New York State Greenhouse Gas Inventory: 1990–2016

Final Report | July 2019

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NYSERDA Record of Revision

Document Title
New York State Greenhouse Gas Inventory: 1990–2016

Revision Date	Description of Changes	Revision on Page(s)
Add Date	Original Issue	Original Issue
9/10/19	Updated Figure	Pg. S-11
9/10/19	Updated Table Data	Pg. 29

New York State Greenhouse Gas Inventory: 1990–2016

Final Report

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Acronyms, Abbreviations, and Selected Definitions

Btu	British thermal units
CH_4	methane
CO_2	carbon dioxide
CO_2e	Carbon dioxide equivalent, a common metric used to measure the radiative forcing impact (i.e., climate impact) of various greenhouse gases as relative to carbon dioxide (e.g., a gas with a CO_2e of 25, is 25 times more potent than CO_2).
CO_2FFC	carbon dioxide from fossil fuel combustion
EIA	Energy Information Administration
EPA	United States Environmental Protection Agency
FHWA	Federal Highways Administration
GSP	gross state product
GHG	greenhouse gas, a gas that acts as a heat-trapping agent in the atmosphere, increasing the amount of heat energy in the climate system.
GWh	gigawatt hours
GWP	global warming potential, a metric used to express the climate impacts of various greenhouse gases relative to carbon dioxide over a specific timescale (e.g., 100 years)
HFC	hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
LPG	liquified petroleum gas
MMt	million metric tons
MSW	municipal solid waste
N_2O	nitrous oxide
DEC	New York State Department of Environmental Conservation
DOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
ODS	ozone depleting substances
PFC	perfluorocarbons
RCI	residential, commercial, industrial
SEDS	State Energy Data System
SF_6	sulfur hexafluoride
SIT	State Inventory Tool, EPA tool for developing state-level GHG inventories
T&D	transmission and distribution
VMT	vehicle miles traveled

Summary

S.1 Introduction

Unequivocal warming of the earth over the past century is documented by observations that include increases in global average temperatures, rapid melting of mountain glaciers and land ice sheets, and higher global average sea levels. In the northeastern United States, mean temperature and precipitation have increased, as have the frequency and duration of extreme events, such as heat waves, drought, and flooding. Intense and damaging storms like Sandy and Irene are occurring more often. The changing climate affects human health, society, and the economy both directly and indirectly, through its disruptive effects on ecosystems, coastal infrastructures, agriculture, fisheries, and other natural resources. The rate and extent of climate change depend on the amount of greenhouse gases (GHG) present in, and delivered to, the atmosphere.

This report provides a detailed account of anthropogenic GHG emissions in New York State from 1990–2016. The report identifies the emissions associated with different sectors and sources as broadly outlined in Intergovernmental Panel on Climate Change (IPCC) guidelines.[1] Each section describes sector-specific calculation methodologies and provides a detailed view of emission contributions from various sources. Accordingly, the sections correspond to the different sectors and are organized as follows:

- Section 1: Energy[2]
- Section 2: Industrial Process and Product Use
- Section 3: Agriculture
- Section 4: Waste

The report looks systematically at six primary GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6). Emissions of these six GHGs are converted to CO_2 equivalent (CO_2e), representing the quantity of CO_2 that would have the same impact on the global climate over a period of 100 years.[3] The emissions of these different GHGs can then be combined and presented in equivalent terms (see appendix A).

This report, which is updated periodically, tracks New York State GHG emissions over time, from 1990–2016. As a new inventory is developed, updates to activity data sources and methodological improvements are applied to all relevant years in the time series. Therefore, it is possible that estimates of GHG emissions presented in a report may differ from values presented in previous iterations of the New York State Greenhouse Gas Inventory for the same year.

In this Summary, New York State's current GHG emissions profile is presented, broken down, and discussed from a variety of perspectives, followed by a discussion of statewide emissions over time.

S.2. New York State GHG Emissions Profile

S.2.1 Current GHG Emissions by Source

The New York State Greenhouse Gas Inventory: 1990–2016 is based on the United States Environmental Protection Agency (EPA) production-based methodology[4] and tailored to estimate current emissions produced within the State's boundaries. By adopting EPA protocols for identified emissions, New York State aims for consistency with international conventions for GHG emissions inventories. A summary of GHG emissions estimated for the State by sector and gas in 2016, the most recent year for which historical data are available, is provided in Table S-1.

Table S-1. 2016 New York State Greenhouse Gas Inventory ($MMtCO_2e$)

	CO_2	CH_4	N_2O	PFC	HFC	SF_6	Total	% of Total
Energy	**168.84**	**3.12**	**0.83**	**-**	**-**	**-**	**172.80**	**84%**
Fossil Fuel Combustion	166.11	0.40	0.78	-	-	-	167.28	81%
Fossil Fuel Combustion (excl. net imports)	162.31	0.39	0.77	-	-	-	163.47	80%
Electricity	27.70	0.00	0.02	-	-	-	27.72	13%
Net Imports	3.80	0.00	0.01	-	-	-	3.82	2%
Residential	30.66	0.17	0.05	-	-	-	30.89	15%
Commercial	20.57	0.07	0.02	-	-	-	20.66	10%
Industrial	10.15	0.03	0.05	-	-	-	10.23	5%
Transportation	73.23	0.12	0.63	-	-	-	73.98	36%
Incineration of Waste	2.74	-	0.05	-	-	-	2.79	1%
Oil & Gas Systems	-	2.73	-	-	-	-	2.81	1%
Industrial Processes and Product Use	**1.16**	**-**	**-**	**0.34**	**9.48**	**0.17**	**11.15**	**5%**
Aluminum Production	0.17	-	-	0.20	-	-	0.38	< 1%
Cement Production	0.26	-	-	-	-	-	0.26	< 1%
Electricity Transmission and Distribution	-	-	-	-	-	0.17	0.17	< 1%
Iron & Steel Production	0.15	-	-	-	-	-	0.15	< 1%
Limestone Use	0.44	-	-	-	-	-	0.44	< 1%
ODS Substitutes	-	-	-	-	9.48	-	9.48	5%
Semiconductor Manufacturing	-	-	-	0.14	-	-	0.14	< 1%
Soda Ash Use	0.13	-	-	-	-	-	0.13	< 1%
Agriculture	**-**	**4.51**	**4.35**	**-**	**-**	**-**	**8.86**	**4%**
Agricultural Animals	-	3.57	-	-	-	-	3.57	2%
Agricultural Soil Management	-	-	4.02	-	-	-	4.02	2%
Manure Management	-	0.94	0.34	-	-	-	1.27	1%
Waste	**-**	**12.20**	**0.61**	**-**	**-**	**-**	**12.80**	**6%**
Landfills	-	10.61	-	-	-	-	10.61	5%
Municipal Wastewater	-	1.59	0.61	-	-	-	2.20	1%
Total (inc. Net Imports of Electricity)	**170.00**	**19.83**	**5.79**	**0.34**	**9.48**	**0.17**	**205.61**	**100%**
% of Total Emissions	83%	10%	3%	< 1%	5%	< 1%	100%	-
Total (excluded Net Imports of Electricity)	*166.20*	*19.82*	*5.74*	*0.34*	*9.48*	*0.17*	*201.80*	**-**

- MMtCO2e = million metric tons of carbon dioxide equivalent; CO2 = carbon dioxide; CH4 = methane; N2O = nitrous oxide; PFC = perfluorocarbon; HFC = hydrofluorocarbon; SF6 = sulfur hexafluoride.
- In the 2016 New York State Energy Plan (SEP) energy-related emissions were defined to include Fossil Fuel Combustion, Net Imports of Electricity, Incineration of Waste, Oil & Gas Systems, and Electricity Transmission and Distribution sources. Note that this definition differs slightly from the Energy source category in this report, which follows IPCC source categorization guidelines and therefore excludes Electricity Transmission and Distribution.
- Methane emissions would increase to 57.11 MMtCO2e were this report to account for emissions using 20-year Global Warming Potential factors derived in the IPCC AR4, rather than the 100-year GWP presented above.

As shown in Table S-1, New York State accounted for approximately 206 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) emissions in 2016, an average of 10 metric tons of CO_2e for each State resident.[5] At these levels, per capita GHG emissions were approximately half the U.S. average. The great majority of the State's GHG emissions came from fuel combustion, which primarily represents the burning of fossil fuels (e.g., coal, natural gas, petroleum products) as an energy source to support various economic activities, including transportation, electric power generation, and heating and hot water needs for homes and businesses.

Figure S-1 provides a sectoral breakdown of New York State's 2016 economy-wide GHG emissions from all sources. The largest contributor of all GHG emissions in the State is vehicle fuel combustion in the transportation sector (36%) followed closely by on-site combustion in the residential, commercial, and industrial sectors (30%). Fuel combustion for electricity generation (including net imports) represents 15% and non-combustion sources (e.g., industrial process, agriculture, and waste) make up 19% of statewide emissions.

Figure S-1. 2016 GHG Emissions by Sector

Notes: "Other Energy" includes the following emission sources in the Energy source category that are not associated with fossil fuel combustion: Incineration of Waste and Natural Gas Systems.

CO_2e = carbon dioxide equivalent GHG = greenhouse gas

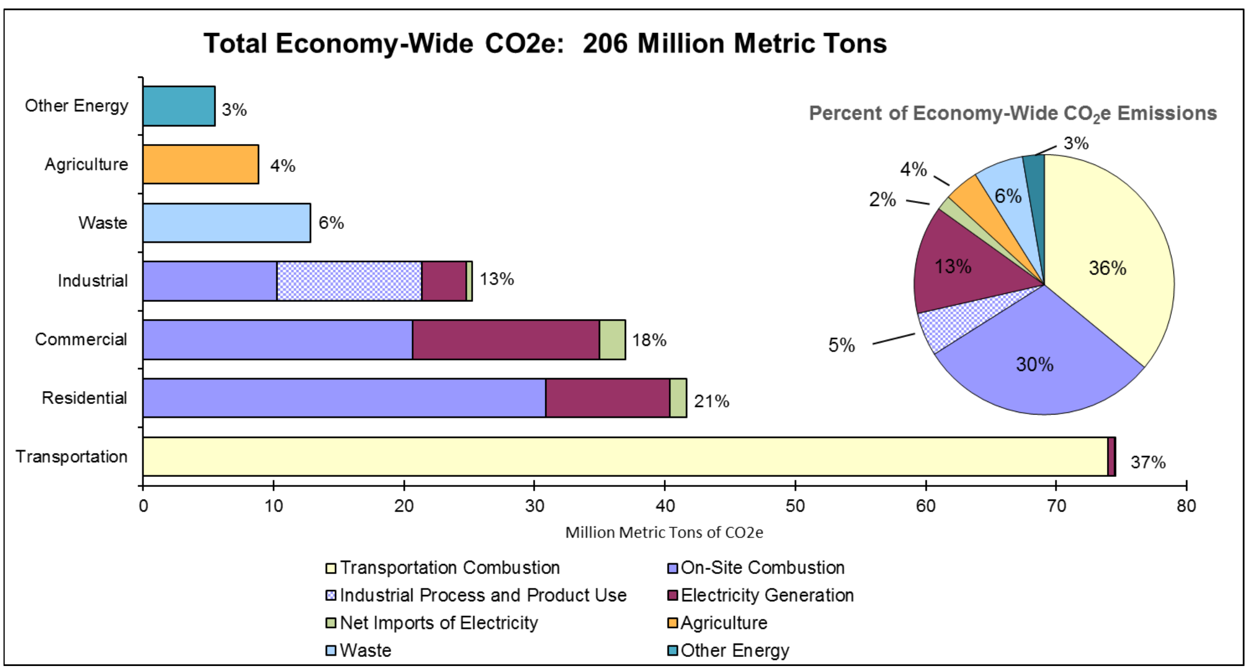
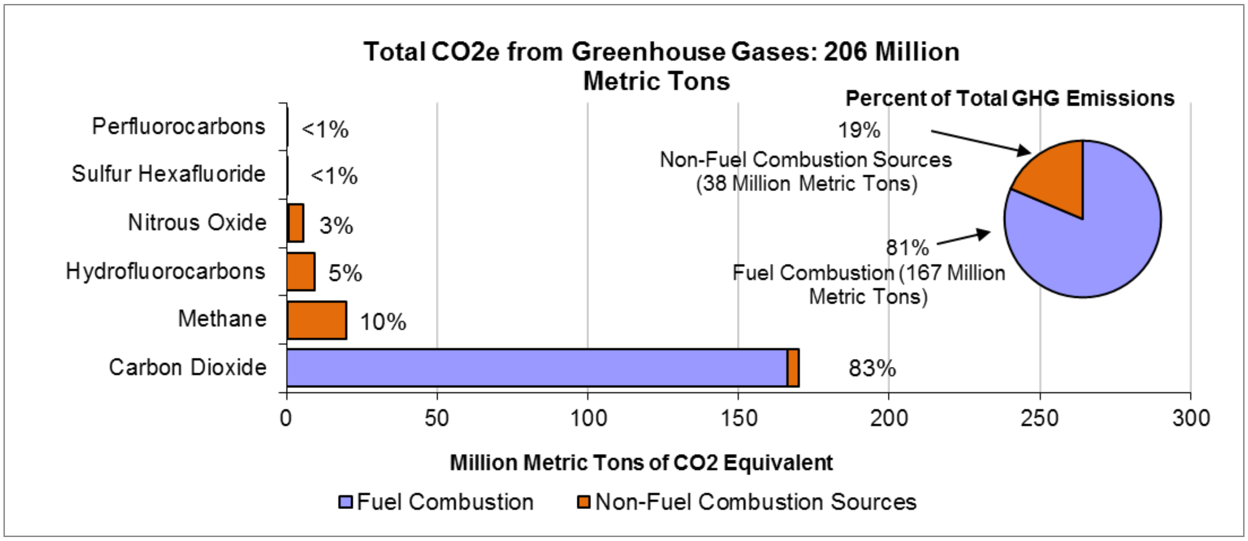


Figure S-2 provides a breakdown of New York State's 2016 GHG emissions by gas. Even when considering the contributions of the six primary GHG emissions on a CO_2e basis, this figure shows that CO_2 contributes the majority (83%) of all GHG emissions in the State.

Figure S-2. Percentage of GHG Emissions by Gas and Source

CO_2e = carbon dioxide equivalent GHG = greenhouse gas



S.2.2 Focus: Current GHG Emissions from Fuel Combustion

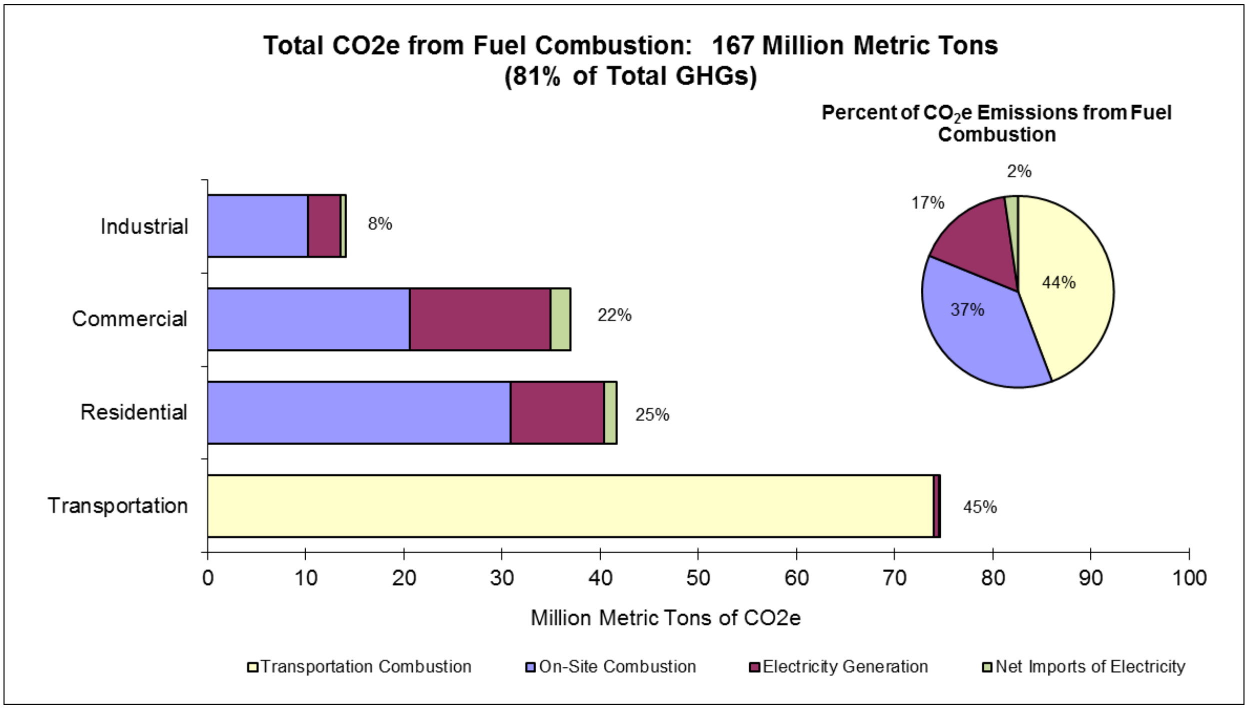
S.2.2.1 Emissions by End Use Sector

The transportation sector accounted for approximately 44% of CO_2 emissions from fuel combustion in 2016 (shown in Figure S-3). The residential and commercial sectors were responsible for roughly 25% and 22%, respectively, after including an allocation of emissions from electricity generation. For both the residential and commercial sectors, emissions from on-site fuel combustion (including heating and hot water) were greater than the combined emissions associated with in-state and imported electricity generation. On-site fuel combustion from the industrial sector contributed approximately 8% of the CO_2 fuel-combustion emissions in New York State.

Figure S-3. 2016 CO_2e Emissions from Fuel Combustion by End Use Sector

Note: Emissions from buildings, that is, emissions from the Residential, Commercial, and Industrial categories, make up 56% of fuel combustion emissions.

CO_2e = carbon dioxide equivalent GHG = greenhouse gas

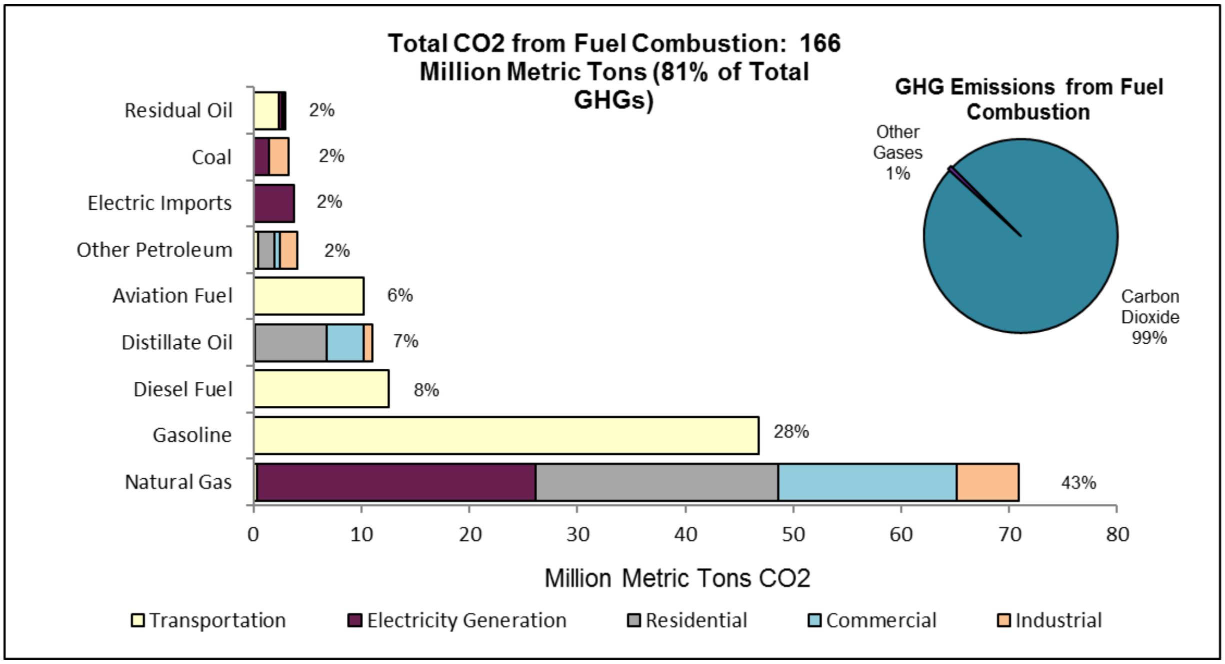


S.2.2.2 Emissions by Fuel

Total CO_2 emissions from fuel combustion have also been allocated to specific fuels, and then further allocated to economic sectors (transportation, electricity generation, residential, commercial, and industrial), providing a more detailed profile. The fuels that contribute to the 2016 New York State CO_2 fuel combustion emissions are shown in Figure S-4. In 2016, natural gas combustion accounted for 43% of CO_2 emissions. These emissions primarily result from natural gas combustion for electricity generation and on-site residential, commercial, and industrial use. An additional 28% of the CO_2 fuel combustion emissions result from the burning of gasoline by the transportation sector. The remaining emissions result from the burning of coal, distillate oil, aviation fuel, residual oil, diesel, and other petroleum fuels as well as from imported electricity that may have been generated using a variety of fuels.

