CITY OF CAMBRIDGE
MUNICIPAL GREENHOUSE GAS INVENTORY
2008-2012

Prepared by the Environmental and Transportation Planning Division
City of Cambridge
March, 2016

MUNICIPAL OPERATIONS EMISSIONS INVENTORY

The concentration of greenhouse gas emissions in the atmosphere is higher than it's been in at least the last 800,000 years. Based on the findings of the Intergovernmental Panel on Climate Change (IPCC), the National Academy of Sciences, and the National Climate Assessment, the effects of increasing concentrations of GHGs in the atmosphere are already causing a change in our climate. The changes we are currently experiencing include changes in temperature, precipitation, and extreme weather.

The degree to which our climate continues to change in the future will be determined by the amount of GHGs we continue to emit into the atmosphere. Globally, the trend in emissions is occurring at a rate that equates to the high emission scenarios used in IPCC climate models. These climate models predict potentially catastrophic effects, including severe weather impacts, flooding, droughts and sea level rise. The recently completed Vulnerability Assessment for the City of Cambridge indicates that by 2070 the City can expect increased flooding from precipitation events, increased consecutive days with temperatures over 90 degrees, putting critical infrastructure and vulnerable populations at risk. In order to mitigate these impacts, substantial emissions reductions need to be achieved over the next few decades. The Intergovernmental Panel on Climate Change's report "Climate Change 2014 Synthesis Report Summary for Policy Makers" asserts that near zero net emissions of CO_2 and other long-lived greenhouse gases needs to be achieved by the end of the century in order to avoid the worst climate impacts. The United Nations Environment Programme's "Emission Gap Report 2014" asserts that global carbon neutrality will need to be achieved sometime between 2055 and 2070 in order to limit global warming to two degrees Celsius above pre-industrial levels.

Emissions from Cambridge's municipal operations are miniscule relative to the world's annual emissions, and miniscule even to emissions from other cities' municipal operations. Because our total emissions from municipal operations are comparatively small, the impact of emissions reductions on a metric ton to metric ton basis is also comparatively small. However, it is important that Cambridge continue to tackle its GHG emissions in order to demonstrate what is possible with leadership and innovation. The City of Cambridge is demonstrating how to take responsibility for its emissions by measuring the emissions from our municipal operations, setting reduction targets, and taking actions to achieve those targets.

The City is pursuing many policies and projects that will reduce emissions, not only from municipal operations but throughout the community as well. For example the Municipal Facilities Capital Improvement Plan will include a 2020 GHG emissions reduction target and facility specific improvements that lead to the reduction target. Also the 2015 Net Zero Action Plan includes actions that set Cambridge on the path to achieving community wide net zero emissions from building energy use, starting with a requirement that all new municipal buildings achieve net zero emissions starting no later than 2020. Completing a municipal greenhouse gas inventory not only gives us a metric for measuring the GHG reduction impacts of those policies and projects on municipal emissions, it also demonstrates a best practice in GHG management that every entity in Cambridge should take.

INVENTORY PROTOCOL

City of Cambridge Municipal GHG emissions from 2008 through 2012 were inventoried using The Climate Registry's Local Government Operations Protocol (LGOP) and General Reporting Protocol (GRP). The emissions inventories were completed using operational control boundaries, as described below, and include Scope 1 and Scope 2 emissions from all City facilities. This includes emissions from stationary combustion, emissions from mobile combustion, fugitive emissions, and emissions from purchased electricity. Emissions of all six Kyoto Protocol gases plus nitrogen trifluoride (NF3) are included; however, the City does not have any PFC, SF6 or NF3 emissions in the years for which inventories have been completed.

Sectors	Scope 1 Direct Emissions	Scope 2 Indirect Emissions	Scope 3 Indirect Emissions
Buildings and other Facilities	√	√	√
Streetlights and Traffic Signals	√	√	no sources
Water Delivery Facilities	√	√	no sources
Vehicle Fleet	√	√	√
Wastewater Facilities	√	√	no sources
Municipal Waste Disposal	no sources	no sources	x
Employee Travel	no sources	no sources	x
Outsourced Activities	no sources	no sources	x
Production of Purchased Materials	no sources	no sources	x
Port Facilities	no sources	no sources	no sources
Airport Facilities	no sources	no sources	no sources
Transit Fleet	no sources	no sources	no sources
Power Generation Facilities	no sources	no sources	no sources
Solid Waste Facilities	no sources	no sources	no sources
Other Process and Fugitive Emissions	no sources	no sources	no sources

Using the City's operational control boundaries for the inventory most accurately represents the emission sources for which the City has direct control over. A local government has operational control over an operation if it has the full authority to introduce and implement its operating policies. This means that the City can exert some influence over operations to achieve further reductions in GHG emissions. For example, emissions from school buses are not included, as the City contracts with a third party for this City, and does not have direct operational control over the school buses and their emissions.

The inventory does not include any Scope 3 emissions. Scope 3 emissions are produced from a variety of other activities within the municipality's operational control, including solid waste, employee commute and travel, waste water treatment, and product procurement. Currently the data sources to estimate emissions from these sources are insufficient. The inventory will be updated to include these emissions as accurate and reliable data for those sources becomes available.

