New York State Energy Research and Development Authority

New York State Greenhouse Gas Inventory and Forecast: Inventory 1990-2011 and Forecast 2012-2030

Final Report
April 2014
Revised June 2015

Energy. Innovation. Solutions.

NYSERDA's Promise to New Yorkers:

NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Mission Statement:
Advance innovative energy solutions in ways that improve New York's economy and environment.

Vision Statement:
Serve as a catalyst—advancing energy innovation and technology, transforming New York's economy, empowering people to choose clean and efficient energy as part of their everyday lives.

Core Values:
Objectivity, integrity, public service, partnership, and innovation.

Portfolios

NYSERDA programs are organized into five portfolios, each representing a complementary group of offerings with common areas of energy-related focus and objectives.

Energy Efficiency and Renewable Energy Deployment

Helping New York State to achieve its aggressive energy efficiency and renewable energy goals – including programs to motivate increased efficiency in energy consumption by consumers (residential, commercial, municipal, institutional, industrial, and transportation), to increase production by renewable power suppliers, to support market transformation, and to provide financing.

Energy Technology Innovation and Business Development

Helping to stimulate a vibrant innovation ecosystem and a clean-energy economy in New York State – including programs to support product research, development, and demonstrations; clean-energy business development; and the knowledge-based community at the Saratoga Technology + Energy Park® (STEP®).

Energy Education and Workforce Development

Helping to build a generation of New Yorkers ready to lead and work in a clean energy economy – including consumer behavior, youth education, workforce development, and training programs for existing and emerging technologies.

Energy and the Environment

Helping to assess and mitigate the environmental impacts of energy production and use in New York State – including environmental research and development, regional initiatives to improve environmental sustainability, and West Valley Site Management.

Energy Data, Planning, and Policy

Helping to ensure that New York State policymakers and consumers have objective and reliable information to make informed energy decisions – including State Energy Planning, policy analysis to support the Regional Greenhouse Gas Initiative and other energy initiatives, emergency preparedness, and a range of energy data reporting.

NYSERDA Record of Revision

Document Title
New York State Greenhouse Gas Inventory and Forecast Inventory 1990-2011 and Forecast 2012-2030 April 2014 Revised June 2015

Revision Date	Description of Changes	Revision on Page(s)
April 2014	Original Issue	Original Issue
June 2015	Corrected table labels on table 6-2	48

New York State Greenhouse Gas Inventory and Forecast: Inventory 1990 – 2011 and Forecast 2012 – 2030

Final Report

Prepared by:

New York State Research and Development Authority

Albany, NY

April 2014
Revised June 2015

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

AEO	Annual Energy Outlook, published by the EIA
Btu	British thermal units
CAFE	Corporate average fuel economy
CH_4	Methane
CNG	Compressed natural gas
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 related 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
FHWA	Federal Highways Administration
GSP	Gross State Product
GDP	Gross Domestic Product
GHG	Greenhouse Gas, a gas that acts as a heat-trapping agent in the atmosphere, increasing the amount of heat energy within the climate system.
Gwh	Gigawatt hours
HFC	Hydrofluorocarbons
HCFC	Hydrofluorochlorocarbons
LPG	Liquid petroleum gas
MMt	Million metric tons
MSW	municipal solid waste
N_2O	Nitrous oxide
NYSDOT	New York State Department of Transportation
NYISO	New York Independent System Operator
ODS	Ozone depleting substance
ORNL	Oak Ridge National Laboratory
PFC	Perfluorinated Chemicals
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 North America, extreme heat and drought events are becoming more frequent and prolonged. Although total precipitation is increasing only slightly, intense and damaging storms like Sandy and Irene are occurring more often. A changing climate affects human health, society and the economy both directly and indirectly, through its effects on agriculture, sea level, fisheries, and other natural resources. The rate and extent of climate change depend on the amount of greenhouse gases (GHGs) present in, and delivered to, the atmosphere.

This report provides a detailed accounting of emissions in New York State from 1990 to 2030, with historical figures from 1990 – 2011 and a future baseline through 2030 based on State policies and economic conditions as of 2013. The forward look does not represent a prediction of GHG emissions, but rather serves as a baseline to help inform future policy and program decision-making. The report identifies the emissions associated with different sectors and how they were calculated to provide greater detail and context on what sectors and sources are driving emissions. Specifically, the chapters are organized as by these sectors, as follows:

- Chapter 1: Residential, Commercial/Institutional, and Industrial Fuel Combustion[1]
- Chapter 2: Industrial Non-Fuel Combustion Processes[2]
- Chapter 3: Transportation Energy Use
- Chapter 4: Power Supply and Delivery
- Chapter 5: Agriculture
- Chapter 6: Waste Management

The report looks systematically at six primary GHG's: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these six GHGs are converted to and presented using a common metric, the CO_2 equivalent (CO_2e), so that the global warming potential of each of these different GHGs can be presented in equivalent terms.

[1] Chapter 1focuses on emissions in the Residential, Commercial, and Industrial sector, but also includes associated emissions from electricity generation that meets the demand for this sector. These electricity generation emissions are included in Chapter 1 for informational purposes only, as Chapter 4 separately identifies emissions from the electricity generation sector. While they appear in both chapters, they are not double counted.

[2] Chapter 2 provides estimates of emissions associated with natural gas T&D.

S.2 New York GHG Emissions: Sources and Trends

A summary of GHG emissions estimated for New York by sector and gas in 2011, the most recent year for which historical data are available, are provided in Table S-1.

Table S-1. 2011 New York State Greenhouse Gas Inventory ($MMtCO_2e$)[a]

	CO_2	CH_4	N_2O	PFC	HFC	SF_6	Total	% of Total
Fuel Combustion (inc. Net Imports of Electricity)	**179.47**	**0.62**	**1.37**	**-**	**-**	**-**	**181.46**	**85.70%**
Fuel Combustion (exc. Net Imports of Electricity)	**170.39**	**0.61**	**1.34**	**-**	**-**	**-**	**172.35**	**81.40%**
Electricity Generation	33.31	0.01	0.06	-	-	-	33.38	15.77%
Net Imports of Electricity	9.08	0.01	0.03	-	-	-	9.12	4.30%
Transportation	70.57	0.11	1.10	-	-	-	71.78	33.90%
Residential	30.91	0.37	0.10	-	-	-	31.37	14.82%
Commercial	24.13	0.10	0.04	-	-	-	24.27	11.46%
Industrial	11.47	0.02	0.05	-	-	-	11.54	5.45%
Other Sources	**3.74**	**15.61**	**2.46**	**0.35**	**7.66**	**0.46**	**30.28**	**14.30%**
Power Supply & Delivery	*2.29*	-	*0.05*	-	-	*0.46*	*2.80*	*1.32%*
Electricity Transmission and Distribution	-	-	-	-	-	0.46	0.46	0.22%
Municipal Waste Combustion	2.29	-	0.05	-	-	-	2.34	1.10%
Agriculture, Forestry & Waste	-	*12.03*	*2.41*	-	-	-	*14.44*	*6.82%*
Agricultural Animals	-	2.85	-	-	-	-	2.85	1.34%
Agricultural Soil Management	-	-	1.55	-	-	-	1.55	0.73%
Landfills	-	7.36	-	-	-	-	7.36	3.48%
Manure Management	-	0.64	0.33	-	-	-	0.96	0.46%
Municipal Wastewater	-	1.19	0.53	-	-	-	1.72	0.81%
Industrial Processes & Manufacturing	*1.45*	*3.58*	-	*0.35*	*7.66*	-	*13.04*	*6.16%*
Aluminum Production	-	-	-	0.24	-	-	0.24	0.11%
Cement Production	0.57	-	-	-	-	-	0.57	0.27%
Iron & Steel Production	0.34	-	-	-	-	-	0.34	0.16%
Limestone Use	0.40	-	-	-	-	-	0.40	0.19%
Natural Gas Leakage[b]	-	3.58	-	-	-	-	3.58	1.69%
ODS Substitutes	-	-	-	-	7.66	-	7.66	3.62%
Semiconductor Manufacturing	-	-	-	0.11	-	-	0.11	0.05%
Soda Ash Use	0.14	-	-	-	-	-	0.14	0.07%
Total (inc. Net Imports of Electricity)	**183.21**	**16.23**	**3.83**	**0.35**	**7.66**	**0.46**	**211.74**	**100%**
% of Total (inc. Net Imports of Electricity)	86.53%	7.67%	1.81%	0.16%	3.62%	0.22%	100%	-
Total (exc. Net Imports of Electricity)	**174.13**	**16.23**	**3.80**	**0.35**	**7.66**	**0.46**	**202.63**	**-**

a MMtCO_2e = million metric tons of carbon dioxide equivalent; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; PFC = perfluorocarbons; HFC = hydrofluorocarbons; SF_6 = sulfur hexafluoride

b A recent study found that measured emissions of methane are approximately 1.5 times greater than those published in the U.S. Environmental Protection Agency national GHG inventory. A commensurate scaling of this analysis would increase the emissions from natural gas leakage to 5.4 MMTonsCO_2e or 2.5% of total emissions. *Source: Brandt, et al. 2014. "Methane Leaks from North American Natural Gas Systems." Science 343, February.*

S.3 Emissions

S.3.1 Overview—Inventory and Status Quo Forecast

The New York State GHG Emissions Inventory is based on the U.S. Environmental Protection Agency (EPA) production-based methodology, and is tailored to estimate current emissions produced within the State's boundaries. The Inventory adopts the EPA protocols for identified emissions, as well as categorization for sources of emissions. Additionally, this New York State GHG Emissions Inventory reflects emissions associated with the electricity sources used to meet all of New York's demands, corresponding to a consumption-based approach for the power supply and delivery sector (i.e. includes emissions associated with imported electricity).

The New York State GHG Emissions Inventory and Forecast: Inventory 1990-2011 and Forecast 2012-2030 (New York State GHG Inventory and Forecast) shows the historical development of GHG emissions. It also provides an estimate of future GHG emissions, based on a synthesis of existing forecasts of 1) electricity generation, 2) fuel use across all sectors, and 3) other GHG-emitting activities, as well as other assumptions described in the subsequent chapters of this report. It is important to note that the forecast contained in this report represents conditions based on existing policies and activities as of the completion of the forecast. The forecast does not represent a prediction of GHG emissions, but rather serves as a reference point to help inform future policy and program decision-making.[3]

The trend in New York's historical GHG emissions from 1990 to 2010 and the forecast from 2015 to 2030 (in five year increments) are shown in Table S-2, along with the most recent year with historical data available, 2011. New York's total GHG emissions in 2011 were slightly lower than emissions in 1990. This reduction follows a period of gradual increases in GHG emissions since 1990, with a peak occurring around the year 2005. The reduction in GHG emissions of 8% from 1990 to 2011 stands in contrast to a national increase in total GHG emissions of 8% over the same time period. Based on existing policies and strategies, the forecast shows that New York emissions remain stable at 2015 levels through 2030.