Figure S-4. 2016 CO_2 Emissions from Fuel Combustion by Fuel Type

CO_2e = carbon dioxide equivalent   GHG = greenhouse gas

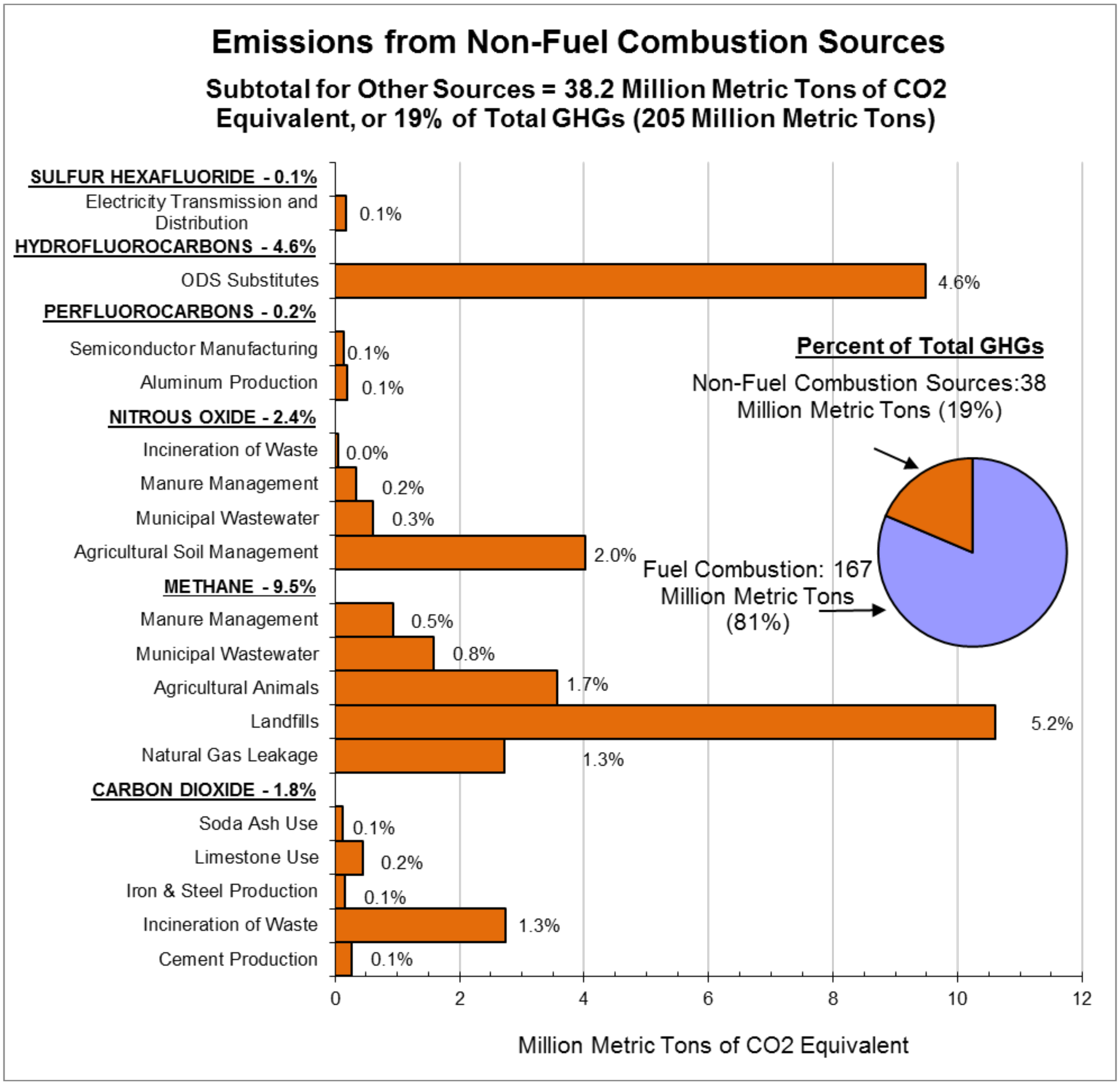


S.2.3 Focus: Current Non-Combustion Emissions Sources

In New York State, the remaining sources of GHG emissions represent 18% of total CO_2e emissions in 2016 (Figure S-5). Methane accounted for the greatest portion of non-carbon dioxide greenhouse gas emissions when measured in CO_2e. Most methane emissions are the result of activities other than fuel combustion, representing 10% of total statewide CO_2e emissions. The major sources of these methane emissions included landfills, natural gas system leakage, agricultural animals, and municipal wastewater facilities. Hydrofluorocarbon (HFC) emissions, resulting from use of substitutes for ozone-depleting substances (ODS), also represent a significant portion of non-fuel combustion emissions, at 5% of total statewide CO_2e emissions.

Figure S-5. 2016 Emissions from Non-Combustion Sources

CO_2e = carbon dioxide equivalent   GHG = greenhouse gas   ODS = ozone depleting substance

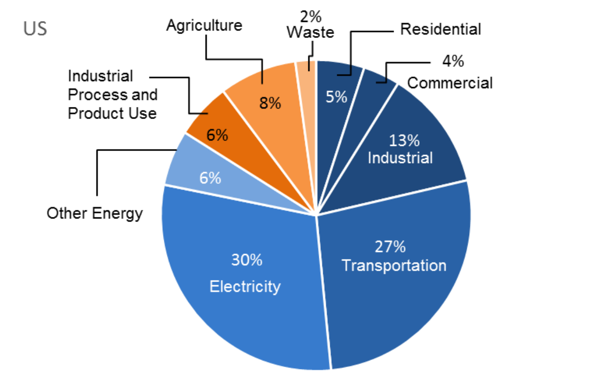


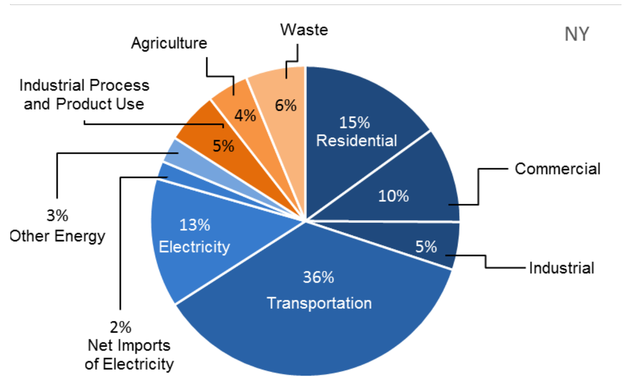
S.2.4 New York State and U.S. GHG Emission Comparison

Figure S-9 compares the U.S. GHG emission profile, drawn from EPA's national inventory,[6] to New York State's GHG emission profile.

Figure S-6. 2016 GHG Emissions by Sector in New York State and U.S. by U.S. Economic Sector

Note: These values may not sum directly due to independent rounding.





In the pie charts above, blue wedges are components of the energy source category. Within this broad category, emissions from the transportation sector; the residential, commercial, industrial sectors (taken together, the RCI sectors); the electricity sector; and net imports of electricity (in the New York chart) come from fuel combustion, while "other energy" emissions include non-fuel combustion emissions associated with the fossil fuel industry and emissions associated with the incineration of waste for energy purposes. Orange wedges represent non-energy source categories: Industrial Process and Product Use, Agriculture, and Waste. The U.S. inventory includes some sources that are either not relevant to New York State or too small to be included in this inventory (e.g., agricultural residue burning, magnesium production).

New York State emissions were equivalent to 3% of U.S. total emissions in 2016. The same three economic sectors are responsible for the largest share of emissions in both the U.S. and New York State; however, in these top three sectors, their sequential ranking differs from the U.S. In New York State, the transportation sector, the RCI sectors, and the electricity sector (including net imports) accounted for 36%, 30%, and 15%, respectively. In the U.S., the electricity sector, the RCI sectors, and the transportation sector accounted for 30%, 22%, and 27%, respectively. Remaining emissions from non-energy sources account for 16% in New York and 26% in the U.S.

S.3 Trends in New York State GHG Emissions

This report also illustrates the historical development of GHG emissions. The trend in New York State's historical GHG emissions from 1990–2016 is shown in Table S-2. State GHG emissions gradually increased from 1990 and peaked in 2005. Since then there has been a decline, and 2016 emissions are approximately 13% lower than in 1990. This 13% reduction in GHG emissions from 1990–2016 stands in contrast to a national increase in total GHG emissions of approximately 2% over the same period.

Table S-2. New York State GHG Emissions, 1990–2016 ($MMtCO_2e$)

Note: For a detailed time series analysis by gas and sector, see appendix B.

GHG = greenhouse gas $MMTCO_2e$ = million metric tons of carbon dioxide equivalent.
Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Category	1990	1995	2000	2005	2010	2015	2016
Energy[a]	**208.96**	**206.87**	**228.20**	**230.69**	**193.21**	**180.69**	**172.79**
Electricity Generation	63.02	51.28	55.68	53.58	37.31	29.13	27.72
Residential	34.25	34.98	40.28	39.83	31.70	35.64	30.89
Commercial	26.55	27.04	32.23	28.66	24.19	21.87	20.66
Industrial	20.02	22.54	17.52	14.89	10.27	10.80	10.23
Transportation	59.37	61.82	71.66	79.26	74.93	74.15	73.98
Net Imported Electricity	1.74	4.52	6.04	7.35	9.20	3.37	3.82
Incineration of Waste	1.27	1.96	2.05	3.60	2.35	2.92	2.79
Natural Gas Systems	2.74	2.74	2.73	3.52	3.25	2.82	2.73
Non-Energy Sources	**27.22**	**28.05**	**30.28**	**31.19**	**31.56**	**32.91**	**32.82**
Agriculture	8.37	7.80	8.55	8.27	8.73	8.86	8.86
Waste	14.86	15.43	15.62	15.62	14.29	13.23	12.80
Industrial Processes and Product Use	3.99	4.83	6.11	7.30	8.54	10.82	11.15
TOTAL	**236.19**	**234.92**	**258.48**	**261.88**	**224.77**	**213.59**	**205.61**
Fuel Combustion	*204.95*	*202.17*	*223.41*	*223.57*	*187.60*	*174.95*	*167.28*
Non-Fuel Combustion[b]	*31.24*	*32.75*	*35.07*	*38.31*	*37.17*	*38.65*	*38.33*

[a] In the 2016 New York State Energy Plan (SEP) energy-related emissions were defined to include Fossil Fuel Combustion, Net Imports of Electricity, Incineration of Waste, Natural Gas Systems, and Electricity Transmission and Distribution sources. Note that this definition differs slightly from the Energy source category in this report, which follows IPCC source categorization guidelines and therefore excludes Electricity Transmission and Distribution.

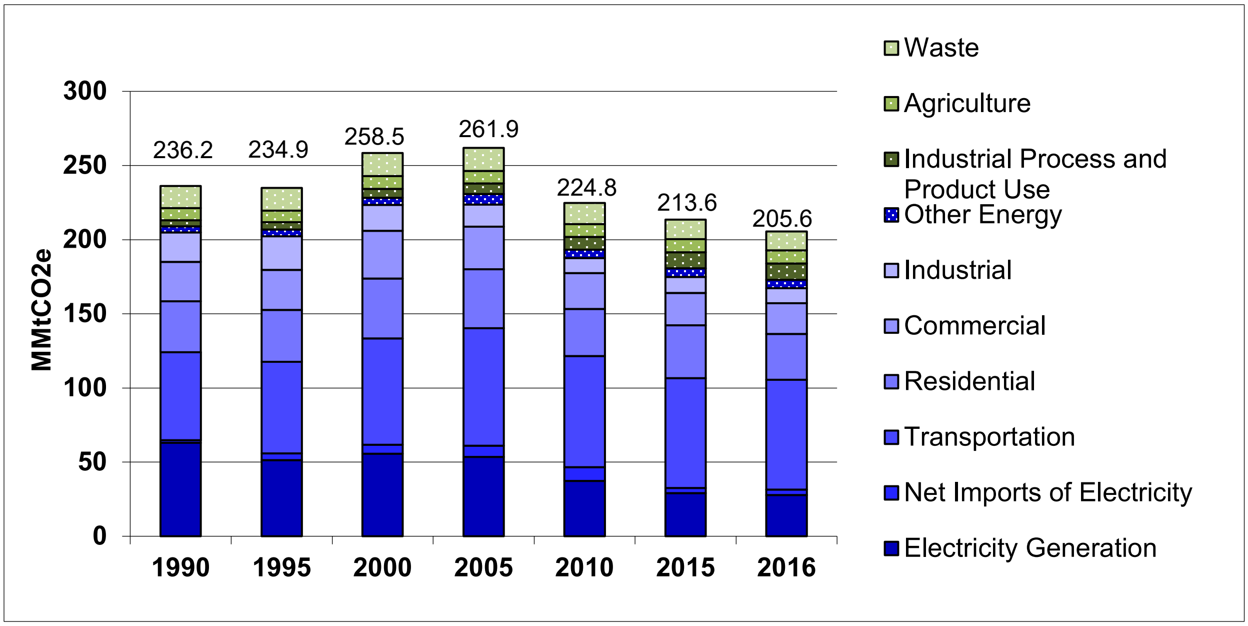
[b] Incineration of Waste and Natural Gas Systems source categories are included in the non-fuel combustion total.

Figure S-6 illustrates several trends in New York State GHG emissions from 1990–2016. Of all in-state energy-related sources of emissions, transportation sector emissions showed by far the greatest growth in the State, with emissions increasing by nearly 24% from 1990–2016. This is due to an increase in the consumption of gasoline and diesel fuels associated with an increase in vehicle miles traveled (VMT) and an increase in the consumption of jet fuel. Emissions from non-energy sources also increased, growing roughly 21% from 1990–2016. This is primarily due to an increase in the use of HFCs as substitutes for ozone-depleting substances in refrigeration and other uses.

In contrast, emissions from electricity generated in-state dropped 56% during this same period, acting as a major driver of New York State's decreasing GHG emissions. This drop is due in part to the significant decrease in the burning of coal and petroleum products in the electricity generation sector. Emissions from residential, commercial, and industrial buildings also decreased, showing a reduction of approximately 23% from 1990–2016. This reduction in emissions was also driven by a decrease in the use of coal and petroleum.

Figure S-7. 2016 New York State GHG Emissions by Source Category, 1990–2016 ($MMtCO_2e$)

Note: "Other Energy" includes the following emissions sources in the Energy source category that are not associated with fossil fuel combustion: Incineration of Waste and Natural Gas Systems.



S.4 Emissions Intensity

New York State emits approximately 10 metric tons of CO_2e per capita (shown in Figure S-7), and the State's energy-related per capita emissions of 9 metric tons is the lowest of the 50 states. The State also leads the nation in having the lowest GHG emissions per unit of economic output, averaging 0.16 kilograms (kg) of CO_2e of emissions per dollar gross state product (GSP), while the U.S. averaged 0.41 kg of CO_2e emissions per dollar gross domestic product (illustrated in Figure S-8).

Figure S-8. New York State and U.S. GHG Emissions per Capita, 1990–2016

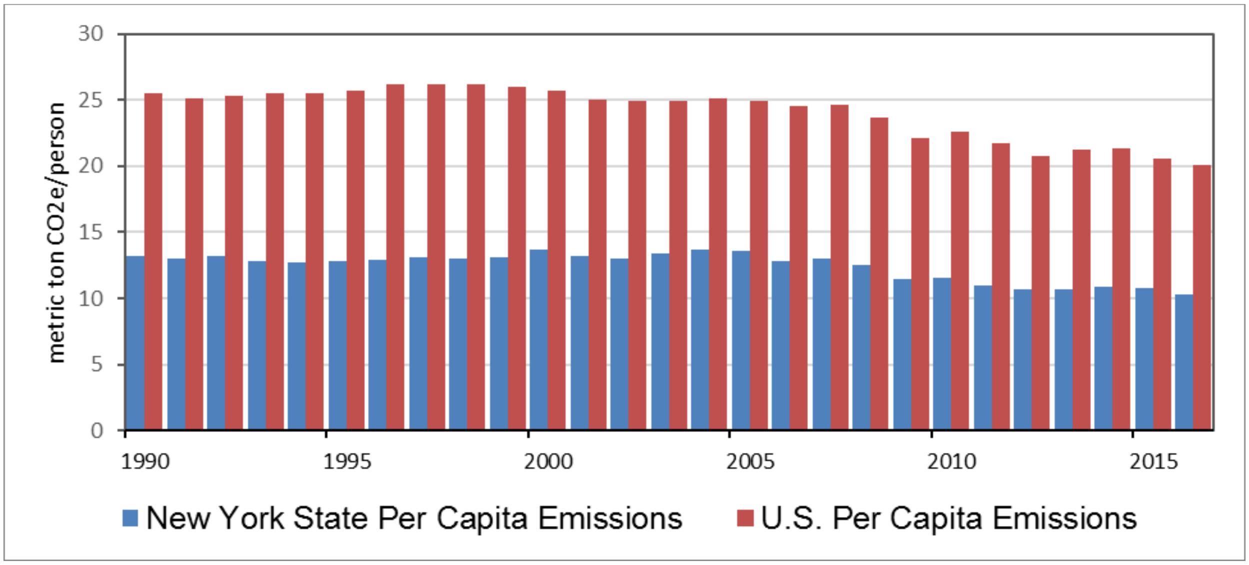
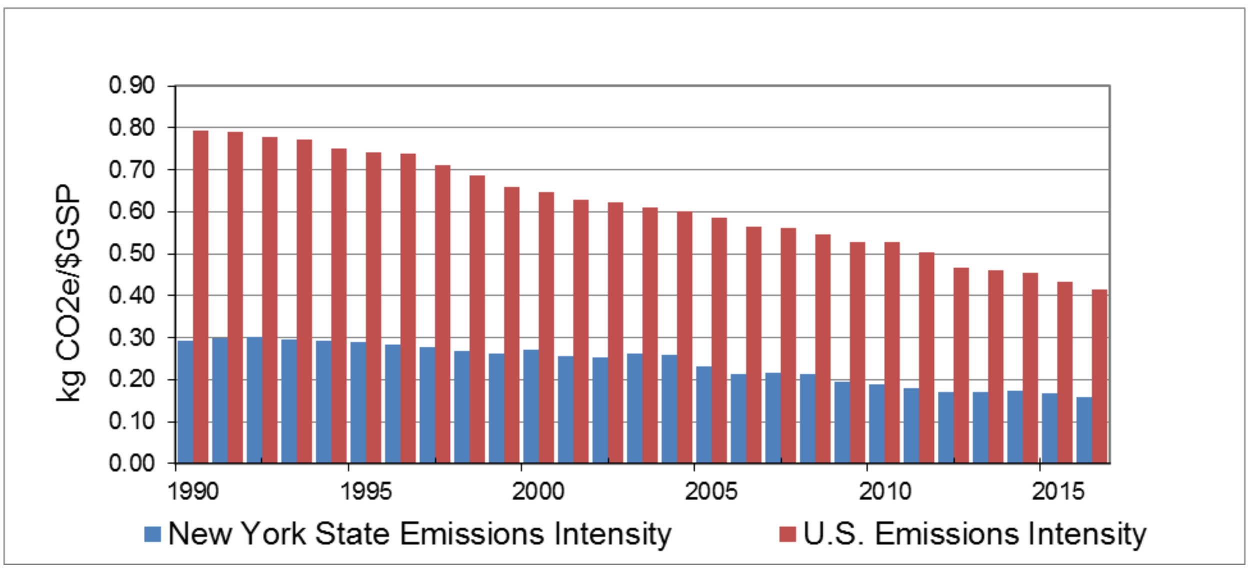


Figure S-9. New York State and U.S. Emissions Intensity per GSP, 1990–2016

Note: Gross State Product (GSP) is the measure of state economic output, which is the sum of all value added by businesses in a state.



