Massachusetts Water Resources Authority

Greenhouse Gas Emissions Inventory 2006–2014

November 2016

Thank you to Lia Cairone, Columbia University Master of International Affairs Candidate, Class of 2016 – Environmental Defense Fund Climate Corps fellow who worked tirelessly researching, meeting with agency representatives, collecting and analyzing all the necessary data to complete this inventory.

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Disclaimer: All calculations presented in this report are based on data collected and estimated by MWRA as well as emissions factors and global warming potentials published by the Intergovernmental Panel on Climate Change (IPCC), Environmental Protection Agency (EPA), Massachusetts Department of Environmental Protection (MA DEP), and the Australian Government Department of the Environment. While every effort has been made to ensure the accuracy of the data, the possibility for errors exists. This report is not intended to be a flawless accounting of MWRA's carbon emissions, but is rather intended to provide a reasonable estimation and provide information from which MWRA can base policy decisions.

Figures And Tables

Executive Summary

Overview and Background

MWRA has long been a leader in environmental stewardship. As part of this commitment, MWRA has implemented many energy conservation programs to reduce the energy demand required to provide safe drinking water and high quality wastewater treatment to its member communities. This Greenhouse Gas (GHG) inventory[1] is MWRA's first attempt to report annual levels of GHG emissions associated with all MWRA operations and to report components and variations in emission levels over time.

Solar Panels at Deer Island – contribute to renewable energy generated and used on-site.

Greenhouse Gas Emissions Inventory & Reductions

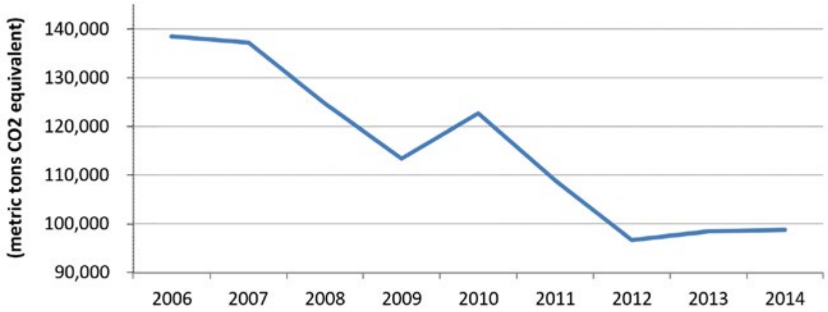
MWRA reduced its GHG emissions by 28.7 percent[2] between 2006 and 2014 as shown in Figure-1 below. By measuring and analyzing GHG emissions, MWRA is able to quantify its emissions and track the progress it is making from on-going energy conservation efforts, as well as target areas for future reductions.

The increase of onsite renewable energy generation is responsible for the majority of emissions reductions, in addition to MWRA using electricity and heating fuel more efficiently in its operations and facilities. The largest source of the GHG emissions is electricity use, accounting for 49 percent of MWRA's total emissions, while 16 and 12 percent are from natural gas and diesel, respectively. The remaining 23 percent is made up of several other sources including fleet vehicle emissions, fugitive emissions, and process methane emissions.

[1] *The analysis was conducted in accordance with international and national standards and best practices, including the Greenhouse Gas Protocol, the EPA's Climate Leadership for Greenhouse Gas Inventories, and the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.*

[2] *28.7% reduction includes total emissions from Scopes 1 and 2, which are the two emissions categories directly or indirectly owned and controlled by the reporting entity. Scopes are defined in the Methodology section and Appendix A.*

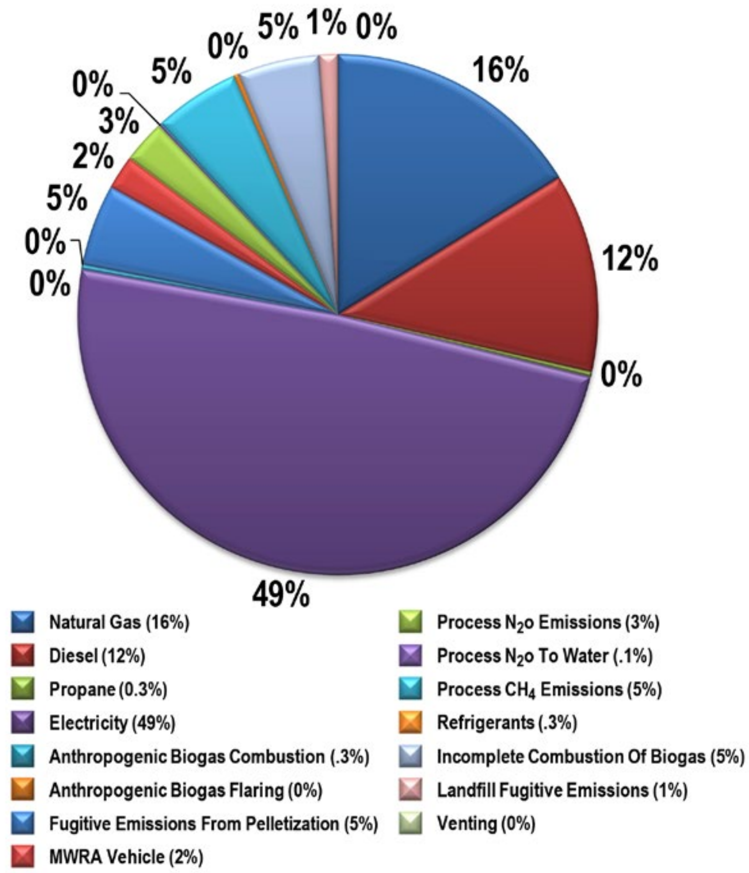
Figure 1: MWRA GHG Emissions (from 2006 – 2014)[3]



The major sources of GHG emissions in the MWRA's operations (as a percent of total emissions) include:

- Electricity, 49%
- Natural gas, 16%
- Diesel, 12%
- Various other sources including fleet vehicle emissions, fugitive emissions, and process methane (CH_4) emissions make up the remaining 23%.

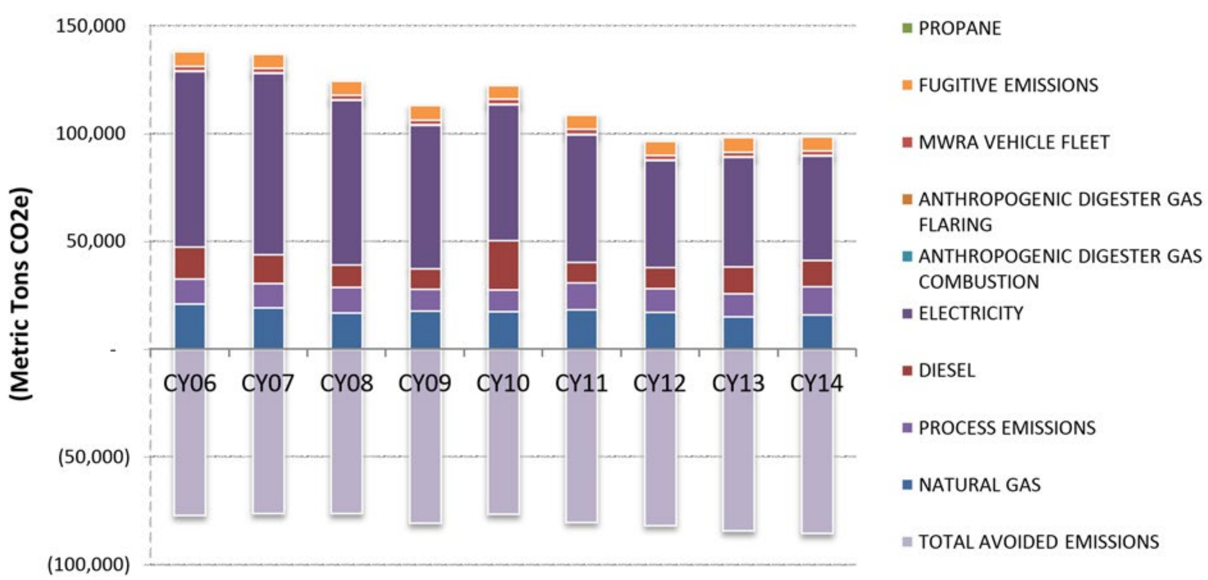
Figure 2: MWRA GHG Emissions Sources, 2014



[3] *The spike in emissions in 2010 was associated with unusual weather patterns that necessitated the extended use of the backup Combustion Turbine Generators (CTGs) at Deer Island, which significantly increased diesel fuel usage for that year.*

Figure 3 below provides a summary of MWRA's GHG emissions from the top two emissions categories[4] (owned or controlled by MWRA), as well as avoided[5] emissions from the use of renewable energy from 2006 through 2014 (by calendar year).