[3] The concept of a reference forecast is to project what is likely to occur given recent history, current trends, and known policies and regulations. The reference forecasts are intended to provide a baseline for future emissions, against which to measure the likely impact of possible policy or regulatory changes. See Section 4 for a discussion of the implications of the revised Regional Greenhouse Gas Initiative (RGGI) cap, which was not included in the State Energy Plan reference case modeling.

Table S-2. New York GHG Emissions, Historical and Status Quo Forecast ($MMtCO_2e$)

Values for 1990 – 2010 are based on historical data, while values for 2015 – 2030 are forecasted based on current state policies and economic conditions. 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.

	Historical						Forward Looking			
Gas and Category	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2015**	**2020**	**2025**	**2030**
Carbon Dioxide	**204.60**	**203.49**	**225.26**	**227.70**	**187.57**	**183.21**	**177.19**	**176.09**	**174.45**	**174.69**
Fuel Combustion	*201.57*	*199.69*	*221.64*	*223.65*	*183.94*	*179.47*	*173.45*	*172.35*	*170.71*	*170.95*
Electricity Generation	62.76	51.10	55.47	53.38	37.20	33.31	30.10	30.85	34.99	38.08
Net Imports of Electricity	1.63	4.24	5.66	6.52	9.55	9.08	8.23	9.43	8.30	8.11
Transportation	57.18	60.72	71.77	81.15	70.08	70.57	64.18	60.80	56.14	52.73
Residential	33.76	34.38	39.41	39.23	31.73	30.91	30.69	29.82	29.06	28.37
Commercial	26.37	26.84	31.97	28.46	24.96	24.13	27.56	28.10	28.51	29.33
Industrial	19.87	22.41	17.35	14.90	10.42	11.47	12.68	13.34	13.73	14.32
Other Sources	*3.03*	*3.79*	*3.62*	*4.06*	*3.63*	*3.74*	*3.74*	*3.74*	*3.74*	*3.74*
Municipal Waste Combustion	1.10	1.72	1.66	2.12	2.29	2.29	2.29	2.29	2.29	2.29
Cement Production	0.67	0.76	0.80	0.79	0.51	0.57	0.57	0.57	0.57	0.57
Iron and Steel Production	0.83	0.83	0.75	0.60	0.24	0.34	0.34	0.34	0.34	0.34
Limestone Use	0.25	0.30	0.22	0.37	0.45	0.40	0.40	0.40	0.40	0.40
Soda Ash Use	0.20	0.19	0.18	0.17	0.14	0.14	0.14	0.14	0.14	0.14
Methane	**18.27**	**19.12**	**18.23**	**16.45**	**15.76**	**16.23**	**16.46**	**16.45**	**16.69**	**16.99**
Fuel Combustion	*0.81*	*0.86*	*1.04*	*0.73*	*0.62*	*0.62*	*0.62*	*0.64*	*0.66*	*0.72*
Electricity Generation	0.03	0.02	0.02	0.03	0.01	0.01	0.00	0.00	0.00	0.00
Net Imports of Electricity	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Transportation	0.33	0.29	0.23	0.16	0.11	0.11	0.11	0.13	0.15	0.21
Residential	0.31	0.40	0.59	0.39	0.37	0.37	0.37	0.37	0.36	0.36
Commercial	0.09	0.11	0.15	0.11	0.11	0.10	0.11	0.11	0.11	0.11
Industrial	0.04	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Other Sources	*17.46*	*18.27*	*17.18*	*15.72*	*15.13*	*15.61*	*15.83*	*15.82*	*16.03*	*16.27*
Agricultural Animals	2.86	2.70	2.79	2.71	2.86	2.85	2.86	2.86	2.86	2.86
Landfills	9.33	9.37	8.54	7.80	6.97	7.36	7.36	7.36	7.36	7.36
Manure Management	0.43	0.48	0.57	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Municipal Wastewater	1.10	1.11	1.16	1.18	1.18	1.19	1.19	1.19	1.19	1.19
Natural Gas Leakage	3.74	4.60	4.12	3.40	3.48	3.58	3.78	3.76	3.98	4.22
Nitrous Oxide	**6.17**	**6.54**	**6.66**	**5.33**	**3.93**	**3.83**	**3.06**	**3.39**	**3.21**	**3.26**
Fuel Combustion	*3.67*	*4.30*	*4.46*	*3.02*	*1.58*	*1.37*	*0.97*	*0.97*	*0.78*	*0.83*
Electricity Generation	0.19	0.13	0.16	0.15	0.08	0.06	0.04	0.04	0.05	0.06
Net Imports of Electricity	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03

Table S-2 continued

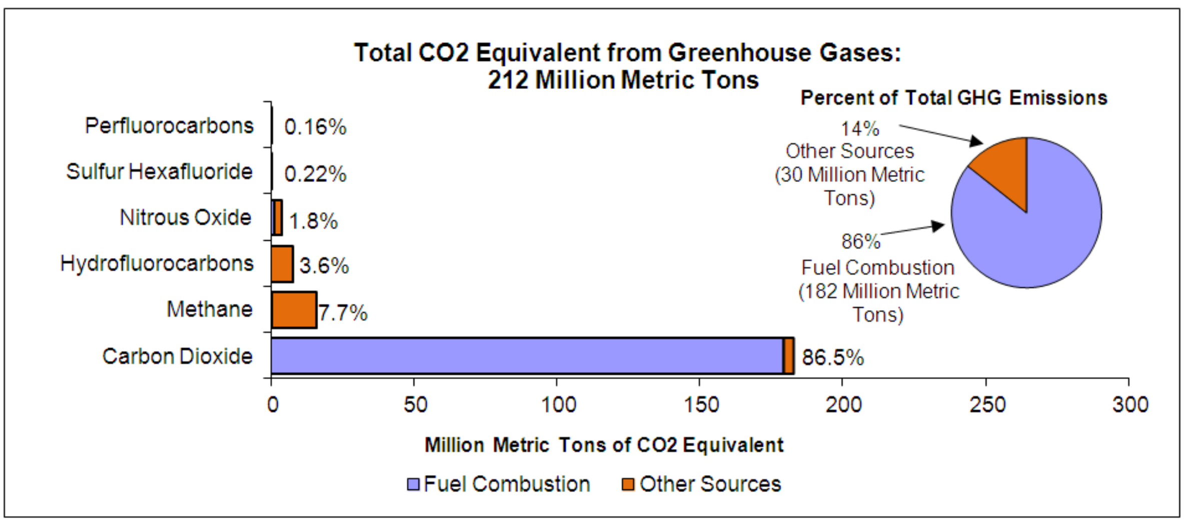
Gas and Category	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Transportation	3.23	3.91	3.98	2.62	1.28	1.10	0.71	0.52	0.57	0.66
Residential	3.23	3.91	3.98	2.62	1.28	0.10	0.09	0.09	0.09	0.09
Commercial	0.09	0.11	0.15	0.11	0.10	0.04	0.04	0.04	0.04	0.04
Industrial	0.05	0.05	0.06	0.05	0.04	0.05	0.05	0.05	0.05	0.05
Other Sources	*2.50*	*2.24*	*2.20*	*2.31*	*2.36*	*2.46*	*2.42*	*2.43*	*2.43*	*2.43*
Agricultural Soil Management	1.69	1.40	1.33	1.42	1.45	1.55	1.52	1.52	1.52	1.52
Manure Management	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Municipal Waste Combustion	0.04	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Municipal Wastewater	0.45	0.46	0.50	0.52	0.53	0.53	0.53	0.53	0.53	0.53
Perfluorocarbons	**0.43**	**0.39**	**0.45**	**0.36**	**0.33**	**0.35**	**0.35**	**0.35**	**0.35**	**0.35**
Aluminum Production	0.38	0.31	0.33	0.27	0.21	0.24	0.24	0.24	0.24	0.24
Semiconductor Manufacturing	0.04	0.07	0.11	0.09	0.11	0.11	0.11	0.11	0.11	0.11
Hydrofluorocarbons										
ODS Substitutes	0.02	2.12	5.12	6.47	7.19	7.66	9.87	13.56	13.56	13.56
Sulfur Hexafluoride										
Electricity Distribution	1.27	0.93	0.63	0.57	0.45	0.46	0.46	0.46	0.46	0.46
TOTAL	**230.76**	**232.59**	**256.34**	**256.89**	**215.23**	**211.74**	**207.71**	**210.12**	**208.77**	**209.39**
All Gases by Source Category										
Gas and Category	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2015**	**2020**	**2025**	**2030**
Fuel Combustion	206.05	204.85	227.14	227.39	186.14	181.46	175.04	173.77	172.21	172.59
Electricity Generation	62.99	51.26	55.65	53.56	37.29	33.38	30.15	30.90	35.05	38.14
Net Imported Electricity	1.63	4.26	5.69	6.55	9.59	9.12	8.27	9.47	8.33	8.15
Transportation	60.74	64.92	75.98	83.93	71.47	71.78	65.01	61.45	56.86	53.60
Residential	34.17	34.88	40.16	39.74	32.20	31.37	31.16	30.28	29.51	28.82
Commercial	26.51	27.00	32.18	28.63	25.11	24.27	27.72	28.26	28.66	29.49
Industrial	20.01	22.53	17.49	14.99	10.48	11.54	12.75	13.42	13.80	14.39
Other Sources	24.71	27.74	29.20	29.50	29.09	30.28	32.68	36.35	36.56	36.80
TOTAL	**230.76**	**232.59**	**256.34**	**256.89**	**215.23**	**211.74**	**207.71**	**210.12**	**208.77**	**209.39**

S.3.2. Emissions Inventory

New York State accounted for approximately 212 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) emissions in 2011, as shown in Table S-1, an average of a little more than 10.8 $MtCO_2e$ for each State resident. At these levels, New York's per capita GHG emissions were approximately half the U.S. average. The great preponderance of New York's GHG emissions came from "fuel combustion," which primarily represents the burning of fossil fuels (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. The breakdown of New York State's 2011 GHG emissions by gas is provided in Figure S-1. 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 (86 %) of all GHG emissions in New York State.