INVENTORY VERIFICATION AND REPORTING

The annual emissions inventory is verified every 5 years by an accredited 3rd party consultant.
Verification ensures that the reported GHG emissions are complete, transparent, estimated and reported according to TCR's robust and nationally recognized protocols. Verification activities also ensure that the data collected by the City and provided to the 3rd party consultant is well documented and free of any material errors or omissions.

Verification is completed to be compliant with both the Climate Registry's General Verification (GVP) Protocol Version 2.1, and ISO's 14064-3 Specification with guidance for the validation and verification of greenhouse gas assertions.

Verification of the emissions inventories has been completed for the 2008 baseline year and 2012. They were submitted to The Climate Registry as historic emissions.

All Municipal GHG annual inventories are posted to the City's webpage, and submitted to CDP.

ANALYSIS

This report provides a summary of greenhouse gas (GHG) emissions from municipal operations from 2008 to 2012, as well as basic analysis of the underlying energy use and refrigerant use data that was used to estimate GHG emissions. The analysis covers a 5 year period and measures GHG emissions within the City's direct control, providing a baseline and emission trend that can inform the City's GHG reduction targets, and be used to measure progress towards those goals.

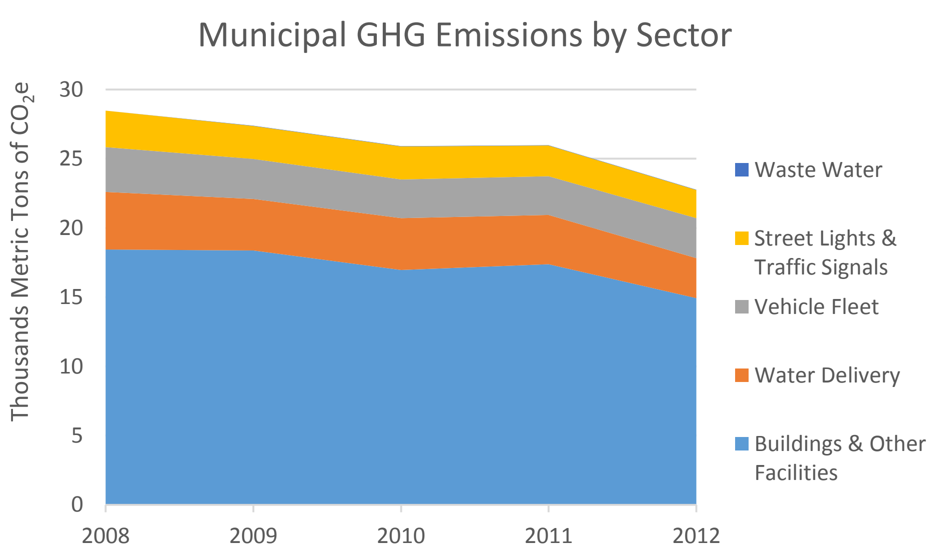
MUNICIPAL GHG EMISSIONS INVENTORY RESULTS

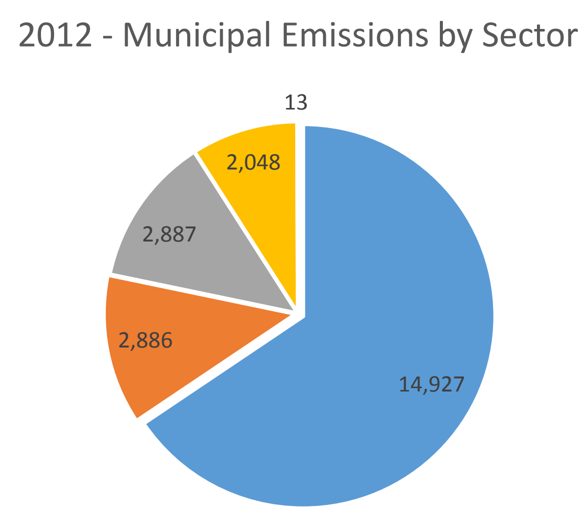
Total GHG emissions in calendar year **(CY) 2012** resulting from municipal operations was **22,762 metric tons of CO_2e.**

This represents a **20.1 % decrease from CY 2008**.

Building and other facilities account for the majority of municipal emissions at **65% of total emissions.**

2012 Emissions from municipal operations is equivalent to…
- emissions from 2,000 average homes in the U.S.
- emissions savings from 6.3 large wind turbines





**Municipal Wastewater accounts for less than 0.1 percent of emission at 13 metric tons of CO_2e, and is not visible in the graphs.*