Figure 3: Total GHG Emissions and Avoided Emissions (Owned and Controlled by MWRA)[4]

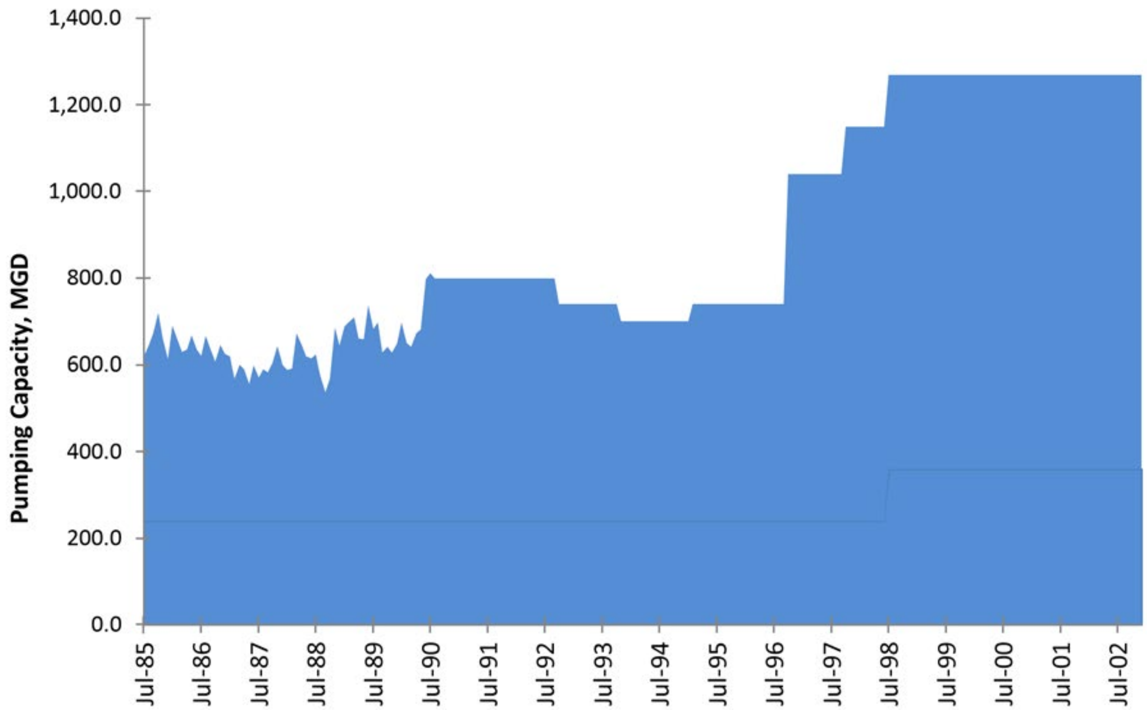


The reductions in GHG have occurred while the MWRA has been making substantial changes in the system to improve drinking water quality and improve the capture and treatment of wastewater. The GHG analysis shows that an average of 11% percent of MWRA's GHG emissions are from transporting and treating drinking water, while 89% are from the transport and treatment of wastewater. Wastewater transport and treatment has a higher energy demand for pumping and treatment than water distribution, which primarily uses gravity for distribution.

[4] Scopes 1 and 2 are the two emissions categories directly or indirectly owned and controlled by the reporting entity. Scopes are defined in the Methodology section and Appendix A.
[5] Total Avoided Emissions includes carbon dioxide equivalents of renewable electricity produced and used on-site, renewable electricity produced and sold to the grid, and digester gas utilized for heating on Deer Island Treatment Plant.

Figure 4 shows the impact of initial fast-track capital improvements to increase wastewater pumping capacity and reliability which reduced combined sewer overflows and improved water quality.

Figure 4: Sewer System Pumping Capacity Improvement



MWRA has significantly improved receiving water quality by ensuring that more wastewater is captured and transported to Deer Island for treatment, rather than being released as overflows to streams and rivers, or the harbor.

Spring Street Water Pump Station Pipe Insulation – condensation on cold incoming water pipes necessitated the use of dehumidification and resulted in puddles on the floor. Insulation eliminated the condensation problem, thereby significantly reducing the need for dehumidification and created a safer work environment by eliminating the puddling.

Recommendations & Next Steps

This GHG inventory provides MWRA with the information to help identify areas to target for additional GHG emissions reductions. Based on the inventory, opportunities for future reductions continue to be related to electricity usage and MWRA will continue to focus on both reducing its electrical demand, identifying opportunities for green power production and options for procurement of low-carbon intensive electricity. MWRA will also work to reduce the use of diesel fuel, both in stationary equipment and in the vehicle fleet, as these sources account for over 12 percent of total emissions. Short term and long term steps have been identified and included in this report to help guide MWRA to continue its mission towards providing high quality water and sewer services while promoting leadership in environmental stewardship and reducing its GHG emissions.

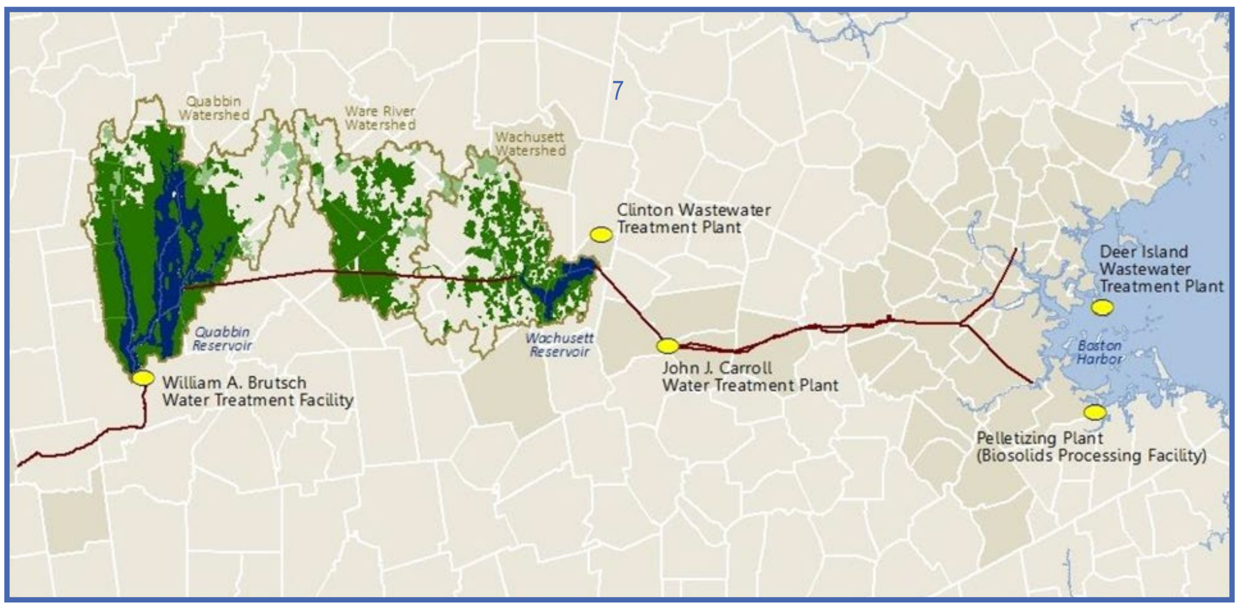
Overview And Background

About MWRA

Massachusetts Water Resources Authority (MWRA) is a large water and wastewater utility that provides wholesale water and sewer services to over 2.5 million people and 5,500 industrial users in 61 metro Boston communities. MWRA facilities include:

- John J. Carroll Water Treatment Plant (JCWTP)
- William A. Brutsch Water Treatment Facility
- 11 water pumping stations
- Deer Island Wastewater Treatment Plant (DITP)
- Clinton Wastewater Treatment Plant
- Biosolids Processing Facility
- 12 wastewater pumping stations
- 4 headworks facilities
- 4 combined sewer overflow (CSO) treatment facilities
- 2 large warehouse and maintenance buildings
- Covered water storage, aqueducts, meter vaults, dams, and numerous other small facilities
- 2 office buildings

Figure 5: MWRA water and wastewater treatment facility locations:



Energy Demand

Providing reliable, cost-effective, and high quality drinking water and wastewater treatment are essential services the MWRA performs each day. Treating and transporting water and wastewater involves significant energy resources. The use of fossil fuels leads to carbon dioxide (CO2) and other greenhouse gas emissions. Wastewater treatment produces methane (CH4) while sewage itself is a contributor of nitrous oxide (N2O), two potent greenhouse gases.

There are additional factors that impact the energy demand for treating and delivering drinking water and treating wastewater, such as weather, regulations, and customer demand. Several MWRA communities have combined sewers that receive both stormwater and wastewater. Therefore, wastewater plant flow and pumping increases significantly during periods of wet weather. In addition, inflow and infiltration (I/I) during wet weather events can drastically increase flows to the wastewater treatment plants.

Changes in environmental regulations have required MWRA to add equipment and processes to their treatment facilities. For example, in 2006 the Environmental Protection Agency's Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) required MWRA to add an additional disinfectant at both the Carroll Water Treatment Plant which treats the water supplied to the greater Boston area and the William A. Brutsch Water Treatment Facility (then called the Ware Disinfection Facility) to treat the water supplied from Quabbin to the CVA communities. Ultraviolet (UV) disinfection was added under the new rule, which mandated all unfiltered water systems to have two primary means of disinfection. The addition of UV may have resulted in an increase in energy usage for the MWRA's treatment of water. At CWTP, MWRA operations did have an increase in energy use but at the same time were able to decrease energy use in the other treatment process (ozone) which provided a balance of energy use and high quality water. The Brutsch Facility is a smaller treatment facility that did see an increase in overall energy use after the addition of UV treatment in late 2014, but MWRA is continuing to work to maximize energy efficiency and water treatment.