Figure S-1. 2011 Percentage of GHG Emissions by Gas and Source (Includes Net Imports of Electricity)

CO_2 = carbon dioxide; GHG = greenhouse gas.



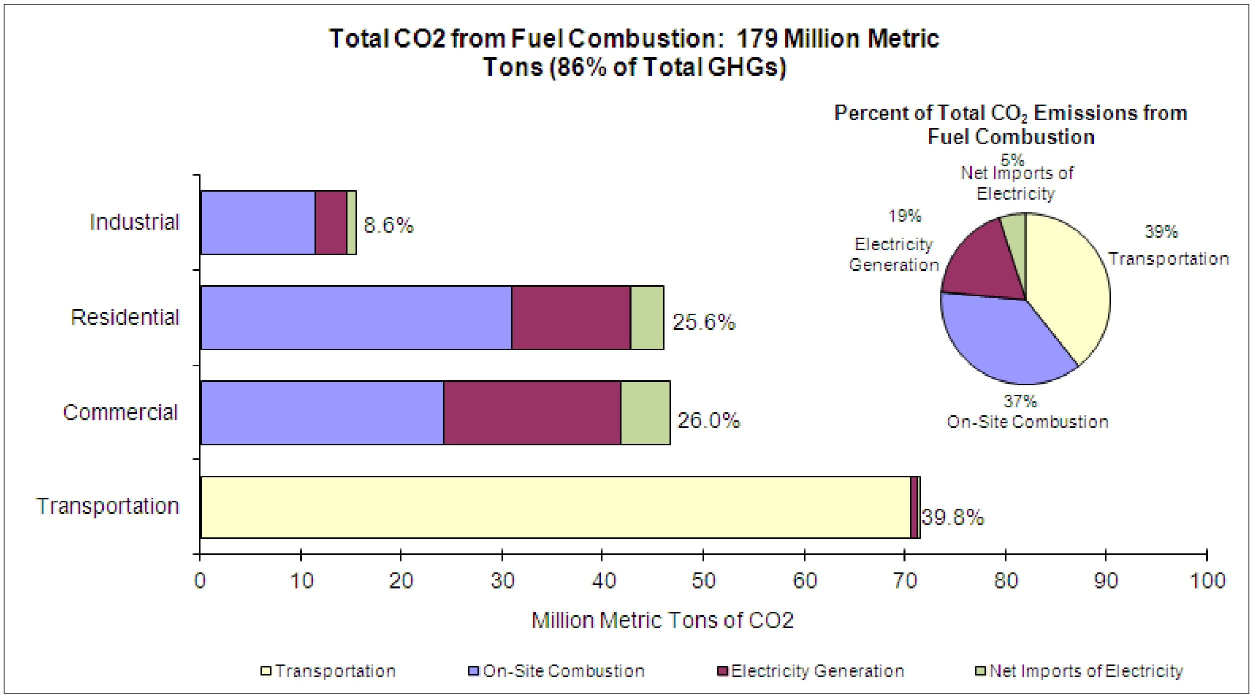
S.3.3 Fuel Combustion

S.3.3.1 Emissions by Economic Sector

The transportation sector accounted for approximately 40 percent of CO_2 emissions from fuel combustion in 2011 (shown in Figure S.2). The residential and commercial sectors were each responsible for roughly 26 percent, 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 9 percent of the CO_2 fuel combustion emissions in New York.

Figure S-2. 2011 CO_2 Emissions from Fuel Combustion by End Use Sector (Includes Net Imports of Electricity)

CO_2 = carbon dioxide; GHG = greenhouse gas.

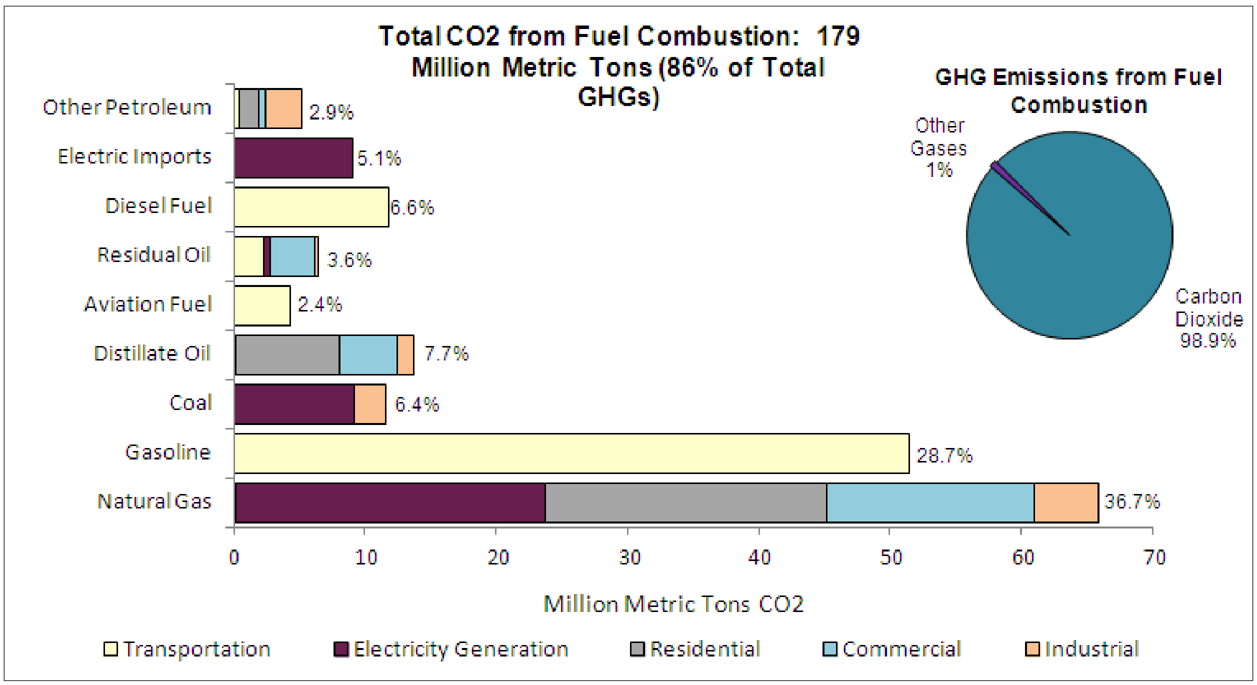


S.3.3.2 Emissions by Fuel

Total CO_2 emissions from fuel combustion have also been allocated to specific fuels, and then further allocated to economic sector (transportation, electricity generation, residential, commercial and industrial), providing a more detailed profile. The fuels that contribute to the 2011 New York State CO_2 fuel combustion emissions are shown in Figure S-3. In 2011, natural gas accounted for 37% of CO_2 emissions, with emissions occurring in all five economic sectors (though primarily from electricity generation and on-site residential, commercial and industrial use). An additional 29% of the CO_2 fuel combustion emissions result from the burning of gasoline by the transportation sector. Remaining emissions contributions are identified across fossil fuels, due primarily to the burning of coal, distillate oil, aviation fuel, residual oil, diesel, and other petroleum sources, as well as imported electricity.

Figure S-3. 2011 CO_2 Emissions from Fuel Combustion by Fuel Type (Includes Net Imports of Electricity)

CO_2 = carbon dioxide; GHG = greenhouse gas.

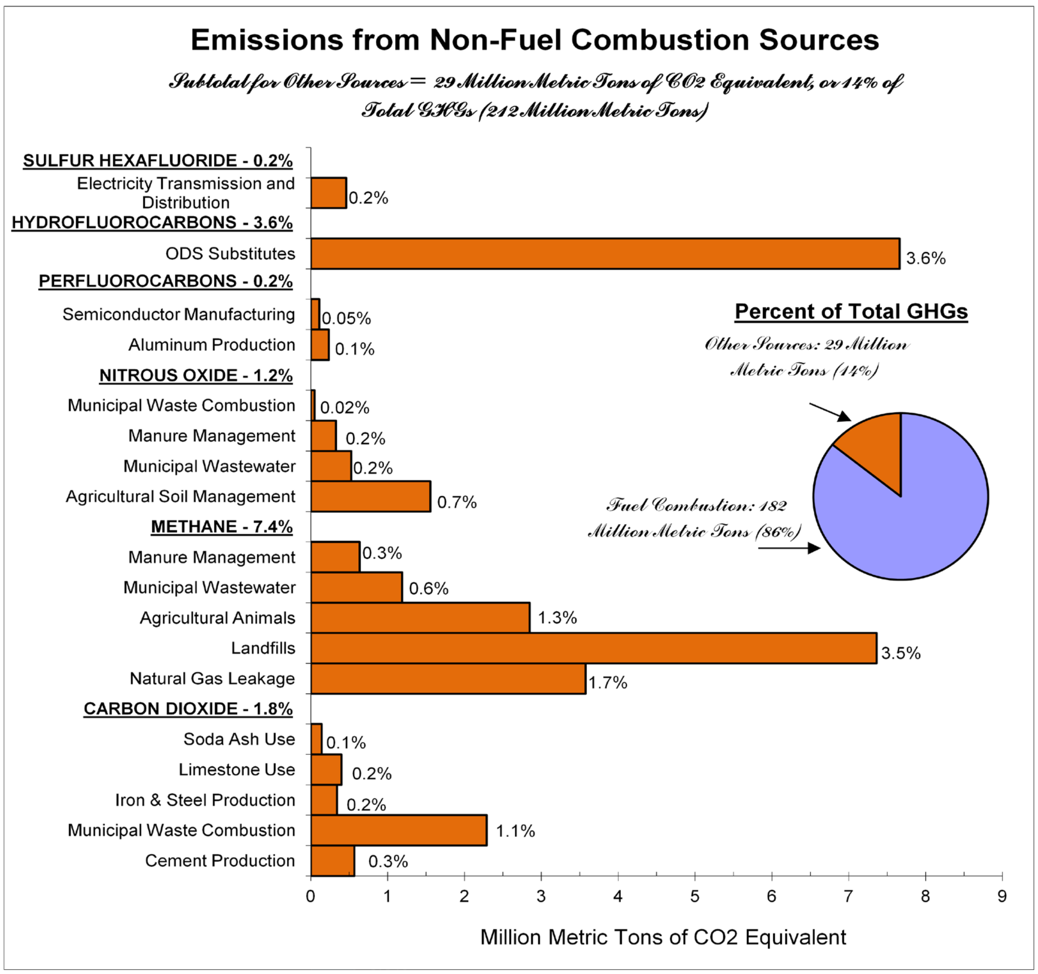


S.3.3.3 Non-Fuel Combustion Emissions

In New York, remaining sources of GHG emissions, representing 14% of total CO_2e emissions, are considered together given the relative contributions from each of the non-CO_2 gases. The origin of emissions from the non-fuel combustion or other sources category is shown in Figure S-4. In 2011, methane (which has a global warming potential 25 times greater than CO_2) accounted for the greatest portion of non-carbon dioxide CO_2e emissions. The majority of methane emissions are the result of activities other than fuel combustion, representing 7.4% 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. Hydrofluorocarbons emissions, resultant from use of substitutes for ozone-depleting substances (ODS), also represent a significant portion of non-fuel combustion emissions, at 3.6% of total statewide CO_2e emissions.

