

Devens 2015 Community and Municipal Greenhouse Gas Emissions Inventory

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Section 1: Overview

Introduction

This greenhouse gas (GHG) inventory report summarizes community-wide and local government GHG emissions in Devens, MA for the baseline year of 2015. The report also contains descriptions of the methodologies and data sources used in the study, which can be replicated in subsequent years to track progress on emissions reduction goals. This GHG inventory report was prepared by Kim Lundgren Associates, Inc. (KLA) from January through April 2019. The results of the GHG inventory will be used for climate action planning for the Town of Devens.

Executive Summary

The results of the community-wide GHG inventory indicate that most of Devens' GHG emissions are a result of industrial and institutional buildings' electricity and natural gas usage. Emissions from buildings accounted for 94% of all GHG emissions in Devens. Transportation was the second highest sector, representing only 5%. Water delivery, wastewater treatment, and solid waste disposal accounted for slightly more than 1% of total emissions in Devens.

In terms of emissions sources, electricity (48.9%), natural gas usage (45.5%), and fugitive gas (0.7%) combined represent more than 95% of Devens GHG emissions. Emissions from gasoline (2.8%) and diesel (1.7%) combine for 4.5% of emissions.

On the municipal side,

electricity was the largest source of municipal GHG emissions (58%), followed by natural gas usage (23%). In terms of departments, Wastewater Treatment was the largest emitter at 28% of municipal emissions, followed by Public Works (19%) and Administrative (17%).

This baseline GHG inventory is the first step toward tracking emissions over time. Subsequent studies shall be performed to monitor GHG emissions in Devens once targets are established and the climate action plan is completed.

Scopes Framework

The scopes framework is a standard method of organizing emissions sources first developed by the World Resources Institute (WRI) in the GHG Protocol Corporate Standard. Scope 1 sources are direct emissions from sources like natural gas burned by the reporting entity in the inventory year. Scope 2 are indirect emissions from electricity use, with emissions actually occurring outside the boundary but as a result of in-boundary activity by the reporting entity. Scope 3 are all other indirect emissions that generally occur outside the boundary or over a timeframe outside of the reporting year. Emissions from solid waste, which occur over decades, are an example of a scope 3 source.

Global Warming Potentials

Three primary greenhouse gases are included in the GHG inventory: carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Each of these gases has a unique lifespan and effect on the atmosphere, thus a common unit of "CO₂ equivalent" (CO₂e) is used to describe the gases in like-terms. The multiplier that converts a metric ton of CH₄ or N₂O to a metric ton CO₂e is called its global warming potential (GWP). The science behind our understanding of the effect of these gases is constantly evolving. The Intergovernmental Panel on Climate Change (IPCC) collects data from climate scientists and publishes Assessment Reports detailing the latest research on the effect of GHGs on the atmosphere. This inventory

uses GWPs from the IPCC’s Fourth Assessment Report (AR4).¹ While newer IPCC reports are available, many US agencies such as the EPA use GWPs from the IPCC’s Fourth Assessment report and this report follows suit. The primary GWPs used for this inventory are listed in **Table 1**.

Table 1. Activities That Release GHGs into Our Atmosphere and their Global Warming Potential²

Greenhouse Gas	Source Activity	GWP
Carbon dioxide (CO ₂)	Burning fossil fuels	1
Methane (CH ₄)	Burning fossil fuels, agriculture activities, landfills, wastewater treatment practices	25
Nitrous oxide (N ₂ O)	Burning fossil fuels, agricultural activities, industrial activities, landfills	298
Perfluorocarbons	Electronics industry	7,390 – 22,800
Hydrofluorocarbons	Air conditioning / refrigeration	124 – 14,800
Sulphur hexafluoride	Switchgear at power installations	22,800

Section 2: Devens Community Greenhouse Gas Emissions Inventory

The Devens community greenhouse gas (GHG) emissions inventory was prepared by Kim Lundgren Associates, Inc. (KLA) following the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC).³ The GPC is adopted by communities around the world to ensure that GHG reports are relevant, complete, consistent, transparent, and accurate. The GPC city-induced Basic reporting level approach was used for this GHG inventory report. The Basic reporting level provides an inventory of the GHGs released as a result of the energy use and waste material generated within the Town of Devens. The GPC provides guidance on what activities need to be included in the inventory and a framework for how to calculate the GHG emissions associated with various activities. There are some activities, like transportation, where the GPC guidance is not specific. In those situations, KLA used guidance provided in ICLEI’s U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Community Protocol) to ensure that the inventory adhered to GPC principles.⁴ The methodology is included in each of the inventory sector summaries below. Methods from the Local Government Operations Protocol (LGOP) were used for process and fugitive wastewater emissions in the interest of synchronizing calculations with the Devens Municipal inventory.

The GPC provides recommendations on what activities and sources should be included in a GHG inventory for any community worldwide, as well as a general framework for the types of data to collect and calculations to be used. The GPC recognizes that country specific GHG protocols may have calculation methods more applicable to communities in that country. US-specific calculation methods in the Devens Community Inventory were obtained, or adapted from, the Community Protocol and the LGOP. Methods from the IPCC were used when no guidance was available from the GPC, Community Protocol, or LGOP.

¹ <http://www.ipcc.ch/report/ar4/>

² The GWP used in this report is from the IPCC AR4 and is the 100-year time horizon.

³ <http://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities>

⁴ <http://icleiusa.org/publications/us-community-protocol/>

Overall Community Greenhouse Gas Emissions

Activities by residents, visitors and workers in Devens resulted in 96,054 metric tons of GHG emissions (MTCO₂e) in 2015. Emissions from 2015 are equivalent to those released by an average passenger vehicle driven approximately 235 million miles.⁵

Emissions are reported below by both the sector (buildings, transportation, waste) and source (electricity, natural gas, and more). Buildings accounted for the vast majority of GHG emissions at 94% in 2015. The high percentage is due to a large number of industrial and commercial energy users relative to residents and vehicle travel. The second highest emitting sector is transportation, accounting for 5% of community emissions in 2015. Wastewater sector emissions accounted for approximately 1% while emissions from the waste and water treatment & delivery sectors accounted for less than 1% of total emissions in 2015. See **Table 2** for GHG totals by sector and **Figure 1** for a visualization of the GHG contribution from each sector.