Renewable On-Site Generation

The majority of renewable on site energy generation is from methane gas captured from sludge digestion at DITP, which is then combusted in a combined heat and power plant, providing the heating equivilent of over 5 million gallons of oil each year, and approximately 30 Million kWh of electricity. Other on-site renewable generation includes three wind turbines at DITP, and one wind turbine at the DeLauri Pumping Station in Charlestown, solar photovoltaic systems at DITP and JCWTP, hydropower turbine generators at the Oakdale Power Station, the Cosgrove Intake, Loring Road Covered Storage facility, and at DITP.

Figure 6: MWRA Renewable Generation Facilities

Wind Turbines at Deer Island, next to Anaerobic Gas Digesters

Energy-efficient lighting at Nut Island Headworks – Explosion proof LED lighting is being at installed at MWRA facilities to reduce energy usage. In most installations, energy usage is being reduced by about 75 percent, while providing a brighter light output, and a safer work environment.

Energy Initiatives

MWRA has long-standing goals of implementing initiatives to reduce energy demand, and continually evaluate sustainable cost-saving opportunities throughout the organization. Additionally, MWRA has been striving to meet or exceed the goals of Massachusetts Executive Order 484 (EO484-Leading by Example) which was issued in 2007. One of the goals of EO 484 is a 40% reduction in Greenhouse Gas (GHG) emissions by 2020, and 80% GHG emissions reductions by 2050 (as compared to a base year of FY02). To this end, MWRA is aggressively pursuing energy efficiency opportunities, optimizing operations and processes, and increasing the use of on-site renewable energy, both to meet these goals and to control energy costs.

MWRA has conducted or is currently in the process of conducting energy audits at almost all of its facilities. Some of the energy efficiency efforts implemented at MWRA's facilities include installation of variable frequency drives (VFDs) in pumping facilities, energy efficient lighting, more efficient heating and cooling systems, and other customized applications. Internal Standard Operating Procedures have been established to ensure that energy efficiency and energy costs are considered whenever facilities are rehabilitated or new facilities are built. Energy Management Systems (EMS) have recently been installed in several MWRA buildings, providing a greater ability for staff to actively manage heating, cooling, and ventilation (HVAC) energy usage. For example, the EMS that was installed at MWRA's Chelsea administration building in 2012 resulted in energy savings of approximately 600,000 kWh per year. Another energy efficiency project at Deer Island Wastewater Treatment Plant enabled 9.2 Million kWh savings in a secondary process optimization by installing dissolved oxygen probes and control panels, substantially reducing oxygen use and blower use.

Loring Road Hydroelectric Generator during construction

Table 1: List of all MWRA Renewable Electricity Generation Facilities and Rated Capacities

Facility	Rated Capacity
Methane	
DI Steam Turbine Generator	18 MW
DI Backpressure Steam Turbine Generator	1 MW
Hydro	
Cosgrove Hydro Generator	2 @ 1.7 MW
Deer Island Hydro Generator	2 @ 1 MW
Loring Rd Hydro Generator	200 kW
Oakdale Hydro Generator	3.5 MW
PV Solar	
Carroll Water Treatment Plant Ground Mounted Solar	496 kW
Deer Island Maintenance/Warehouse Roof Mounted Solar	180 kW
Deer Island Grit Roof Mounted Solar	222 kW
Deer Island Parking Lot Ground Mounted Solar	234 kW
Deer Island Residuals Odor Control Roof Mounted Solar	100 kW
Wind	
Charlestown Wind Turbine	1.5 MW
Deer Island Wind Turbine 1	600 kW
Deer Island Wind Turbine 2	600 kW
Ogin Wind Turbine (formerly FloDesign Wind)	100 kW

Greenhouse Gas Assessment

While MWRA has aggressively pursued energy reduction strategies for many years, it had not comprehensively measured and assessed the GHG emission impacts of its operations or its energy management program until this report. MWRA has had a regulatory obligation to report GHG emissions to EPA and MA DEP for certain activities at the DITP and Biosolids Processing Facility since 2008.

MWRA Greenhouse Gas Emissions Inventory

Objectives

The objectives of the GHG Emissions Inventory were fourfold:

- Calculate historical GHG emissions to identify major sources and reveal trends
- Highlight successes to date regarding GHG emission reductions
- Manage GHG risks
- Identify emissions reduction opportunities

As outlined in the next section below, the analysis followed standard GHG reporting protocols, involving significant data collection and staff input.

Methodology

The approach to building the inventory is consistent with international and national standards and best practices. Both the Greenhouse Gas Protocols[6] - Corporate Accounting and Reporting Standard[7], and the Local Government Operations Protocol (LGOP), version 1.1[8], were used as the core guiding documents. The EPA Climate Leadership for Greenhouse Gas Inventories[9] was used to identify emissions factors and the IPCC Fourth Assessment Report[10] was referenced for global warming potentials. The Australian National Greenhouse and Energy Reporting[11] (NGER) protocol was used in substitute for the estimation of nitrogen emissions from WWTP effluent to receiving bodies of water; due to the lack of research in the current LGOP protocol for this emission source[12]. Massachusetts Department of Environmental Protection electricity emission factors were used along with supplier specific factors in substitute of EPA estimated factors for the New England Region; this represents a more accurate estimate of emissions from electricity purchases in Massachusetts.

In addition, interviews were conducted with MWRA's facilities managers, operators, and engineers in order to identify any additional potential emissions sources.

There are seven major greenhouse gases included in the Protocol; however the five listed below are the only ones that MWRA's operations contribute to:

- Carbon dioxide (CO2)
- Methane (CH4)
- Nitrous oxide (N2O)
- Hydrofluorocarbons (HFCs) (minor contribution)
- Sulphur hexafluoride (SF6) (minor contribution)

[6] *See Appendix A: Methodolgy and Appendix E: Endnotes for more details on the methodology and sources for protocols*
[7] http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf
[8] http://www.arb.ca.gov/cc/protocols/localgov/pubs/lgo_protocol_v1_1_2010-05-03.pdf
[9] http://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf
[10] https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf
[11] http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/nger
[12] *The NGER is referenced as being a more advanced method for estimating emissions from WWTP effluent from a research article in the Water Environment Research journal titled "Wastewater GHG Accounting Protocols as Compared to the State of GHG Science". This article compares major GHG estimating protocols and methodologies for wastewater treatment.*

The GHG Protocol breaks down emissions into three categories, or scopes:

Scope 1 includes direct emissions from on-site energy use and process emissions from MWRA operations

Scope 2 includes indirect emissions associated with the consumption of fuels for operational purposes (i.e. electricity) and

Scope 3 includes indirect emissions not included in Scope 2 and are from facilities or operations not owned or controlled by the MWRA, such as those from employee's vehicles used to commute to work and emissions from the cities and towns in MWRA's service area (Scope 3 is optional to report on).

Table 2 below shows MWRA's emission types broken down by Scope.

Table 2: GHG Emissions by Scope

Scope	Category	Emission Source
Scope 1	Stationary	Natural gas Diesel Propane Anthropogenic digester gas combustion[13] Anthropogenic digester gas flaring
	Mobile	Gasoline Diesel Mileage
	Process	Process CH_4 emissions Process N_2O emissions Incomplete combustion of digester gas
	Fugitive	Fugitive CO_2 emissions Fugitive CH_4 emissions Landfill CH_4 emissions Digester gas venting Refrigerants
Scope 2	Indirect	Electricity (location & market-based)
Scope 3	Indirect	Employee commuting Communities in MWRA's Service Area Electrical Transmission & Distribution losses Septic systems in areas not served

[13] *The combustion of biomass and biomass-based fuels, such as wood, landfill gas, ethanol, etc., emit CO_2 emissions, but these CO_2 emissions are distinct from Scope 1 emissions generated by combusting fossil fuels. The CO_2 emissions from biomass are tracked separately because the carbon in biomass is of a biogenic origin – meaning that it was recently contained in living organic matter. Conversely, the carbon in fossil fuels has been trapped in geologic formations for millennia are known as an anthropogenic emission. (See EPA Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources). Also in Appendix A.*

See Appendix A for more detail on scopes and methodology. This analysis also examines emissions by MWRA functional areas - water and wastewater, as well as by specific source (e.g. electricity, gas, etc.). This approach allows for easier identification of trends and opportunities by source or function.

Since Scope 1 and 2 categories are sources that are owned and/or operated by MWRA, there is a greater opportunity to potentially reduce those related emissions. These Scope 1 and 2 emissions account for approximately 85% of MWRA's total GHG emissions annually; therefore they are the primary focus of this GHG Emissions Inventory. A more complete analysis of Scope 3 emissions and any targeted reductions in these emissions will be addressed in a future analysis. Information collected to date on Scope 3 emissions can be found in Appendix C.