S.5 A Closer Look at the Major Source of Emissions

The great majority of New York State's GHG emissions are associated with fuel combustion. The transportation sector accounts for the largest share of GHG emissions in the State, at 36% of its GHG emissions in 2016. During that year, motor gasoline, used by on-road vehicles and recreational marine vehicles, accounted for the largest share of transportation GHG emissions. Jet fuel combustion contributes the second-highest transportation GHG emissions, and diesel fuel, used by on-road vehicles, commercial marine vehicles, and locomotives, ranks third among fuels contributing to transportation emissions. Residual fuel, liquefied petroleum gas, and other transportation fuels account for the remaining transportation GHG emissions in 2016. From 1990–2016, emissions experienced a net increase. However, the peak in transportation emissions occurred in 2006; emissions fell 10% percent from 2006–2016. The main drivers of both the 2006 peak are the consumption patterns of motor gasoline, diesel fuel, and jet fuel, while the subsequent decline was driven by a decrease in gasoline vehicle emissions, which can be explained by improvements in fuel economy as well as decreases in vehicle miles traveled.

Activities in the RCI[7] fuel combustion sectors produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications. This sector can also be referred to as building or on-site fuel combustion, and it accounted for 30% of New York State's GHG emissions in 2016, with a decrease in total emissions from 1990–2016. In 2016, the residential sector's contribution toward total RCI emissions from on-site fuel combustion was 50%, while the commercial sector accounted for 33%, and the industrial sector accounted for 17%.

Including emissions from electricity consumed in the RCI category, buildings contributed approximately 93 MMtCO_2e to the State's emissions profile in 2016; this is approximately a 45% share of total New York emissions.

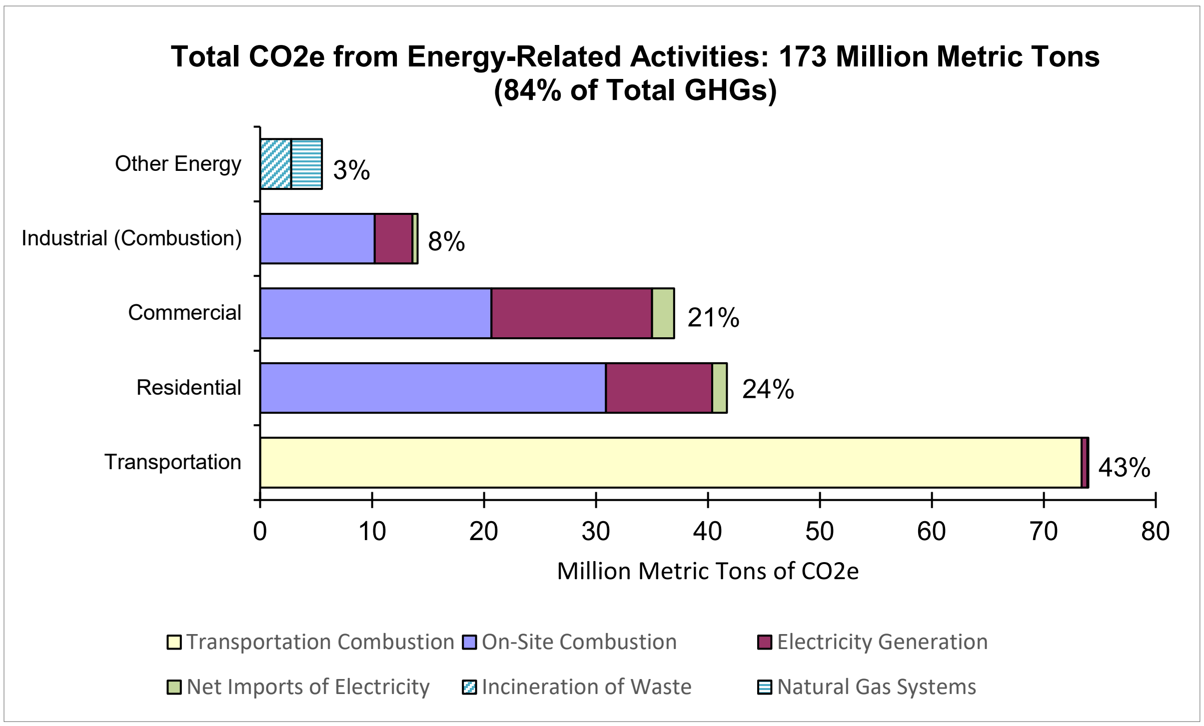
In 2016, GHG emissions from fuel combustion in New York State's electricity sector, including net imports, accounted for 15% of statewide emissions and have decreased by approximately 56% from 1990. Emissions associated with the State's electricity consumption are 4 MMtCO_2e higher than those associated with in-state electricity production. The higher level for consumption-based emissions reflects GHG emissions associated with net imports of electricity.[8] Electricity generation is dominated by natural gas, hydro, and nuclear-powered units, with coal and oil also important sources of historical generation in the State.

Collectively, non-combustion emissions sources in the industrial process, agriculture, and waste sectors account for 19% of statewide GHG emissions in 2016. Methane emissions, sources of which include landfills, natural gas system leakage, agricultural animals, and municipal wastewater facilities, account for 50% of non-combustion emissions, hydrofluorocarbon (HFC) emissions, resulting from use of substitutes for ozone-depleting substances (ODS) primarily for refrigeration, have increased substantially from 0% of non-combustion emissions in 1990 to 25% in 2016.

1 Energy

Emissions from energy-related sources account for most of the New York State's total GHG emission profile. These State sources—which include fuel consumption for transportation and in buildings, electricity production, net imports of electricity, oil and gas infrastructure, and municipal waste combustion—release emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Emissions from fossil fuel combustion—which includes transportation, on-site combustion in the RCI sectors, generation of electricity, and net imports of electricity—account for 97% of energy-related GHG emissions. The remainder of the energy category consists of energy-related emissions not associated with the combustion of fossil fuels, such as emissions resulting from the incineration of waste and the transmission, distribution, and storage of natural gas.

Figure 1. 2016 Energy Related GHG Emissions by Sector



1.1 Fossil Fuel Combustion

1.1.1 Electricity Generation and Net Imports

1.1.1.1 Overview

Emissions of CO_2, CH_4, and N_2O are produced from the generation of electricity used to meet electricity demand in New York State. Electricity sector GHG emission sources include the combustion of fossil fuels such as natural gas, petroleum fuels, and coal by in-state power plants.

The State has historically imported more electricity than it has exported. Net imports are the difference between total in-state imports and exports. This inventory also includes CO_2, CH_4, and N_2O emissions that are associated with net imported electricity.

1.1.1.2 Emissions Inventory Data and Methodology

Electricity sector GHG emissions represent emissions produced at the point of electric generation only. In addition, in accordance with current EPA inventory protocols, the CO_2 emissions from the combustion of biogenic fuels (e.g., wood, landfill gas, and the biomass component of municipal waste) are assumed to be full carbon neutral and therefore not included in estimates of GHG emissions. Emissions from direct fuel use were estimated using the SIT (State Inventory Tool, EPA tool for developing state-level GHG inventories) and the methods provided in the national inventory for electric sector fuel combustion.[9]

Electricity generation: The default fuel consumption data in SIT for New York State, which came from the EIA State Energy Data System, were updated with fuel consumption data from NYSERDA's Patterns and Trends.[10]

Net imports of electricity: Emissions from net imports of electricity from 1990–2015 were based on net electricity imports data from NYSERDA's Patterns and Trends and a weighted emission factor associated with net electricity imports to New York drawn from the Regional Greenhouse Gas Initiative (RGGI)[11] 2015 Monitoring Report. This report monitors GHG emissions in the regional electricity systems that provide electricity to RGGI states, including those managed by the New York Independent System Operator, the New England Independent System Operator, Hydro-Quebec, Ontario's Independent Electricity System Operator, and the Pennsylvania-New Jersey-Maryland Interconnection. The 2016 net imports emissions factor is developed in a similar manner to the method described above, but rather than using regional values from RGGI, values were developed from the New York Generation Attribute System.

1.1.1.3 Results

A 2016 breakdown of electricity generation and net imports of electricity for New York State by source category is provided in Figure 2. The primary energy sources were natural gas (35%) and nuclear power (26%) followed by conventional hydropower (16%) and net imports of electricity (16%). Figure 2 shows that nearly half of New York State's electricity generation comes from sources that produce little or no emissions, such as conventional hydropower, nuclear power, and wind energy.

Figure 2. Proportion of New York State Electricity Generation and Net Imports by Source Category, 2016

Wood category includes wood waste. Emissions for the incineration of waste are presented in section 1.

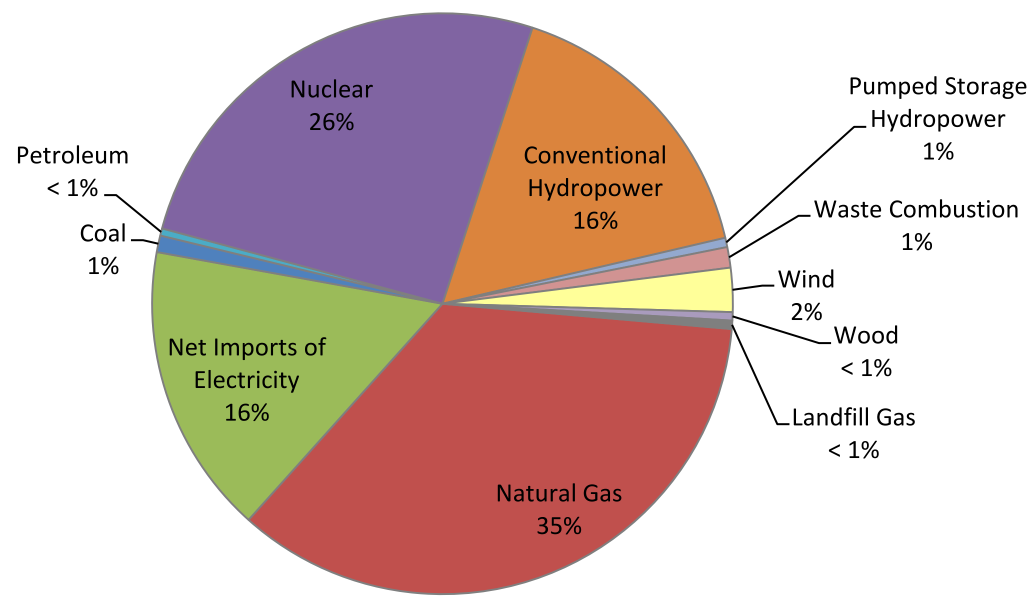
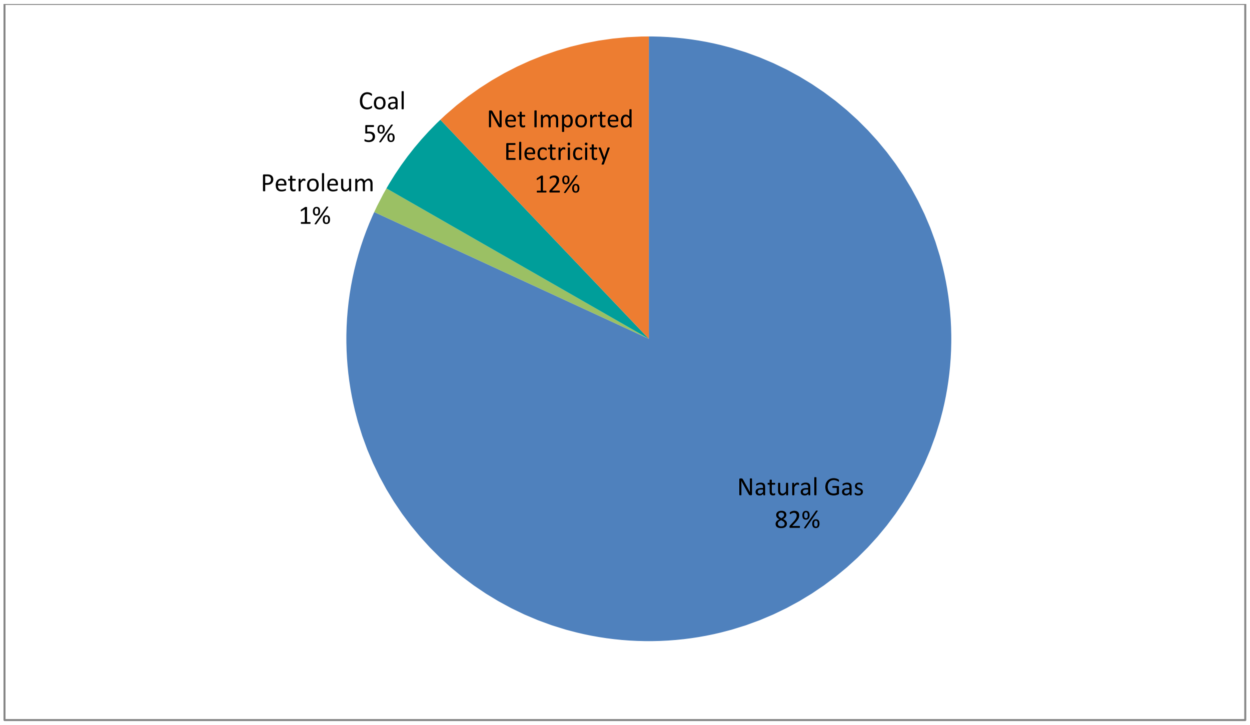


Figure 3 provides a breakdown by percentage of emissions from power supply and delivery in New York State by source category in 2016. The largest contributor of emissions is natural gas combustion (82%), while coal accounts for 5% of emissions, although it only provides a relatively small proportion of the State's electricity generation (as seen in Figure 2). Net imports of electricity also contribute approximately 12% of GHG emissions. However, based on the approach outlined above, there is some uncertainty associated with the estimation of emissions from this out-of-state source category.

Figure 3. Proportion of Electricity Sector GHG Emissions from by Source Category, 2016



Electricity generation and net imports of electricity for New York State by source category for 1990–2016 are shown in Figure 4. During this period the largest absolute increase in electricity generation by source comes from natural gas, which increases from approximately 23,000 gigawatt-hours (GWh) of generation in 1990 to approximately 57,000 GWh of generation in 2016. As indicated in Table 1, the renewables category, which includes renewable energy sources such as solar, wind, and bioenergy, saw the greatest average annual growth percentage with an estimated average annual growth rate of 200% between 2000 and 2016. Net imports of electricity have increased substantially, from approximately 5,000 GWh in 1990 to 26,000 GWh in 2016.

Figure 4. New York State Electricity Generation and Net Imports of Electricity by Source Category ($MMtCO_2e$), 1990–2016

Note: The category "Other" includes wood, landfill gas, and waste. The category "Hydropower" includes both conventional and pumped storage hydropower.

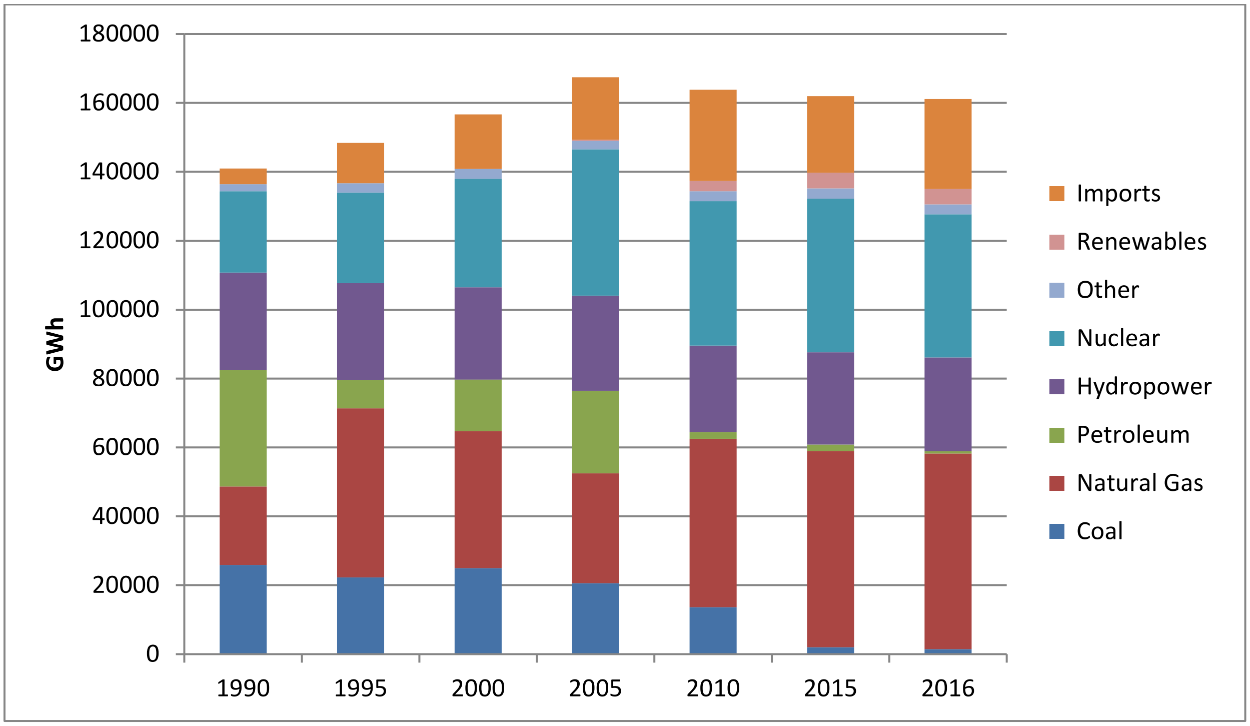


Table 1. Electric Generation (GWh) and Annual Average Growth Rates by Fuel Type

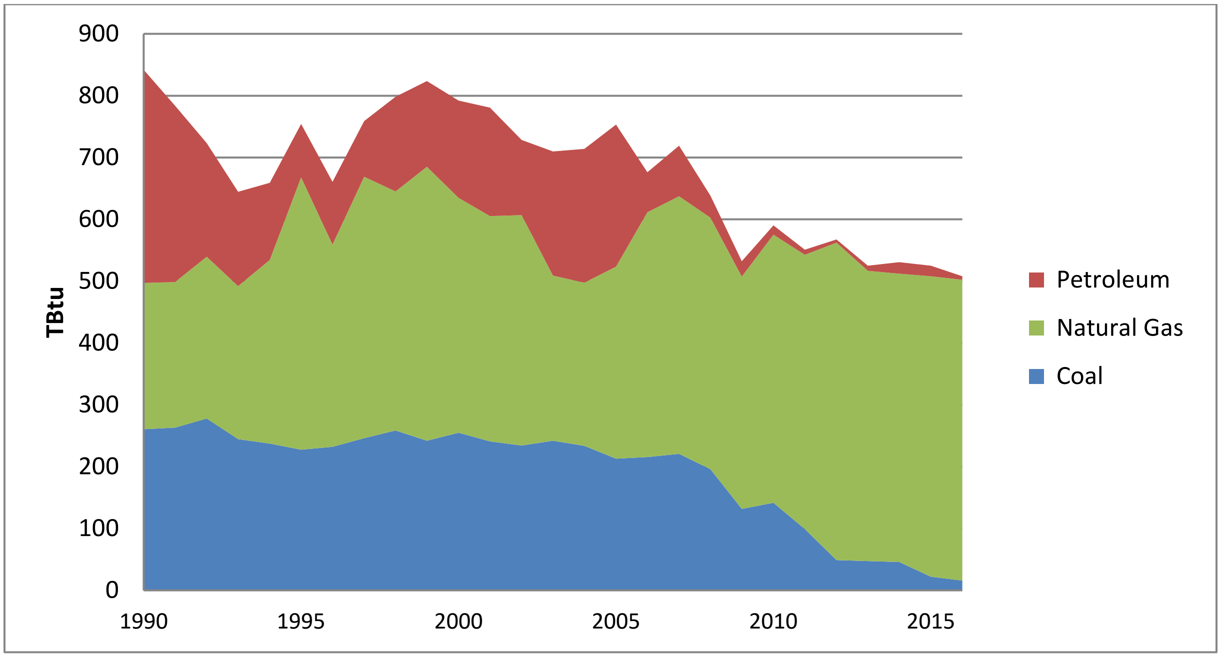
Note: The category "Other" includes wood, landfill gas, and waste. The category "Hydropower" includes both conventional and pumped storage hydropower.