Figure S-4. 2011 Emissions from Non-Fuel Combustion Sources (Total Emissions Include Net Imports of Electricity)

CO_2 = carbon dioxide; GHG = greenhouse gas; ODS = ozone-depleting substance.



S.3.3.4 Emission Trends

The transportation sector emission showed by far the greatest growth in New York, with emissions increasing by nearly 18 percent from 1990 to 2011. This is due to an increase in the consumption of gasoline and diesel, driven by an increase in vehicle miles traveled (VMT) in New York State, as well as an increase in the consumption of jet fuel kerosene. Emissions from non-fuel combustion sources also increased, growing roughly 17% from 1990 to 2011. This is primarily due to an increase in the use of HFCs as ODS substitutes.

In contrast, emissions from electricity generated in-state dropped 47% during this same period, acting as a major driver of New York's decreasing GHG emissions. This drop is largely due to the significant decrease in 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 17% from 1990 to 2011. This reduction in emissions was primarily due to a decrease in the use of coal and petroleum, and an increase in the use of natural gas.

S.3.3.5 GHG Emissions Intensity

New Yorkers emit approximately 11 metric tons of CO_2e per capita (shown in Figure S-5) and New York's energy-related per capita emissions of 8.8 tons are the lowest of the 50 states. New York also leads the nation in having the lowest GHG emissions per unit of economic output, averaging 0.19 kilograms (kg) of CO_2e of emissions per dollar gross state product (GSP), while the U.S. averaged 0.50 kg of CO_2e emissions per dollar gross domestic product (illustrated in Figure S-6).

Figure S-5. New York and U.S. GHG Emissions per Capita

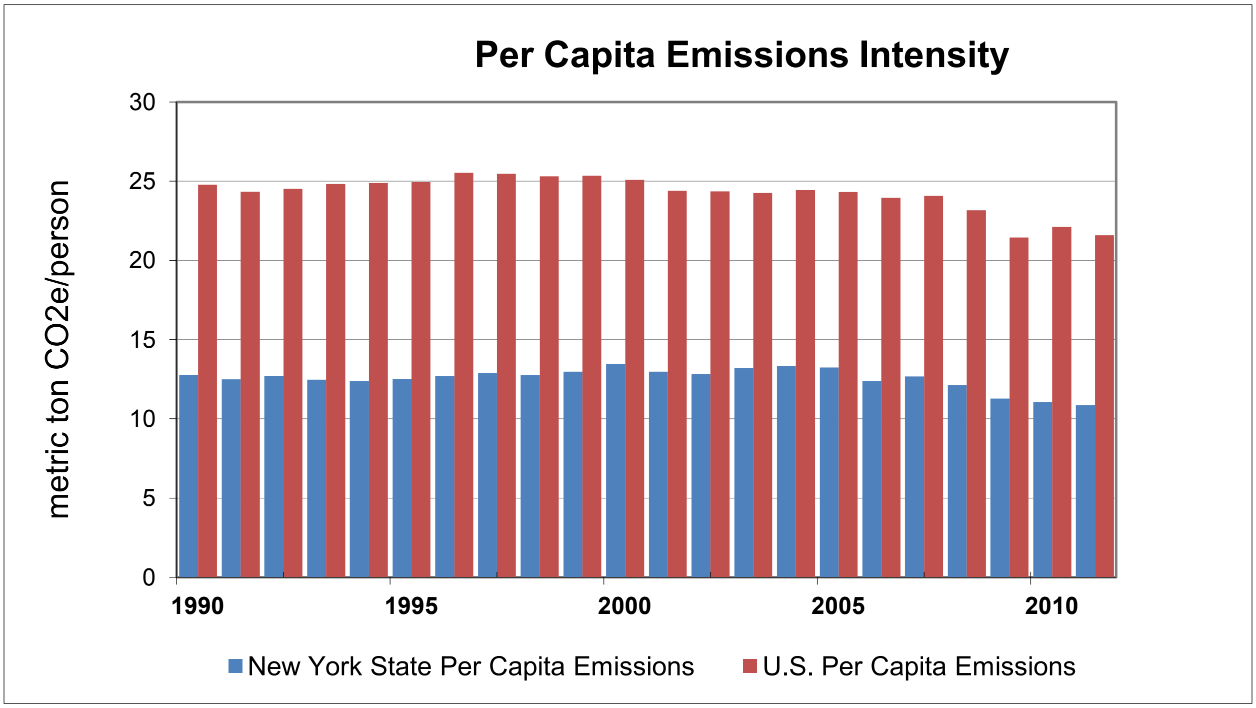
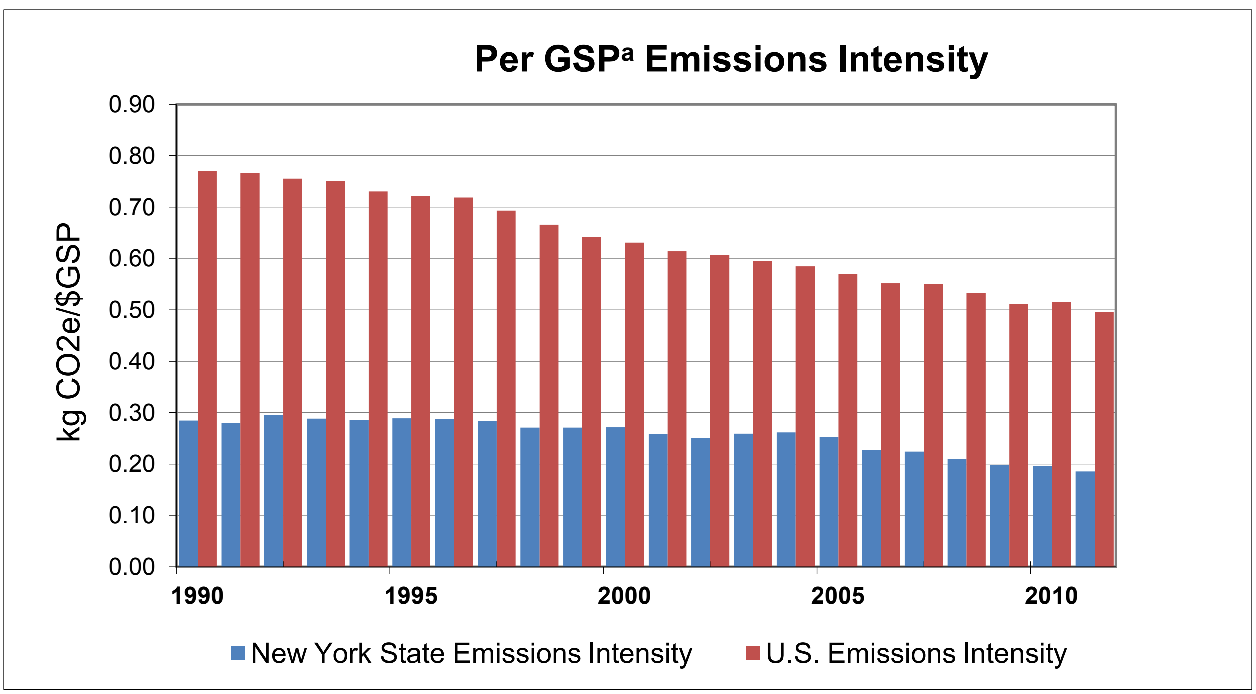


Figure S-6. New York and U.S. Emissions Intensity



[a] 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.3.3.6 Future Baseline

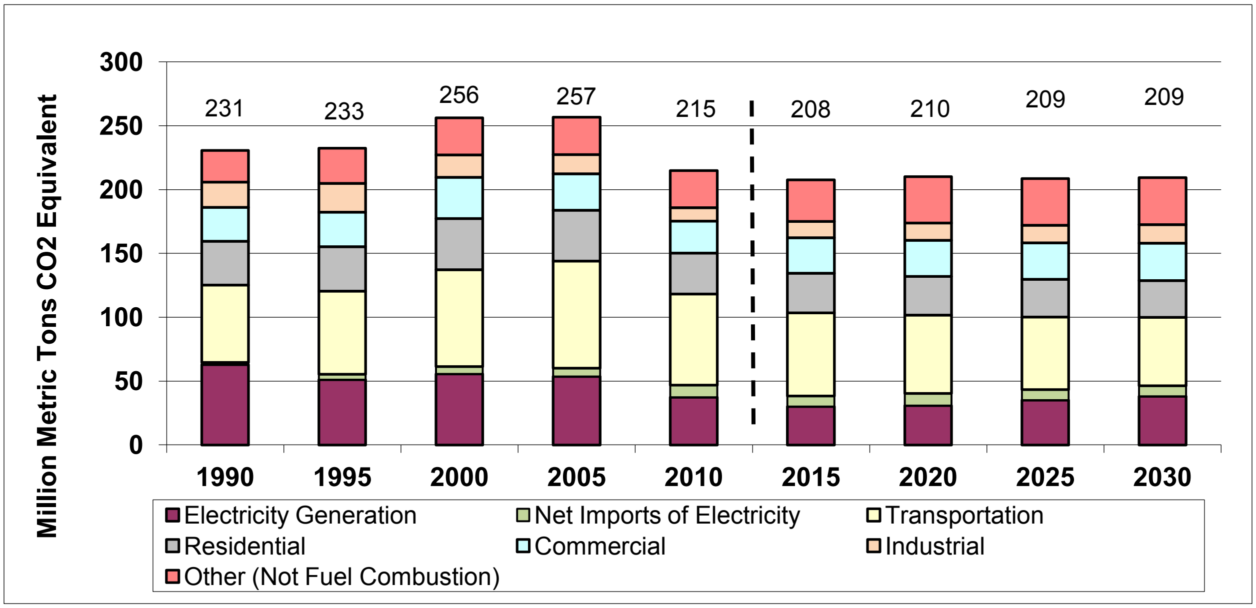
In the absence of new and forthcoming policies, New York's future baseline total GHG emissions are anticipated to decrease by about 2.4 $MMtCO_2e$ from 2011 levels to reach about 209.4 $MMtCO_2e$ by 2030, or 9% below 1990 levels, as illustrated in Figure S-7 and shown numerically in Tables S-1 and S-2,. This downward trend in the forecast is largely due to changes in the transportation sector, and continued low emissions from the electricity sector. Electricity sector emissions have decreased substantially since 1990 and are forecasted to continue to decrease in the near future. The key driver of the decreasing emission forecast is conversion to natural gas as the primary source of generation, as well as an increase in non-emitting resources such as wind. Policies currently in place that contribute to these declines include emission caps and support programs for energy efficiency and carbon-free renewable energy. Non-policy drivers include continued anticipated advantages of natural-gas over other, more- GHG-intense fossil fuels and steadily improving economics of clean energy investments