Analysis Results

In 2014, MWRA had a total carbon footprint of **98,739** Metric tons of carbon dioxide-equivalent from Scope 1 and 2 emissions. Between 2006 and 2014, these emissions were reduced by **28.7%**.

Emissions by Scope

MWRA's contributions to greenhouse gas emissions, in metric tons of CO_2e14 by Scope and year are shown in Table 3 below. It is important to note that 2006 was established as the base year since it was the earliest year for which reliable and comprehensive data was available. Some of the categories that are impacted by external factors such as weather, regulations, and customer demand, show variation in emissions from year to year rather than a steady trend. For example, emissions spiked in 2010 as a result of increased diesel fuel usage for that year. There was an extended period of record rainfall that necessitated the use of the emergency backup generators at DITP to ensure the plant had reliable power to support continuous wastewater pumping and treatment.

[14] *CO_2e is carbon dioxide equivalent, which is a measure that allows the comparison of the emissions of other greenhouse gases relative to one unit of CO_2.*

Table 3: GHG Emissions by Scope – 2006 through 2014[15]

Metric tons CO_2e by type	2006	2007	2008	2009	2010	2011	2012	2013	2014
Scope 1 (Direct)									
Stationary	36,523	33,356	27,597	27,932	40,774	28,196	27,787	27,959	28,770
Mobile	2,137	2,173	2,125	2,082	2,155	2,131	2,083	2,099	2,081
Process	6,726	6,655	7,498	5,263	5,599	7,777	6,082	5,780	8,115
Fugitive	11,664	11,066	10,993	11,548	11,001	11,544	11,227	11,671	11,458
Total Scope 1	57,049	53,250	48,213	46,824	59,529	49,649	47,179	47,508	50,424
Scope 2 (Indirect)									
Electricity	81,458	83,950	76,420	66,626	63,145	59,330	49,503	50,953	48,314
Total (metric tons CO_2e) S1,S2	**138,508**	**137,200**	**124,633**	**113,450**	**122,674**	**108,979**	**96,681**	**98,461**	**98,739**

As the data in Table 3 shows, MWRA's GHG emissions have been relatively stable with the exception of emissions from stationary sources and from indirect emissions from electricity purchased, both of which have generally decreased. These reductions are due to MWRA's efforts to reduce the energy used by its pump stations, headworks, and water and wastewater treatment plants in addition to the increase of on-site renewable energy at some of these stationary MWRA facilities. There has also been a slight decrease in mobile emissions due to the use of more fuel efficient fleet vehicles.

Emissions data was calculated using MWRA activity data and emission factors from the EPA Climate Leadership for Greenhouse Gas Inventories[16] with the following generalized equation:

Activity Data x Emission Factor = Emissions

Examples of activity data include fuel consumption by fuel type, metered annual energy consumption, and annual vehicle mileage by vehicle type.

[15] *Annual data based on Calendar Year (January 1 – December 31).*
[16] *http://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf*
The Australian National Greenhouse and Energy Reporting (NGER) protocol was used in substitute for the estimation of nitrogen emissions from WWTP effluent to receiving bodies of water; due to the lack of research in the current LGOP protocol for this emission source. Massachusetts Department of Environmental Protection electricity emission factors were used along with supplier specific factors in substitute of EPA estimated factors for the New England Region (see methodology section).

MWRA uses electric vehicles in and around its large treatment facilities

As Table 3 shows, indirect energy consumption is the largest single source of emissions. These emissions were calculated using Massachusetts Department of Environmental Protection electricity emission factors along with supplier specific factors in substitute of EPA estimated factors for the New England Region; this represents a more accurate estimate of emissions from electricity purchases in Massachusetts.

Large contributors to direct energy consumption associated GHG emissions include natural gas use - primarily by the heaters and dryers at the Biosolids Processing Facility, and diesel use - most significantly by the backup generators at DITP, and in the MWRA's vehicle fleet.

The GHG inventory shows that the largest source of MWRA's GHG emissions is related to electricity use as shown in Table 4. In 2014, emissions from the generation of the electricity purchased, contributed to approximately 49% of MWRA's total GHG emissions (Scope 1 and 2).

Table 4: GHG Emissions by Category within Scope 1 and 2 for 2006 (base year) and 2014[17]

GHG Emissions Sources (Scope 1 and 2)	CY2006 tCO_2e[18]	CY2006 % of Total Emissions	CY2014 tCO_2e	CY2014 % of Total Emissions	2006-2014 % change in Total Emissions
Electricity	81,458	58.8%	48,314	48.9%	-40.7%
Natural Gas	20,964	15.1%	15,967	16.2%	-23.8%
Diesel	14,954	10.8%	12,216	16.2%	-18.3%
Fugitive Emissions from Pelletization	5,212	3.8%	5,001	12.4%	-4.1%
Incomplete Combustion of Digester Gas	4,861	3.5%	4,974	5.1%	2.3%
Process CH4 Emissions	4,124	3.0%	5,315	5.0%	28.9%
Process N2O Emissions	2,465	1.8%	2,652	5.4%	7.6%
MWRA Vehicle Fleet	2,137	1.5%	2,081	2.7%	-2.6%
Landfill Fugitive Emissions	891	0.6%	1,167	2.1%	31.0%
Refrigerants	699	0.5%	316	1.2%	-54.7%
Propane	329	0.2%	304	0.3%	-7.4%
Anthropogenic Digester Gas Combustion	265	0.2%	274	0.3%	3.6%
Process N2O to Aquatic Environments	138	0.1%	148	0.3%	7.2%
Anthropogenic Digester Gas Flaring	11	0.01%	9	0.01%	-22.9%
Digester Gas Venting	0.3	0.0%	0.0	0.00%	-100.0%
Total (S1 & S2)	**138,508**	**100.0%**	**98,739**	**100.0%**	**-28.7%**

[17] *Emissions totals are rounded to the nearest whole number.*

[18] *tCO_2e is metric tons of carbon dioxide equivalent, which is a measure that allows the comparison of the emissions of other greenhouse gases relative to one unit of CO_2.*

Emissions by System – Water and Wastewater

MWRA's mission is to provide clean, safe drinking water to 51 cities and towns and treat an average of 350 MGD of wastewater from 45 communities (61 total communities served), therefore the GHG emissions contributed individually by water and wastewater systems is of interest. Table 5 shows the Scope 1 and 2 GHG emissions by water and wastewater systems. Since MWRA's wastewater systems uses more energy for treatment and pumping of wastewater compared to the water system (which primarily uses gravity for distribution), there are more emissions from the wastewater system.

Eleven percent of MWRA's GHG emissions are from transporting and treating drinking water, while 89% are from the transport and treatment of wastewater.

Table 5: GHG Emissions by System – Water and Wastewater

GHG Emissions (S1 & S2)	2006	2007	2008	2009	2010	2011	2012	2013	2014
Water (metric tonsCO_2e)	15,436	16,713	13,490	12,812	12,759	11,569	10,676	11,162	10,681
Wastewater (metric tons CO_2e)	123,072	120,487	111,143	100,639	109,915	97,410	86,006	87,299	88,057
Total (metric tons CO_2e) S1 & S2	***138,508***	***137,200***	***124,633***	***113,450***	***122,674***	***108,979***	***96,681***	***98,461***	***98,739***

GHG Intensity of Water Delivered and Wastewater Treated

In order to provide context to MWRA GHG emissions, the following information has been compiled and GHG intensity indicators derived from services provided and populations served:

2014 MWRA water system:
Metric tons CO_2e per household per year: 0.010
Metric tons CO_2e per million gallons of water delivered: 0.15
Millions of gallons treated: 71,522
(Includes Scope 1 & Scope 2 emissions)

Table 6: Intensity of Water Delivered

Water	2014	Unit
Average household water consumption/ year	46,114	gallons
Per capita annual water consumption	18,766	gallons
Number of households served	1,061,301	households
Population served	2,549,002	people

2014 MWRA wastewater system:
Metric tons CO_2e per household per year: 0.090
Metric tons CO_2e per million gallons of water delivered: 0.73
Millions of gallons treated: 120,148
(Includes Scope 1 & Scope 2 emissions)

Table 7: Intensity of Wastewater Treated

Wastewater	2014	Unit
Average household gallons wastewater treated*/ year	129,584	gallons
Per capita annual gallons wastewater treated*	54,116	gallons
Number of households served	927,186	households
Population served	2,220,192	people

**figures include percentage of household/per capita wastewater treated including infiltration/inflow*

Greenhouse Gas Emissions Reductions To Date

MWRA's optimization and on-site renewable energy efforts have resulted in a reduction of total GHG emissions by 28.7% or 39,769 tCO_2e (Scope 1 and 2 emissions) from 2006 through 2014. This has occurred even as new facilities have come online to meet new regulatory requirements.
A breakdown of the percent change in total GHG emissions by activity is shown below:

- 41%reduction in emissions from electricity use
- 18% reduction in emissions from diesel use
- 24% reduction in emissions from natural gas use
- 3% reduction in emissions from the vehicle fleet
- 7% reduction in emissions from propane use
- 23% reduction in emissions from digester gas flaring
- 55% reduction in fugitive emissions from refrigerants
- 100% reduction in emissions from digester gas venting[19]