Table 2. Devens Community GHG Emissions by Sector

Sector	2015 (MTCO ₂ e)	% of Total 2015
Buildings	90,570	94%
Transportation	4,339	5%
Wastewater	722	1%
Waste	223	<1%
Water Treatment & Delivery	200	<1%
Total	96,054	100%

Figure 1. Devens Community GHG Emissions by Sector

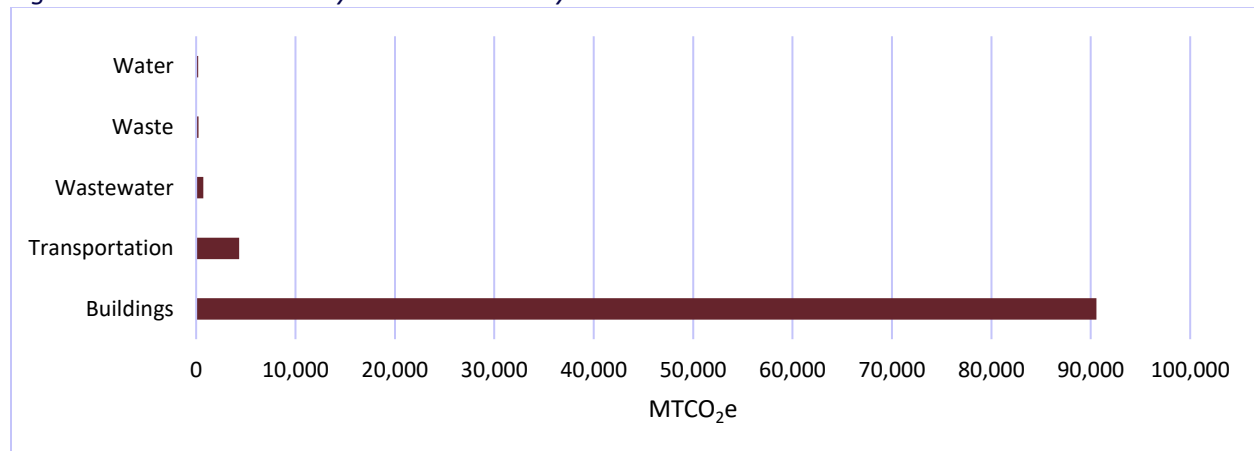


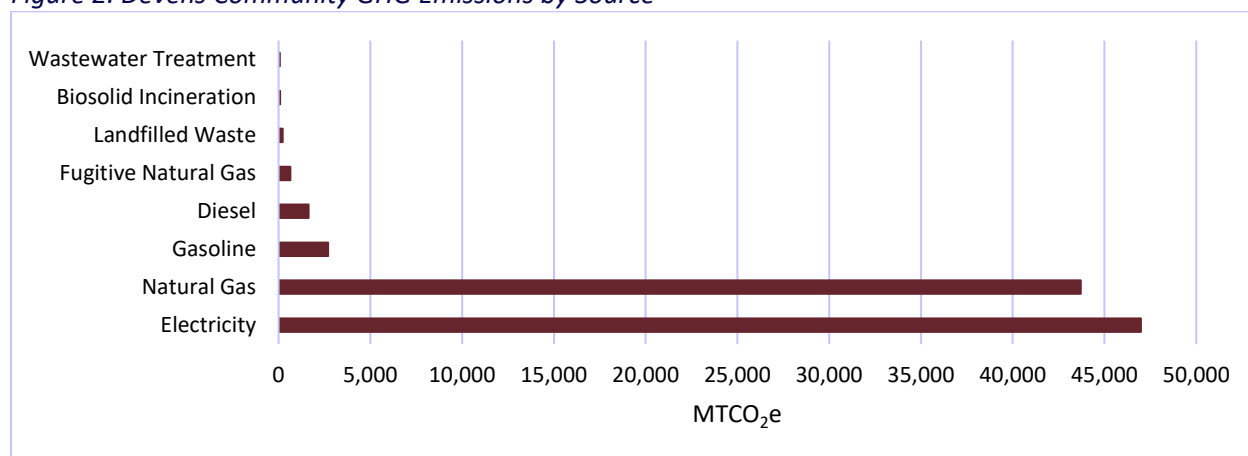
Table 3 lists emissions by source, and **Figure 2** shows the relative contribution of each source for 2015.

⁵ Assumes 4.71 MTCO₂e per vehicle per year and 11,507 VMT per year per vehicle. See EPA Greenhouse Gas Equivalencies Calculator available at: <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>

Table 3. Devens Community GHG Emissions by Source

Sector	2015 (MTCO ₂ e)	% of Total 2015
Electricity	46,984	48.9%
Natural Gas	43,709	45.5%
Gasoline	2,697	2.8%
Diesel	1,642	1.7%
Fugitive Natural Gas	646	0.7%
Landfilled Waste	223	0.2%
Biosolid Incineration	81	0.1%
Wastewater Treatment	71	0.1%
Total	96,054	100%

Figure 2. Devens Community GHG Emissions by Source



Community Emissions by Sector

This section outlines the methods used to calculate emissions for each sector of the community inventory and details fuel use and emissions by source. For more detail on calculation methods and activity data, see the Devens Community GHG Inventory Workbook.xlsx.⁶

Stationary Energy

The Stationary Energy sector is comprised of emissions that result from energy consumption in the residential, commercial, institutional and industrial sectors. Emissions were calculated on the basis of the town's electricity and natural gas use following methodologies in the Community Protocol. Fugitive emissions from natural gas pipelines within the town boundary were calculated based on total natural gas consumption. A summary of the results and methodologies used for 2015 is provided in **Table 4**.

⁶ [https://www.dropbox.com/s/0q1fsr197pv376g/Devens Community GHG Emissions Inventory Final.xlsx?dl=0](https://www.dropbox.com/s/0q1fsr197pv376g/Devens_Community_GHG_Emissions_Inventory_Final.xlsx?dl=0)

Table 4. Summary of Stationary Energy Sector Data and Methodologies

Sub-sector	Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Residential	Electricity	USCP BE 2.1	910,145	kWh	311
Commercial	Electricity	USCP BE 2.1	8,126,403	kWh	2,775
Institutional	Electricity	USCP BE 2.1	27,734,726	kWh	9,471
Industrial	Electricity	USCP BE 2.1	98,668,964	kWh	33,693
Residential	Natural Gas	USCP BE 1.1	140,035	therms	744
Commercial	Natural Gas	USCP BE 1.1	564,243	therms	2,997
Institutional	Natural Gas	USCP BE 1.1	2,089,545	therms	11,099
Industrial	Natural Gas	USCP BE 1.1	5,428,744	therms	28,835
Residential	Fugitive Natural Gas	IPCC Chap. 4.2*	**3,886	therms	11
Commercial	Fugitive Natural Gas	IPCC Chap. 4.2*	**15,657	therms	44
Institutional	Fugitive Natural Gas	IPCC Chap. 4.2*	**58,167	therms	164
Industrial	Fugitive Natural Gas	IPCC Chap. 4.2*	**150,643	therms	427

*No methodology exists in the Community Protocol for calculating emissions from fugitive natural gas, so a method from IPCC was used.