The forecast of non-fuel combustion indicates a modest increase in methane emissions, primarily due to increased electricity generation from natural gas and fuel switching to natural gas from higher carbon fuel sources for on-site uses. While non-fuel combustion emissions from natural gas are forecasted to represent only 2% of statewide emissions in 2030, policy approaches may be adoptable to further control such emissions.

ODS substitutes (and as a result, HFCs) are increasing due to the provisions of the Montreal Protocol and are forecasted to continue increasing going forward. While the protocol has been effective at protecting the ozone layer by phasing ODSs, it has led to an increase in HFCs which are a potent greenhouse gas. Given the risk HFCs pose to the climate, the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) has launched an initiative to promote HFC alternative technologies and standards with a goal to reduce their use and emissions going forward.[4] These types of initiatives could help to mitigate the impact of HFCs in the future.

[4] Refrigeration and Air Conditioning Magazine, April 1, 2014. http://www.racplus.com/news/us-climate-body-launches-low-gwp-case-studies-for-developing-countries/8660997.article

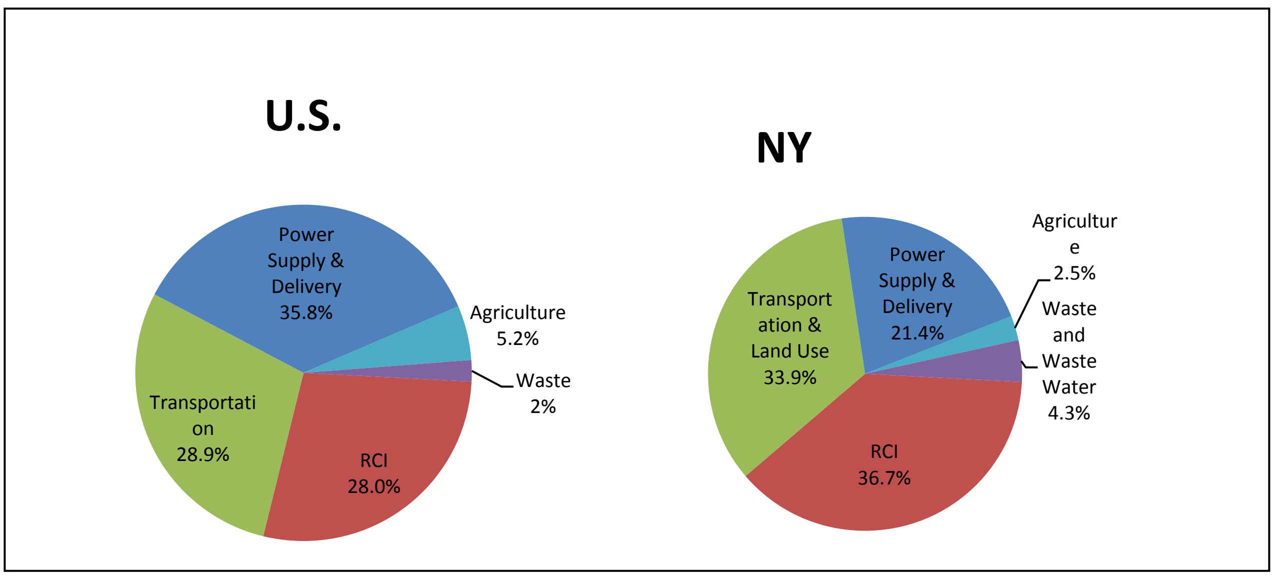
Figure S-7. Greenhouse Gas Emissions by Source Category, 1990 – 2030, Status Quo Forecast



S.4 NY and U.S. Emission Comparisons

Figure S-8. 2011 GHG Emissions by Sector: New York and U.S.

RCI = Residential, commercial/institutional, and industrial sector.



The breakdown of emissions by major sector differs in New York State as compared to the United States, as demonstrated by Figure S-8. The principal sources of New York State's GHG emissions in 2011 are the residential, commercial/institutional, and industrial sector; the transportation sector; and the power supply and delivery sector. Emissions for the residential, commercial, and industrial fuel use sectors are associated with the direct use of fuels (natural gas, petroleum, coal, and wood) to provide space heating, water heating, process heating, cooking, and other energy end-uses in the residential, commercial/institutional, and industrial sectors. This sector also accounts for GHG emissions from non-fuel sources in the industrial sector, such as CO_2 emissions from cement production, as well as emissions from the fossil fuel industry (e.g., natural gas leakage).

The transportation sector accounts for emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, railway locomotives, boats, and ships. Emissions from non-highway agricultural and construction equipment are included in the RCI sector. The power supply and delivery sector includes emissions associated with electricity generated within the state and electricity imported from outside of New York as well as the emissions associated with municipal waste combustion (waste-to-energy facilities) and electricity transmission and distribution. The waste category includes emissions from landfills and wastewater. The U.S. agriculture emissions also include CH_4 and N_2O emissions from forest fires.

These sectors account for 37%, 34%, and 21% of New York State's GHG emissions, respectively. These sectors are also the three largest emitters in the U.S., but in a different order, with the power supply and delivery sector at 36%, the transportation sector at 29%, and the RCI sector at 28%. In New York State, emissions from waste and agriculture combine to account for the remaining 7% of GHG emissions in 2011, while these two sectors account for 7% of GHG emissions in the U.S. Overall, in 2011 New York State emissions accounted for 3% of U.S. total emissions.

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

The transportation sector accounts for the largest share of GHG emissions in New York State, at 40% of New York State's GHG emissions in 2011. In 2011, motor gasoline, used by on-road vehicles and recreational marine vehicles, accounts for the majority of transportation GHG emissions; diesel fuel, used by on-road vehicles, commercial marine vehicles, and locomotives contributes the second-highest transportation GHG emissions; and jet fuel, 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 2011.

Despite transportation emissions increasing for the period 1990 – 2011, emissions were highest in 2006 and have fallen each year from 2007 through 2011. Uses of motor gasoline, diesel fuel, and jet fuel kerosene are the main drivers of both the 2006 peak and subsequent decline, as maximum consumption of each fuel occurred in this year. While some of this drop in fuel use may have been due to the economy, this downward trend is anticipated to continue going forward due to changes in VMT and fuel economy. While VMT are projected to continue to grow from 2012 – 2030, the growth rate is lower than previously expected, and when coupled with a forecasted increase in vehicle fuel economy across all vehicle categories, the result is a decrease in transportation fuel consumption, which lowers the emission forecast.

Activities in the RCI[5] fuel combustion sector produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications. Fuel combustion within the RCI sector accounts for 37% of New York State's GHG emissions in 2011, with a decrease in total emissions from 1990 to 2011. In 2011, the residential sector's contribution toward the total RCI emissions from direct fuel use was 47%, while the commercial/institutional sector accounted for 36% and the industrial sector accounted for 17%.

In 2011, emissions from fuel combustion associated with New York's electricity consumption are 9 $MMtCO_2e$ 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.[6] Electricity generation in New York State is dominated by natural gas and nuclear-powered units, with coal, oil, and hydro also important sources of historical generation in the State. Forecasts of electricity sales for 2011 – 2030 indicate that New York State will remain a net importer of electricity. Emissions from electricity imports are forecasted to decrease slightly (by approximately 1 $MMtCO_2e$) from 2011 to 2030.

---

5 The industrial sector includes emissions associated with agricultural energy use and fuel used by the fossil fuel production industry.

6 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 Chapter 4.

1 Residential, Commercial/Institutional, and Industrial Fuel Combustion

1.1 Overview

Activities in the Residential, Commercial/Institutional, and Industrial (RCI[7]) sectors produce carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions when fuels are combusted to provide space heating, water heating, process heating, cooking, and other energy end-uses. Carbon dioxide accounts for 99% of these emissions on a million metric tons (MMt) of CO_2 equivalent (CO_2e) basis in New York. In addition, since these sectors consume electricity, one can also attribute emissions associated with electricity generation to these sectors in proportion to their electricity use.[8]

1.2 Emissions Inventory and Forecast

1.2.1 Inventory Data and Methodology

Historical emissions from direct fuel use were estimated using the United States Environmental Protection Agency's (U.S. EPA) State Greenhouse Gas Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for RCI fuel combustion.[9] The default historical fuel consumption data in SIT for New York, which came from the United States Department of Energy (U.S. DOE)

---

[7] The industrial sector includes emissions associated with agricultural energy use and fuel used by natural gas transmission and distribution (T&D) and oil and gas production industries.

[8] Emissions associated with the electricity supply sector (presented in Chapter 4) have been allocated to each of the RCI sectors for comparison of those emissions to the fuel-consumption-based emissions presented in Chapter 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, other fuels production, 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 Chapter 3, and estimates of emissions associated with natural gas T&D are provided in Chapter 2.

[9] GHG emissions were calculated using the U.S. Environmental Protection Agency's State Inventory Tool (SIT), with reference to *EIIP, Volume VIII*: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", December 2006, and Chapter 2 "Methods for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion", December 2006.