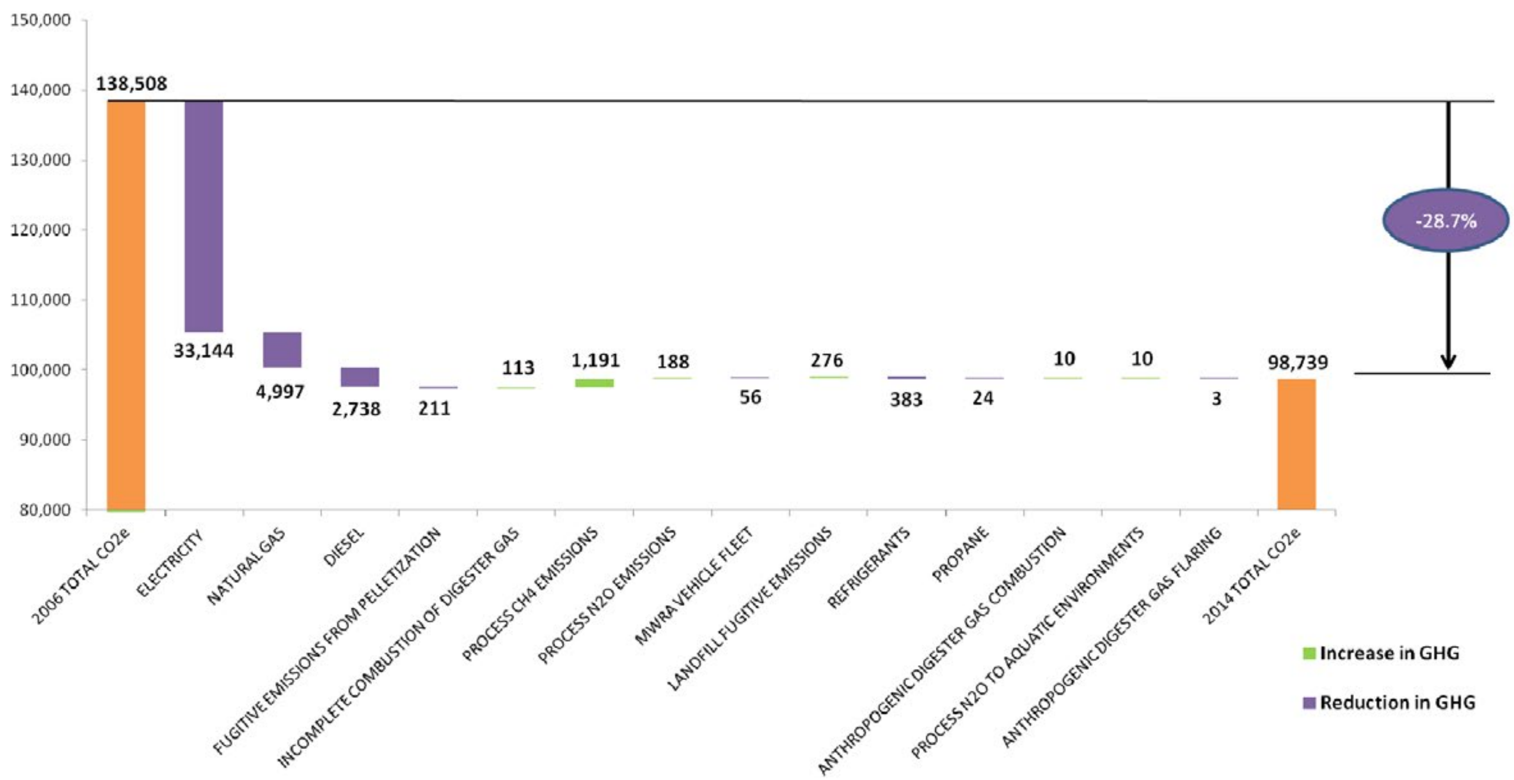
Reductions in emissions from energy usage reflect the progress made in the renewable energy and energy efficiency programs at MWRA. Reductions in natural gas are primarily due to increased operating efficiency at the Biosolids Processing Facility. Diesel emissions reductions are primarily due to a decrease in diesel fuel used for heating and backup generation at DITP as well as a shift to using natural gas for heating at several smaller facilities. Propane use is relatively low although use has decreased further since 2006 primarily due to the decommissioning of the Cosgrove Disinfection Facility once the Carroll plant was fully on-line. Propane use at other facilities has held generally constant.

[19] *GHG emissions from digester gas venting were reduced from 0.28 tCO_2e in 2006 to 0.00 tCO_2e in 2014.*

Figure 7 below displays each category of emissions as a bar and the total reduction (shown in purple) or increase (shown in green) in emissions for each from 2006-2014.

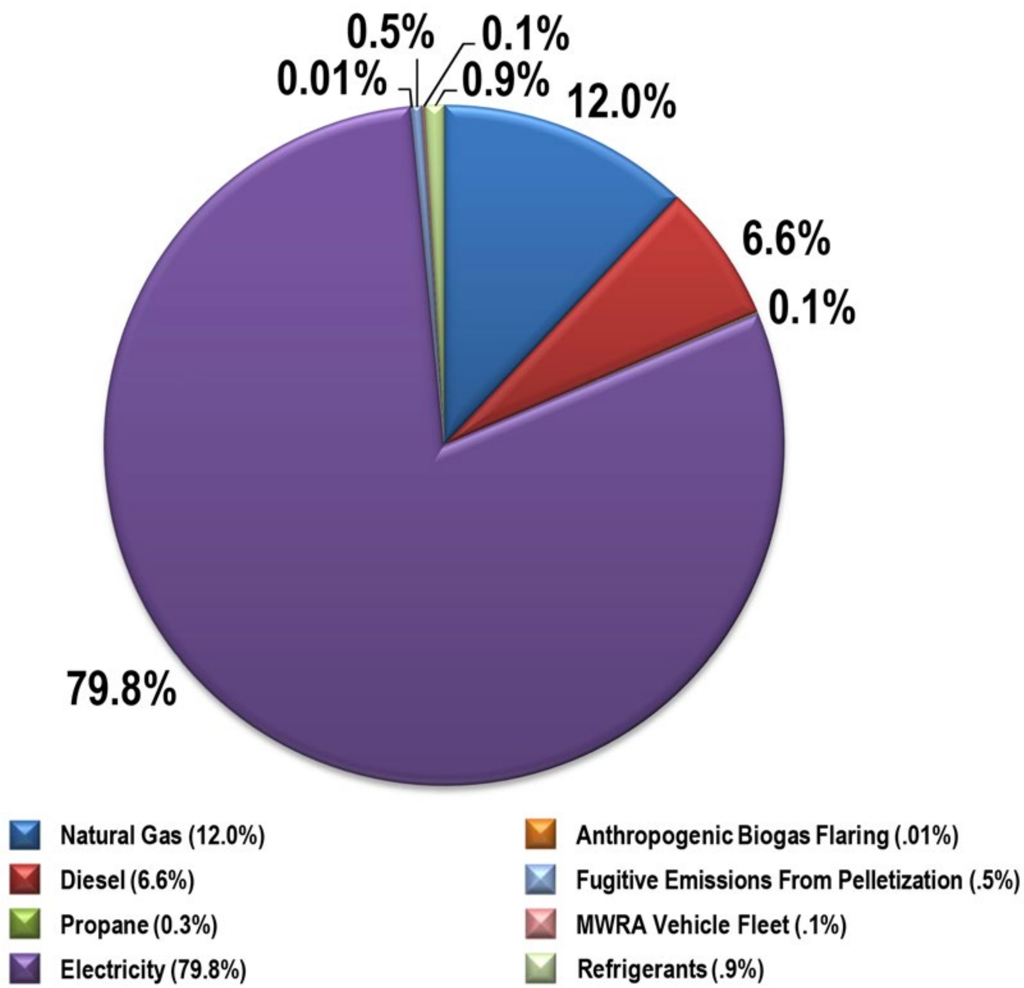
The first bar on the far left of the graph shows the total GHG emissions in 2006, while the last bar on the far right shows the total GHG emissions in 2014. As shown in the graph, there has been a reduction of 39,769 tCO_2e in MWRA's GHG emissions during this time-frame. In between the two totals, the purple bars show the sources of GHG that contributed to the reduction in emissions, while the bars in green show the sources that went up. As the data in the graph illustrates, the largest contributors to MWRA's overall reduction in GHG emission during this time period were electricity, natural gas, and diesel.

Figure 7: 2006 to 2014 Changes in GHG Emissions (tCO_2e)



The pie chart below compares only those sources that had reductions in order to demonstrate the relative emissions reductions by source. Looking at just reductions, electricity accounts for the largest reduction in emissions, nearly 80% of MWRA's entire GHG emissions reductions from 2006–2014. Overall MWRA has reduced GHG emissions from Scope 2 (indirect emissions from electricity production) by almost 41%.

