reduction goal from 2020 (30% reduction) to 2050 (80% reduction) was used to establish interim targets for years 2030 (46.7%) and 2040 (63.3%). Using the 2012 GHG Inventory, landfilled emissions resulting from DPW Curbside Pickup (16,422 MT CO2e) and waste incineration emissions from DPW Curbside Pickup (430 MT CO2e) were summed to establish the 2012 residential waste emissions baseline for City trash service of 16,852 MT CO2e. The resulting emissions avoided from City Measure 6 are summarized in Table 25.

Table 25: Summary of Emissions Avoided from Reduction in Residential Waste Collected by City Trash Service

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **BAU Residential City Service Waste Emissions** | **Percent Reduction in Waste Below 2008 Levels** | **Emissions Avoided**  **(MT CO2e)** |
| 2012 | 16,852 | N/A | N/A |
| 2030 | 18,669 | 46.7% | 9,681 |
| 2040 | 19,443 | 63.3% | 13,264 |
| 2050 | 20,462 | 80% | 17,092 |

#### Emissions Forecast with State Measures + City Measures

Table 26 summarizes the emissions avoided impact of all State measures and City measures for forecast years 2030, 2040 and 2050.

Table 26: 2030-2050 Summary of Emissions Avoided from all State + City Measures

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of Measure** | **Measure Description** | **Emissions Avoided in Forecast Year**  **(MT CO2e)** | | |
| **2030** | **2040** | **2050** |
| State | Renewable Portfolio Standard | 108,477 | 179,488 | 258,459 |
| State | Vehicle Efficiency Standards + EV Market Growth | 68,742 | 83,700 | 90,896 |
| **State** | **All State Measures** | **177,218** | **263,189** | **349,355** |
| City | Measure 1: Reduction in Municipal Operations Emissions | 2,821 | 2,821 | 2,821 |
| City | Measure 2: Net Zero New & Existing Buildings | 261,883 | 493,951 | 493,951 |
| City | Measure 3: Solar Installations in Cambridge | 38,315 | 47,651 | 39,570 |
| City | Measure 4: Reduce Vehicle Miles Travelled | 9,668 | 10,645 | 12,954 |
| City | Measure 5: Reduce Vehicle Ownership Per Household | 8,357 | 9,202 | 11,198 |
| City | Measure 6: Reduce Residential Waste | 9,681 | 13,264 | 17,902 |
| **City** | **All City Measures** | **330,727** | **577,535** | **577,586** |
| **State + City** | **All State & City Measures** | **507,945** | **840,723** | **926,942** |

Table 27 and Figure 4 summarize BAU emissions in the absence of State or City measures, the cumulative emissions avoided impact of State and City Measures, and the remaining emissions in Cambridge once all State and City Measures are implemented.

Table 27: 2030-2050 Emissions Forecast Factoring in State + City Measures

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **2030** | **2040** | **2050** |
| Business-as-usual Emissions | 1,677,284 | 1,734,681 | 1,809,067 |
| Emissions Avoided from State Measures | -177,218 | -263,189 | -349,355 |
| Emissions Avoided from City Measures | -330,727 | -577,535 | -577,586 |
| Remaining Emissions with State + City Measures Implemented | 1,169,339 | 893,958 | 882,125 |

Figure 4: Forecasted Emissions for BAU, State Measures Only and State & City Measures Scenarios for 2030, 2040 & 2050

1. The Global Covenant of Mayor’s for Climate and Energy is the new designation for the Compact of Mayors. The Compact of Mayors was launched by UN Secretary, C40 Cities Climate Leadership Group (C40), ICLEI – Local Governments for Sustainability (ICLEI) and the United Cities and Local Governments (UCLG) –with support from UN-Habitat, the UN’s lead agency on urban issues. [↑](#footnote-ref-2)
2. MassDEP. “Massachusetts Greenhouse Gas Inventory.” 2012. http://www.mass.gov/eea/air-water-climate-change/climate-change/massachusetts-global-warming-solutions-act/ma-ghg-emission-trends/ [↑](#footnote-ref-3)
3. ISO New England. “2012 ISO New England Electric Generator Air Emissions Report”