Energy Source	1990	2016	Average % Annual Growth 1990–2016
Coal	25,913	1,493	-8%
Natural Gas	22,724	56,793	5%
Petroleum	33,885	643	-4%
Hydropower	28,188	27,150	0%
Nuclear	23,623	41,638	3%
Net Imports of Electricity	4,519	26,117	15%
Renewables [a]	-	4,375	200%
Other	2,066	2,881	1%
Total	**140,919**	**161,090**	**1%**

[a] Renewables had no value until the year 2000 (10 GWh); this average annual growth rate is representative of the years between 2000 and 2016.

The primary fossil fuel energy use at in-state power stations for natural gas, coal, and petroleum from 1990–2016 is shown in Figure 5. The data show natural gas replacing coal and petroleum generation during this time.

Figure 5. Primary Fossil Fuel Energy Use at New York State Power Stations by Fuel Type



GHG emissions from the electricity sector in New York State by source category for 1990–2016 are shown in Figure 6. Between 1990 and 2016, total GHG emission from power supply and delivery (including imports) decreased by approximately 26.4 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) to reach approximately 40.8 $MMtCO_2e$.

The largest absolute increase in GHG emissions between 1990 levels and 2016 levels comes from natural gas, with emissions rising from approximately 12.6 $MMtCO_2e$ in 1990 to approximately 25.8 $MMtCO_2e$ in 2016, as indicated by Table 2. Emissions associated with coal and petroleum combustion decline from 24.5 $MMtCO_2e$ in 1990 to 1.5 $MMtCO_2e$ in 2016, and 26.0 $MMtCO_2e$ in 1990 to 0.4 $MMtCO_2e$ in 2016, respectively.

Emissions from natural gas have increased as a share of total electricity sector emissions from 19% in 1990 to 79% in 2016, while coal's share of emissions has decreased from 38% to 6%, and petroleum's share has decreased from 40% to 4% over the same period. Emissions associated with net electricity imports have increased as a share of total emission from 3% in 1990 to 12% in 2016.

Figure 6. GHG Emissions from Electric Generation by Source Category ($MMtCO_2e$), 1990–2016

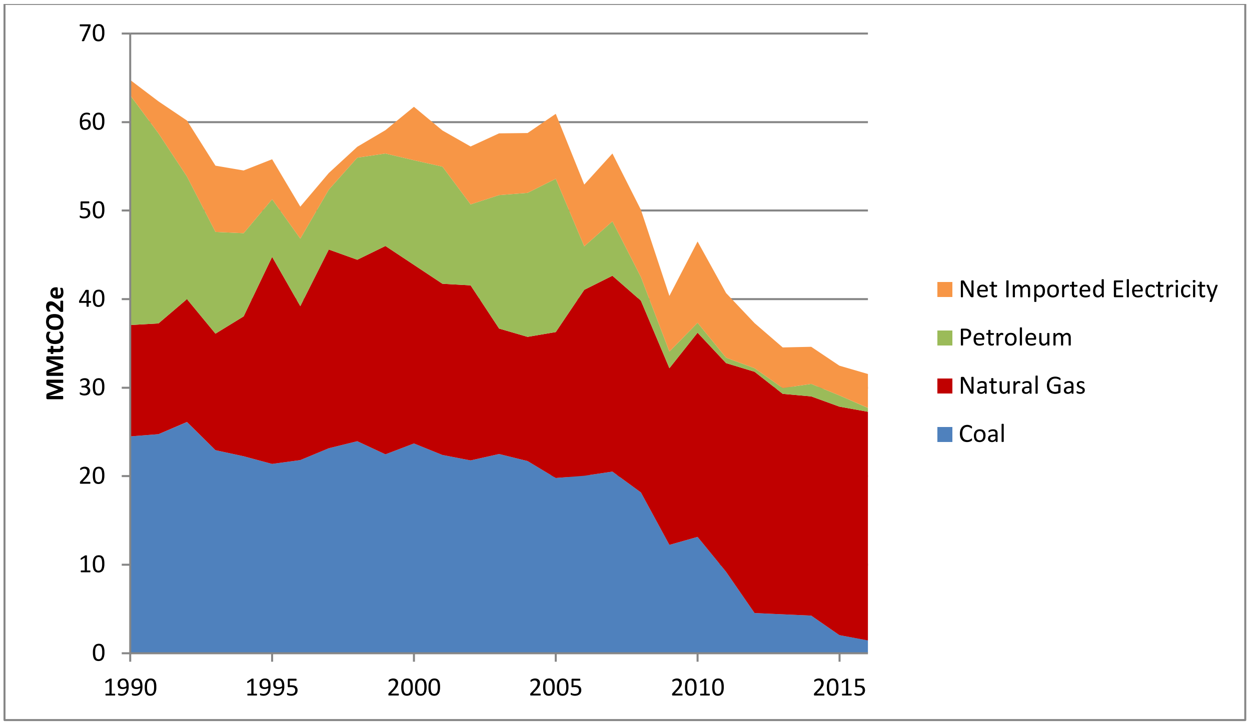


Table 2. GHG Emissions from Electric Generation by Source Category, 1990–2016 ($MMtCO_2e$)

Source Category	1990	1995	2000	2005	2010	2015	2016
Natural Gas	12.6	23.4	20.2	16.5	23.0	25.8	25.8
Coal	24.5	21.4	23.7	19.8	13.2	2.0	1.5
Petroleum	26.0	6.5	11.8	17.3	1.1	1.3	0.4
Net Imported Electricity	1.7	4.5	6.0	7.4	9.2	3.4	3.8
Total	**64.8**	**55.8**	**61.7**	**60.9**	**46.5**	**32.5**	**31.5**

Table 3. Electricity Sector Proportions of Total Emissions by Fuel Type, 1990–2016 (%)

The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table 2 and corresponds to the data shown in Figure 6.

Source Category	1990	1995	2000	2005	2010	2015	2016
Natural Gas	19%	42%	33%	27%	50%	79%	82%
Coal	38%	38%	38%	32%	28%	6%	5%
Petroleum	40%	12%	19%	28%	2%	4%	1%
Net Imported Electricity	3%	8%	10%	12%	20%	10%	12%

1.1.2 On-Site Fuel Use from the Residential, Industrial, and Commercial Sectors

1.1.2.1 Overview

Activities in the residential, commercial, and industrial sectors produce CO_2, CH_4, and N_2O emissions when fossil fuels and biomass are combusted to provide space heating, water heating, process heating, cooking, and other energy end uses. CO_2 accounts for 99% of these emissions on a CO_2 equivalent (CO_2e) basis in New York State. Standard international protocols separate biogenic emissions (such as carbon dioxide produced from biomass combustion) from the anthropogenic emissions inventoried in this report.[12] Since these sectors consume electricity, one can also attribute emissions associated with electricity generation to these sectors in proportion to their electricity use.[13] Although all six Kyoto Protocol GHGs are inventoried in this report, including the three man-made fluorinated GHGs, they are accounted for in the Industrial Process and Product Use source category, as opposed to the Energy and end use sector source categories, following international protocols. In addition, note that in this analysis vehicles not primarily used for transportation (e.g., construction cranes and bulldozers, farming vehicles, and warehouse tractors and forklifts) are classified in the sector of primary use, be it commercial or industrial.

1.1.2.2 Emissions Inventory Data and Methodology

Historical emissions from direct fuel use were estimated using the EPA SIT with reference to the methods provided in the Annexes to the Inventory of U.S. GHG Emissions and Sinks guidance document for residential, commercial, and industrial sector fuel combustion.[14] The default historical fuel consumption data in the SIT for New York—which came from the United States Department of Energy (DOE) Energy Information Administration's (EIA) State Energy Data System (SEDS)—were updated with fuel consumption data for the residential, commercial, and industrial sectors from The New York State Energy Research and Development Authority's (NYSERDA) Patterns and Trends report.[15]

In addition to the fuel consumed directly by each of the residential and commercial sectors, the proportion of each sector's electricity sales to total electricity sales was used to allocate emissions associated with the electricity supply sector to each of the residential and commercial sectors. Electricity sales associated with these sectors were estimated based on information from the Patterns and Trends report.[16]

Note that the U.S. inventory methods for the industrial sector exclude the amount of carbon that is stored in products produced from fuels for non-energy uses. For example, fuel demand inputs are adjusted to account for carbon stored in petrochemical feedstocks and in liquefied petroleum gases (LPG) and natural gas used as feedstocks by chemical manufacturing plants (i.e., not used as fuel) as well as carbon stored in asphalt and road oil produced from petroleum. The carbon storage assumptions for these products are expressed in the SIT and explained in the national inventory.[17] The primary tool to determine industrial combustion emissions is the Carbon Dioxide from Fossil Fuel State Inventory Tool Module (CO_2FFC SIT Module). In this module, fuel types are given carbon content values, combustion efficiencies,[18] and storage percentages. The fuel types for which the national inventory methods are applied in the SIT software to account for the industrial sector are shown in the appendix, Table A-3.

1.1.2.3 Results

Note that the "Other" category used in this section includes emissions associated with coal and wood combustion. Wood is a biomass fuel and carbon dioxide emissions from biomass fuels are not included in GHG emissions totals in governmental GHG inventories per international convention, based in the assumption that these emissions are accounted for in national-level reporting on carbon stocks in forests and other lands. Consequently, GHG emissions associated with bioenergy fuels are limited to methane and nitrous oxide. Future New York State inventories may include information on carbon stocks as well as biomass combustion, as needed to inform policy.

Residential Sector

The emissions inventory for the residential sector is presented in Figure 7, which was developed from the emissions data in Table 4. The relative contributions of emissions associated with each fuel type to total residential sector emissions are shown in Table 5. For the residential sector, emissions from direct fuel use (including heating and hot water) and electricity consumption decrease by 22%, from approximately 54 MMtCO_2e in 1990 to 42 MMtCO_2e in 2016. Emissions associated with natural gas consumption were the greatest source of emissions in 2016, accounting for approximately 54% of total residential emissions. Emissions associated with electricity use were the second greatest source of residential emissions in 2016, with 26% of the total in this sector. Petroleum use accounted for the next largest portion of residential sector emissions, accounting for 20% of emissions in 2016. Coal and wood emissions account for 1% or less of residential sector emissions throughout the analysis period.

Figure 7. Residential Sector GHG Emissions from Fuel Combustion and Electricity, 1990–2016

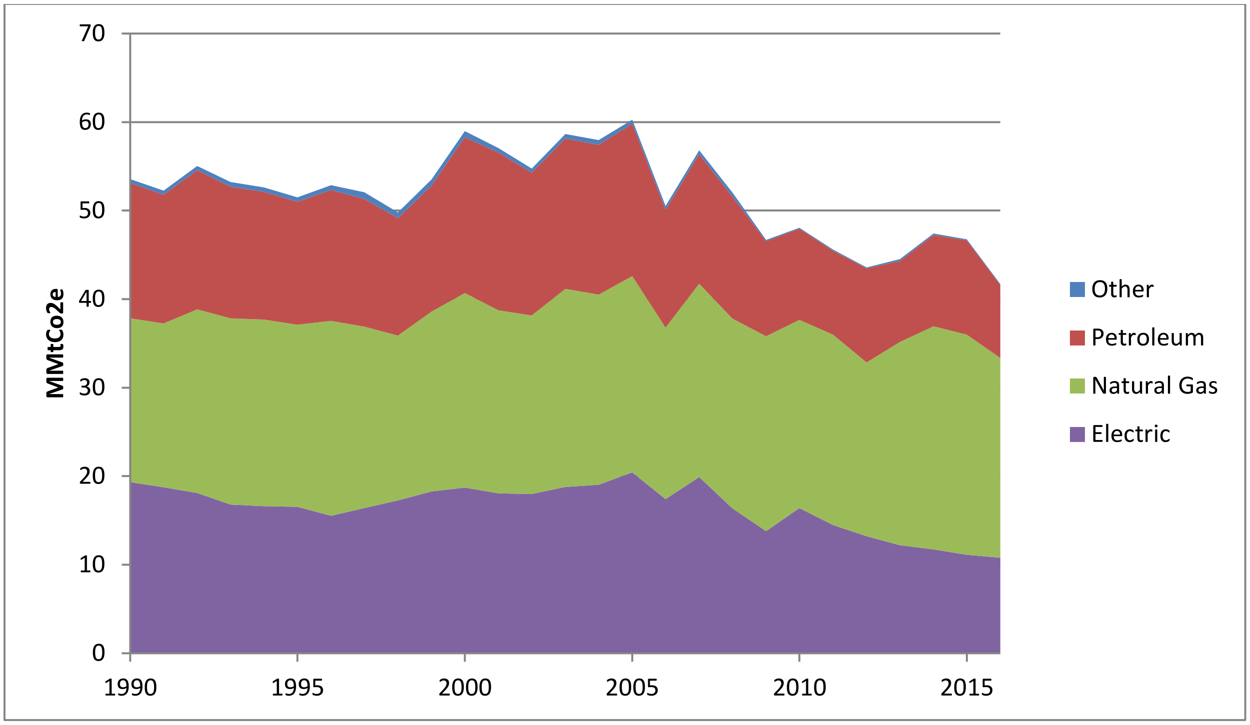


Table 4. Residential Sector Emissions Inventory, 1990–2016 (MMtCO$_2$e)

Anthropogenic carbon dioxide, nitrous oxide, and methane associated with fossil fuel combustion.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Other	0.5	0.5	0.7	0.4	0.1	0.1	0.1
Petroleum	15.3	13.9	17.6	17.2	10.3	10.7	8.2
Natural Gas	18.5	20.6	22.0	22.2	21.3	24.8	22.6
Electricity	19.3	16.5	18.7	20.4	16.4	11.1	10.8
Total	**53.6**	**51.5**	**59.0**	**60.3**	**48.1**	**46.8**	**41.7**

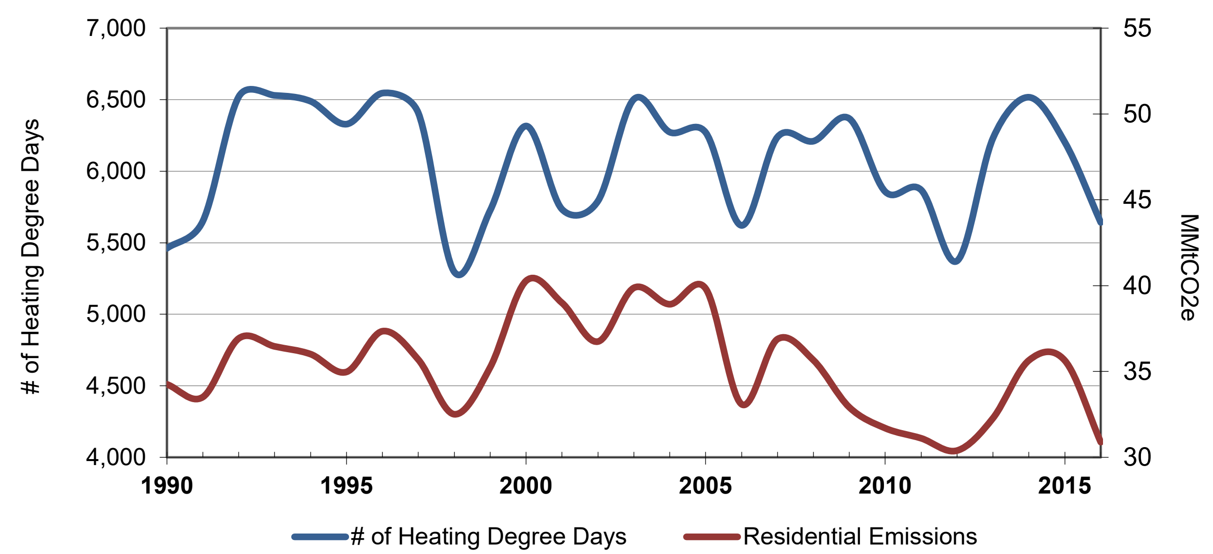
Table 5. Residential Sector Proportions of Total Emissions by Fuel Type, 1990–2016 (%)

The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table 4 and corresponds to the data shown in Figure 7.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Other	1%	1%	1%	1%	0%	0%	0%
Petroleum	29%	27%	30%	29%	21%	23%	20%
Natural Gas	35%	40%	37%	37%	44%	53%	54%
Electricity	36%	32%	32%	34%	34%	24%	26%

The trend in GHG emissions from fuel combustion for the residential sector, excluding emissions associated with electricity use, correlates with the trend in the number of heating degree days[19] for each year from 1990–2016, as demonstrated in the comparison in Figure 8. The two sets of data show a correlation coefficient of 0.55. Although the magnitude of the effect of heating degree days on emissions varies over time, the important point to note is that the peaks and valleys of both sets of data occur in the same years. In years with a greater number of heating degree days, the emissions are also generally higher, and in years with a low number of heating degree days, such as 1998 and 2006, GHG emissions from residential sector were also lower.

Figure 8. Residential Sector Heating Demand and GHG Emissions, 1990–2016



Commercial Sector

The emissions inventory for the commercial sector is presented in Figure 9, which was developed from the emissions data in Table 6. The relative contributions of emissions associated with each fuel type to total commercial sector emissions are shown in Table 7.

For the commercial sector, emissions from direct, on-site, fossil fuel use (including for space heating and hot water) and electricity decreased from approximately 54 $MMtCO_2e$ in 1990 to 37 $MMtCO_2e$ in 2016. Natural gas consumption became the largest source of all commercial sector emissions at 20% in 1990 and 43% in 2016. In 1990, electricity use accounted for approximately 51% of total commercial emissions, decreasing to 42% of total commercial emissions. Petroleum emissions accounted for 28% of commercial sector emissions in 1990 and declined to 11% of emissions in 2016. Commercial sector emissions associated with the use of coal accounted for approximately 1% of total commercial emissions in 1990 and less than 1% of total commercial emissions in 2016.