** This is the amount of natural gas leaked. Emissions factors for fugitive natural gas are based on total throughput which includes community usage and the amount leaked each year.

In **Table 4**, the “Institutional” subsector includes energy usage from federal, municipal, military, school and non-profit buildings. Electricity use from residential, commercial, institutional and industrial customers was provided by email from Lawrence Bearce at MassDevelopment. For 2015 electricity emissions, an ISO New England⁷ CO₂ factor was used in conjunction with 2016 NEWE New England Region factors for CH₄ and N₂O⁸ from eGRID. A 2016 eGRID emission factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 is 752.83 lbs. CO₂e/MWh.

Natural gas activity data for the residential and commercial sectors was provided by Lawrence Bearce at MassDevelopment. Natural gas emissions factors from EPA Mandatory Reporting Rule, published in November 2015, and last updated in March 2018, were used to calculate natural gas emissions for 2015.⁹

The amount of fugitive natural gas from distribution attributable to the Town of Devens was determined using a Harvard University study conducted in 2015 finding that 2.7% of all natural gas distributed in the Boston area is leaked and released into the atmosphere.¹⁰ Total natural gas distributed to Devens (including community consumption and leaked gas) was used to calculate the emissions from natural gas leaked into the atmosphere based on guidance provided in Chapter 4 of the 2006 IPCC Guidelines for Greenhouse Gas Inventories.¹¹ IPCC emission factors for fugitive natural gas from distribution based on total throughput were used to determine the associated GHG emissions with this source.

No community fuel oil or propane use was reported by the Town of Devens. **Figure 3** shows GHG emissions by fuel type in the stationary energy sector.

Figure 3. GHG Emissions from Devens Stationary Energy Sector by Building Type and Energy Source

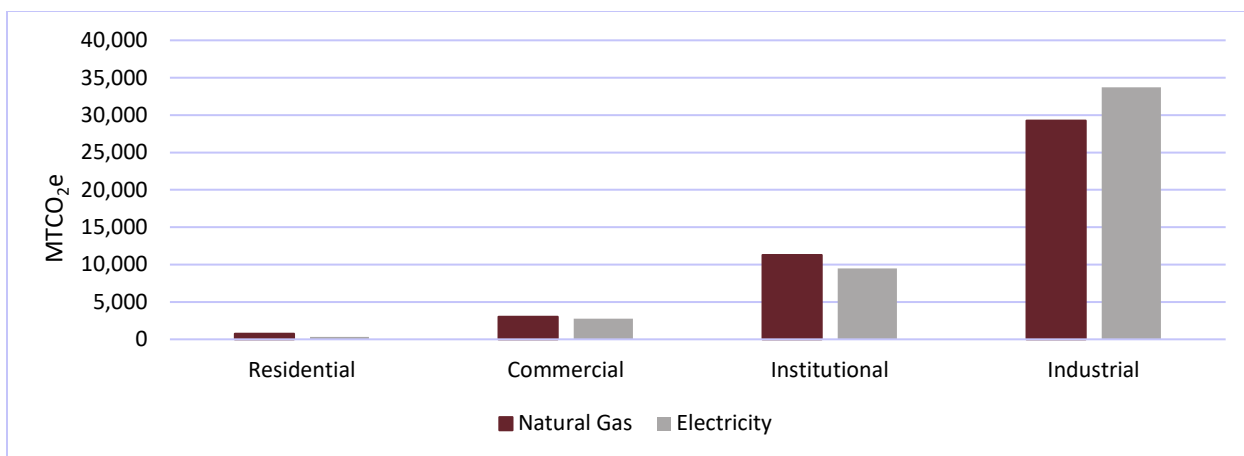
⁷ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

⁸ https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

⁹ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

¹⁰ Summary of study available at: <https://www.seas.harvard.edu/news/2015/01/boston-s-natural-gas-infrastructure-releases-high-levels-of-heat-trapping-methane>

¹¹ <https://www.ipcc-nggip.iges.or.jp/public/2006gl/>



Transportation

The Transportation sector comprises emissions that result from vehicle miles travelled (VMT) and fuel consumption by vehicle trips that begin or end within the Devens community boundary. Pass-through traffic was not included. Transportation activity data was obtained from the 2015 Devens Traffic Monitoring Program. Emissions were calculated following the methodologies in the Community Protocol. Activity data for the MBTA commuter rail serving Devens was obtained from 2015 Devens Traffic Monitoring Program and calculated using factors from EPA Mandatory Reporting Rule last updated March 2018.¹² A summary of the results and methodologies used for 2015 are provided in **Table 5**.

Table 5. Summary of Transportation Sector Data and Methodologies

Sub-sector	Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
On-road Transport	Gasoline Light Trucks	USCP TR.1.B	2,215,107	VMT	1,136
On-road Transport	Gasoline Passenger Vehicles	USCP TR.1.B	4,143,070	VMT	1,561
On-road Transport	Diesel Heavy Trucks	USCP TR.1.B	369,184	VMT	1,347
On-road Transport	Diesel Light Trucks	USCP TR.1.B	88,878	VMT	48
On-road Transport	Diesel Passenger Vehicles	USCP TR.1.B	20,510	VMT	8
Railways	Diesel railway	USCP TR.4.A&B	1,473,397	pass miles	239

Activity data in the form of daily VMT for 2015 was obtained from the Devens Traffic Monitoring Program: Five-Year Traffic Report (Traffic Report) from December 2015.¹³ The Traffic Report listed 2015 weekday VMT for trips that begin or end in Devens – excluding trips that pass through Devens (trips that neither begin nor end in the town). As a result, this VMT accounts for miles travelled both inside the community boundary and travelled outside of the community boundary – making on-road transportation emissions a mix of Scope 1 and Scope 3 according to the GPC. Based on anecdotal information from the Town, weekend traffic VMT was assumed to be the same as weekday VMT. Daily VMT was multiplied by the number of days per year to get yearly VMT.

Total VMT was attributed to diesel and gasoline burning vehicles according to national averages for on-road vehicles as provided by the Community Protocol. Similarly, the types of vehicles on the road in Devens (heavy duty, light duty, passenger vehicles) were assumed to conform to national averages as provided by the Community Protocol. VMT was used to calculate emissions from CH₄ and N₂O with emission factors obtained from the U.S. EPA's Emission Factors for Greenhouse Gas Inventories last updated March 2018.¹⁴

¹² https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

¹³ http://www.devensec.com/meetings/Executive_Summary.pdf

¹⁴ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

To estimate emissions from CO₂, VMT was converted to fuel use using fuel efficiencies for each vehicle type obtained from the U.S Department of Energy’s Alternative Fuel Data Center.¹⁵ CO₂ emission factors for each fuel were obtained from the U.S. EPA’s Emission Factors for Greenhouse Gas Inventories last updated March 2018.