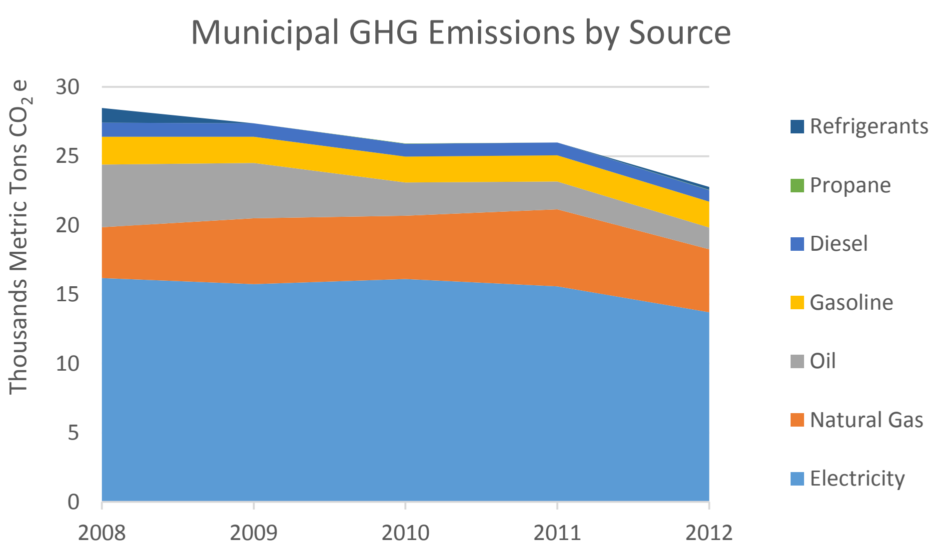
CY 2012 emissions are broken down as follows:

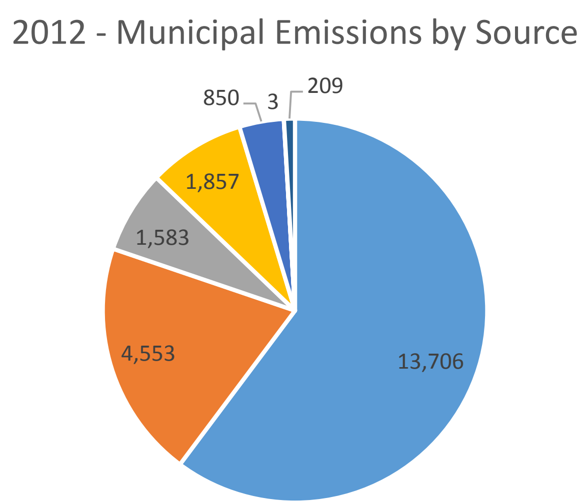
- **Scope 1 emissions**: 9,055 metric tons CO_2e
- **Scope 2 emissions**: 13,705 metric tons CO_2e

Scope 1 emissions have declined across all sectors. The City's Scope 1 emissions are generated from fuels that are combusted directly onsite, and fugitive emissions. This includes emissions from combustion of natural gas, oil, propane, gasoline and diesel, and fugitive emissions from HFC's in vehicles, heating, ventilation and cooling (HVAC) equipment and fire suppression systems. Scope 1 emissions reductions are a direct result of reducing combustion of fuel onsite.

Scope 2 emissions have declined across all sectors. Scope 2 emissions are attributed to electricity purchased by the City. The emissions from electricity are generated in the process of producing electricity from the combustion of fossil fuels. The amount of emissions generated from the production of electricity depends on the mix of fuels used to produce the electricity. Scope 2 emissions reduction are a result of both reducing electricity use, as well as the use of cleaner fuels used to produce the electricity.

Reductions have occurred across all sectors. The building sector has seen the greatest absolute reduction with 3,504 metric tons of CO_2e reduction (19% percent) between 2008 and 2012. Waste water treatment has seen the greatest reduction as a percent of its total sector emissions with a 37% reduction (7.6 tons) in CO_2e emissions between 2008 and 2012.





**Propane accounts for less than 0.1% of emissions by source at 3 metric tons of CO_2e and is not visible in the graph.*

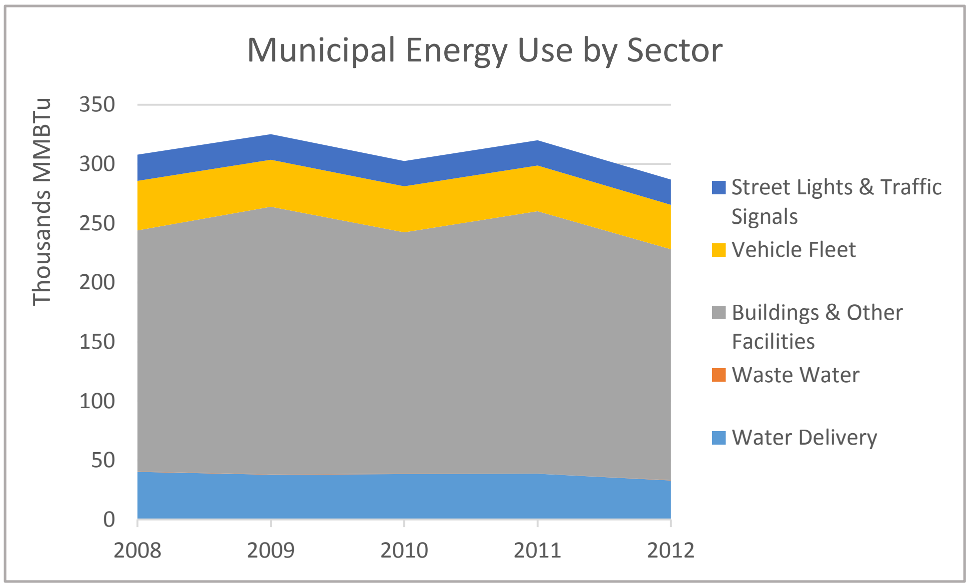
EMISSIONS ANALYSIS

The City's GHG emissions reductions are largely the result of fuel and energy use reductions from fuel conservation, energy efficiency, fuel switching, and cleaner energy supplying the electrical grid in Massachusetts.