Figure 9. Commercial Sector GHG Emissions from Fuel Combustion and Electricity (MMtCO$_2$e), 1990–2016

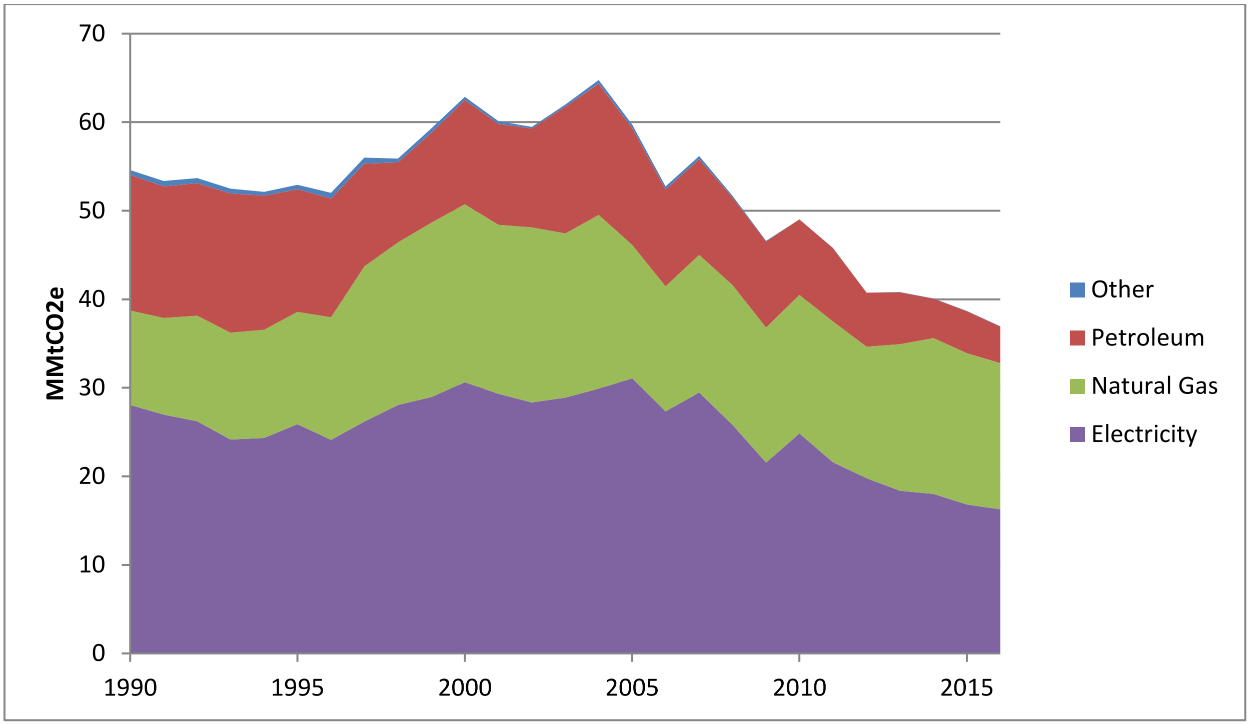


Table 6. Commercial Sector Emissions Inventory, 1990–2016 (MMtCO$_2$e)

Anthropogenic carbon dioxide, nitrous oxide, and methane associated with fossil fuel combustion.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Other	0.6	0.5	0.3	0.4	0.0	0.0	0.0
Petroleum	15.3	13.8	11.8	13.2	8.5	4.7	4.1
Natural Gas	10.7	12.7	20.1	15.1	15.6	17.1	16.5
Electricity	28.1	25.9	30.6	31.1	24.8	16.8	16.3
Total	**54.6**	**52.9**	**62.9**	**59.7**	**49.0**	**38.7**	**36.9**

Table 7. Commercial Sector Proportions of Total Emissions by Fuel Type (%)

The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table 6 and correspond to the data shown in Figure 9.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Other	1%	1%	<1%	1%	0%	0%	0%
Petroleum	28%	26%	19%	22%	17%	12%	12%
Natural Gas	20%	24%	32%	25%	32%	44%	44%
Electricity	51%	49%	49%	52%	51%	43%	44%

Industrial Sector

The emissions inventory for the industrial fuel combustion sector is presented in Figure 10, which was developed from the emissions data in Table 8. The relative contributions of emissions associated with each fuel type to total industrial sector emissions is shown in Table 9.

For the industrial fuel combustion sector, emissions from direct fuel use and electricity in 1990 were approximately 36 MMtCO_2e, decreasing to approximately 14 MmtCO_2e in 2016. In 1990, the emissions associated with electricity use accounted for the largest share of industrial emissions at 44% of the industrial sector's total. However, this contribution declined to 27% in 2016. In contrast, emissions from petroleum fuels accounted for 18% of the industrial sector emissions in 1990 and 19% in 2016. The share of emissions from natural gas consumption increased from 16% of industrial fuel use emissions in 1990 to 41% of these emissions in 2016. Coal consumption accounted for approximately 22% of total industrial emissions in 1990 and decreased to approximately 13% of total industrial emissions in 2016.

Figure 10. Industrial Sector GHG Emissions from Fuel Combustion and Electricity (MMtCO$_2$e), 1990–2016

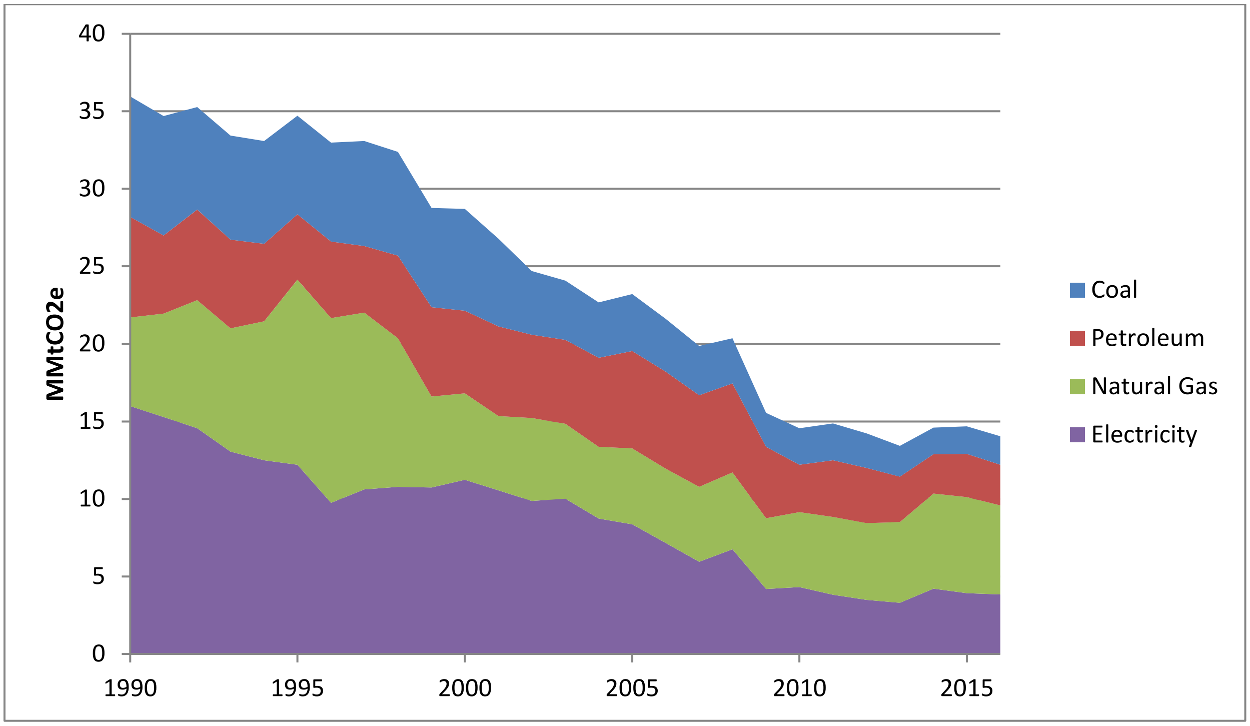


Table 8. Industrial Sector Emissions Inventory, 1990–2016 (MMtCO$_2$e)

Anthropogenic carbon dioxide, nitrous oxide, and methane associated with fossil fuel combustion.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Coal	7.8	6.4	6.6	3.7	2.4	1.8	1.8
Petroleum	6.5	4.2	5.3	6.3	3.1	2.8	2.6
Natural Gas	5.7	11.9	5.6	4.9	4.8	6.2	5.7
Electricity	16.0	12.2	11.2	8.4	4.3	3.8	3.8
Total	**36.0**	**34.7**	**28.8**	**23.2**	**14.6**	**14.7**	**14.1**

Table 9. Industrial Sector Proportions of Total Emissions by Fuel Type (%)

The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table 8.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Coal	22%	18%	23%	16%	16%	12%	13%
Petroleum	18%	12%	19%	27%	21%	19%	19%
Natural Gas	16%	34%	19%	21%	33%	42%	41%
Electricity	44%	35%	39%	36%	30%	27%	27%

1.1.3 Transportation

1.1.3.1 Overview

The transportation sector is one of the largest sources of greenhouse gas (GHG) emissions in New York State. Carbon dioxide (CO_2) largely accounts for transportation GHG emissions from fuel use, and most of the remaining GHG emissions from the transportation sector are due to nitrous oxide (N_2O) emissions from on-road, gasoline-fueled vehicles. In addition, note that in this analysis vehicles not primarily used for transportation (e.g., construction cranes and bulldozers, farming vehicles, and warehouse tractors and forklifts) are classified in the sector of primary use, be it commercial or industrial.

On-Road Vehicles

Gasoline: CO_2, N_2O, and CH_4 emissions are produced from gasoline combusted by passenger cars, light-duty trucks, heavy-duty vehicles, and motorcycles. Although gasoline contains virtually no CH_4, this GHG is produced as a byproduct of gasoline combustion, and its emissions can be influenced by various factors such as emission control technologies, combustion conditions, and fuel composition. In New York State gasoline contains up to 10% ethanol by volume; however, since ethanol is considered a biofuel in the national inventory, no CO_2 emissions associated with the combustion of ethanol are included in the inventory.[20]

Diesel: CO_2, N_2O, and CH_4 emissions are produced from distillate fuel that is combusted by passenger cars, light-duty trucks, and heavy-duty vehicles. Although diesel contains virtually no CH_4, it is produced as a byproduct of diesel combustion and its emissions are influenced by various factors such as emission control technologies, combustion conditions, and fuel composition. To the extent that diesel fuel is blended with biodiesel, CO_2 emissions from the biodiesel component of this mixed fuel are not included in the inventory per EPA guidance.

Natural gas: Light-duty and heavy-duty alternative fuel vehicles[21] produce CO_2, N_2O and CH_4 emissions as a result of natural gas combustion.

Non-road Vehicles

Gasoline: CO_2, N_2O, and CH_4 emissions are produced from gasoline that is combusted by non-road and marine vehicles.

Diesel: CO_2, N_2O, and CH_4 emissions are produced from distillate fuel that is combusted by such sources as locomotives and marine vehicles.

Residual oil: CO_2, N_2O, and CH_4 emissions are produced from residual fuel that is combusted by marine vehicles.

Liquefied petroleum gas: CO_2, N_2O, and CH_4 emissions are produced from liquefied petroleum gas (LPG) that is combusted by internal combustion engines.[22]

Jet fuel (kerosene): CO_2, N_2O, and CH_4 emissions are produced from jet fuel that is combusted by aircraft.

Lubricants

CO_2 emissions are produced from lubricants that are consumed during vehicle operation. Lubricants are assumed to have an oxidation factor of 1.00,[23] which represents the fraction of consumed product (on an energy-content basis) that is combusted and releases GHG emissions.

1.1.3.2 Emissions Inventory and Methodology

GHG emissions were estimated using the SIT and the methods provided in the national inventory for the transportation sector.[24,25] The SIT module was used to determine emissions from the following sources: highway vehicles, aviation, boat and marine vessels, locomotives, other non-highway sources, and alternative fuel vehicles.

On-Road Vehicles Fuels

Gasoline and diesel: The SIT Mobile Combustion module was used to calculate CO_2, CH_4, and N_2O emissions based on vehicle miles traveled in millions of miles by vehicle type. The SIT calculates emissions from highway vehicles through the following steps: converting the VMT data for use with existing emissions factors, distributing vehicle miles of travel (VMT) by vehicle age, and determining emissions control systems for each vehicle type. The default SIT fuel consumption values for New York State were replaced with State-specific information calculated from annual VMT data provided by the Federal Highway Administration (FHWA), and the New York State Department of Transportation (DOT). The State annual VMT data for gasoline and diesel on-road vehicles were allocated to differing vehicle types to calculate the VMT by vehicle type for 1990, 2002, and 2007 shown in Table 10.[26] The fraction of VMT by vehicle type for years 1991–2001, 2003–2006, and 2008–2016 were calculated by interpolation. These fractions were applied to the corresponding annual statewide total VMT value to produce annual VMT by vehicle type. Note that consumption of biofuel in blended fuels is not included in the State's CO_2 emission total.

Table 10. New York State VMT by Vehicle Type (million miles)

Vehicle Type	1990	2002	2007
Heavy Duty Diesel Vehicle	4,056	4,538	8,022
Heavy Duty Gasoline Vehicle	206	320	1,414
Light Duty Diesel Truck	582	1,890	1,459
Light Duty Diesel Vehicle	26	20	19
Light Duty Gasoline Truck	17,552	61,268	64,119
Light Duty Gasoline Vehicle	84,372	64,420	60,817
Motorcycle	107	603	887
Total	**106,900**	**133,058**	**136,737**

Natural Gas: Historical annual VMT data by natural gas vehicle type were calculated based on consumption data from the EIA State Energy Data System and fuel efficiency data from Oak Ridge National Laboratory and the FHWA. The resultant VMT values were then input into the SIT Mobile Combustion Module to calculate emissions of CO_2, N_2O and CH_4.

Non-road Vehicle Fuels

Gasoline: Non-road motor gasoline consumption was estimated based on SEDS gasoline sales data for marine vehicles and other non-highway sources in New York State. Gasoline consumption data in Btu were subsequently input into the SIT Mobile Combustion Module to produce GHG emissions estimates.

Diesel: Non-road diesel sales data from SEDS were used to estimate non-road diesel consumption for marine vehicles, locomotives, and other non-highways sources in the State. Diesel consumption data in Btu were subsequently input into the SIT Mobile Combustion Module to produce GHG emissions estimates.

Residual oil, liquefied petroleum gas, and jet fuel (kerosene): For these other non-road fuels, emissions estimates were calculated in the SIT CO_2FFC and Mobile Combustion modules using fuel consumption data in Btu from SEDS.[27]

Lubricants

Historical emissions estimates were calculated using fuel consumption data in Btu from NYSERDA's Patterns and Trends and the historical CO_2 emission estimates were calculated in the SIT CO_2FFC module.

1.1.3.3 Results

Gasoline consumption accounts for the largest share of transportation GHG emissions, as shown in Table 11 and Figure 11. The relative contributions of emissions associated with each fuel type to total transportation sector emissions are shown in Table 12.

In 2016, emissions from gasoline accounted for approximately 64% of total transportation emissions, while GHG emissions from diesel fuel accounted for approximately 17% of GHG emissions from the transportation sector. Emissions from jet fuel increased to account for approximately 14% of transportation emissions in 2016. Emissions from residual oil accounted for about 3% of total transportation emissions in 2016, while emissions from all other categories combined (natural gas, LPG, and lubricants) contributed approximately 1% of total transportation emissions in 2016.

Transportation emissions associated with gasoline consumption increased 6% from 1990–2016, from 49.1 MMtCO_2e to 47.6 MMtCO_2e. Emissions associated with jet fuel experienced a substantial increase over the same period, from 1.6 MMtCO_2e to 10.3 MmtCO_2e. Emissions from diesel consumption increased over the analysis period, at 7.1 MMtCO_2e in 1990 and 12.9 in 2016.

Figure 11. Transportation GHG Emissions by Fuel, 1990–2016

Liquefied petroleum gas (LPG)

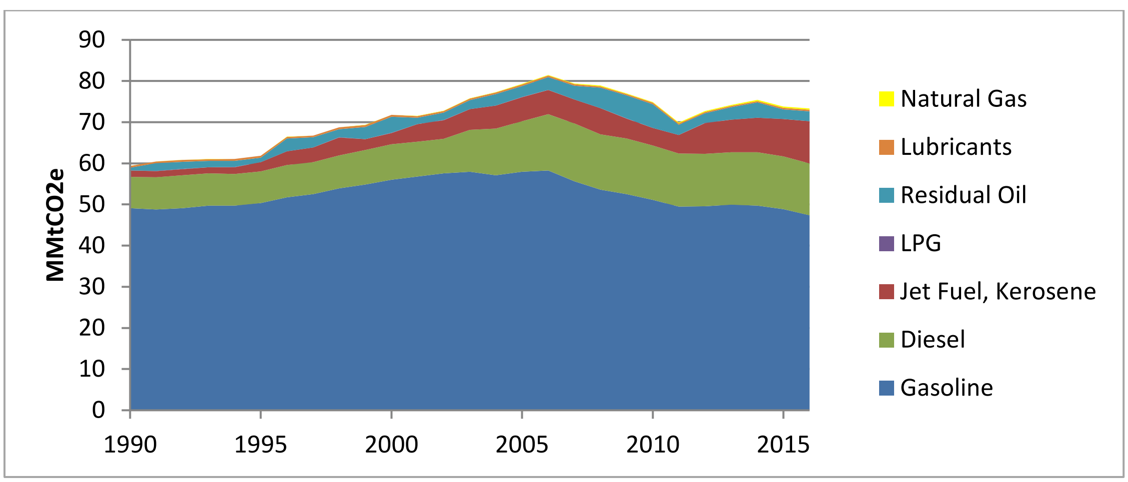


Table 11. Transportation Sector Emissions Inventory, 1990–2016 ($MMtCO_2e$)

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Gasoline	49.1	50.4	56.0	58.0	51.1	49.1	47.6
Jet Fuel, Kerosene	1.6	2.2	2.8	5.9	4.3	9.1	10.3
Diesel	7.6	7.6	8.4	12.2	13.2	12.9	12.9
Residual Oil	0.6	1.1	3.9	2.7	5.8	2.3	2.4
Lubricants	0.4	0.4	0.5	0.4	0.4	0.4	0.4
LPG	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Natural Gas	0.0	0.0	0.1	0.2	0.2	0.4	0.4
Total	**59.4**	**61.8**	**71.7**	**79.2**	**74.9**	**74.2**	**74.0**

Table 12. Transportation Sector Proportions of Total Emissions by Fuel Type, 1990–2016 (%)

The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table 11.

Fuel Type	1990	1995	2000	2005	2010	2015	2016
Gasoline	83%	82%	78%	73%	68%	66%	64%
Jet Fuel, Kerosene	3%	4%	4%	7%	6%	12%	14%
Diesel	13%	12%	12%	15%	18%	17%	17%
Residual Oil	1%	2%	5%	3%	8%	3%	3%
Lubricants	1%	1%	1%	< 1%	< 1%	1%	1%
LPG	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%
Natural Gas	< 1%	< 1%	< 1%	< 1%	< 1%	1%	1%

1.2 Incineration of Waste

1.2.1 Overview

Some of New York State's municipal waste is incinerated in facilities that are equipped to use the heat produced by an incineration process to generate electricity. This source category includes the CO_2 and N_2O emissions that are produced during the incineration process at these conventional waste-to-energy facilities. Note that this inventory does not currently capture any other forms of waste combustion, including medical waste, hazardous waste incineration, and commercial/industrial waste incineration.