Energy Information Administration's (EIA) *State Energy Data System* (SEDS), were updated with fuel consumption data for the Residential, Commercial/Institutional, and Industrial sectors from NYSERDA's *Patterns and Trends* report.[10]

Note that the EIIP methods for the Industrial sector exclude from CO_2 emissions estimates the amount of carbon that is stored in products produced from fuels for non-energy uses. For example, the methods 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 explained in detail in the EIIP guidance document.[11] The primary tool to determine RCI 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,[12] and storage percentages. The fuel types for which the EIIP methods are applied in the SIT software to account for the Industrial Sector are shown in Table 1-1.

Table 1-1. 2011 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

10 *Patterns and Trends, New York State Energy Profiles: 1997-2011*, New York State Energy Research and Development Authority, June 2013, available at https://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/EA-Reports-and-Studies/Patterns-and-Trends.aspx

11 EIIP, Volume VIII: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", December 2006.

12 Combustion Efficiency is defined as fuel specific percentage of carbon oxidized during combustion.

In addition to the fuel consumed directly by each of the RCI sectors, the proportion of each RCI sector's electricity sales to total electricity sales was used to allocate emissions associated with the electricity supply sector to each of the RCI sectors. Electricity sales associated with the RCI sectors were estimated based on information from the Patterns and Trends report released in June 2013.[13]

1.2.2 Forecast Data and Methodology

Future emissions under existing state policies and economic conditions from direct fuel combustion for each of the RCI sectors are estimated based on fuel consumption forecasts developed for the draft 2014 New York State Energy Plan. Natural gas and petroleum products are the fuels that dominate GHG emissions from direct fuel combustion for the RCI sectors.

1.2.2.1 Residential Sector

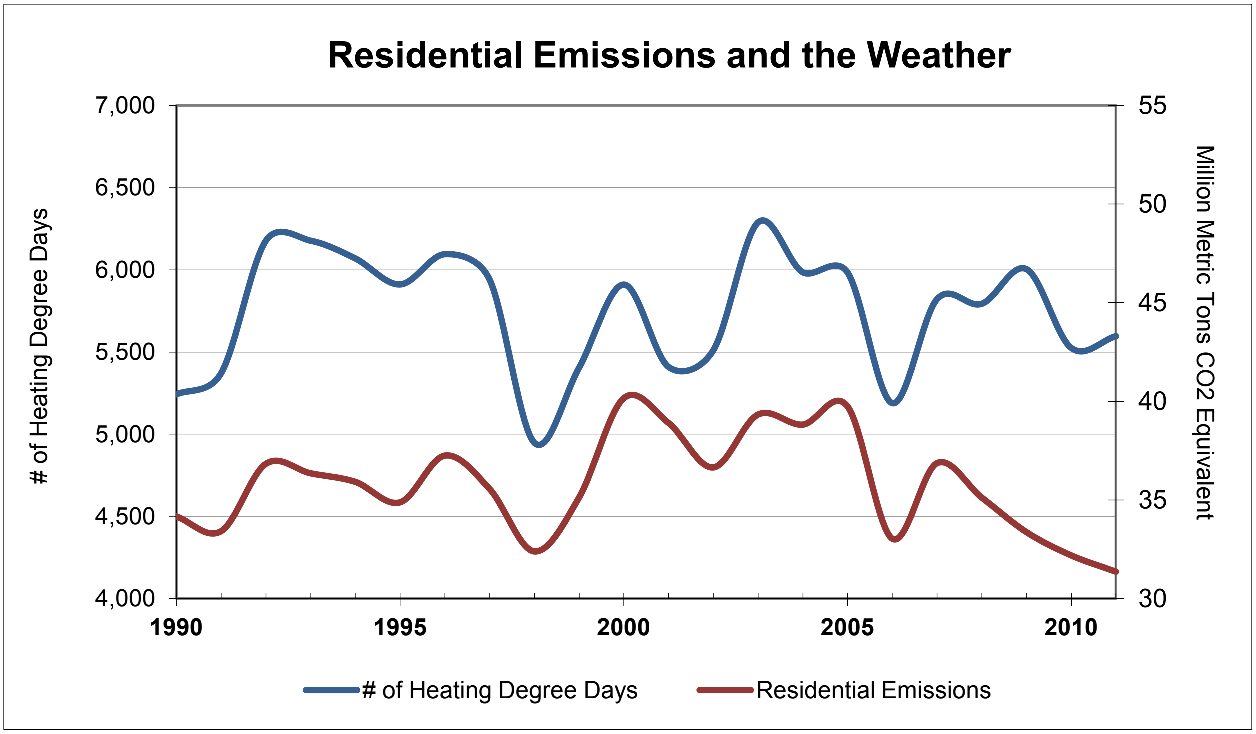
For the Residential sector, emissions from direct fuel use (including heating and hot water) and electricity consumption in 1990 were approximately 46.49 $MMtCO_2e$, and are estimated to decrease slightly to 42.24 $MMtCO_2e$ by 2030. Residential sector emission trends are presented in Table 1-2 and Figure 1-2. Emissions associated with natural gas consumption were the greatest source of emissions in 2011, accounting for approximately 46% of total residential emissions, and is estimated to continue be the largest source of residential fuel use emissions in 2030, accounting for approximately 50% of total residential emissions.

Emissions associated with electricity use were the second greatest source of residential emissions in 2011, with 33% of the total in this sector. This percentage is forecasted to decrease slightly to 32% by 2030. Petroleum use accounted for the next largest portion of Residential sector emissions, accounting for 20% of emissions in 2011 and 17% in 2030. Wood and coal emissions each account for 1% or less of Residential sector emissions throughout the analysis period. Total GHG emissions for this sector decrease by an annual average of approximately 0.01% over the 19-year period. The Residential sector's share of total RCI emissions from direct fuel use and electricity was 37% in 1990 and increased through 2011 to 43%, and it is forecasted to decrease to 36% by 2030.

[13] https://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/EA-Reports-and-Studies/Patterns-and-Trends.aspx

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 for each year from 1990 to 2011, as demonstrated in the comparison in Figure 1-1.[14] The two sets of data show a correlation coefficient of 0.60. 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. There are two outliers in this chart, between 2008 and 2009, and 2010 and 2011, when heating degree days increased but residential emissions decreased.

Figure 1-1. Residential Sector Heating Demand and GHG Emissions, 1990 – 2011



[14] 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.

Figure 1-2. Residential Sector GHG Emissions from Fuel Combustion and Electricity, 1990 – 2030, Status Quo Forecast

The Other category includes emissions associated with coal and wood combustion. Wood is assumed to be a biomass fuel, and carbon dioxide emissions from biomass fuels grown sustainably are not counted. Therefore, the CO_2 emissions are zero. Consequently, the GHG emissions associated with this category include methane and nitrous oxide. In general, GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

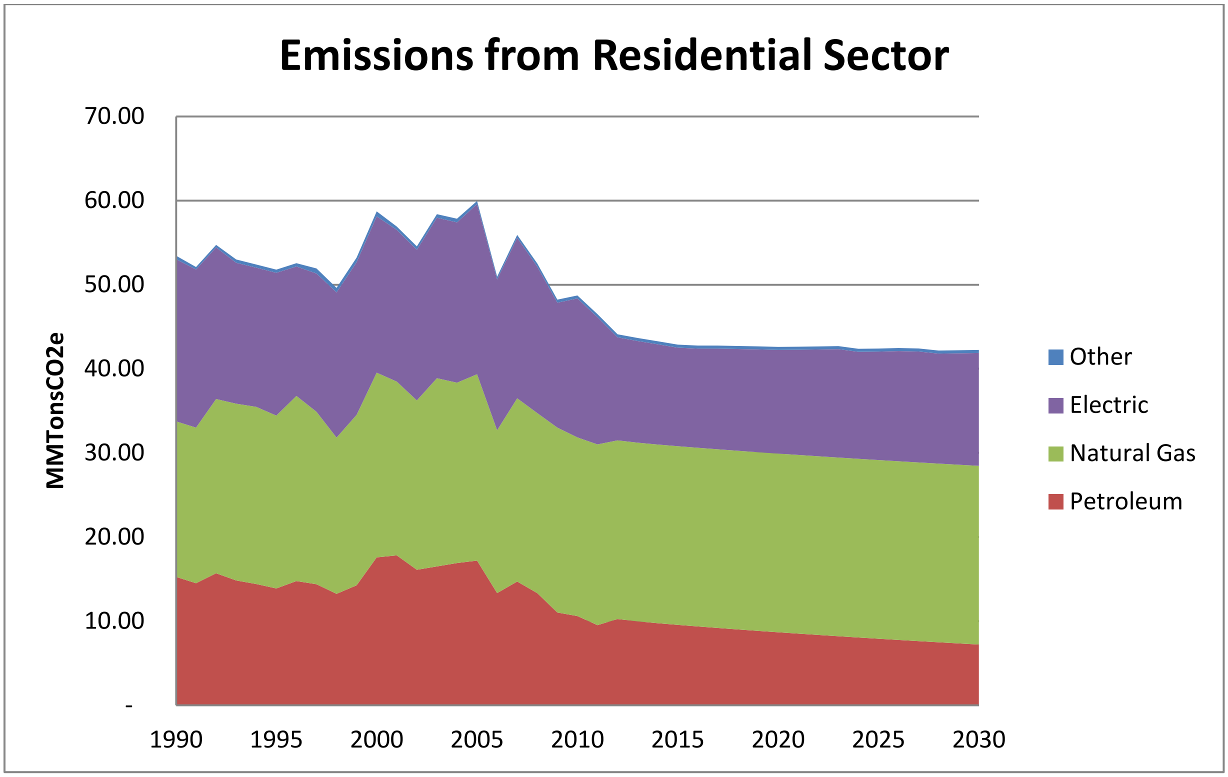


Table 1-2. Residential Sector Emissions Inventory and Forecast ($MMtCO_2e$)

The Other category includes emissions associated with coal and wood combustion. Wood is assumed to be a biomass fuel, and carbon dioxide emissions from biomass fuels grown sustainably are not counted. Therefore, the CO_2 emissions are zero. Consequently, the GHG emissions associated with this category include methane and nitrous oxide. In general, GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

Fuel Type	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Other	0.3	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Petroleum	15.3	13.9	17.6	17.2	10.6	9.5	9.6	8.7	7.9	7.2
Natural Gas	18.5	20.5	22.0	22.2	21.2	21.5	21.2	21.2	21.2	21.2
Electricity	19.3	17.0	18.6	20.2	16.5	15.1	11.7	12.3	12.9	13.4
Total	**53.4**	**51.9**	**58.7**	**60.0**	**48.7**	**46.5**	**42.9**	**42.6**	**42.4**	**42.2**

1.2.2.2 Commercial/Institutional Sector

The emissions inventory and forecasts under existing state policies and economic conditions for the Commercial/Institutional sector are presented in Figure 1-3, which was developed from the emissions data in Table 1-3. The relative contributions of emissions associated with each fuel type to total Commercial/Institutional sector emissions is shown in Table 1-4.