For the purpose of comparing and analyzing the use of different energy sources, all fuel use is converted from native units (kWh for electricity, therms for natural gas etc.) British thermal units, or Btu. Btu is a measure of heat energy, and is the most commonly used unit for comparing fuels. MMBtu is uses throughout this report to represent a million metric, or a thousand thousand BTUs.

ENERGY USE EMISSIONS

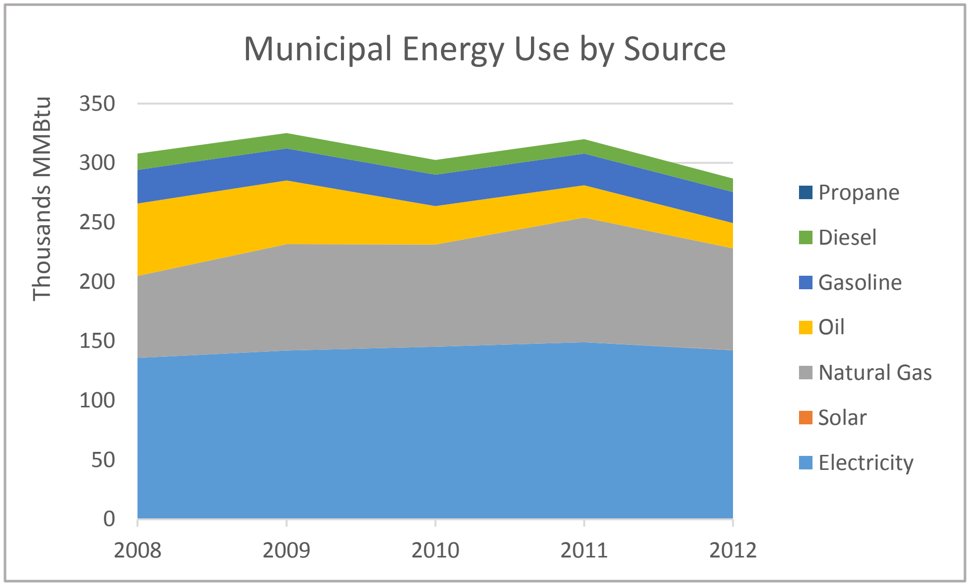
Municipal energy use has decreased 6.8% between 2008 and 2012, from 307,981 MMBtu to 286,960 MMBtu.[1]



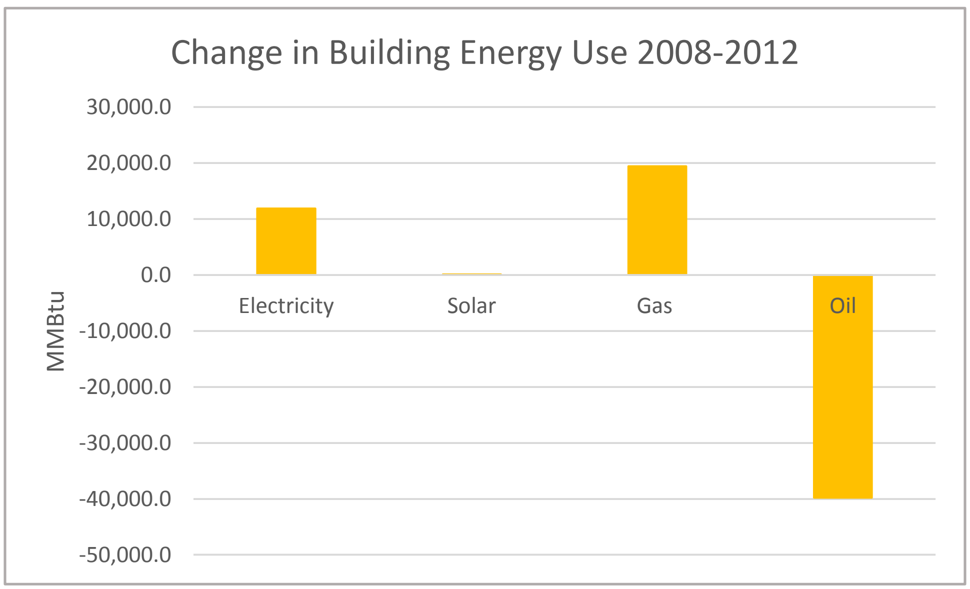
The Municipal building sector accounts for the vast majority of the City's energy use, and has achieved the greatest reductions in energy use in absolute reductions. Buildings account for 68% of the City's energy use, and have reduced energy use by almost 8,400 MMBtu. Water delivery and waste water account for less of the City' total energy use, but have achieved the highest reductions as a percent of their total energy use in 2008.

[1] This represents total energy use. The City of Cambridge is a state-designated Green Community and has been credited for achieving a 20% energy use reduction between 2008 and 2012, however this excluded new buildings that came online between 2008 and 2012.