Figure 8: Percent Contribution to GHG Emissions Reductions by Source (from 2006 to 2014)



Renewable Energy and Avoided Emissions

Renewable electricity generated by MWRA from 2006 through 2014, relates to 233,278 metric tons of CO_2e of avoided GHG emissions. This is equivalent to avoiding the GHG emissions from 559 million miles driven by an average passenger vehicle.[20]

In 2014 alone, the renewable electricity generated by MWRA prevented the emission of 29,022 metric tons of CO_2e. This level of avoided emissions is equal to almost 70 million miles driven by an average passenger vehicle.[20]

Additionally, the use of digester gas at the Deer Island and Clinton wastewater treatment plants has allowed MWRA to avoid significant diesel and electricity use for plant operations. If diesel was used for heating instead of digester gas for the period of 2006-2014, there would have been an additional 484,963 metric tons of CO_2e emissions. If you consider the 2,368 metric tons of human-made CO_2e emitted from digester gas combustion from 2006–2014, the use of digester gas avoided the potential emissions of up to 482,595 metric tons of CO_2e during this period. This is equal to almost 1.2 billion miles driven by an average passenger vehicle or the carbon sequestered by over 456,000 acres of U.S. forests in one year, a land mass about 8 times that of the Boston area.[20]

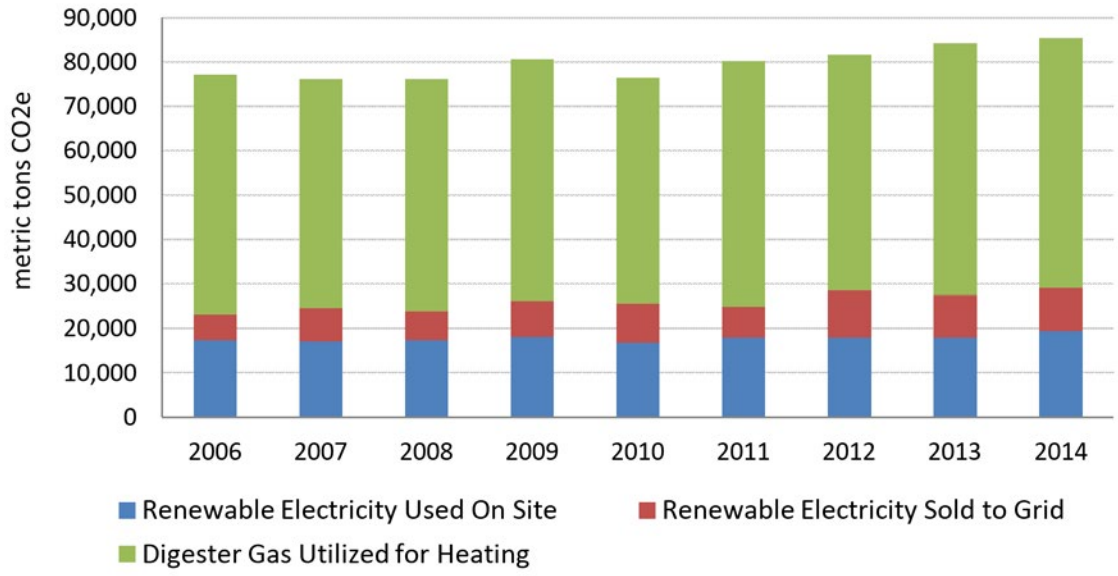
Table 8: MWRA Avoided GHG Emission Totals from 2006-2014 and Comparison Equivalents

	GHG Emissions Avoided (metric tons CO2e)	Equivalent miles driven by average passenger vehicle (miles)	Equivalent amount of coal burned (pounds)	Carbon sequestered by acres of U.S. forests in one year (acres)
Renewable Electricity Generated	233,278	559,087,028	248,929,810	220,822
Digester Gas Utilized for Heating	482,595	1,156,614,015	514,974,759	456,826

[20] http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

The chart below illustrates the impact of renewable electricity generated and used on site, renewable electricity generated and sold to the grid, and the use of digester gas for heating, and the associated avoided GHG emissions in metric tons CO_2e.

Figure 9: Renewable Energy Generation & Associated Avoided Emissions



Steam Turbine Generator at Deer Island - Methane generated from sludge digestion process ("digester gas") is collected and used in DITP's on-site power plant to create steam that supplies hot water and heat for the plant. The steam is also run through two steam turbine generators that produce electricity. This co-generation facility provides MWRA the heating equivalent of approximately 5 million gallons of fuel oil, and approximately 30 million kWh of electricity annually.

Strategic Recommendations

The MWRA will continue its efforts to implement projects that offer reductions in energy use and attendant greenhouse gas emissions in the most cost-effective manner. Since electricity use is the largest contributor to GHG emissions, focusing on reducing MWRA's electricity use and considering procuring low-carbon-intensive electricity remain a priority. Procuring low-carbon intensive electricity could offer a way to further reduce emissions beyond what can be accomplished solely on MWRA sites.

Recommendations to continue to reduce MWRA's GHG emissions include:

1. Set MWRA GHG emissions reduction targets and develop an implementation plan

2. Consider energy mix and emissions factors in electricity supply requirements

3. Include emissions analysis in new technology and investment considerations

4. Central energy data management
    a. Electricity use
    b. Vehicle fleet data (gasoline use, diesel use, refrigerant inventories, mileage)
    c. Digester gas, diesel, propane, and natural gas use

5. Conduct a Green Vehicle Fleet analysis
    a. Downsize/Elimination of vehicles
    b. Optimize travel, operations, and maintenance
    c. Fuel efficiency, alternative fuel, electric vehicle procurement expansion
    6. Develop energy management employee engagement program

7. Explore opportunities to expand employee commuting opportunities

8. Investigate potential for process and fugitive emissions reductions, and assess for feasibility and cost, including:
    a. Reductions in process N_2O
    b. Reductions in process methane
    c. Landfill methane capture

Next Steps

Action Plan & Timeline

The MWRA will consider projects that offer greenhouse gas emissions reductions at low cost to the ratepayer, that are significant in scope, or that demonstrate to employees and the public MWRA's commitment to a low-carbon workplace.

Short term implementation

- Expand the focus of the Energy Task Force Committee to extend to GHG emissions reduction efforts.
  - Assessments should include project scope, timeline, costs, energy savings, payback period based on life cycle cost analysis, GHG reductions potential, list of co-benefits, technical feasibility

- Develop an action plan for completing Phase 2 of the GHG Inventory project
  - Phase 2 should include the addition of previously excluded GHG emissions in Scope 3 optional categories e.g. those associated with chemicals and transportation

  - Phase 2 should also include conducting a baseline emissions inventory and forecast (what GHG emissions are expected in future years given no changes to business as usual) as detailed in Step 1 of ICLEI's21 Five Milestone Methodology

- Assign responsibility for maintaining the GHG inventory
  - Timeline: update all data and inputs at the end of each year
  - Republish updated PDF report and web summary of findings each year.

Long term implementation

- Use bi-monthly agency wide Energy Task Force meeting to engage senior management to review findings of GHG Inventory project and follow-up GHG reductions project assessments

- Conduct a peer review of greenhouse gas emissions at other wastewater treatment plants to see what opportunities may exist to further reduce GHG emissions in such an energy intensive business.

- Use available information to create publicly available reductions targets consistent with state and national targets.

As public GHG reductions targets are set, MWRA will benefit in several ways. MWRA will have a continued opportunity to demonstrate agency leadership in environmental stewardship while achieving cost savings and potentially stimulating continual innovation. It will also prepare the agency for any future changes to regulatory standards.

The Oakdale Hydroelectric Generation facility captures energy as water enters the Wachusett Reservoir from the Quabbin Reservoir.

Hydroelectric generators at the Cosgrove Intake capture energy as water leaves the Wachusett Reservoir headed toward metropolitan Boston area.

Appendices

Appendix A: Methodology

What went into creating the inventory

This inventory was designed to help the MWRA evaluate the greenhouse gas emissions associated with its operations. It helps to provide a baseline for tracking emission trends.

In line with the stated objectives of the GHG Protocol[i], in developing this inventory, the MWRA seeks to:

- Create an inventory that represents a true and fair account of its GHG emissions, through the use of standardized approaches and principles.
- Provide useful and actionable information to build an effective strategy to manage and reduce GHG emissions
- Ensure consistency and transparency in GHG accounting and reporting

The Local Government Operations Protocol (LGOP), version 1.1 and the Greenhouse Gas Protocol developed by World Resources Institute and the World Business Council for Sustainable Development were used to guide the methodology in this inventory. These tools are the standard for local government agencies in the United States, are consistent with methodologies used throughout the world, and represent best practices with regard to reporting emissions.