Transit railway data from the MBTA was obtained from the Devens Traffic Monitoring Program: Five-Year Traffic Report from December 2015. The Traffic Report determined that 4% of the Devens population used the MBTA railway. Ayer and Fitchburg MBTA stations represent the closest and farthest of the four stations that serve Devens according to the Traffic Report. An average distance between these two stations and the North Boston Terminal was used to estimate the average distance travelled during a passenger trip on the MBTA. All commuter rail miles were assumed to end at the North Boston Terminal for the sake of this analysis. This average commute distance was multiplied by the number of passengers using the MTA according to the 2015 Devens Traffic Monitoring Report’s assumption of 4% ridership, and then multiplying by two to assume a round trip journey.

Total passenger miles were used to calculate emissions from CO₂, CH₄ and N₂O with emission factors obtained from the EPA’s Emission Factors for Greenhouse Gas Inventories last updated March 2018.

Waste

The Waste sector is comprised of methane emissions that result from the decomposition of residential, commercial, institutional and industrial waste generated and deposited in a landfill in the inventory year. While these emissions occur over time, they are attributed to the year in which the waste was generated and deposited. Waste deposition per capita was estimated based on total waste deposition in the State of Massachusetts available from the Massachusetts Department of Environmental Protection (MassDEP). Alternative Daily Cover (ADC) tons deposited were estimated using state averages of the ratio of ADC to municipal solid waste landfilled. Emissions were calculated following the methodologies in the Community Protocol. A summary of the results and methodologies used for 2015 are provided in **Table 6**.

Table 6. Summary of Waste Sector Data and Methodologies

Sub-sector	Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Solid Waste Disposal	Waste Deposited	USCP SW.4	713	tons	198
Solid Waste Disposal	Alternative Daily Cover (ADC)	USCP SW.4	66	tons	5
Solid Waste Disposal	Landfilled Biosolids	USCP SW.4	226	tons	20

Yearly waste deposition for all sectors of the community were estimated based on total landfilled waste deposition for the State of Massachusetts in 2015 as reported by MassDEP in the Massachusetts 2015 Solid Waste Data Update published in 2017.¹⁶ Total state landfilled tons were divided by the 2015 population of Massachusetts as listed in the 2011-2015 American Community Survey 5-Year Estimates.¹⁷ Per capita waste disposal for Massachusetts was then multiplied by the 2015 population of Devens obtained from the same ACS survey. State level waste data was not able to be disaggregated into residential, commercial, institutional or industrial sectors. Due to the large amount of industrial and commercial facilities in Devens, the waste tonnage estimated here is likely a low estimate.

The characterization or types of materials that comprise the waste stream was estimated using MassDEP’s Solid Waste Master Plan’s Summary of Waste Combustor Class II Recycling Program Waste Characterization Studies document (Includes 2010, 2013 and 2016 Data).¹⁸ Emissions were determined

¹⁵ <https://www.afdc.energy.gov/data/categories/fuel-consumption-and-efficiency>

¹⁶ <https://www.mass.gov/files/documents/2017/02/zi/15swdata.pdf>

¹⁷ https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_DP05&src=pt

¹⁸ <https://www.mass.gov/guides/solid-waste-master-plan>

using emission factors from the California Air Resources Board’s Landfill Tool v1.3 and methodologies adapted from the Community Protocol.¹⁹

ADC used at landfills was estimated using state averages for ratios of ADC/MSW calculated from MassDEP’s 2011 Solid Waste Master Plan.²⁰ Emissions from ADC were determined using emission factors from the California Air Resources Board’s Landfill Tool v1.3 and methodologies adapted from the Community Protocol.

Dry weight tons of biosolids landfilled were provided by Lawrence Bearce of MassDevelopment. Emissions were determined using “sludge” emission factors from the California Air Resources Board’s Landfill Tool v1.3 and methodologies adapted from the Community Protocol.

Roughly half of the biosolids produced in 2015 were landfilled. The other half were incinerated according to Lawrence Bearce of MassDevelopment. See the Wastewater Treatment section below for more information on how incinerated biosolid emissions were calculated.

Water Treatment and Delivery

The Water Treatment and Delivery sector comprises emissions that result from electricity and natural gas used to treat and convey water throughout the community during the inventory year. A summary of the results and methodologies used for 2015 activities are provided in **Table 7**.

Table 7. Summary of Water Treatment Sector Data and Methodologies

Sub-sector	Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Water Treatment	Electricity	USCP BE.2.1	577,480	kWh	197
Water Treatment	Natural Gas	USCP BE.1.1	544	therms	3

Electricity use was provided by email from Lawrence Bearce at MassDevelopment. For 2015 electricity emissions, an ISO New England²¹ CO₂ factor was used in conjunction with 2016 eGRID NEWE New England Region factors for CH₄ and N₂O.²² A 2016 eGRID emissions factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 is 752.83 lbs. CO₂e/MWh

Natural gas activity data for water treatment was provided by Lawrence Bearce at MassDevelopment. Natural gas emissions factors from the EPA’s Mandatory Reporting Rule, last updated in March 2018, were used to calculate natural gas emissions for 2015.²³

Wastewater Treatment

The Wastewater Treatment sector comprises emissions that result from electricity and natural gas used to treat and convey wastewater throughout the community during the inventory year. It also includes process, fugitive, and biosolid incineration emissions that result from the treatment of organic materials in wastewater. A summary of the results and methodologies used for 2015 are provided in **Table 8**.

¹⁹ https://www.arb.ca.gov/cc/protocols/localgov/pubs/landfill_emissions_tool_v1_3_2011-11-14.xls

²⁰ <https://www.mass.gov/files/documents/2016/08/rr/11swdata.pdf>

²¹ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

²² https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

²³ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

Table 8. Summary of Wastewater Treatment Sector Data and Methodologies

Sub-sector	Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Wastewater Treatment and Discharge	Electricity	USCP BE.2.1	1,573,926	kWh	537
Wastewater Treatment and Discharge	Natural Gas	USCP BE.1.1	6,083	therms	32
Wastewater Treatment and Discharge	Process and Fugitive Emissions	LGOP 10.3, 10.7, 10.9	3,321	pop served	71
Wastewater Treatment and Discharge	Biosolid Incineration	USCP WW.4, WW.5*	275	tons	81

*Calculation methodologies from the US Community Protocol were adapted to use dry weight factors from the IPCC and BEAM.