Total municipal energy use has decreased despite an increase in use of both electricity and natural gas over the same time period.

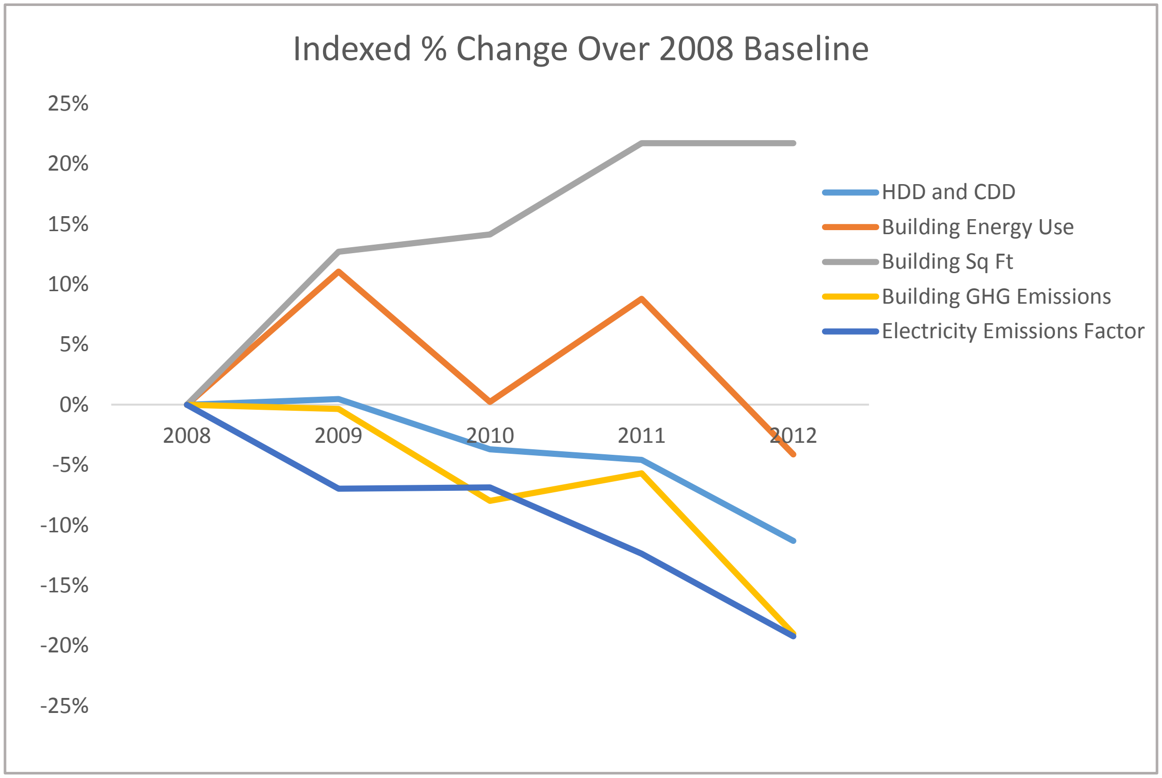


The increase in natural gas and electricity use is entirely in the building sector, which increased use of electricity by 11,990 MMBtu (14.4 %) and natural gas by 19,419 MMBtu (32.7 %). The increase in electricity and natural gas is likely due to new buildings coming on line and fuel switching from oil to natural gas and electricity.



Overall reductions in building energy use between 2012 and 2008 was achieved as the increase in building energy use from electricity and natural gas was entirely offset by the decrease in oil use in the building sector. Oil use was reduced by 39,780 MMBtu (65.1%), primarily as a result of replacing inefficient oil boilers with more efficient natural gas boilers.

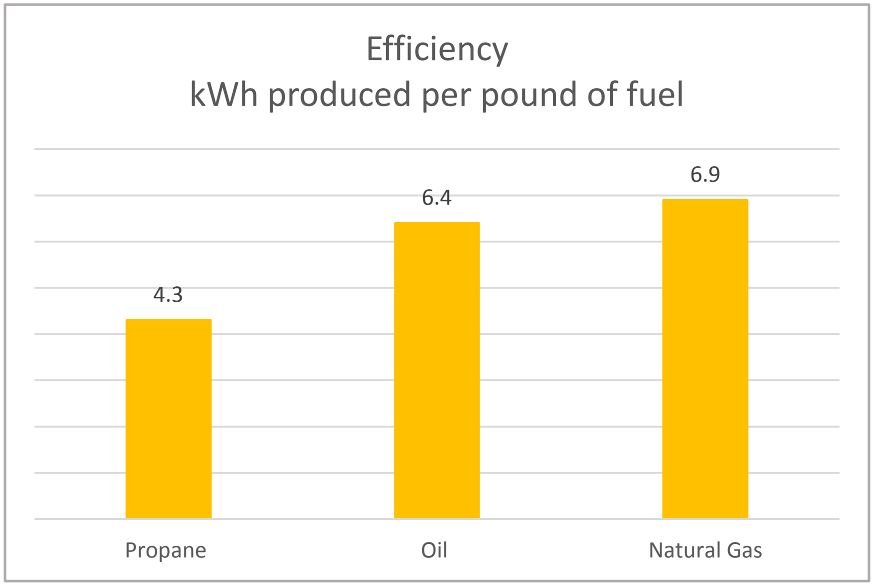
Building energy use is also impacted by the number of heating degree days (HDD) and cooling degree days (CDD), however statistical analysis to determine the impact that fewer HDD and CDD had on energy use was not conducted.