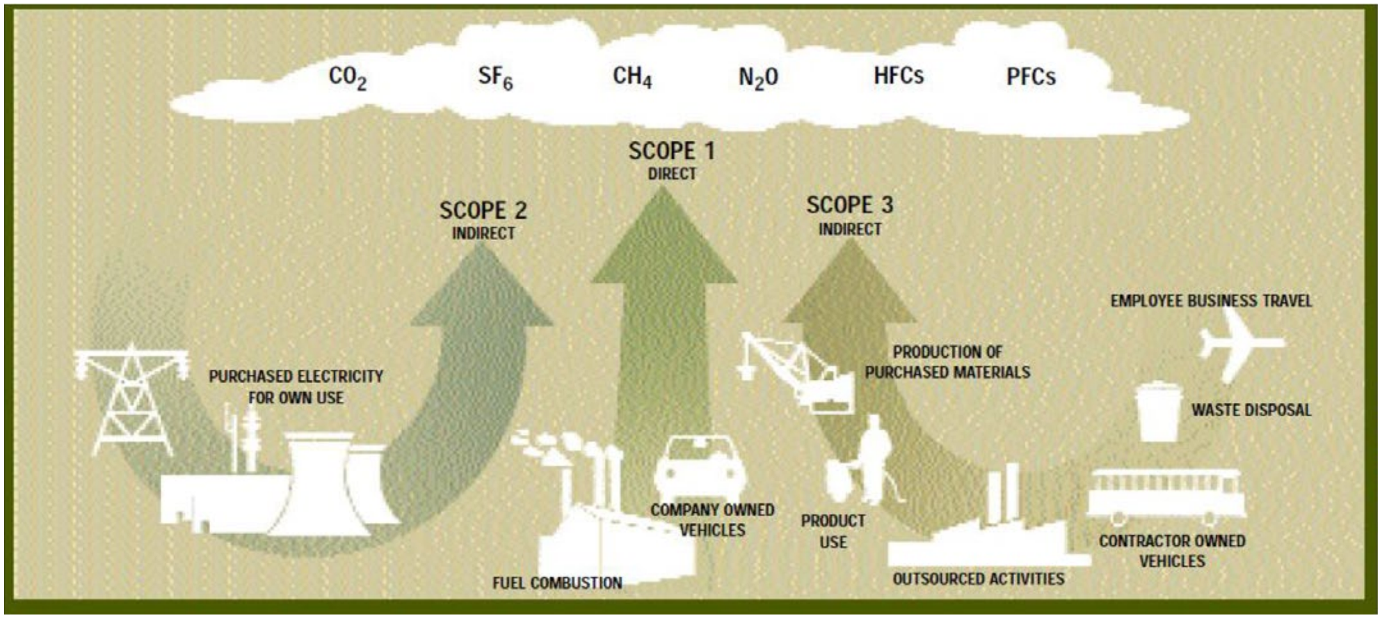
The Australian National Greenhouse and Energy Reporting (NGER)[ii] protocol was used in substitute for the estimation of nitrogen emissions from WWTP effluent to receiving bodies of water; due to the lack of research in the current LGOP protocol for this emission source.

Massachusetts Department of Environmental Protection electricity emission factors[iii] were used along with supplier specific factors in substitute of EPA estimated factors for the New England Region; this represents a more accurate estimate of emissions from electricity purchases in Massachusetts.

MWRA has adhered to the principles of relevance, completeness, consistency, transparency, and accuracy for sound GHG accounting and reporting.[iv]

All GHG emissions in Scope 1 and 2 occurring during the selected calendar years have been included. The Local Government Operations Protocol (LGOP) indicates that reporting on a calendar year basis is considered standard under existing international, national, state, and voluntary reporting programs, therefore MWRA has reported on a calendar year basis.

The base year for this greenhouse gas inventory is 2006 because it is the earliest year with consistent and reliable data for all emissions sources. As the MWRA monitors and tracks progress over time in reducing GHG emissions, 2006 will remains as the performance base year.



Source: GHG Protocol

Operational Boundaries

In order to categorize direct and indirect emissions, to improve transparency, to standardize accounting practices, and to identify different types of climate policies and goals, emissions are reported within the bucket of one of three scopes:

Process emissions include:

- Process CH_4 from WWTP
- Process N_2O from WWTP without nitrification
- Process N_2O from WWTP with nitrification
- Process N_2O from effluent discharge to receiving aquatic environments

Fugitive emissions include:

- CH_4 from incomplete combustion of digester gas
- CH_4 emissions from venting digester gas
- CH_4 fugitive emissions from distribution
- CO_2 fugitive emissions from dry tonnage sludge
- CH_4 from landfill without LFG collection

Electricity Scope 2 emissions include:

- Emissions estimated with MA DEP and supplier-based EF

Biogenic emissions were also accounted for, but not included in the inventory (aggregate emissions) per standard practices and guidance from the GHG Protocol and LGOP.

Biogenic emissions include:

- Digester gas combustion and flaring (CO_2)
- Process CO_2 from digester gas
- Mobile emissions from biodiesel and ethanol

Biogenic vs. Anthropogenic Emissions[v]

The combustion of biomass and biomass-based fuels (such as wood, wood waste, landfill gas, ethanol, etc.) emit CO_2 emissions, but these CO_2 emissions are distinct from Scope 1 emissions generated by combusting fossil fuels. The CO_2 emissions from biomass combustion are tracked separately because the carbon in biomass is of a biogenic origin—meaning that it was recently contained in living organic matter—while the carbon in fossil fuels has been trapped in geologic formations for millennia. Because of this biogenic origin, the IPCC Guidelines for National Greenhouse Gas Inventories requires that CO_2 emissions from biomass combustion be reported separately.[vi]

Not included in the MWRA GHG inventory:

Scope 1

- Refrigerants from field operations (Deer Island and Biosolids Processing Facility refrigerants are included)
- CH4 and N2O emissions from operating field equipment
- Deer Island landfill (assumed negligible)

Scope 3

- Grit & screenings disposed of in landfills by MWRA contractor
- Life cycle emissions of chemicals used (including liquid oxygen and soda ash)
- Contracted transportation
- Energy extraction/production/transportation
- Contracting construction and new projects
- Life cycle emissions of goods and services procured
- Waste emissions

Rationale for exclusion of certain emissions sources

Per the guidelines set forth in the LGOP, the water and wastewater systems at MWRA were studied and interviews conducted with facilities managers and engineers in order to identify any additional potential emissions sources.

Emissions from refrigerants were only accounted for at the Deer Island and Biosolids Processing facilities for the following reasons:

1) emissions from refrigerants in field operations were perceived to be insignificant relative to other sources based on the mandatory reporting of HFCs by MWRA for the Deer Island Wastewater Treatment facility and the Biosolids Processing Facility
2) the data was difficult to collect and in some cases not available
3) insufficient time during this phase of the project.

Several Scope 3 emissions sources, which are by definition optional to report, were excluded because of limited time during this phase of the project. The next inventory update may be expanded to include Scope 3 emissions from sources such as contracted transportation (trucks, trains, barges), life cycle of chemicals (especially liquid oxygen and soda ash), and energy extraction and distribution. Scope 3 emissions, despite being indirect, often provide important and actionable information. For this reason, MWRA conducted an authority-wide Employee Commuter Survey to assess Scope 3 emissions associated with employee commuting. The results of this commuter survey will to aid in the strategic emissions reduction plan.

Calculation methods:

Activity data[vii] are the relevant measurement of energy use or other GHG generating processes. Examples of activity data referenced in this Protocol include fuel consumption by fuel type, metered energy consumption, and vehicle mileage by vehicle type. Activity data are used in conjunction with an emission factor (see Appendix B) to determine emissions using the following generalized equation:

Activity Data x Emission Factor = Emissions

Appendix B: Emission Factors and Global Warming Potentials

Emission factors[viii] are calculated ratios relating GHG emissions to a proxy measure of activity at an emissions source. Emission factors are used to convert activity data, like energy usage, into the associated GHG emissions and thus are central to creating an emissions inventory. Emissions factors are usually expressed in terms of emissions/energy used (i.e., lbs of CO_2/kWh).

Emission factors are determined by means of direct measurement, laboratory analyses or calculations based on representative heat content and carbon content. The Local Government Operations Protocol (LGOP) provides default emission factors for most calculation methodologies.

When available, the MWRA has worked to identify location-based and supplier-specific emission factors for electricity that are representative of the technology and energy mix employed.

Location-based (local eGrid subregion): method reflects the average emissions intensity of electricity grids on which energy consumption occurs (using mostly grid-average emission factor data).[ix]

Supplier-specific: reflects emissions from electricity that companies have purposefully chosen (or their lack of choice). It derives emission factors from contractual instruments, which include any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims.[ix] Massachusetts-based (MA DEP) approach reflects the average emissions of electricity generation for all energy that is consumed by the state.[x]

Where supplier-specific or MWRA-specific data or emissions factors were not available, default data were used that was made available by either the LGOP v1.1 or the MA DEP. The default data are gathered by federal agencies and other sources covering the default emission factors and system assumptions needed to calculate emissions according to the LGOP.

Global Warming Potentials (GWP) are conversion factors used to compare all greenhouse gas emissions to carbon dioxide equivalent units. The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation. All calculations presented in this report are based on global warming potentials published by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.[xi]

Appendix C: Scope 3 Emissions

Scope 3 is an optional reporting component and includes indirect emissions not included in Scope 2 from facilities or operations not owned or controlled by the MWRA, such as those from employee's vehicles used to commute to work and emissions from the cities and towns in MWRA's service area. Most of the indirect emissions are not within MWRA's operational control, such as emissions from septic systems in MWRA's service area and from water and wastewater transmission and distribution in the 61 communities served by MWRA. Scope 3 categories that the MWRA evaluated during this GHG inventory are described below along with tables including emissions estimates from 2006 through 2014. A more complete analysis of Scope 3 emissions and any targeted reductions in these emissions may be addressed in a future analysis.