Electricity use was provided by email from Lawrence Bearce at MassDevelopment. For 2015 electricity emissions, an ISO New England²⁴ CO₂ factor was used in conjunction with 2016 eGRID NEW New England Region factors for CH₄ and N₂O.²⁵ A 2016 eGRID emission factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 is 752.83 lbs. CO₂e/MWh.

Natural gas activity data for wastewater treatment was provided by Lawrence Bearce at MassDevelopment. Natural gas emissions factors from EPA Mandatory Reporting Rule, last updated in March 2018, were used to calculate natural gas emissions for 2015.²⁶

MassDevelopment operates the wastewater treatment plant located in Devens that serves Devens as well as the Town of Shirley and part of the Town of Ayer. Lawrence Bearce provided the number of wastewater gallons treated by each community. Gallons of wastewater from Devens and Shirley along with the populations from both these towns were used to estimate people per million gallons of wastewater produced. This was then applied to the gallons of wastewater processed from Ayer to determine the population served from Ayer. Once a total population served by the wastewater treatment plant was estimated, it was applied in standard equations from the LGOP to determine CH₄ and N₂O process and fugitive emissions. Facility-specific data on biochemical oxygen demand (BOD5) and nitrogen discharged per day were provided by Lawrence Bearce at MassDevelopment.

Emissions from biosolid incineration were estimated using data on the total amount of sludge produced in 2015, provided by Lawrence Bearce at MassDevelopment with supporting information from Jim Moore of MassDevelopment. Emissions were calculated using methods from the Community Protocol that were adapted to calculate emissions from dry weight of biosolids rather than wet weight. Dry weight emission factors for CH₄ were obtained from the Biosolids Emissions Assessment Model (BEAM).²⁷ Dry weight emission factors for N₂O were obtained from the IPCC 2006 Chapter 5: Incineration and Open Burning of Waste.²⁸ Jim Moore indicated that all biosolids are incinerated at a facility in Woonsocket, Rhode Island, making emission from incinerated biosolids Scope 3.

Roughly half of the biosolids produced in 2015 were incinerated. The other half was landfilled according to Lawrence Bearce of MassDevelopment. See the Waste section above for more information on how landfilled biosolid emissions were calculated.

²⁴ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

²⁵ https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

²⁶ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

²⁷ https://www.ccme.ca/files/Resources/waste/biosolids/beam_final_report_1432.pdf

²⁸ https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf

Section 3: Devens Municipal Greenhouse Gas Inventory

The Devens municipal GHG inventory was prepared by Kim Lundgren Associates, Inc. (KLA) following the Local Government Operations Protocol (LGOP).²⁹ The LGOP has been used by communities around the United States to ensure that each report adheres to its principles of relevance, completeness, consistency, transparency, and accuracy. This report uses the operational control reporting level approach, providing an inventory of the GHGs released by those municipal activities where the Town of Devens, through the Massachusetts Development Finance Agency (MassDevelopment), has full authority to introduce and implement operating polices in the year 2015. This report summarizes the results of the GHG inventory and provides details on the methodologies used to calculate emissions.

For more detail on calculation methods and activity data, see the Devens Municipal GHG Inventory Workbook.xlsx.³⁰

Overall Municipal Greenhouse Gas Emissions

Devens municipal operations released 2,667 MTCO₂e in 2015. The 2015 emissions are equivalent to those released by an average passenger vehicle driven approximately 6.5 million miles.³¹

Emissions from municipal operations were reported using the scopes framework. The scopes framework is a standard method of organizing emissions sources first developed by the World Resources Institute (WRI) in the GHG Protocol Corporate Standard. Scope 1 sources are direct emissions from sources like natural gas burned by the reporting entity in the inventory year. Scope 2 are indirect emissions from electricity use, with emissions actually occurring outside the boundary but as a result of in-boundary activity by the reporting entity. Scope 3 are all other indirect emissions that generally occur outside the boundary or over a timeframe outside of the reporting year. Emissions from solid waste, which occur over decades, are an example of a scope 3 source. Employee Commute is also considered a Scope 3 source since trips may begin or end outside the community boundary. **Table 9** shows emissions by scope and sector for 2015.

²⁹ https://s3.amazonaws.com/icleiusaresources/lgo_protocol_v1_1_2010-05-03.pdf

³⁰ https://www.dropbox.com/s/u63hy3oms5dft34/Devens_Municipal_GHG_Emissions_Inventory_Final.xlsx?dl=0

³¹ Assumes 4.71 MTCO₂e per vehicle per year and 11,507 VMT per year per vehicle. See EPA Greenhouse Gas Equivalencies Calculator available at: <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>

Table 9. Devens Municipal Greenhouse Gas Emissions by Scope and Sector

Scope and Sector	2015 MTCO ₂ e	% of MTCO ₂ e
Scope 1	910	34%
Facilities and Infrastructure	581	22%
Vehicle Fleet	222	8%
Wastewater Treatment	103	4%
Water	3	0%
Scope 2	1,540	58%
Facilities and Infrastructure	691	26%
Streetlights and Traffic Signals	115	4%
Wastewater Treatment	537	20%
Water	197	7%
Scope 3	217	8%
Employee Commute	119	4%
Solid Waste	5	0%
Wastewater Treatment	94	4%
Total	2,667	100%

In 2015, 58% of Devens municipal GHG emissions were a result of electricity use and are Scope 2. Scope 1 emissions, such as the combustion of natural gas in buildings or combustion of gasoline and diesel in government owned vehicles, accounted for 34% of GHG emissions. Scope 3 emissions from solid waste, employee commute, and wastewater biosolids accounted for 8% of emissions.

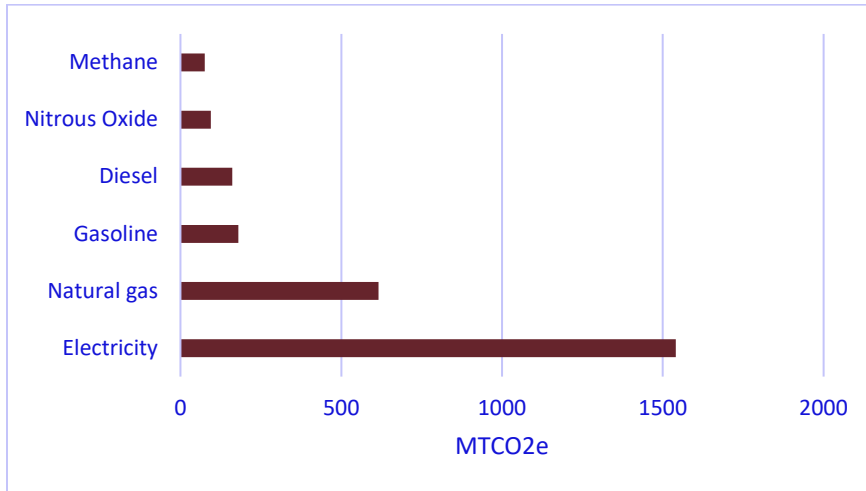
Table 10 shows emissions by sector for Devens’s municipal operations with emissions from all Scopes included in each sector.