1.2.2 Emissions Inventory Data and Methodology

Emissions from waste combustion were based on waste-to-energy, facility-specific tonnage data and emission factors from EPA's SIT module. Facility data were input into the SIT from the New York State Department of Environmental Conservation, and the methods provided in the SIT for municipal solid waste emissions were used to estimate the CO_2 and N_2O produced. Per international convention, SIT emission factors do not include CO_2 emissions from the combustion of organic materials in waste.[28]

Note that many of the materials that comprise municipal solid waste—aluminum cans, steel cans, glass, plastic, paper—represent significant embedded GHG emissions. Embedded emissions include emissions from the entire energy-cycle of a material, including emissions from raw material extraction, transportation of the raw material, manufacture of a product or packaging, and transportation of the goods or packaging to the marketplace. Only those embedded emissions that have taken place in the State since 1990 are accounted for implicitly in this inventory in other source categories (e.g., commercial, industrial, electricity, or transportation).

1.2.3 Results

The emission estimates for the incineration of waste category are shown in Figure 12 and Table 13, and include emissions associated with waste burned in New York State. Overall, the category accounted for 1.3 $MMtCO_2e$ in 1990 and 2.8 $MMtCO_2e$ in 2016.

Figure 12. GHG Emissions from the Incineration of Waste ($MMtCO_2e$), 1990–2016

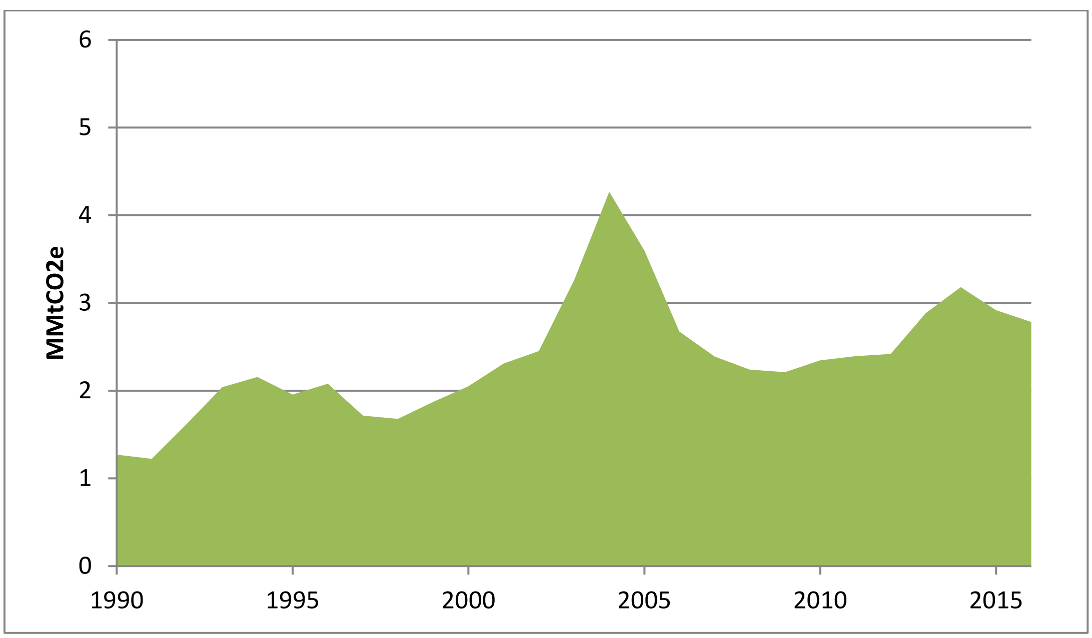


Table 13. GHG Emissions from Incineration of Waste ($MMtCO_2e$), 1990–2016

Source Category	1990	1995	2000	2005	2010	2015	2016
Incineration of Waste	1.3	2.0	2.0	3.6	2.4	2.9	2.8

1.3 Oil and Natural Gas Systems

1.3.1 Overview

Oil and gas production activities and transmission and distribution infrastructure are a source of CH_4 emissions in New York State. The various elements of the State's oil and gas systems can be divided into three broad categories: upstream, mid-stream, and downstream. Each of these categories is further explained in the following definitions.[29]

Upstream: This category includes activities such as exploration (well drilling, completions, testing, etc.), production (extracting crude oil or raw natural gas), and gathering and boosting (transferring resources to transmission pipelines or processing facilities).

Midstream: This category includes activities such as the processing of crude or raw material, the transmission and compression of resources through main transmission lines, underground storage of natural gas, as well as the storage and import/export terminal activities of liquified natural gas.

Downstream: This category includes activities associated with the distribution of oil and gas to end users through truck delivery or service pipelines.

1.3.2 Emissions Inventory Data and Methodology

Emissions from oil and gas systems were generated estimates by applying emissions factors selected from a detailed review of the literature to different site-level activity data covering the full range of oil and gas system sources. The general equation for emissions estimates is: E = A * EF, where, E= emissions; A = activity rate; and EF = emissions factor. A more detailed description of the methodology can be found in NYSERDA's New York State Oil and Gas Methane Emissions Inventory Report.[30]

1.3.3 Results

Emissions from natural gas systems from 1990–2016 are shown in Figure 13, and Table 14 shows the historical emission values upon which the figure is based. Total New York State GHG emissions for this source totaled approximately 2.7 MMtCO_2e in both 1990 and 2016, albeit increasing above that value through the duration of that period. Upstream emissions over time reflect supply conditions in the State, as well as sensitivity to fluctuations in national and global gas markets and policy considerations, such as the State's ban on high-volume hydraulic fracturing. Midstream emissions have grown over time by 16% in 2016 from 1990 levels, driven by gas transmission capacity expansions to supply increasing demand for natural gas. Downstream emissions have fallen by 27% in 2016 from 1990 levels as leak-prone pipeline has been replaced with newer materials over time. Gas transmission compressor stations are the largest source category, accounting for about a quarter of total CH_4 emissions. Taken together, the top five source categories in this inventory (Gas transmission compressor stations, gas storage compressor stations, cast iron distribution mains, unprotected steel distribution mains, and customer meters) account for about three quarters of total CH_4 emissions.

Figure 13. GHG Emissions from Natural Gas Systems (MMtCO_2e), 1990–2016

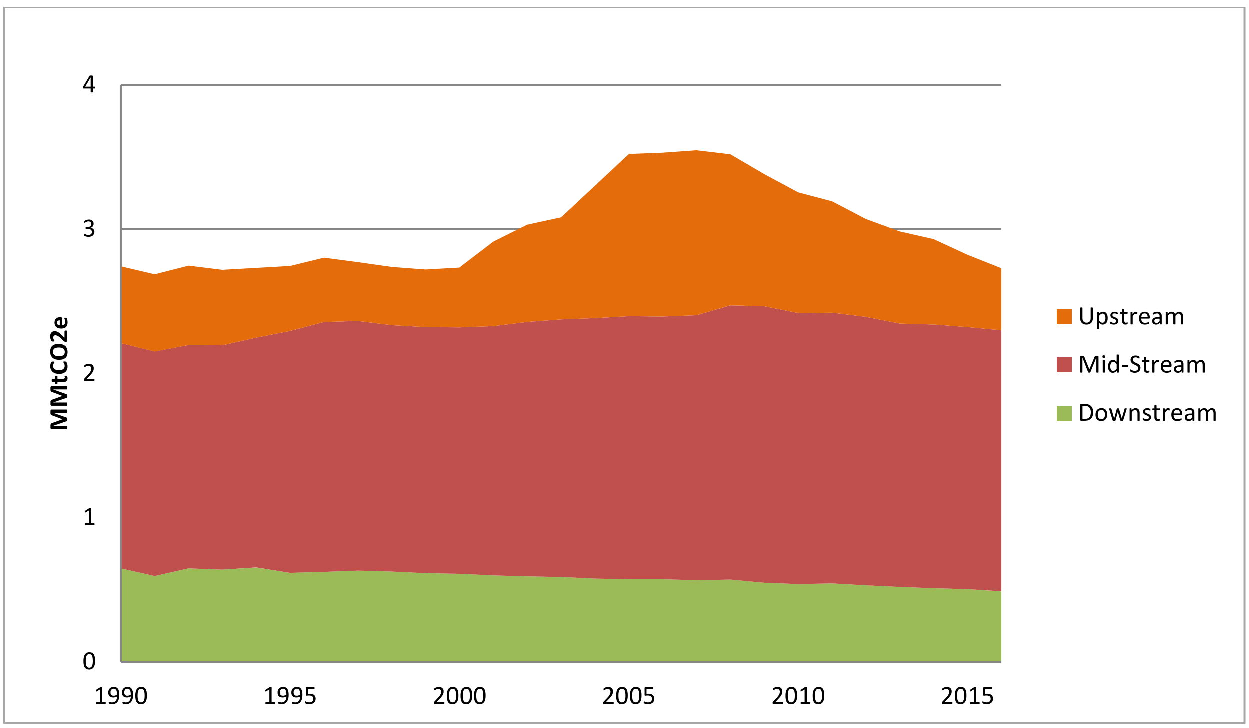


Table 14. GHG Emissions from Natural Gas Systems ($MMtCO_2e$), 1990–2016

Source Category	1990	1995	2000	2005	2010	2015	2016
Upstream	0.5	0.5	0.4	1.1	0.8	0.5	0.4
Mid-Stream	1.6	1.7	1.7	1.8	1.9	1.8	1.8
Downstream	0.7	0.6	0.6	0.6	0.5	0.5	0.5
Total	**2.8**	**2.7**	**2.7**	**3.5**	**3.3**	**2.8**	**2.7**

2 Industrial Process and Product Use

2.1 Overview

Emissions from industrial non-fuel combustion sources span a wide range of industrial process and product use activities. The industrial processes and activities that exist in New York State, and for which emissions are estimated in this inventory, are described in the following sections.[31]

2.1.1 Sources of Carbon Dioxide (CO_2) Emissions

Cement production: Greenhouse gas (GHG) emissions related to cement production can come from both clinker and cement kiln dust. Clinker is an intermediate product from which finished Portland and masonry cement are made. Clinker production releases CO_2 when calcium carbonate is heated in a cement kiln to form lime (calcium oxide) and CO_2.

Iron and steel production: The production of iron and steel generates process-related CO_2 emissions. Pig iron, which is used as a raw material in the production of steel, is created by reducing iron ore with metallurgical coke in a blast furnace, and this process emits CO_2. The production of metallurgical coke from coking coal produces CO_2 emissions as well.

Limestone and dolomite use: Limestone and dolomite are basic raw materials used by a wide variety of industries, including the construction, agriculture, chemical, glass manufacturing, and environmental pollution control industries as well as metallurgical industries such as magnesium production. Emissions associated with the use of limestone and dolomite to manufacture steel and glass and for use in flue-gas desulfurization scrubbers to control sulfur dioxide emissions from the combustion of coal in boilers are included in the Industrial Processes source category.[32]

Soda ash use: Commercial soda ash (sodium carbonate) is used in many consumer products such as glass, soap and detergents, paper, textiles, and food. Carbon dioxide is released when soda ash is consumed.

Other industrial processes that produce CO_2 emissions, but are not found in New York State or for which reliable or complete data are lacking, are taconite and lime production and ammonia production. In addition, CO_2 emissions can also result from urea consumption. While the SIT provides default data for urea consumption in the State, the estimated amount of emissions from this source is small and the emissions are excluded from the inventory.[33]

Aluminum production: CO_2 emissions occur during the smelting process when alumina is reduced to aluminum using materials such as petroleum coke. Although the sources of carbon in this process are fossil fuels, the resulting CO_2 emissions are not associated with combustion for energy production.

2.1.2 Sources of Perfluorocarbon (PFC) Emissions

Aluminum production: Emissions of tetrafluoromethane (CF4) and hexafluoroethane (C2F6), both PFCs, also occur during the primary smelting process as anode effects, which can be operationally controlled at the facility. As noted in the national inventory, aluminum production has decreased nationwide, but particularly at facilities that have reduced their PFC emissions.

Semiconductor manufacturing:[34] Manufacturers of semiconductors use fluorinated GHGs in the plasma etching and plasma enhanced chemical vapor deposition processes. Plasma etching of dielectric films creates the pattern of pathways connecting individual circuit components in semiconductors. Vapor deposition chambers are used for depositing the dielectric films and are cleaned periodically using fluorinated gases. Fluorinated gases are converted to fluorine atoms in plasma, which etches away dielectric material or cleans the chamber walls and hardware. Fluorinated gases that are not dissociated and other products end up in the waste streams and, unless captured by abatement systems, into the atmosphere. Some fluorinated compounds can also be transformed in the plasma processes into other compounds (e.g., CF_4 generated from C_2F_6). If they are not captured by emission control systems, the process-generated gases will also be released into the atmosphere.[35]

2.1.3 Sources of Hydrofluorocarbon (HFC) Emissions

Ozone-depleting substances (ODS) substitutes: HFC emissions result from the consumption of substitutes for ozone-depleting substances.[36] HFCs are specifically replacing two common types of ODS as they are phased out of usage, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Although, CFCs and HCFCs are also potent greenhouse gases, they are not included in governmental GHG inventories because governments have already agreed to phase these down to protect the ozone layer.

2.1.4 Sources of Sulfur Hexafluoride (SF_6) Emissions

Electricity transmission and distribution: SF_6 is used as an electrical insulator and interrupter in the electric power transmission and distribution (T&D) system. Because of its high-dielectric strength and arc-quenching abilities, SF_6 is largely used as an insulator in T&D equipment such as gas-insulated, high-voltage circuit breakers, substations, transformers, and transmission lines. However, not all electric utilities in the U.S. use SF_6, since the use of the gas is more common in urban areas where space is valuable and limiting the footprint of electric power T&D facilities is a significant factor in siting these assets.[37]

2.2 Emissions Inventory Data and Methodology

GHG emissions for 1990–2016 were estimated using the following methods. For most sources, emissions were estimated using the SIT tool and the methods provided in the national inventory for industrial processes.[38]

2.2.1 Sources of CO_2 Emissions

Cement Production: Emissions from cement production are calculated by multiplying annual metric tons of clinker production by emission factors to estimate emissions associated with the clinker production process [0.507 metric tons (Mt) of CO_2 emitted per Mt of clinker produced] and cement kiln dust (0.020 MtCO_2 emitted per Mt of clinker CO_2 emitted). Data on the metric tons of clinker produced in New York State were derived from the cement statistics in United States Geological Survey's (USGS) Minerals Yearbook.[39] This methodology follows that outline in the SIT guidance, although the SIT default data are based on shipments.

Iron and steel production: New York State's emissions from iron and steel production were prorated from the EPA's estimates of total U.S. emissions[40] based on New York's market share of national iron and steel manufacturing derived from American Iron and Steel Institute (AISI) data.[41] The basic activity data used are the quantities of crude steel produced (defined as first cast product suitable for sale or further processing). This information is available in the SIT module as default. For inventory years 2011–2016, an annual average of emission data was used from production facilities as reported to EPA through its Greenhouse Gas Reporting Program.

Limestone and dolomite use: New York State emissions were assigned to each of the relevant industrial sectors based on the apportionment used to calculate EPA's estimates of total U.S. emissions from limestone and dolomite consumption[42] and based on the quantity of crushed stone sold in the State derived from USGS data.[43]

Soda ash use: Emissions from soda ash use are calculated in the SIT module by scaling national soda ash consumption (estimated using sales data) based on the ratio of state to national population.[44] Data on the metric tons of soda ash consumed in the U.S. were derived from the soda ash statistics in the Inventory of U.S. Greenhouse Gas Emissions and Sinks.[45]

Aluminum Production: Emissions from aluminum production are estimated using the SIT module, which scales U.S. production based on in-state capacity, as reported in the United States Geological Survey's (USGS) 2017 minerals yearbook. Prior to 2018, the SIT did not provide a methodology for estimating CO_2 emissions, so this emission source had not been previously reported. The SIT emission factor for CO_2 reflects an estimated percentage of Soderberg smelters among U.S. facilities, which are higher emission, compared to prebake smelters. However, emission factors and production values were adjusted from the SIT defaults in later years to reflect two issues. First, U.S. production has been affected by closures in New York and other states, so the calculation of in-state production was adjusted to reflect this on an annual basis. Secondly, the remaining large production facilities in the State had fully transitioned to prebake smelters in 2014, leading to a lower emission factor.

2.2.2 Sources of PFC Emissions

Aluminum Production: Emissions from aluminum production are calculated based on the methodology implemented in the SIT Industrial Processes module driven by the capacity for aluminum production in New York State as reported in the United States Geological Survey's (USGS) 2017 minerals yearbook and adjusted as needed to reflect plant closures.[46]

Semiconductor manufacturing: Emissions associated with semiconductor manufacturing are estimated using the SIT calculation methodology. The SIT calculates these emissions based on economic census data indicating the State's portion of the national dollar value of semiconductor shipments along with estimates of national emissions per shipment dollar from the EPA national GHG inventory.

2.2.3 Sources of HFC Emissions

ODS substitutes: In previous NYS GHG Inventory reporting, the SIT method was used to estimate HFC emissions, which scales national emissions based on population. However, the SIT method is not preferred as it does not take into account situations where HFC consumption is not correlated to population size or growth and may vary due to climatic and economic factors, such as in the case of residential and motor vehicle air-conditioning.[47]

For 2005–2016, emissions from ODS substitutes were calculated using a model provided by the California Air Resources Board (CARB), based on methodology used in California's GHG inventory. For earlier years, national emissions were scaled from national emission rates, but based on the relative proportion attributed to New York in CARB's modeling, rather than population size. State and regional data were used to apply CARB's model to individual states (e.g., vehicle registrations in the state). The underlying CARB model is consistent with EPA modeling used in the national inventory, but it is more conservative.

2.2.4 Sources of SF_6 Emissions

Electric Transmission and Distribution: Emissions were estimated using the methodology used in the Industrial processes SIT module, which scales national SF_6 emissions based on a state's proportion of electricity sales[48] using the assumption that SF_6 consumption is reflected in electricity sales in each state.

2.3 Results

Emissions from industrial non-fuel combustion processes from 1990–2016 are shown in Figure 14, and Table 15 shows the historical emission values on which Figure 14 is based. Total New York State GHG emissions for these sources totaled approximately 4.0 $MMtCO_2e$ in 1990 and grew to 11.2 $MMtCO_2e$ in 2016. Emissions growth is primarily associated with the increasing use of ozone-depleting substances (ODS) substitutes as shown in Figure 14. The share of each category relative to total Industrial Process and Product Use emissions is presented in Table 16.