For the Commercial/Institutional sector, emissions from direct fuel use (including heating and hot water) and electricity in 1990 were approximately 54 $MMtCO_2e$, and are estimated to increase to approximately 61 $MMtCO_2e$ by 2030. Electricity use was the largest source of emissions in the Commercial/Institutional sector, with 51% of emissions in 1990, as well as in 2030. Petroleum emissions accounted for 28% of Commercial/Institutional sector emissions in 1990, and are projected to decline to 15% of emissions by 2030. In 1990, natural gas consumption accounted for approximately 20% of total commercial/institutional emissions and is estimated to account for approximately 33% of total commercial/ institutional emissions by 2030. Commercial/Institutional sector emissions associated with the use of coal and wood accounted for approximately 1% of total commercial/ institutional emissions in 1990 and is estimated to account for less than 1% of total commercial/institutional emissions by 2030. The Commercial/Institutional sector’s share of total RCI emissions from direct fuel use and electricity use was 38% in 1990 and is forecasted to increase to 50% by 2030.

Figure 1-3. Commercial/Institutional Sector GHG Emissions from Fuel Combustion and Electricity, 1990 – 2030, Status Quo Forecast

The Other category includes emissions associated with coal and wood combustion. Wood is assumed to be a biomass fuel, and carbon dioxide emissions from biomass fuels grown sustainably are not counted. Therefore, the CO_2 emissions are zero. Consequently, the GHG emissions associated with this category include methane and nitrous oxide. In general, GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

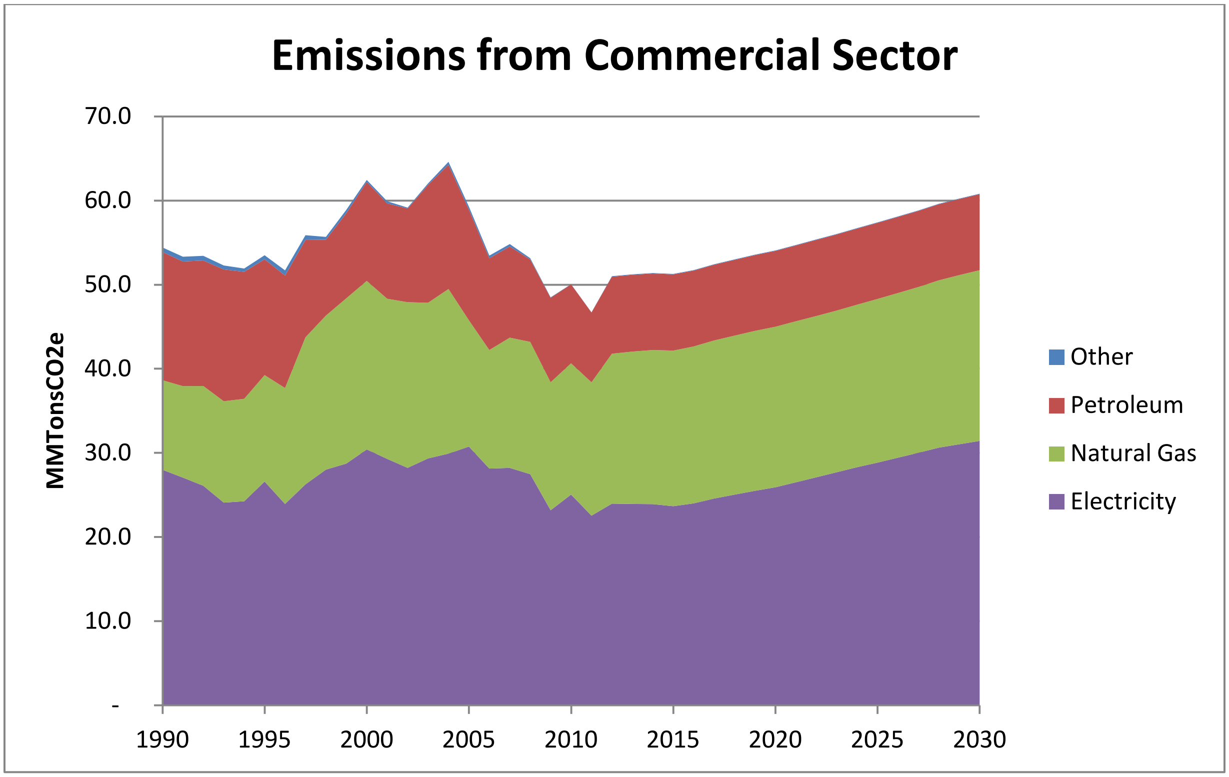


Table 1-3. Commercial/Institutional Sector Emissions Inventory and Forecast ($MMtCO_2e$)

The Other category includes emissions associated with coal and wood combustion. Wood is assumed to be a biomass fuel, and carbon dioxide emissions from biomass fuels grown sustainably are not counted. Therefore, the CO_2 emissions are zero. Consequently, the GHG emissions associated with this category include methane and nitrous oxide. In general, GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

Fuel Type	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Other	0.5	0.5	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Petroleum	15.2	13.8	11.8	8.3	9.4	8.3	9.1	9.0	9.0	9.0
Natural Gas	10.6	12.7	20.0	15.9	15.6	15.9	18.5	19.1	19.5	20.3
Electricity	28.0	26.6	30.4	22.5	25.1	22.5	23.7	25.9	28.8	31.4
Total	**54.4**	**53.5**	**62.4**	**46.7**	**50.1**	**46.7**	**51.3**	**54.1**	**57.4**	**60.8**

Table 1-4. Commercial/Institutional 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 1-3.

Fuel Type	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Other	1.0%	0.9%	0.4%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%
Petroleum	28.0%	25.7%	18.8%	17.8%	18.8%	17.8%	17.7%	16.7%	15.8%	14.9%
Natural Gas	19.6%	23.6%	32.1%	33.9%	31.2%	33.9%	36.1%	35.3%	33.9%	33.4%
Electricity	51.4%	49.7%	48.7%	48.3%	50.0%	48.3%	46.2%	47.9%	50.3%	51.7%

1.2.2.3 Industrial Sector

The emissions inventory and forecasts for the Industrial sector are presented in Figure 1-4, which was developed from the emissions data in Table 1-5. The relative contributions of emissions associated with each fuel type to total Industrial sector emissions is shown in Table 1-6.

For the Industrial sector, emissions from direct fuel use and electricity in 1990 were approximately 36 $MMtCO_2e$ and are estimated to decrease to approximately 15 $MMtCO_2e$ by 2030. 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 declines throughout the period, and electricity use only accounts for 5% of the Industrial sector emissions by 2030. In contrast, emissions from petroleum fuels accounted for 18% of the Industrial sector emissions in 1990, but increase to 29% of the industrial emissions by 2030. The share of emissions from natural gas consumption also increases, from 16% of industrial fuel use emissions in 1990 to 51% of these emissions in 2030. Coal consumption accounted for approximately 22% of total industrial emissions in 1990, and is estimated to decrease to approximately 15% of total industrial emissions by 2030. The Industrial sector's share of total RCI emissions from direct fuel use and electricity use was 25% in 1990 and is forecasted to decrease to 13% by 2030.

Figure 1-4. Industrial Sector GHG Emissions from Fuel Combustion and Electricity, 1990 – 2030, Status Quo Forecast

Emissions associated with wood combustion are too small to be seen on this graph. In accordance with the US EPA SIT methodology, wood is assumed to be a biomass fuel, and carbon dioxide emissions from biomass fuels grown sustainably are not counted. Therefore, the CO_2 emissions are zero. Consequently, the GHG emissions associated with this category include methane and nitrous oxide. In general, GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

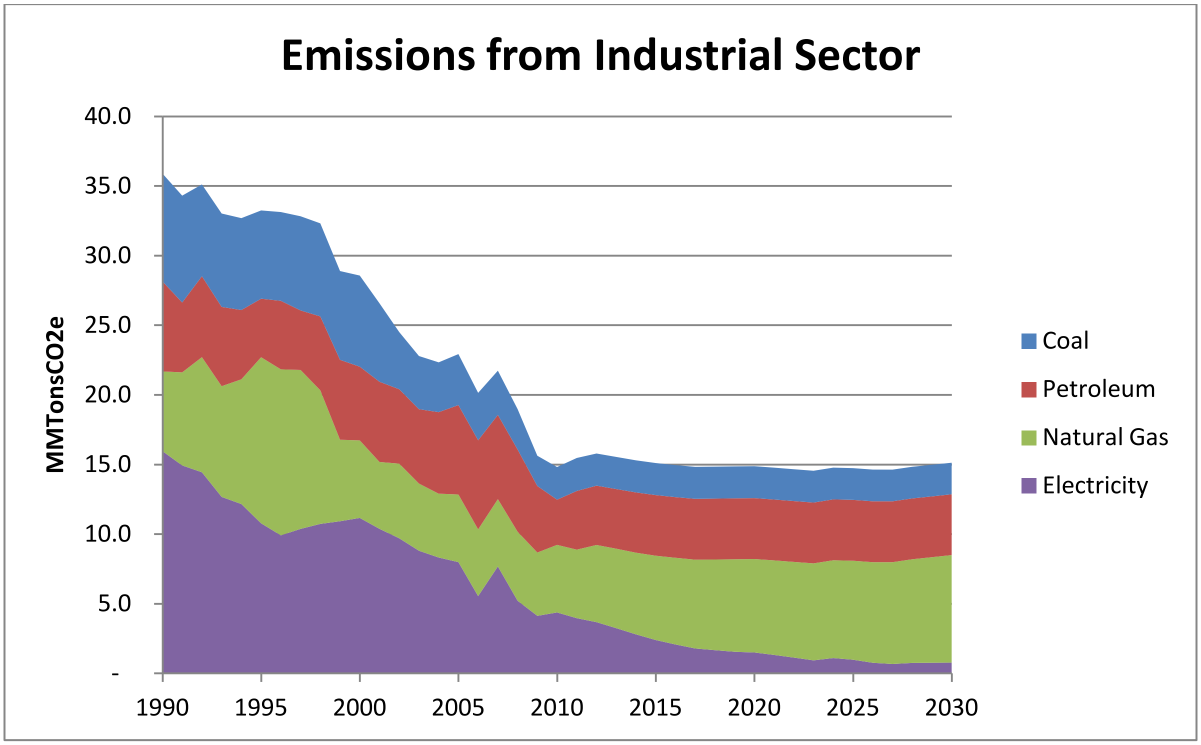


Table 1-5. Industrial Sector Emissions Inventory and Forecasts ($MMtCO_2e$)