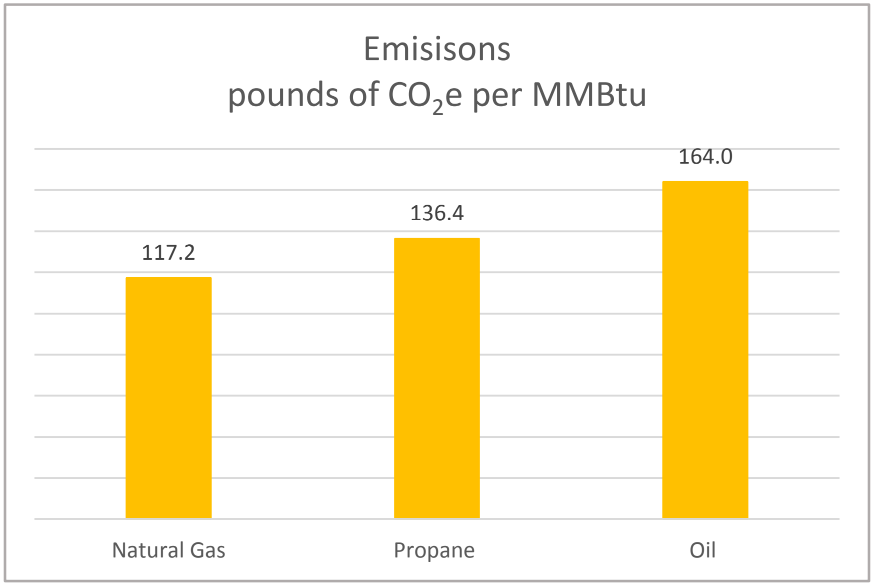


While energy use has only decreased 6.8%, GHG emissions from energy use have decreased 17.7% between 2008 and 2012.

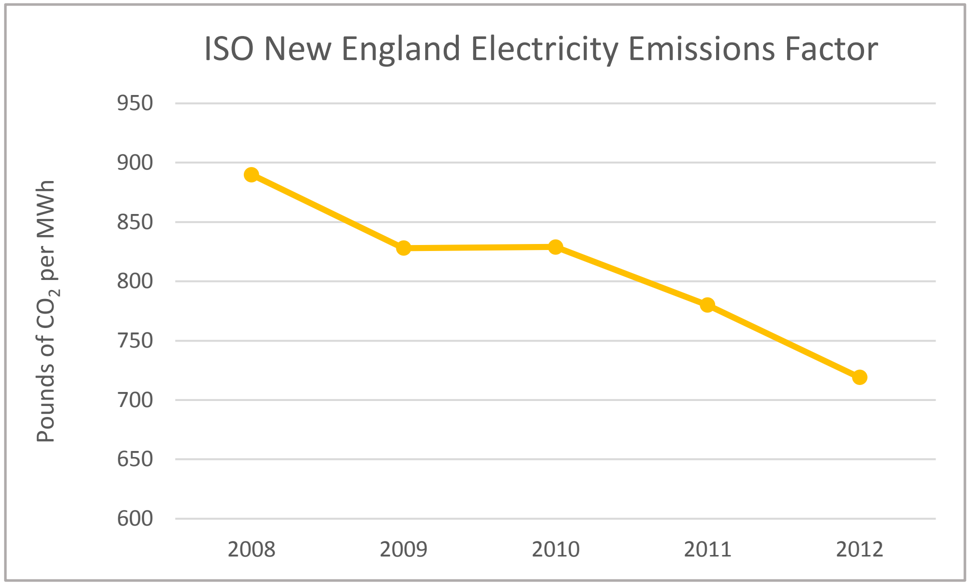
One major driver of this trend is that natural gas is more efficient than oil, resulting in energy use savings when switching from oil to natural gas. This is true not only for onsite combustion, but also for electricity generation. The energy use saving when switching from oil to natural gas results in decreased emissions as well.

Because natural gas also has a lower emissions factor than oil per unit of energy generated, switching from oil to natural gas results in additional emissions reduction from the energy that is used.





The other major driver in the decrease of emissions is the fact that the electricity supply is becoming cleaner. The emissions factor for electricity has dropped from 896 lbs of CO_2e per MWh (263 lbs of CO_2e per MMBtu) to 725 lbs of CO_2e per MWh (216 pounds of CO_2e per MMBtu). So, while electricity use in 2012 increased 4.8% over 2008, GHG emissions associated with electricity use have gone down by 15% over the same time period. This trend illustrates the fact that emissions from electricity can decrease as a function of the electricity emissions factors, use reduction, or both. This means there is potential for electricity produced from an increasing proportion of renewable sources to drastically reduce GHG emissions, despite increased demand for electricity.