Figure 14. GHG Emissions from Industrial Process and Product Use (MMtCO$_2$e), 1990–2016

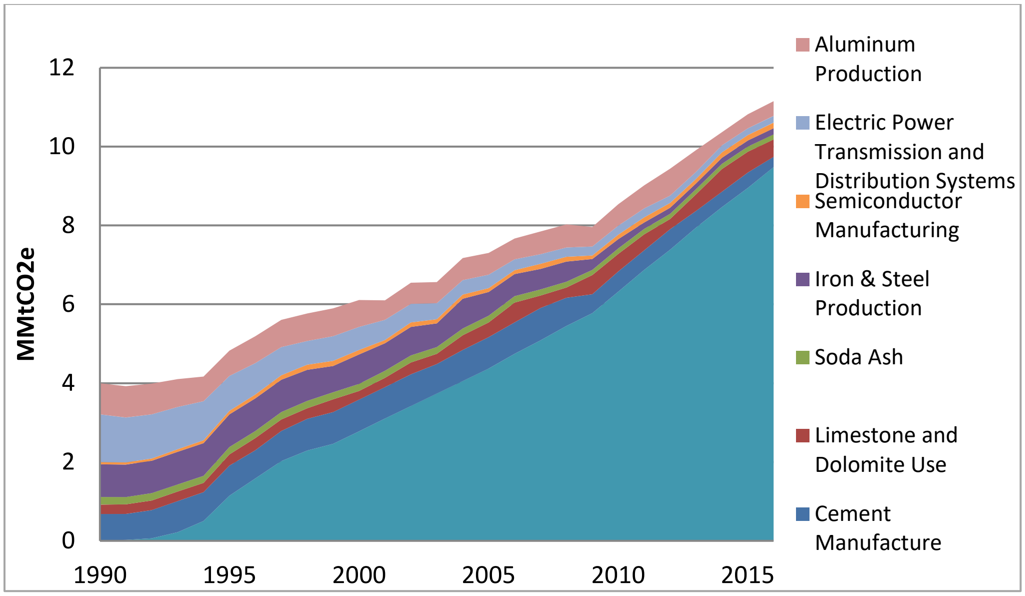


Table 15. GHG Emissions from Industrial Process and Product Use (MMtCO$_2$e), 1990–2016

Emission Source	1990	1995	2000	2005	2010	2015	2016
CO_2 Emissions							
Cement Manufacture	0.7	0.8	0.8	0.8	0.5	0.4	0.3
Iron & Steel Production	0.8	0.8	0.8	0.6	0.2	0.2	0.1
Limestone & Dolomite Use	0.2	0.3	0.2	0.4	0.4	0.5	0.4
Soda Ash	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Aluminum Production	0.4	0.3	0.4	0.3	0.2	0.2	0.2
PFC Emissions							
Aluminum Production	0.4	0.3	0.3	0.3	0.3	0.2	0.2
Semiconductor Manufacturing	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HFC Emissions							
ODS Substitutes	0.0	1.1	2.8	4.4	6.3	9.0	9.5
SF_6 Emissions							
Electric Transmission & Distribution	1.2	0.9	0.6	0.3	0.2	0.2	0.2
TOTAL	**4.0**	**4.8**	**6.1**	**7.3**	**8.5**	**10.8**	**11.2**

Table 16. Industrial Processes and Product Use Sector Proportions of Total Emissions by Fuel Type, 1990–2016 (%)

Industrial Process	1990	1995	2000	2005	2010	2015	2016
CO_2 Emissions							
Cement Manufacture	17%	17%	13%	11%	6%	4%	2%
Iron & Steel Production	21%	17%	12%	8%	3%	1%	1%
Limestone & Dolomite Use	6%	6%	4%	5%	5%	5%	4%
Soda Ash	5%	4%	3%	2%	2%	1%	1%
Aluminum Production	10%	&%	6%	4%	3%	1%	2%
PFC Emissions							
Aluminum Production	9%	6%	5%	4%	4%	2%	2%
Semiconductor Manufacturing	1%	2%	2%	1%	1%	1%	1%
HFC Emissions							
ODS Substitutes	0%	23%	46%	60%	74%	83%	85%
SF6 Emissions							
Electric Transmission & Distribution	30%	18%	10%	5%	3%	2%	2%

2.3.1 Sources of CO_2 Emissions

Cement manufacturing: Emissions from this source were estimated to be approximately 0.7 $MMtCO_2e$ in 1990 and decreased slightly to 0.3 $MMtCO_2e$ in 2016, as shown in Figure 14 and Table 15.

Iron and steel production: Emissions in 1990 were 0.8 $MMtCO_2e$ and decreased to about 0.1 $MMtCO_2e$ in 2016, as shown in Figure 14 and Table 15.

Limestone and Dolomite use: Emissions from limestone consumption were approximately 0.2 $MMtCO_2e$ in 1990 and 0.4 $MMtCO_2e$ in 2016.

Soda ash use: Emissions from soda ash consumption were estimated at approximately 0.2 $MMtCO_2e$ in 1990 and 0.1 $MMtCO_2e$ in 2016.

Aluminum production: Carbon dioxide emissions from aluminum production were estimated at approximately 0.4 $MMtCO_2e$ in 1990 and 0.2 $MMtCO_2e$ in 2016.

2.3.2 Sources of PFC Emissions

Semiconductor manufacturing: Calculated GHG emissions from this source have remained relatively flat at 0.1 MMtCO_2e in New York State throughout the analytic period, as shown in Figure 14 and Table 15.

Aluminum production: PFC emissions from aluminum production in the State were estimated at 0.4 MMtCO_2e in 1990 and 0.2 MMtCO_2e in 2016.

2.3.3 Sources of HFC Emissions

ODS substitutes: Emissions in New York State from this source are estimated to have increased from 0.0 MMtCO_2e in 1990 to about 9.5 MMtCO_2e in 2016. ODS substitutes (and as a result, HFCs) have increased due to the phasedown and replacement of CFCs and other ODS as part of the successful implementation of the Montreal Protocol. While the protocol has been effective at protecting the ozone layer by phasing out ODS, it has led to an increase in HFCs, which are potent greenhouse gases. More recently, the Montreal Protocol was amended October of 2016 to phasedown HFC usage.

2.3.4 Sources of SF_6 Emissions

Electric transmission and distribution: Emissions of SF_6 from electrical equipment have experienced declines since the mid-1990s, mostly due to voluntary action by industry. SF_6 emissions from electric power T&D were approximately 1.2 MMtCO_2e in 1990 and decreased to approximately 0.2 MMtCO_2e in 2016.

3 Agriculture

3.1 Overview

The emissions discussed in this section refer to non-combustion methane (CH_4) and nitrous oxide (N_2O) emissions from both livestock and crop production. Energy emissions related to agricultural practices (i.e., combustion of fossil fuels to power agricultural equipment) are included in other fuel consumption sector estimates (see section 1).

The inventory accounts for both direct and indirect emissions of N_2O that are related to livestock and crop production. Direct emissions occur at the site of application where enteric fermentation, manure, fertilizer, and sewage sludge are added to agricultural soils. When nitrogen is applied to soils, indirect emissions can occur through the volatilization of ammonia and oxides of nitrogen. These products can then (1) be redeposited, (2) enter the nitrification/denitrification cycle, and (3) be emitted as N_2O in another location. Indirect emissions can also occur through leaching or runoff of nitrogen, which can enter the nitrification/denitrification cycle on or offsite and then be emitted as N_2O.

The primary agricultural GHG sources (e.g., livestock and agricultural soils) are further subdivided as described in the following sections.

3.1.1 Livestock

Enteric Fermentation: CH_4 emissions from enteric fermentation are the result of normal digestive processes in ruminant and non-ruminant livestock. Microbes in the animal digestive system break down food and emit CH_4 as a by-product. More CH_4 is produced in ruminant livestock because of digestive activity in the large forestomach.

Manure management: CH_4 and N_2O emissions from the storage and treatment of livestock manure occur as a result of decomposition. The environmental conditions of decomposition drive the relative magnitude of emissions. In general, the more anaerobic the conditions are, the more CH_4 is produced because decomposition is aided by CH_4-producing bacteria that thrive in oxygen-limited conditions. In contrast, N_2O emissions are increased under aerobic conditions.

Emission estimates from manure management are based on manure that is stored and treated on livestock operations (e.g., dairies, feedlots, swine, etc.). Emissions from manure deposited directly on land by grazing animals and emissions from manure that is applied to agricultural soils as an amendment are accounted for under animal production in the following sections on agricultural soil emissions.

3.1.2 Agricultural Soils

Fertilizers: The application of synthetic and organic fertilizers can result in N_2O emissions. Nitrogen additions drive the underlying soil nitrification and de-nitrification cycle, which produces N_2O as a by-product.

Crops: The decomposition of crop residues and the production of nitrogen fixing crops result in N_2O emissions.

Animal production: Animal excretions directly on agricultural soils (e.g., pasture, paddock, or range) or manure spreading on agricultural soils, including leaching and runoff.

3.2 Emissions Inventory Data and Methodology

GHG emissions for this sector were drawn from state-level estimates reported in the appendices of the national inventory. When state-level values were not available in the inventory, GHG emissions were estimated using the SIT and the methods provided in the national inventory for the sector.[49] In general, the SIT methodology applies emission factors developed for the U.S. for activity data in the agriculture sector. Activity data include livestock population statistics and trends in manure management practices. Historical data on the number of animals in the State were obtained from the National Agricultural Statistical Service of the United States Department of Agriculture (USDA NASS), some of which is available as defaults in the SIT.[50]

3.2.1 Livestock

Enteric fermentation: SIT default data on livestock populations are taken from the U.S. Department of Agriculture's National Agricultural Statistical Service (USDA NASS). Methane emission factors specific to each type of animal by region (e.g., dairy cattle, beef cattle, sheep, goats, swine, and horses) are provided in the SIT. For years 2015 and 2016, New York State emissions reported in the U.S. inventory are adopted for this inventory.[51]

Manure management: The same population data used for enteric fermentation are also used as input to estimate CH_4 and N_2O emissions from manure management. Population estimates are multiplied by an estimate for typical animal mass and a volatile solids production rate to estimate the total volatile solids produced. The volatile solid estimate for each animal type is then multiplied by a maximum potential CH_4 emissions factor and a weighted CH_4 conversion factor to derive total CH_4 emissions. The methane conversion factor adjusts the maximum potential CH_4 emissions based on the types of manure management systems employed in New York State.

Nitrous oxide emissions are derived using the animal population estimates discussed above multiplied by the typical animal mass and a total Kjeldahl nitrogen (K-nitrogen) production factor. The total K-nitrogen is multiplied by a non-volatilization factor to determine the fraction that is managed in manure management systems. The portion not volatilized is then divided into fractions that are processed in either liquid (e.g., lagoons) or solid waste management systems (e.g., storage piles, composting). Each of these fractions is then multiplied by an N_2O emission factor and the results summed to estimate total N_2O emissions. For 2015 and 2016, the State emissions reported in the national inventory are used in this report.[52]

3.2.2 Agricultural Soils

Fertilizers, crops, and animal production: Emissions of N_2O associated with fertilizers, crops, and animal production are reported in the national inventory by state and were provided to New York State by EPA for all years (1990–2015). For the year 2016, the 2015 value is held constant. EPA used the DAYCENT biogeochemical simulation, a complex model with high spatial resolution, to estimate emissions from these sources. According to EPA, "key processes simulated by DAYCENT include (1) plant growth; (2) organic matter formation and decomposition; (3) soil water and temperature regimes by layer; (4) nitrification and denitrification processes; and (5) methanogenesis."[53]

3.3 Results

Annual GHG emissions from agricultural sources in New York State increase from 8.4 to 8.9 $MMtCO_2e$ during the period between 1990 and 2016 as shown in Figure 15. Detailed information on GHG emissions from agricultural sources is provided in Table 17. Enteric fermentation accounted for about 41% of total agricultural emissions in 1990 and 40% in 2016 (3.4 and 3.6 $MMtCO_2e$, respectively). The manure management category accounted for 10% (0.94$MMtCO_2e$) of total agricultural emissions in 1990 and is estimated to account for about 14% (1.3 $MMtCO_2e$) of total agricultural emissions in 2016. The agricultural soils category shows 1990 emissions accounting for 48% (4.1 $MMtCO_2e$) of total agricultural emissions and 2016 emissions estimated to be about 45% (4.0 $MMtCO_2e$) of total agricultural emissions.

Figure 15. GHG Emissions from Agriculture ($MMtCO_2e$), 1990–2016

The Agricultural Soil Management category includes emissions from fertilizers, crops (crop residues and nitrogen fixing crops), and animal production.

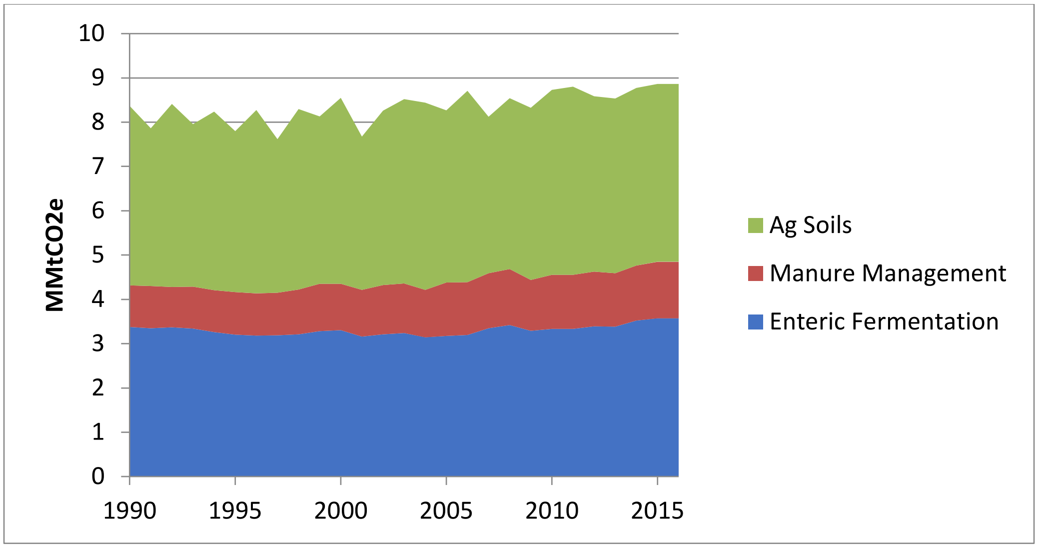


Table 17. GHG Emissions from Agriculture, 1990–2016 ($MMtCO_2e$)

Source Category	1990	1995	2000	2005	2010	2015	2016
Enteric Fermentation	3.4	3.2	3.3	3.2	3.3	3.6	3.6
Manure Management	0.9	1.0	1.1	1.2	1.2	1.3	1.3
Agriculture Soil Management	4.1	3.6	4.2	3.9	4.2	4.0	4.0
Total	**8.4**	**7.8**	**8.6**	**8.3**	**8.7**	**8.9**	**8.9**

Table 18. Agriculture Sector Proportions of Total Emissions by Category, 1990–2016 (%)

The percentages shown in this table reflect the emissions for each category as a percentage of total emissions shown in Table 17 and correspond to the data shown in Figure 15.

Source Category	1990	1995	2000	2005	2010	2015	2016
Enteric Fermentation	40%	41%	39%	38%	38%	40%	40%
Manure Management	11%	12%	12%	15%	14%	15%	15%
Agriculture Soil Management	48%	47%	49%	47%	48%	45%	45%

4 Waste

4.1 Overview

The sources of GHG emissions from waste management included in this inventory report cover both solid waste and wastewater. These primary sources are further subdivided as follows:

4.1.1 Landfills

Municipal solid waste landfills: Methane (CH_4) emissions are generated from the anaerobic decomposition of the organic matter present in landfilled waste by methane-producing bacteria. Some municipal solid waste landfills employ control technologies, such as flares that convert the CH_4 portion of recovered landfill gas to carbon dioxide (CO_2), a GHG associated with a lower impact on global warming.

Industrial solid waste landfills: This source category covers CH_4 emissions that are produced from waste discarded in non-hazardous industrial landfills.

4.1.2 Municipal Wastewater Management

This source category covers both CH_4 and N_2O emissions that are produced at municipal wastewater treatment facilities.

4.2 Emissions Inventory Data and Methodology

4.2.1 Landfills

Municipal solid waste landfills: For municipal solid waste landfills, emissions for 1990–2016 were calculated using a New York State Department of Environmental Conservation (DEC) data, and, when not available, default SIT data.[54] Activity drivers for this emissions source are of waste quantities methane flaring and capture and landfill gas-to-energy. [55] SIT default waste data were used for 1990–2008 and DEC data are used from 2009–2016. Additionally, following SIT methodology, organic decomposition in industrial landfills is also estimated. Control technologies such as flaring and landfill gas-to-energy projects are employed at landfills. SIT default values were used for 1990–2012, while DEC data were used from 2012–2016 to reduce emissions by the amount of gas captured.

4.2.2 Wastewater Management

For municipal wastewater treatment, emissions are calculated using the SIT methodology, which is based on State household census data, assumed biochemical oxygen demand (BOD) and protein consumption per capita, and emission factors for N_2O and CH_4. Municipal wastewater treatment emissions were therefore based on the population growth rate for 1990–2016.

4.3 Results

The emission estimates for the waste management sector are shown in Figure 16 and Table 19 and include GHG emissions associated with waste generated in New York State. Overall, the sector accounted for 14.9 MMtCO_2e in 1990 and 12.8 MMtCO_2e in 2016. The share of emissions from landfills decreases slightly over the analysis period from 87% of the sector total in 1990 to 83% in 2016, while the share of emissions from wastewater increased from 13% in 1990 to 17% over the same period.

Figure 16. GHG Emissions from Waste Management (MMtCO_2e), 1990–2016

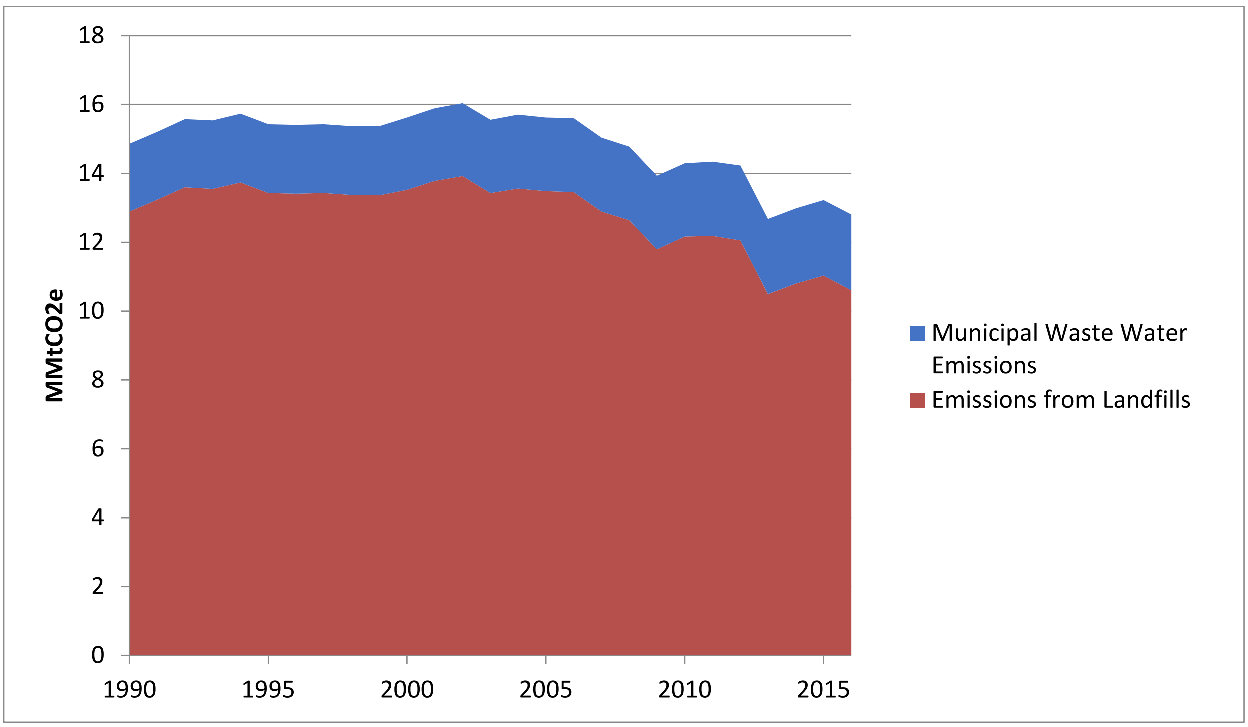


Table 19. GHG Emissions from Waste Management ($MMtCO_2e$), 1990–2016

Source Category	1990	1995	2000	2005	2010	2015	2016
Landfills	12.9	13.4	13.5	13.5	12.2	11.0	10.6
Municipal Wastewater	1.9	1.9	2.0	2.1	2.1	2.2	2.2
Total	**14.9**	**15.4**	**15.6**	**15.6**	**14.3**	**13.2**	**12.8**

Table 20. Waste Management Residential Sector Proportions of Total Emissions by Category by Fuel Type, 1990–2016 (%)

The percentages shown in this table reflect the emissions for each category as a percentage of total emissions shown in Table 19 and corresponds to the data shown in Figure 16.