As a representative example emissions from water and wastewater of one MWRA Community Member (city of Boston) totaled 3,737 metric tons of CO_2-equivalent in 2014.

Metric tons CO_2e by type	2006	2007	2008	2009	2010	2011	2012	2013	2014
Boston (BWSC)[xii]	3,656	3,656	3,656	3,656	3,656	3,656	3,656	3,575	3,737

Indirect emissions also include transmission and distribution losses associated with the electricity purchased by MWRA. These losses totaled 514 metric tons of CO_2-equivalent in 2014.

Metric tons CO_2e by type	2006	2007	2008	2009	2010	2011	2012	2013	2014
T&D Losses (eGrid)	536	524	523	499	517	538	509	510	514

In 2014 fugitive GHG emissions from septic systems in MWRA communities, but not served by MWRA, were estimated at 18,591 metric tons of CO_2-equivalent.

Metric tons CO_2e by type	2006	2007	2008	2009	2010	2011	2012	2013	2014
Septic systems	17,243	17,515	17,714	17,993	17,972	18,139	18,341	18,592	18,591

Emissions per capita from septic systems are estimated to be four times greater than emissions per capita from MWRA wastewater treatment. This data may help when towns are deciding whether they should connect

Employee Commuting

Another category of indirect emissions is from employee commuting (including carpooling and public transit).

In order to estimate GHG emissions from employee commuting, an Employee Commute Survey was developed and distributed to staff in July 2015, with a response rate of approximately 50% (of 1205 total employees). The results were used to understand the quantity and sources of GHG emissions from employee commuting. Based on the survey results, emissions from employee commuting in 2014 was an estimated total of **4,208 metric tons of CO_2-equivalent**. Approximately 9,207,000 miles were driven by employees. Note - this is an estimated number to represent all MWRA employees, based on an extrapolation of the data received from the survey. These commuting related emissions are equivalent to the CO_2 emissions from more than 4.5 million pounds of coal burned.

Of those who responded to the commuter survey, 79% drive alone to work every day, 5% take public transportation only, 1% carpool every day, and 15% took various forms of transportation throughout the year including driving alone, riding a bike, car pooling, and public transportation. Not surprisingly, those who commute the farthest, drive to work. MWRA promotes the use of public transportation to its largest office building, providing shuttle bus services for employees to/from the local subway/bus station.

Appendix D: Glossary[xiii]

Anthropogenic emissions: Emissions that are human-made and not a result of the natural carbon cycle. In the instance of the combustion of digester gas, methane (CH_4) and nitrous oxide (N_2O) emissions are considered anthropogenic, while carbon dioxide (CO_2) emissions are considered biogenic.

Base Year: A measurement, calculation, or time used as a basis for comparison. According to LGOP, it is good practice to aim for a base year that is likely to be representative of the general level of emissions over the surrounding period.

BAU: Business As Usual. Used to refer to a future scenario in which there are no changes to the status quo.

Biogenic: Biogenic emissions or fuels are produced by the biological processes of living organisms.
Note that this term refers only to recently produced
(i.e., non-fossil)

BOD5: Biological Oxygen Demand. The amount of oxygen consumed in five days by decomposing waste, used to measure the amount of waste input or output into a system.

BPF: Biosolids Processing Facility (aka Pellet Plant)

Btu: British Thermal Units, a measure of energy

CEMS: Continuous Emissions Monitoring System

CFC: chorofluorocarbon, a greenhouse gas.

CHP: combined heat and power

CO_2: Carbon dioxide

CO_2e: Carbon dioxide equivalent emissions. This is determined by multiplying the emissions of methane and nitrous oxide by their Global Warming Potential.

CH4: Methane. Methane is a greenhouse gas with a GWP that is 21 times that of CO_2. It is produced through anaerobic decomposition of waste, enteric fermentation, production of natural gas and petroleum products, and other industrial processes.

Denitrification: The process by which microorganisms remove nitrogen from its fixed form in the soil and release it into the atmosphere in the form of nitrous oxide (N_2O)

Direct Emissions: The emissions generated on-site (as opposed to electricity delivered through a grid system), such as from the combustion of fossil fuels

DITP: Deer Island Treatment Plant

EF: See Emission Factor.

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Direct Emissions: The emissions generated on-site (as opposed to electricity delivered through a grid system), such as from the combustion of fossil fuels

DITP: Deer Island Treatment Plant

EF: See Emission Factor.

Indirect emissions: Refers to indirect emissions associated with the consumption of purchased or acquired electricity, steam, heating, or cooling. These emissions can be allocated in an inventory to an entity, but are generated offsite. An example is electricity that is not generated directly at a facility. A facility uses electricity on-site, but the fuels used to generate the electricity are combusted off-site, perhaps at a regional power plant. If the generation source is at a different site that is also operated by the city, it is not an indirect emission source.

IPCC: Intergovernmental Panel on Climate Change

kg: kilogram(s)

kWh: kilowatt-hour(s)

lb(s): pound(s)

LFG: landfill gas

LGOP: Local Government Operations Protocol

LHV: lower heating value

mcf: thousand cubic feet of natural gas

MG: million gallons

mmBtu: million British Thermal Units, a measure of energy

Mobile combustion: The combustion of fuels to power a moving vehicle, such as gasoline or diesel fuel in a car or truck

mpg: miles per gallon

MT CO_2e: Metric tons of carbon dioxide equivalent. This is the standard unit for measuring greenhouse gas emissions.

MWh: megawatt-hour(s)

MWRA: Massachusetts Water Resources Authority

N2O: nitrous oxide

NF3: nitrogen trifluoride

Nitrification: Biological process in which ammonia is converted to nitrate (NO_3).

Operational control: A local government has operational control over an operation if it has the full authority to introduce and implement its operating procedures
PFC: perfluorocarbon

Process Emissions: emissions from physical or chemical processes such as CO_2 from the calcination step in cement manufacturing, CO_2 from catalytic cracking in petrochemical processing, PFC emissions from aluminum smelting, etc.

REC: renewable energy certificates

S1: see Scope 1 emissions

S2: See scope 2 emissions

S3: See scope 3 emissions

Scope 1 Emissions: All direct GHG emissions

Scope 2 Emissions: Indirect GHG emissions from the consumption of purchased electricity, heat, or steam.

Scope 3 Emissions: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, outsourced activities, etc. The Scope 3 emissions included in this inventory are employee commutes, imported water consumption, waste generation, urban forestry, and agriculture & land management.

Short tons: American ton, equal to 2,000 lbs. One short ton = 0.907 metric tons

Stationary Combustion: The on-site combustion of fuels to produce electricity, heat, or motive power using equipment in a fixed location

SF6: sulfur hexafluoride

T&D: transmission and distribution (electricity)

tCO_2e: metric tons carbon dioxide equivalent. This is the standard unit for measuring greenhouse gas emissions.

WBCSD: World Business Council for Sustainable Development

WRI: World Resources Institute

WW: Wastewater

WWTP: Wastewater treatment plant

Appendix E: Endnotes

i Greenhouse Gas Protocol Corporate Standard: http://www.ghgprotocol.org/standards/corporate-standard

ii http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/nger

iii http://www.mass.gov/eea/agencies/massdep/climate-energy/climate/approvals/magreenhouse-gas-emissions-reporting-program.html#1

iv Greenhouse Gas Protocol Corporate Standard: http://www.ghgprotocol.org/standards/corporate-standard

v See EPA Accounting Framework for Biogenic CO2 Emissions from Stationary Sources: https://www.epa.gov/sites/production/files/2016-08/documents/biogenic-co2-accounting-framework-report-sept-2011.pdf

vi See the LGOP v1.1, http://www.arb.ca.gov/cc/protocols/localgov/localgov.htm

vii See the LGOP v1.1, http://www.arb.ca.gov/cc/protocols/localgov/localgov.htm

viii See the LGOP v1.1, http://www.arb.ca.gov/cc/protocols/localgov/localgov.htm

ix GHG Protocol: Scope 2 Guidance: http://ghgprotocol.org/files/ghgp/Scope2_ExecSum_Final.pdf

x Technical Support Document: Draft 2013 GHG Emission Factors: http://www.mass.gov/eea/docs/dep/air/climate/rse13tsd.pdf

xi https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

xii Emissions data from one of the 61 communities in MWRA's Service Area (the Boston Water and Sewer Commission) was used as a representative example to quantify the total emissions associated with bringing drinking water to a customer's tap from the MWRA's water pipelines and transporting wastewater from local homes and businesses to the MWRA's sewer system. Each community would have a different total emissions amount.

xiii Definitions provided by the EPA's Local Greenhouse Gas Inventory Tool: https://www.epa.gov/statelocalclimate/state-inventory-and-projection-tool