Table 10. Devens Municipal GHG Emissions by Sector

Sector	2015 MTCO ₂ e
Facilities and Infrastructure	1,272
Wastewater Treatment	734
Vehicle Fleet	222
Water	200
Employee Commute	119
Streetlights and Traffic Signals	115
Solid Waste	5
Total	2,667

Figure 4 shows GHG emissions from each emission source for 2015. Electricity accounted for 58% of emissions in 2015. Natural gas was the second highest emitter, accounting for 23% of total emissions. Gasoline accounted for 7% of total emissions while diesel fuel accounted for 6% in 2015. N₂O and CH₄ from landfilled waste and wastewater treatment accounted for 4% and 3% (respectively) of total emissions.

Figure 4. Devens Municipal GHG Emissions by Source



When organized by department, GHG emissions are shown to be highest in the Wastewater Treatment Department at 28% of total emissions. MassDevelopment operates the wastewater treatment plant that serves Devens, Shirley and part of Ayer. The majority of these emissions occur as a result of electricity and natural gas use. Unlike the Community GHG inventory, landfilled biosolids are included in the Wastewater sector here in order to more easily categorize emissions by department. Employee Commute is listed below for the purposes of comparison and completeness even though it is not a Town department. **Table 11** shows emissions by department for 2015.

Table 11. Devens Municipal GHG Emissions by Department

Department	2015 MTCO ₂ e	% of MTCO ₂ e
Wastewater Treatment	734	28%
Public Works	519	19%
Administrative	467	17%
Rental	418	16%
Water	200	8%
Employee Commute	119	4%
Streetlights and Traffic Signals	115	4%
Fire	52	2%
Police	43	2%
Total	2,667	100%

Municipal GHG Inventory Methodology

The Devens Government Operations GHG Inventory followed the recommended guidance in ICLEI’s Local Government Operations Protocol (LGOP).³² This protocol provides recommended and alternative methods for calculating GHG emissions released as a result of energy use from facilities, vehicles and equipment owned and operated by the Town of Devens, water and wastewater treatment, solid waste deposition, and from fuel used for employee commute during 2015. Emissions from biosolid incineration

³² <http://icleiusa.org/ghg-protocols/>

were calculated using methods from ICLEI’s U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Community Protocol).³³

Typically, a government operations inventory is based on activity data that is either from a fiscal year or a calendar year. Due to data availability, this inventory uses both. Electricity and natural gas from Town buildings were provided on a fiscal year basis. Fuel use in Town owned vehicles and waste deposition data was provided on a calendar year basis. A Town employee commute survey was completed for fiscal year 2015. While the difference between fiscal and calendar year data is not expected to significantly affect the inventory, there may be small discrepancies that arise from the difference in activity data boundary.

Below is a detailed accounting of how GHGs were calculated for each sector of the municipal inventory.

Facilities and Infrastructure

The Facilities and Infrastructure sector is comprised of emissions that result from energy consumption in buildings that are owned and operated by the Town of Devens. Emissions were calculated based on the town’s electricity and natural gas use, following the methodologies in the LGOP. A summary of the results and methodologies used for 2015 are provided in **Table 12**.

Table 12. Summary of Facilities and Infrastructure Sector Data and Methodologies

Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Electricity	LGOP 6.2.1	2,022,879	kWh	691
Natural Gas	LGOP 6.1.1	109,405	therms	581

Electricity use from government buildings was obtained from Lawrence Bearce at MassDevelopment. For 2015 electricity emissions, an ISO New England³⁴ CO₂ factor was used in conjunction with 2016 eGRID NEWE New England Region factors for CH₄ and N₂O.³⁵ A 2016 eGRID emission factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 is 752.83 lbs. CO₂e/MWh.

Natural gas activity data for municipally owned and operated buildings was provided by Lawrence Bearce at MassDevelopment. Natural gas emissions factors from EPA Mandatory Reporting Rule, last updated in March 2018, were used to calculate natural gas emissions for 2015.³⁶

No community fuel oil or propane use was reported by the Town of Devens.

Streetlight and Traffic Signals

The Streetlights and Traffic Signals sector is comprised of emissions that result from electricity used to power streetlights, traffic signals and other outdoor lighting across all town departments that are owned and operated by the Town of Devens. Emissions were calculated based off the town’s electricity use in streetlights and traffic signals, following the methodologies in the LGOP. A summary of the results and methodologies used for 2015 are provided in **Table 13**.

Table 13. Summary of Streetlights and Traffic Signals Sector Data and Methodologies

Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Electricity	LGOP 6.2.1	336,172	kWh	115

³³ <http://iclei.org/publications/us-community-protocol/>

³⁴ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

³⁵ https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

³⁶ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

Electricity use from streetlights and traffic signals was provided by email from Lawrence Bearce at MassDevelopment. All kWh consumption for “lights”, “unmetered lights” and “traffic signals” were included as streetlights and traffic signals. For 2015 electricity emissions, an ISO New England³⁷ CO₂ factor was used in conjunction with 2016 eGRID NEWWE New England Region factors for CH₄ and N₂O.³⁸ A 2016 eGRID emission factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 factors is 752.83 lbs. CO₂e/MWh.

Vehicle Fleet

The Vehicle Fleet sector is comprised of emissions that result from vehicle miles travelled and fuel consumption by vehicles that are owned and operated by the Town of Devens. Emissions were calculated from diesel and gasoline fuel use data provided by Melissa Ouellette at MassDevelopment and follow the methodologies in the LGOP.

A summary of the results and methodologies used for 2015 are provided in **Table 14**.

Table 14. Summary of Vehicle Fleet Sector Data and Methodologies

Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Gasoline	LGOP 7.1.1	11,536	gallons	102
Diesel	LGOP 7.1.1	11,798	gallons	121

Activity data for 2016, in the form of gallons of diesel and gasoline fuel consumed in the inventory year, was obtained from Melissa Ouellette at MassDevelopment. Since fuel use was not reported by vehicle type, national averages for vehicle types on the road were used. To estimate emissions from CO₂, total gasoline and diesel use was multiplied by CO₂ emission factors obtained from the U.S. EPA's Emission Factors for Greenhouse Gas Inventories last updated in March 2018.