Unlike emissions factors for electricity, emissions factors for fossil fuels remain relatively constant. This means that while emissions from electricity can decrease even as use increases, emissions from any given fossil fuel can only decrease as a function of decreasing use.

The amount of municipal electricity use supplied by onsite solar generation also increased from 80 MMBTu in 2008 to 188 MMBTu in 2012. This resulted in a reduction from what the total building GHG emissions from energy use would have been had that electricity been supplied by the grid.

FUGITIVE EMISSIONS

Cambridge's fugitive emissions are generated from the use of refrigerants in building HVAC equipment and refrigeration in the City's fleet vehicles' air conditioning systems. Emissions occur as a result of leakage over the operational life of the equipment. These refrigerants include R-22, R-134a, R-407c and R-410a.

The City's verified municipal GHG inventory includes only fugitive emissions from R-134a, R-407c and R-410a. Emissions from R-22 is calculated separately from the other refrigerants and is NOT included in the City's official GHG inventory. HCFCs and CFCs like R-22, R-12 and R-11 are being phased out as part of the Montreal Protocol, are not included in the Kyoto Protocol definition for GHGs, and therefore are not reported in inventories per the LGOP or GRP.

The majority of the City's HAVC systems still used R-22, which will eventually be replaced with a refrigerant that is included in the GHG inventory. Due to this switching, reported emissions from refrigerants has the potential to increase as equipment using R-22 is switched to refrigerants that are included in the LGOP. However, the portion of the City's GHG emissions from municipal operations that comes from refrigerants is expected to remain very low relative to other GHG emissions sources.

Fugitive emissions from vehicles and HVAC account for 8.9 % of total Scope 1 emissions in 2008 and 2.3 % of total Scope 1 emissions in 2012.

The decrease in reported emissions is due to improved data and tracking of refrigerant use. Emissions for all refrigerants in 2008 were estimated using either the refrigerant charge capacity for each piece of equipment or the upper bound capacity value from the TCR's default values, along with an estimated average leakage rate of operation. This likely results in an overestimation of GHG emissions from refrigerants in 2008. In 2012 emissions from building HVAC equipment were calculated based on invoices for pounds of refrigerant purchase by the City to recharge HVAC equipment, and reflect actual use and emissions rather than an upper bounds estimate.

1. The City tracks its energy use using MassEnergyInsight (MEI), a web based platform for collecting and analyzing energy use. MEI organizes and analyzes data based on fiscal year, while the TCR protocol requires reports to be based on calendar year.

2. MEI separates energy use into different sectors than the TCR protocol (e.g. MEI reports open space separately from buildings and TCR combines the two).

3. MEI does not include new buildings that came online after the 2008 baseline year in their energy use totals. Five buildings are excluded; The Main Library, the Robert W. Healy Public Safety Facility, The War Memorial Recreation Center, the West Cambridge Youth Center, and 101 Rogers St. The TCR protocol used to complete this inventory includes those buildings. This provides a more accurate and complete description of the total emissions due to City operations.

4. The emissions factors and unit conversion factors that MEI uses are different than the factors used in the TCR protocol. While these differences may seem small, it can lead to differences that are in the magnitude of a couple hundred tons when they are multiplies by the thousands.

Comparison of Emissions Factors

	MEI	TCR	
Electricity (2010)	0.96	0.83	lbs per kWh
Natural gas	11.71	11.69	lbs per therm
Fuel Oil	22.38	22.51	lbs per gallon
Propane	12.70	12.32	lbs per gallon
Diesel	22.38	22.51	lbs per gallon
Gasoline	19.53	19.36	lbs per gallon

SUMMARY OF MUNICIPAL ENERGY USE AND EMISSIONS TRENDS

		Use	Emissions
Water Delivery	Electricity	↓	↓
	Natural Gas	↓	↓
	Propane	↑	↑
Waste Water	Electricity	↓	↓
	Natural Gas	↓	↓
Buildings and Other Facilities	Electricity	↑	↓
	Natural Gas	↑	↑
	Oil	↓	↓
	Diesel	no change	
Vehicles	Gasoline	↓	↓
	Diesel	↓	↓
Street Lights and Traffic Signals	Electricity	↓	↓
	Natural Gas	↓	↓
OVERALL		↓	↓