   www.iso-ne.com/static-assets/documents/genrtion\_resrcs/reports/emission/2012\_emissions\_report\_final\_v2.pdf [↑](#footnote-ref-4)
4. EPA. “eGRID: Technical Support Document for eGRID with Year 2012 Data.” https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012\_technicalsupportdocument.pdf [↑](#footnote-ref-5)
5. 2015 Climate Registry Default Emissions Factors, released April 2015 [↑](#footnote-ref-6)
6. Executive Office of Labor and Workforce Development. “EOWLD ES-292 Employment and Wages Survey” http://lmi2.detma.org/lmi/lmi\_es\_a.asp [↑](#footnote-ref-7)
7. Executive Office of Labor and Workforce Development. “EOWLD ES-292 Employment and Wages Survey” http://lmi2.detma.org/lmi/lmi\_es\_a.asp [↑](#footnote-ref-8)
8. Reardon, Timothy, Elizabeth Irvin, Susan Brunton, Meghan Hari, Paul Reim, and Kenneth Gillingham. 2015. “Quantifying Vehicle Miles Traveled from Motor Vehicle Inspection Data: The Massachusetts Vehicle Census.” Transportation Research Board. [↑](#footnote-ref-9)
9. Social Explorer. 2016. “B08201. Household Size by Vehicles Available - American Community Survey Tables.” https://www.socialexplorer.com/data/ACS2013\_5yr/metadata/?ds=ACS13\_5yr&table=B08201. [↑](#footnote-ref-10)
10. City of Cambridge, CDD. 2012. “Electric Vehicle Charging Stations.”

    www.cambridgema.gov/CDD/News/2012/05/electricvehiclechargingstations.aspx [↑](#footnote-ref-11)
11. This estimate was used in the City of Boston Greenhouse Gas Inventory 2005-2013, but it has not been verified by the MBTA, so it should be treated with caution and revisited as more information becomes available. [↑](#footnote-ref-12)
12. This calculation assumes that electricity usage per vehicle mile traveled is roughly similar between heavy rail, light rail, and trackless trolley. Ideally, this value would be further weighted by an electricity efficiency factor. [↑](#footnote-ref-13)
13. 2012 was a leap year, which gave it one extra week day. Two holidays changed week day schedules to Saturday schedules, and five holidays changed week days to a Sunday schedule. [↑](#footnote-ref-14)
14. Archived GTFS data can be found here: http://www.gtfs-data-exchange.com/agency/massachusetts-bay-transportation-authority/ [↑](#footnote-ref-15)
15. This calculation assumes a geographically even distribution of CNG and Diesel busses. The MBTA does not currently have estimates of fuel mix by bus line. [↑](#footnote-ref-16)
16. County of Los Angeles, Dept. of Regional Planning, Vesting Tentative Tract No. 47905 (August, 1992) [↑](#footnote-ref-17)
17. [EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, Domestic Wastewater N2O Emissions Estimates](https://www3.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2016-Main-Text.pdf) [↑](#footnote-ref-18)
18. http://www.mass.gov/eea/docs/dep/air/laws/lev15freg.pdf [↑](#footnote-ref-19)
19. http://www.fueleconomy.gov/ [↑](#footnote-ref-20)
20. Database of State Incentives for Renewable & Efficiency (DSIRE) http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2014/11/Renewable-Portfolio-Standards.pdf [↑](#footnote-ref-21)
21. Massachusetts Executive Office of Energy and Environmental Affairs, “RPS and APS Program Summaries” http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/rps-and-aps-program-summaries.html [↑](#footnote-ref-22)
22. Massachusetts RPS & APS Annual Compliance Report for 2012 http://www.mass.gov/eea/docs/doer/rps-aps/rps-aps-2012-annual-compliance-report-042214.pdf [↑](#footnote-ref-23)
23. Electricity and natural gas usage associated with the co-generation facilities is not included in this estimation [↑](#footnote-ref-24)