To calculate emissions from CH₄ and N₂O, fuel use was converted to VMT by vehicle type using fuel efficiencies obtained from the U.S Department of Energy's Alternative Fuel Data Center.³⁹ Total fuel use was assumed to have been generated by diesel and gasoline vehicles according to national averages for the percent of vehicle types that combust gasoline and diesel fuel as provided by the US Community Protocol. Similarly, the breakout of this fuel use by type of vehicle (heavy duty, light duty, passenger vehicles) was assumed to conform to national averages as provided by the US Community Protocol. CH₄ and N₂O emission factors for each fuel were obtained from the U.S. EPA's Emission Factors for Greenhouse Gas Inventories last updated in March 2018.

Employee Commute

The Employee Commute sector is comprised of emissions that result from fuel consumption by vehicles that are used by employees at the Town of Devens to get to-and-from work. A summary of the results and methodologies used for 2015 are provided in **Table 15**.

Table 15. Summary of Employee Commute Sector Data and Methodologies

Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Gasoline	N/A	7,200,107	VMT	3,054
Diesel	N/A	541,944	VMT	1,588

³⁷ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

³⁸ https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

³⁹ <https://www.afdc.energy.gov/data/categories/fuel-consumption-and-efficiency>

To estimate emissions from employee commute, the Town provided a 2015 Transportation Survey of the commuting habits of employees of all businesses in Devens for the fiscal year 2015. This survey was not specific to Town employees or MassDevelopment. The survey listed the hometowns and cities of people employed in Devens. An average commute distance to work was estimated using the town/city of residence and the distance to the MassDevelopment home office at 33 Andrew Parkway. Distances were calculated using Google Maps. The average commute distance from people employed in Devens was then multiplied by the total number of MassDevelopment employees in 2015, including members of the Devens Enterprise Commission and the Devens Eco-Efficiency Center. Total employees for 2015 were estimated at 35. All employees were assumed to be full time and drive to work every day.

Total VMT was assumed to have been generated by diesel and gasoline vehicles according to national averages for on-road vehicles that consume these fuels as provided by the US Community Protocol. Similarly, the amounts of each type of vehicle (heavy duty, light duty, passenger vehicles) were assumed to conform to national averages as provided by the US Community Protocol. VMT by fuel type and vehicle type was then used to calculate emissions from CH₄ and N₂O. CH₄ and N₂O emission factors for each fuel were obtained from the U.S. EPA's Emission Factors for Greenhouse Gas Inventories last updated in March 2018.⁴⁰

To estimate fuel use by commuting vehicles, VMT (by fuel and vehicle type) was divided by fuel efficiencies obtained from the U.S. EPA's Emission Factors for Greenhouse Gas Inventories last updated in March 2018. Emissions from CO₂ were calculated by multiplying total gasoline and diesel use by CO₂ emission factors obtained from the U.S. EPA's Emission Factors for Greenhouse Gas Inventories.

Solid Waste

The Solid Waste sector is comprised of CH₄ emissions that result from the decomposition of materials deposited in a landfill that are generated at government owned and operated facilities in the GHG inventory year. While these emissions occur over time, and in landfills outside of the Town's jurisdictional boundary, they are attributed to the Town's government operations for the year in which the waste was generated. Waste sent to landfills was obtained from the 2015 Devens Recycling and Solid Waste Survey. Emissions were calculated using methodologies adapted from the LGOP. A summary of the results and methodologies used for 2015 is provided in **Table 16**.

Table 16. Summary of Waste Sector Data and Methodologies

Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Waste Landfilled	LGOP, CARB Landfill Tool v1.3	12.0	tons	5
ADC Landfilled	LGOP, CARB Landfill Tool v1.3	0.1	tons	<1

Yearly waste deposition from Devens municipal facilities was estimated using tons of trash and bulky items collected according to the 2015 Devens Recycling and Solid Waste Survey, provided by Melissa Ouellette at MassDevelopment. Municipal buildings and schools are included in the survey. No residents or businesses are served by the Municipal Trash Program - all waste collected and reported was assumed to be from Town facilities. Waste characterization or types and quantities of different materials present in the waste stream was obtained from CalRecycle's Targeted Statewide Waste Characterization Study: Waste Disposal and Diversion Findings for Selected Industry Groups.⁴¹ All of The Town of Devens buildings were assumed to be "large office space" as defined in the CalRecycle report. Emissions were determined using emission factors by waste type obtained from the California Air Resources Board's Landfill Tool v1.3 and methodologies adapted from the LGOP.⁴²

⁴⁰ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

⁴¹ <https://www2.calrecycle.ca.gov/Publications/Details/1184>

⁴² https://www.arb.ca.gov/cc/protocols/localgov/pubs/landfill_emissions_tool_v1_3_2011-11-14.xls

Alternative daily cover (ADC) used at landfills was estimated using Massachusetts state averages for ratios of ADC/MSW calculated from MassDEP’s 2011 Solid Waste Master Plan.⁴³ Emissions from ADC were determined using emission factors from the California Air Resources Board’s Landfill Tool v1.3 and methodologies adapted from the LGOP.⁴⁴

Water Treatment and Delivery

The Water Treatment and Delivery sector comprises emissions that result from energy consumption in facilities related to water treatment, well water extraction, pumping stations, and other related facilities that are owned and operated by the Town of Devens. Emissions were calculated based on the Town’s electricity and natural gas use activity data, following the methodologies in the LGOP. Since 1999, United Water has provided operations, maintenance and management services for water treatment and delivery in Devens. This includes services for four wells, 50 miles of water main and 425 hydrants. MassDevelopment is assumed to have full implementation authority over water treatment and delivery facilities operated by United Water. A summary of the results and methodologies used for 2015 are provided in **Table 17**.

Table 17. Summary of Water Treatment and Delivery Sector Data and Methodologies

Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Electricity	LGOP 6.2.1	577,480	kWh	197
Natural Gas	LGOP 6.1.1	544	therms	3

Electricity use from water delivery operations was obtained from Lawrence Bearce at MassDevelopment. Electricity was reported from four wells: Grove Pond, Macpherson Road, Patton Road and Sheboken wells. For 2015 electricity emissions, an ISO New England⁴⁵ CO₂ factor was used in conjunction with 2016 eGRID NEWE New England Region factors for CH₄ and N₂O.⁴⁶ A 2016 eGRID emission factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 is 752.83 lbs. CO₂e/MWh.