MUNICIPAL ENERGY USE AND EMISISONS

	METRIC TONS CO_2e					Change 2008-2012	% Change 2008-2012
	2008	2009	2010	2011	2012		
Water Delivery							
Electricity	3661.8	3300.2	3287.6	3061.1	2520.8	-1141.0	-31.2%
Gas	509.7	425.4	461.3	490.3	362.3	-147.4	-28.9%
Oil	0	0	0	0	0	0	0%
Gasoline	0	0	0	0	0	0	0%
Diesel	0	0	0	0	0	0	0%
Propane	3.1	3.9	3.3	2.9	3.3	0.3	8.6%
Waste Water							
Electricity	20.6	18.0	19.3	17.0	13.2	-7.5	-36.2%
Gas	0.1	0.1	0.4	0.0	0.0	-0.1	-100.0%
Oil	0	0	0	0	0	0	0%
Gasoline	0	0	0	0	0	0	0%
Diesel	0	0	0	0	0	0	0%
Propane	0	0	0	0	0	0	0%
Buildings and Other Facilities							
Electricity	9870.9	10033.4	10439.3	10271.0	9124.4	-746.5	-7.6%
Gas	3157.9	4333.7	4106.0	5083.9	4190.6	1032.6	32.7%
Oil	4542.8	3999.9	2418.0	2028.9	1583.5	-2959.3	-65.1%
Gasoline	0	0	0	0	0	0	0%
Diesel	0.0	0.3	0.0	0.0	0.0	0.0	0%
Propane	0	0	0	0	0	0	0%
Refrigerants	860.0	0.0	0.0	0.0	29.0	-831.0	-96.6%
Vehicles							
Electricity	0	0	0	0	0	0	0%
Gas	0	0	0	0	0	0	0%
Oil	0	0	0	0	0	0	0%
Gasoline	2004.7	1908.1	1870.7	1892.6	1857.2	-147.5	-7.4%
Diesel	1029.3	968.7	926.9	908.3	849.5	-179.8	-17.5%
Propane	0	0	0	0	0	0	0%
Refrigerants	198.0	0.0	0.0	0.0	180.0	-18.0	-9.1%
Street Lights and Traffic Signals							
Electricity	2625.1	2388.3	2372.1	2220.3	2047.6	-577.6	-22.0%
Gas	2.3	0.4	0.2	0.5	0.3	-2.0	-86.2%
Oil	0	0	0	0	0	0	0%
Gasoline	0	0	0	0	0	0	0%
Diesel	0	0	0	0	0	0	0%
Propane	0	0	0	0	0	0	0%
Total Scope 1	12307.9	11640.5	9786.8	10407.4	9055.7	-3252.2	-26.4%
Total Scope 2	16178.5	15739.9	16118.3	15569.3	13705.9	-2472.5	-15.3%
Total Scope 1 & Scope 2	28486.3	27380.4	25905.1	25976.7	22761.6	-5724.7	-20.1%
Percent reduction from 2008 baseline		**-3.9%**	**-9.1%**	**-8.8%**	**-20.1%**		

	ENERGY USE MMBtu					Change 2008-2012	% Change 2008-2012
	2008	2009	2010	2011	2012		
Water Delivery							
Electricity	30,734.9	29,773.7	29,637.4	29,315.8	26,173.9	-4,561	-14.8%
Solar	0	0	0	0	0	0	0.0%
Gas	9,586.0	7,999.9	8,674.8	9,220.5	6,813.1	-2,773	-28.9%
Oil	0	0	0	0	0	0	0.0%
Gasoline	0	0	0	0	0	0	0.0%
Diesel	0	0	0	0	0	0	0.0%
Propane	49.8	63.3	54.3	47.3	54.0	4	8.6%
Waste Water							
Electricity	173.1	162.0	173.6	162.9	136.6	-36.5	-21.1%
Solar	0	0	0	0	0	0	0%
Gas	2.1	2.1	7.1	0.0	0.0	-2.1	-100.0%
Oil	0	0	0	0	0	0	0%
Gasoline	0	0	0	0	0	0	0%
Diesel	0	0	0	0	0	0	0%
Propane	0	0	0	0	0	0	0%
Buildings and Other Facilities							
Electricity	82,850.8	90,518.9	94,108.2	98,365.9	94,740.7	11,889.8	14.4%
Solar	79.8	78.3	29.9	36.0	187.7	107.9	135.2%
Gas	59,388.0	81,498.4	77,217.5	95,606.7	78,807.7	19,419.7	32.7%
Oil	61,067.7	53,770.0	32,504.4	27,274.9	21,286.8	-39,780.9	-65.1%
Gasoline	0	0	0	0	0	0	0.0%
Diesel	0.0	4.1	0.0	0.0	0.0	0	0.0%
Propane	0	0	0	0	0	0	0.0%
Vehicles							
Electricity	0	0	0	0	0	0	0%
Solar	0	0	0	0	0	0	0%
Gas	0	0	0	0	0	0	0%
Oil	0	0	0	0	0	0	0%
Gasoline	28,216.8	26,858.1	26,331.1	26,638.7	26,140.6	-2,076.2	-7.4%
Diesel	13,755.6	12,945.3	12,386.2	12,138.5	11,352.9	-2,402.7	-17.5%
Propane	0	0	0	0	0	0	0%
Street Lights and Traffic Signals							
Electricity	22,033.8	21,546.8	21,384.0	21,263.5	21,260.4	-773.4	-3.5%
Solar	0	0	0	0	0	0	0%
Gas	42.9	7.2	4.7	9.2	5.9	-37.0	-86.2%
Oil	0	0	0	0	0	0	0%
Gasoline	0	0	0	0	0	0	0%
Diesel	0	0	0	0	0	0	0%
Propane	0	0	0	0	0	0	0%
Scope 1	172,109	183,148	157,180	170,936	144,461	-27,648	-16.1%
Scope 2	135,872	142,080	145,333	149,144	142,499	6,627	4.9%
Scope 1 & Scope 2	307,981	325,228	302,513	320,080	286,960	-21,021	-6.8%
Percent reduction from 2008 baseline		**5.6%**	**-1.8%**	**3.9%**	**-6.8%**		