Source Category	1990	1995	2000	2005	2010	2015	2016
Landfills	87%	87%	87%	86%	85%	83%	83%
Municipal Wastewater	13%	13%	13%	14%	15%	17%	17%

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Appendix A

Table A-1. Fuel Combustion Emission Factors by Sector

Values represent aggregate CO_2, CH_4 and N_2O emissions.

Fuel Type	Emission Factor (lb. CO_2e / MMBtu)
Aviation Fuel	159.2
Coal	204.9
Distillate Fuel Oil (No. 2)	162.9
Gasoline	158.0
Kerosene	161.2
Natural Gas	117.2
Propane/Liquefied Petroleum Gas	136.1
Residual Fuel Oil (No. 6)	166.0
Wood	18.2
Source: Emissions Factors were derived from the EPA State Inventory Tool (released Nov 2018)	

Table A-2. Global Warming Potentials

Greenhouse Gas	Global Warming Potential
CO_2	1
CH_4	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
HFC-4310mee	1,640
PFCs	7,390-13,300
SF_6	22,800
Source: IPCC Fourth Assessment Report (2007)	

Table A-3. 2016 Fuel Types for the Industrial Sector

Fuel Type
Coking Coal
Other Coal
Asphalt & Road Oil
Distillate Fuel
Feedstocks, Naphtha less than 401°F
Feedstocks, Other Oils greater than 401°F
Kerosene
Liquefied Petroleum Gas
Lubricants
Miscellaneous Petroleum Products
Petroleum Coke
Pentanes Plus
Residual Fuel
Special Naphthas
Waxes
Natural Gas

Table A-4. Breakdown of Source Types from Oil and Gas Systems Methane Emissions Inventory

Section	Category	Segment	Source
1	Upstream	Onshore Exploration	Drill Rigs
2	Upstream	Onshore Exploration	Oil Well: Mud Degassing
	Upstream	Onshore Exploration	Gas Well: Mud Degassing
3	Upstream	Onshore Exploration	Oil Well: Completions
	Upstream	Onshore Exploration	Gas Well: Completions
4	Upstream	Onshore Production	Oil: Abandoned Wells
	Upstream	Onshore Production	Gas: Abandoned Wells
5	Upstream	Onshore Production	Oil Well: Conventional Production
	Upstream	Onshore Production	Gas Well: Conventional Production
6	Mid-Stream	Gathering and Boosting	Oil: Gathering and Processing
	Mid-Stream	Gathering and Boosting	Gas: Gathering and Processing
7	Mid-Stream	Gathering and Boosting	Gathering Pipeline
8	Mid-Stream	Natural Gas Processing	Gas Processing Plant
9	Mid-Stream	Natural Gas Transmission and Compression	Transmission Pipeline
10	Mid-Stream	Natural Gas Transmission and Compression	Gas Transmission Compressor Stations
11	Mid-Stream	Crude Oil Transmission	Oil: Truck Loading
	Mid-Stream	Natural Gas Transmission and Compression	Gas: Truck Loading
12	Mid-Stream	Underground Natural Gas Storage	Gas Storage Compressor Stations
13	Mid-Stream	LNG Storage	LNG Storage Compressor Stations
14	Mid-Stream	Liquefied Natural Gas Import/Export	LNG Terminal
15	Downstream	Natural Gas Distribution	Cast Iron Distribution Pipeline: Main
	Downstream	Natural Gas Distribution	Cast Iron Distribution Pipeline: Services
	Downstream	Natural Gas Distribution	Unprotected Steel Distribution Pipeline: Main
	Downstream	Natural Gas Distribution	Unprotected Steel Distribution Pipeline: Services
	Downstream	Natural Gas Distribution	Protected Steel Distribution Pipeline: Main
	Downstream	Natural Gas Distribution	Protected Steel Distribution Pipeline: Services
	Downstream	Natural Gas Distribution	Plastic Distribution Pipeline: Main
	Downstream	Natural Gas Distribution	Plastic Distribution Pipeline: Services
	Downstream	Natural Gas Distribution	Copper Distribution Pipeline: Main
	Downstream	Natural Gas Distribution	Copper Distribution Pipeline: Services
16	Downstream	Natural Gas Distribution	Meters

Appendix B

Table B-1. Detailed New York State GHG Emissions, 1990–2016 ($MMtCO_2e$)

Gas and Category	1990	1995	2000	2005	2010	2015	2016
Carbon Dioxide	**204.02**	**201.31**	**222.30**	**225.59**	**189.45**	**177.48**	**169.40**
Fuel Combustion	*200.45*	*197.01*	*217.99*	*219.84*	*185.58*	*173.25*	*165.51*
Electricity Generation	62.80	51.13	55.50	53.41	37.22	29.09	27.70
Net Imports of Electricity	1.73	4.50	6.01	7.32	9.16	3.35	3.80
Transportation	55.87	57.70	67.67	76.59	73.48	73.95	72.63
Residential	33.79	34.40	39.43	39.25	31.44	35.37	30.66
Commercial	26.39	26.86	32.00	28.48	24.08	21.77	20.57
Industrial	19.88	22.41	17.38	14.79	10.20	10.72	10.15
Other Sources	*3.57*	*4.30*	*4.31*	*5.75*	*3.87*	*4.23*	*3.89*
Incineration of Waste	1.23	1.90	2.00	3.52	2.30	2.87	2.74
Cement Production	0.67	0.76	0.80	0.79	0.51	0.39	0.26
Iron and Steel Production	0.83	0.83	0.75	0.60	0.24	0.16	0.15
Limestone Use	0.24	0.29	0.22	0.37	0.45	0.52	0.44
Aluminum Production	0.41	0.34	0.36	0.29	0.23	0.16	0.17
Soda Ash Use	0.20	0.19	0.18	0.17	0.14	0.13	0.13
Methane	21.91	22.40	22.99	23.43	21.66	20.41	19.83
Fuel Combustion	*0.97*	*1.02*	*1.24*	*0.87*	*0.48*	*0.46*	*0.40*
Electricity Generation	0.04	0.02	0.03	0.03	0.01	0.01	0.00
Net Imports of Electricity	0.00	0.00	0.00	0.01	0.01	0.00	0.00
Transportation	0.40	0.35	0.28	0.19	0.14	0.13	0.12
Residential	0.37	0.47	0.70	0.47	0.20	0.21	0.17
Commercial	0.11	0.13	0.18	0.14	0.08	0.07	0.07
Industrial	0.05	0.05	0.05	0.03	0.03	0.03	0.03
Other Sources	*20.97*	*21.38*	*21.75*	*22.56*	*21.18*	*19.95*	*19.43*
Agricultural Animals	3.37	3.20	3.30	3.17	3.33	3.57	3.57
Landfills	12.89	13.43	13.52	13.49	12.16	11.03	10.61
Manure Management	0.50	0.56	0.68	0.83	0.88	0.94	0.94
Municipal Wastewater	1.44	1.45	1.52	1.55	1.55	1.59	1.59
Natural Gas Leakage	2.75	2.75	2.74	3.53	3.26	2.82	2.81
Nitrous Oxide	**8.60**	**8.79**	**9.53**	**7.85**	**6.68**	**5.90**	**5.79**
Fuel Combustion	*3.54*	*4.15*	*4.32*	*2.93*	*1.54*	*0.89*	*0.78*
Electricity Generation	0.18	0.13	0.15	0.14	0.08	0.03	0.02
Net Imports of Electricity	0.01	0.02	0.02	0.03	0.03	0.01	0.01
Transportation	3.12	3.78	3.85	2.53	1.29	0.73	0.63
Residential	0.09	0.10	0.15	0.11	0.06	0.06	0.05
Commercial	0.05	0.05	0.06	0.05	0.03	0.02	0.02
Industrial	0.09	0.08	0.09	0.06	0.05	0.05	0.05

Table B-1 continued

Gas and Category	1990	1995	2000	2005	2010	2015	2016
Nitrous Oxide	**8.48**	**8.67**	**9.43**	**7.78**	**6.65**	**5.91**	**5.80**
Other Sources	*5.07*	*4.64*	*5.21*	*4.92*	*5.14*	*5.01*	*5.01*
Agricultural Soil Management	4.06	3.63	4.20	3.89	4.18	4.02	4.02
Manure Management	0.44	0.41	0.38	0.37	0.34	0.34	0.34
Incineration of Waste	0.04	0.06	0.05	0.08	0.04	0.05	0.05
Municipal Wastewater	0.53	0.54	0.58	0.59	0.58	0.61	0.61
Perfluorocarbons	0.43	0.40	0.44	0.36	0.42	0.33	0.34
Aluminum Production	0.38	0.31	0.33	0.27	0.31	0.19	0.20
Semiconductor Manufacturing	0.05	0.09	0.11	0.10	0.11	0.14	0.14
Hydrofluorocarbons							
ODS Substitutes	0.01	1.14	2.78	4.37	6.32	8.95	9.48
Sulfur Hexafluoride							
Electricity Transmission and Distribution	1.21	0.88	0.58	0.34	0.23	0.17	0.17
TOTAL	236.19	234.93	258.62	261.94	224.76	213.25	205.02

Endnotes

[1] The approach taken in this report is based on 2006 IPCC Guidelines for National Greenhouse Gas Inventories (https://www.ipcc-nggip.iges.or.jp/public/2006gl/) as interpreted by EPA in its national inventory. Considerations are made to focus on sources that occur within New York State's borders, with limited exception noted throughout. GHG emission sources and sinks associated with land use, land-use change, and forestry are not included in this report.

[2] Section 1 includes emissions from fuel combustion and non-combustion sources associated with energy production and use. Section 1.1.1 presents emissions from the residential, commercial, and industrial sector fuel combustion, but also includes associated emissions from electricity generation that meets the demand for these sectors. These electricity generation emissions are included in section 1.1.1 for informational purposes only, as section 1.1.3 separately identifies emissions from the electricity generation sector. While emissions from electricity generation appear in each section, they are not double counted.

[3] This report adopts global warming potentials from the IPCC's Fourth Assessment Report (2007) https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

[4] See U.S. EPA. 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

[5] Historic U.S. and New York State population data is drawn from the American Community Survey.

[6] U.S. EPA. 2018. Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018.

[7] Residential, commercial, and industrial (RCI). Fuel combustion in the industrial sector includes emissions associated with agricultural energy use and fuel used by the fossil fuel production industry. The commercial sector includes businesses and other institutions (e.g., education and government).

[8] Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-State and out-of-State) used by utilities to meet consumer demand. For further details, see section 1.1.1.

[9] GHG emissions were calculated using SIT, with reference to Annexes to the Inventory of US GHG Emissions and Sinks "Annex 2.1: Methodology for Estimating CO_2 Emissions from Fossil Fuel Combustion," and "Section 2: Methods for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion."

[10] NYSERDA. 2018. "Patterns and Trends, New York State Energy Profiles: 2001-2016" https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Patterns-and-Trends.

[11] RGGI. 2018. "CO_2 Emissions from Electricity Generation and Imports in the Regional Greenhouse Gas Initiative: 2015 Monitoring Report"

[12] Methane and nitrous oxide emissions from biomass combustion are included in emissions totals.

[13] Emissions associated with the electricity supply sector (presented in section 1.1.3) have been allocated to each of the RCI sectors for comparison of those emissions to the fuel-consumption-based emissions presented in section 1.1.1. Note that this comparison is provided for informational purposes and that emissions estimated for the electricity supply sector are not double-counted in the total emissions for the State. One could similarly allocate GHG emissions from natural gas T&D and transport-related GHG sources to the RCI sectors based on their direct use of gas and other fuels, but we have not done so here due to the difficulty of ascribing these emissions to particular end users. Estimates of emissions associated with the transportation sector are provided in section 1.1.2 and estimates of emissions associated with natural gas T&D are provided in section 1.3.

[14] GHG emissions were calculated using the EPA State Inventory Tool (SIT), with reference to: Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018. "Annex 2.1: Methodology for Estimating CO_2 Emissions from Fossil Fuel Combustion." and "Annex 3.1: Methodology for Estimating Emissions of CH_4, N_2O, and Indirect Greenhouse Gases from Stationary Combustion."

[15] NYSERDA. 2018. "Patterns and Trends, New York State Energy Profiles: 2001-2016," (https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Patterns-and-Trends)

[16] ibid.

[17] U.S. EPA. 2018. Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018. "Annex 2.1: Methodology for Estimating CO_2 Emissions from Fossil Fuel Combustion."

[18] "Combustion efficiency" is defined as fuel specific percentage of carbon oxidized during combustion.

19 Heating degree days provide a measurement of how cold a location is relative to a base temperature, which is typically 65°F, over a period of time. The measure is calculated by subtracting the average of a day's high and low temperatures from the base temperature, with negative values set to equal zero.

20 Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018. "Annex 2.1: Methodology for Estimating CO_2 Emissions from Fossil Fuel Combustion."

21 Note that natural gas use for transportation application is often called "compressed natural gas" or "CNG" in other state and federal documents and databases.

22 U.S. Energy Information Administration. State Energy Data System Technical Notes and Documentation, Consumption, Section 4: Petroleum. http://www.eia.gov/state/seds/sep_use/notes/use_petrol.pdf.

The LPG data from the United States Department of Energy's Energy Information Administration (EIA) captures LPG sales for the internal combustion engines of highway vehicles, forklift, industrial tractors, and for use in oil field drilling and production. It is assumed that New York State has very few highway vehicles that consume LPG, therefore all LPG data is attributed to Non-road vehicles.

23 The oxidation factor for lubricants was derived from EPA State Inventory Tool CO_2FFC Module, with reference to Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018. "Annex 2.1: Methodology for Estimating CO_2 Emissions from Fossil Fuel Combustion."

24 CO_2 emissions were calculated using SIT, with reference to Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018. "Annex 2.1: Methodology for Estimating CO_2 Emissions from Fossil Fuel Combustion."

25 CH_4 and N_2O emissions were calculated using SIT, with reference to Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2016. 2018. "Annex 3.2: Methodology for Estimating Emissions of CH4, N2O, and Indirect Greenhouse Gases from Mobile Combustion and Methodology for and Supplemental Information on Transportation-Related GHG Emissions."

26 New York State Department of Transportation VMT modeling.

27 NYSERDA. 2018. "Patterns and Trends, New York State Energy Profiles: 2001-2018," (https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Patterns-and-Trends)

28 GHG emissions were calculated using SIT, with reference to Annexes to the Inventory of US GHG Emissions and Sinks "Annex 3.14: Methodology for Estimating CH4 Emissions from Landfills."

29 See appendix Table A-4 for a detailed breakdown of source types in each category

30 NYSERDA. 2019. "New York State Oil and Gas Sector Methane Emissions Inventory," (https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Greenhouse-Gas-Inventory)

31 For further detail, see U.S. EPA. 2018 "Chapter 4: Industrial Processes and Product Use". Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.

32 In accordance with EPA State Inventory Tool (SIT) methods, emissions associated with the following uses of limestone and dolomite are not included in this category: (1) crushed limestone consumed for road construction or similar uses (because these uses do not result in CO_2 emissions), (2) limestone used for agricultural purposes (which is counted under the methods for the agricultural sector), and (3) limestone used in cement production (which is counted in the methods for cement production).

33 The default SIT data indicate that CO_2 emissions from urea consumption amounted to <0.005 $MMtCO_2e$ annually between 1990 and 2016.

34 Emissions from semiconductor manufacturing were estimated using the EPA State Inventory Tool (SIT) software, with reference to EPA. 2018. "Chapter 4: Industrial Processes and Product Use". Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. Though SIT provides an aggregate emissions value for PFCs, hydrofluorocarbons, and sulfur hexafluoride, it is assumed PFCs constitute the majority of the emissions.

35 California Environmental Protection Agency, Air Resources Board. 2009. California's 1990-2004 Greenhouse Gas Emissions Inventory and 1990 Emissions Level: Technical Support Document.

36 Environmental Protection Agency. 2016. Draft User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF6 Emissions from Industrial Processes Using the State Industrial Tool. Substitutes for ozone-depleting substances, which include chlorofluorocarbons, halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons, are used in a variety of industrial products that may be used in New York State including refrigeration and air conditioning equipment, inhalers, aerosols, solvent cleaning, fire extinguishing, foam blowing, and sterilization. Although their substitutes, HFCs, are not as harmful to the stratospheric ozone layer, they are powerful GHGs.

37 Environmental Protection Agency. 2013 User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF_6 Emissions from Industrial Processes Using the State Inventory Tool. Prepared by ICF International.

38 GHG emissions were calculated using SIT, with reference to "Chapter 4: Industrial Processes and Product Use." Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.

39 U.S. Geological Survey. 2018. "Minerals Yearbook: Cement Statistics and Information" Last modified March 2018. http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb. The metric tons of cement clinker produced in New York State are assumed to be half of the total production value for Maine and New York.

40 EPA. 2018. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016." https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2016

41 NY's Market Share of U.S. Iron & Steel Manufacture was prorated from national data provided by the American Iron and Steel (AISI) Annual Statistics Report 2009 (AISI 2011) in the SIT Module.

42 EPA. 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2016

43 U.S. Geological Survey. 2018 "Minerals Yearbook Crushed Stone Statistics and Information." Last modified November 2018. http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/

44 U.S. Census Bureau. 2010. http://www.census.gov/2010census/

45 EPA. 2018. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2016.

46 U.S. Geological Survey. 2018. "Minerals Yearbook, Aluminum Statistics and Information." Last modified January 2018. http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/

47 U.S. Census Bureau. 2010. http://www.census.gov/2010census/

48 GHG emissions were calculated using SIT, with reference to "Chapter 4: Industrial Processes and Product Use". Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.

49 With reference to EPA. 2018. Annexes to Inventory of US GHG Emissions and Sinks. "Annex 3.10: Methodology for Estimating CH4 Emissions from Enteric Fermentation," "Annex 3.11: Methodology for Estimating CH4 and N2O Emissions from Manure Management," and "Annex 3.12: Methodology for Estimating N2O Emissions, CH4 Emissions and Soil Organic C Stock Changes from Agricultural Lands (Cropland and Grassland)."

50 National Agricultural Statistical Service. https://www.nass.usda.gov/Statistics_by_State/New_York/

51 See EPA. 2018. "Annex 3.10: Methodology for Estimating CH4 Emissions from Enteric Fermentation." Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.

52 See EPA. 2018. "Annex 3.11: Methodology for Estimating CH4 and N2O Emissions from Manure Management." Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.

53 The DAYCENT model "simulates biogeochemical C and N fluxes between the atmosphere, vegetation, and soil; and provides a more complete estimation of soil C stock changes and N2O emissions than IPCC Tier 1 or 2 methods by more thoroughly accounting for the influence of environmental conditions." See EPA. 2018 "Annex 3.12: Methodology for Estimating N2O Emissions, CH4 Emissions and Soil Organic C Stock Changes from Agricultural Lands (Cropland and Grassland)." Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.

54 DEC data are drawn from the Solid Waste Information Management System (SWIMS) database and estimates of exported waste DEC prepared for Northeast Waste Management Officials' Association (NEWMOA) reporting.

55 GHG emissions were calculated using SIT, with reference to Annexes to the Inventory of US GHG Emissions and Sinks "Annex 3.14: Methodology for Estimating CH4 Emissions from Landfills."

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