Natural gas activity data for water treatment and delivery facilities was provided by Lawrence Bearce at MassDevelopment. Natural gas emissions factors from EPA Mandatory Reporting Rule, last updated in March 2018, were used to calculate natural gas emissions for 2015.⁴⁷

Wastewater Treatment

The Wastewater Treatment sector is comprised of emissions that result from electricity and natural gas used to treat and convey wastewater throughout the community during the inventory year, process and fugitive emissions that result from the treatment of organic materials in the wastewater, and emissions associated with landfilling or incinerating biosolids removed during wastewater treatment. Electricity and natural gas use were provided by Lawrence Bearce at MassDevelopment and emissions were calculated following the methodologies in the LGOP. Process and fugitive emissions were estimated at the community-level based on per capita emissions rates contained within the Community Protocol. Landfilled and incinerated biosolids were provided by Lawrence Bearce at MassDevelopment, and emissions were calculated using methods from the LGOP and Community Protocol. Since 1999, United

⁴³ <https://www.mass.gov/files/documents/2016/08/rr/11swdata.pdf>

⁴⁴ https://www.arb.ca.gov/cc/protocols/localgov/pubs/landfill_emissions_tool_v1_3_2011-11-14.xls

⁴⁵ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

⁴⁶ https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

⁴⁷ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

Water has been providing operations, maintenance and management services for wastewater treatment in Devens. MassDevelopment is assumed to have full implementation authority at the wastewater treatment facility. A summary of the results and methodologies used for 2015 are provided in **Table 18**.

Table 18. Summary of Wastewater Treatment Sector Data and Methodologies

Sub-sector	Source/Activity	Methodology	Activity Data	Units	MTCO ₂ e
Electricity	Electricity	LGOP 6.2.1	1,573,926	kWh	537
Natural Gas	Natural Gas	LGOP 6.1.1	6,083	therms	32
Process	Methane	LGOP 10.3	50	MTCO ₂ e	50
Process	Nitrous Oxide	LGOP 10.7, 10.10	21	MTCO ₂ e	21
Biosolids Landfilled*	Methane	LGOP 9.7	226	tons	20
Biosolids Incinerated	Methane and Nitrous Oxide	USCP WW.4&5	275	tons	74

**Landfilled biosolids are included in the Wastewater Treatment Sector of the Municipal Inventory because measures to reduce these emissions will have to be aimed at the MassDevelopment wastewater treatment plant. Methodologically, landfilled biosolids are treated similarly to other Solid Waste. At the Community Inventory level, landfilled biosolid emissions are included in the Solid Waste Sector.*

Total electricity used to treat wastewater at the Macpherson Road treatment center, usage from other related facilities and pump stations at the Town wastewater treatment plant, and pumping stations operated by MassDevelopment were obtained from Lawrence Bearce at MassDevelopment. For 2015 electricity emissions, an ISO New England⁴⁸ CO₂ factor was used in conjunction with 2016 eGRID NEW England New England Region factors for CH₄ and N₂O.⁴⁹ A 2016 eGRID emission factor was used as a proxy for 2015 since eGRID values are only published every couple of years. ISO New England does not publish CH₄ or N₂O factors.

The blended ISO New England and eGRID electricity emission factor used to calculate emissions for Devens community electricity use in 2015 is 752.83 lbs. CO₂e/MWh.

Natural gas activity data for water treatment and delivery facilities was provided by Lawrence Bearce at MassDevelopment. Natural gas emissions factors from EPA Mandatory Reporting Rule, last updated in March 2018, were used to calculate natural gas emissions for 2015.⁵⁰

MassDevelopment operates the wastewater treatment plant located in Devens and serving Devens as well as the Town of Shirley and part of the Town of Ayer. Lawrence Bearce provided the number of wastewater gallons treated by each community. Gallons of wastewater from Devens and Shirley along with the populations from both these towns were used to estimate people per million gallons of wastewater produced. This was then applied to the gallons of wastewater processed from Ayer to determine the population served from Ayer. Once a total population served for the wastewater treatment plant was calculated, it was applied in standard equations from the LGOP to determine CH₄ and N₂O process and fugitive emissions. Facility-specific data on biochemical oxygen demand (BOD5) and nitrogen discharged per day were provided by Lawrence Bearce at MassDevelopment.

Emissions from biosolid incineration were estimated using data on the total amount of biosolids produced in 2015, provided by Lawrence Bearce at MassDevelopment with supporting information from Jim Moore of MassDevelopment. Emissions were calculated using methods from the Community Protocol that were adapted to calculate emissions from dry weight of biosolids rather than wet weight. Dry weight emission factors for CH₄ were obtained from the Biosolids Emissions Assessment Model (BEAM).⁵¹ Dry weight

⁴⁸ ISO NE emissions reports available at: <https://www.iso-ne.com/system-planning/system-plans-studies/emissions>

⁴⁹ https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf

⁵⁰ https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf

⁵¹ https://www.ccme.ca/files/Resources/waste/biosolids/beam_final_report_1432.pdf

emission factors for N₂O were obtained from the IPCC 2006 Chapter 5: Incineration and Open Burning of Waste.⁵² Jim Moore indicated that all biosolids are incinerated at a facility on Woonsocket, Rhode Island making emission from incinerated biosolids Scope 3.

Dry weight tons of biosolids landfilled were provided by Lawrence Bearce of MassDevelopment. Emissions were determined using “sludge” emission factors from the California Air Resources Board’s Landfill Tool v1.3 and methodologies adapted from the Community Protocol.⁵³

Section 4. Conclusions and Next Steps

The community and municipal GHG inventories are first steps toward completing a Climate Action Plan. Devens GHG emissions are primarily a result of electricity and natural gas usage in buildings. Emissions reductions in the industrial sector, specifically, will be crucial to lowering overall GHG levels. Opportunities also exist in the institutional sector, the second largest category of buildings in Devens. For municipal operations, efficiency improvements that target electricity and natural gas use will be focal points for achieving GHG reductions.

MassDevelopment currently runs Devens and plans to phase out its operations within 15 years. A Climate Action Plan containing specific strategies to achieve GHG reductions should consider how the transition of operational control to local authority will affect the implementation of GHG reduction measures.

Next steps for the Town of Devens include long-term planning, establishing an emissions forecast based on anticipated growth or changes in the community, setting a GHG reduction target, and creating a local Climate Action Plan containing various programs and local policies that reduce GHG emissions.

⁵² https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf

⁵³ https://www.arb.ca.gov/cc/protocols/localgov/pubs/landfill_emissions_tool_v1_3_2011-11-14.xls

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