The Other category includes emissions associated wood combustion. Wood is assumed to be a biomass fuel, and carbon dioxide emissions from biomass fuels grown sustainably are not counted. Therefore, the CO_2 emissions are zero. Consequently, the GHG emissions associated with this category include methane and nitrous oxide. In general, GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

Fuel Type	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Coal	7.7	6.3	6.5	3.7	2.3	2.4	2.3	2.3	2.3	2.3
Petroleum	6.5	4.2	5.3	6.4	3.2	4.2	4.4	4.4	4.4	4.4
Natural Gas	5.7	11.9	5.6	4.9	4.9	4.9	6.1	6.7	7.1	7.7
Electricity	16.0	10.8	11.2	8.0	4.4	4.0	2.4	1.5	1.0	0.8
Other	0.03	0.0	0.04	0.0	0.02	0.0	0.0	0.02	0.0	0.02
Total	**35.9**	**33.3**	**28.6**	**22.9**	**14.8**	**15.5**	**15.1**	**14.9**	**14.8**	**15.1**

Table 1-6. 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 1-5.

Fuel Type	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Coal	21.6%	19.1%	22.9%	16.0%	15.8%	15.3%	15.2%	15.4%	15.5%	15.0%
Petroleum	18.0%	12.6%	18.5%	28.0%	21.9%	27.2%	28.8%	29.4%	29.6%	28.8%
Natural Gas	15.9%	35.9%	19.5%	21.2%	32.7%	31.8%	40.1%	45.1%	48.2%	51.0%
Electricity	44.4%	32.4%	39.0%	34.8%	29.5%	25.6%	15.8%	10.1%	6.6%	5.1%
Other	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%

2 Industrial Non-Fuel Combustion Processes

2.1 Overview

Emissions from industrial non-fuel combustion sources span a wide range of industrial process and energy supply 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.

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.[15] About 0.02 metric tons (Mt) of CO_2 is emitted for every Mt of cement kiln dust produced, relative to the CO_2 emitted during the production of a metric ton of clinker.[16]

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 sector.[17]

---

15 For further detail, see EPA's EIIP, Volume VIII: Chapter 6 "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes," December 2006.

16 EPA's EIIP, Volume VIII: Chapter 6 "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes," December 2006.

17 In accordance with EIIP Chapter 6 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).

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 also released when soda ash is consumed.[18]

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 New York, the estimated amount of emissions from this source is small and the emissions are excluded from the inventory and forecast.[19]

2.1.2 Sources of Methane (CH_4) Emissions

Natural gas leakage: Methane emissions are associated with the transmission, storage, and distribution of natural gas in New York State.[20] Transmission pipelines are large diameter, high-pressure lines that transport gas from production fields, processing plants, storage facilities, and other sources of supply over long distances to local distribution companies or to large volume customers. Sources of CH_4 emissions from transmission pipelines include leaks, compressor fugitives, vents, and pneumatic devices. Distribution pipelines are extensive networks of generally small diameter, low-pressure pipelines that distribute gas within cities or towns. Sources of CH_4 emissions from distribution pipelines include leaks, meters, and regulators.

The vast majority of New York State's natural gas supply is brought in via pipeline from other states and Canada. The Transcontinental and Tennessee Gas Transmission pipelines from the Gulf Coast and the Iroquois pipeline from Canada link up with local gas distribution networks that supply the New York City metropolitan area and Long Island. Other parts of the state receive gas from Pennsylvania and Canada via other gas transmission systems. Electric generation and residential consumption each account for about one-third of the natural gas consumed in the state. Methods of estimating emissions may be reevaluated and refined going forward based on identified best practices.

---

18 For further detail, see EPA's EIIP, Volume VIII: Chapter 6 "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes," December 2006.

19 The default SIT data indicate that CO_2 emissions from urea consumption amounted to <0.005 $MMtCO_2e$ annually between 1990 and 2011.

20 Note that CH_4, N_2O, and CO_2 emissions from natural gas consumed as lease fuel (used in well, field, and lease operations), plant fuel (used in natural gas processing plants), and pipeline fuel (used in pipeline compressor station internal combustion engines) are included in Chapter 1 in the industrial fuel combustion category.

2.1.3 Sources of Perfluorocarbon (PFC) Emissions

Aluminum production: Emissions of tetrafluoromethane and hexafluoroethane, both PFCs, occur during the reduction of alumina in the primary smelting process. The aluminum production industry is thought to be the largest source of these two PFCs.

Semiconductor manufacturing:[21] 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. Un-dissociated fluorinated gases 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.[22]

2.1.4 Sources of Hydrofluorocarbon (HFC) Emissions

Ozone-depleting substances (ODS) substitutes: HFC emissions result from the consumption of substitutes for ozone-depleting substances used in cooling and refrigeration equipment.[23] The most notable HFC substitution is for CFCs, which are also potent warming gases that have global warming potentials on the order of thousands of times that of CO_2 per unit of mass. This substitution is in compliance with the Montreal Protocol and the Clean Air Act

[21] Emissions from semiconductor manufacturing were estimated using the United States Environmental Protection Agency's (U.S. EPA) State Greenhouse Gas Inventory Tool (SIT) software, with reference to the Emission Inventory Improvement Program (EIIP) guidance document Volume VIII: Chapter 6 "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes," December 2006. Though SIT provides an aggregate emissions value for PFCs, hydrofluorocarbons, and sulfur hexafluoride, it is assumed PFCs constitute the majority of the emissions.

[22] Excerpt from California Environmental Protection Agency, Air Resources Board. *California's 1990-2004 Greenhouse Gas Emissions Inventory and 1990 Emissions Level: Technical Support Document.* May 2009.

[23] Substitutes for ozone-depleting substances, which include chlorofluorocarbons, halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons, are used in a variety of industrial applications including refrigeration and air conditioning equipment, aerosols, solvent cleaning, fire extinguishing, foam blowing, and sterilization. Although their substitutes, HFCs, are not harmful to the stratospheric ozone layer, they are powerful GHGs. (EPA's *Draft User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC and SF6 Emissions from Industrial Processes Using the State Inventory Tool*, February 2013)

Amendments of 1990.[24] Even low amounts of HFC emissions (for example, from leaks and other releases associated with normal use of the products) can lead to high GHG emissions on a CO_2e basis. [25]HCFC-22 production is another industrial process that can produce HFC emissions. However, specific data for New York State in this source category are lacking.

Nitrous Oxide Emissions: Nitric acid production is an industrial process that can result in nitrous oxide emissions. However, specific data for New York State in this source category are lacking.

Sulfur Hexafluoride Emissions: Magnesium production and processing are industrial processes that can result in sulfur hexafluoride emissions. However, specific data for New York State in this source category are lacking.

2.2 Emissions Inventory and Forecast

2.2.1 Inventory Data and Methodology

GHG emissions for 1990 through 2011 were estimated using the following methods. For most sources, emissions were estimated using the SIT tool and the methods provided in the EIIP guidance document for industrial processes.[26]

---

24 As noted in EIIP Chapter 6, ODS substitutes are primarily associated with refrigeration and air conditioning, but also many other uses including as fire control agents, cleaning solvents, aerosols, foam blowing agents, and in sterilization applications. The applications, stocks, and emissions of ODS substitutes depend on technology characteristics in a range of equipment types. For the U.S. national inventory, a detailed stock vintaging model was used to track ODS substitutes uses and emissions, but this modeling approach has not been completed at the state level.

25 Emissions from semiconductor manufacturing were estimated using the United States Environmental Protection Agency's (U.S. EPA) State Greenhouse Gas Inventory Tool (SIT) software, with reference to the Emission Inventory Improvement Program (EIIP) guidance document Volume VIII: Chapter 6 "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes," December 2006. Though SIT provides an aggregate emissions value for PFCs, HFCs, and sulfur hexafluoride, HFCs constitute the majority of the emissions.

26 GHG emissions were calculated using SIT, with reference to EIIP, Volume VIII: Chapter. 6. "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes," December 2006. Referred to as "EIIP" below.

2.2.1.1 Sources of CO_2 Emissions

Cement production: Emissions from cement production are calculated within SIT 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 were derived from the cement statistics in United States Geological Survey's (USGS) Minerals Yearbook.[27] This information is contained within the SIT module as the default option.

Iron and steel production: New York State's emissions from iron and steel production were pro-rated from the U.S. EPA's estimates of total U.S. emissions[28] based on New York's market share of national iron and steel manufacturing derived from American Iron and Steel (AISI) data.[29] 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 within the SIT module as default.

Limestone use: Historical New York emissions were pro-rated from the U.S. EPA's estimates of total U.S. emissions from limestone and dolomite consumption,[30] based on the quantity of crushed stone sold in the state derived from USGS data.[31] This information is available within the SIT module as default.

---

27 USGS Minerals Yearbook, Cement Statistics and Information, various years (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.

28 U.S. GHG Emissions from Iron and Steel Manufacture were obtained from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, U.S. EPA, April 2013 (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf)

29 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) within the SIT Module.

30 U.S. GHG emissions from limestone and dolomite consumption were obtained from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, U.S. EPA, April 2013 (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf)

31 Historical sales for New York and the U.S. from USGS Minerals Yearbook, Crushed Stone Statistics and Information (http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/)

Soda ash use: Emissions from soda ash use are calculated within the SIT module by scaling national soda ash consumption (estimated using sales data) based on the ratio of state to national population.[32] Data on the metric tons of soda ash consumed in the U.S. were derived from the soda ash statistics in the USGS Minerals Yearbook.[33] This information is available within the SIT module as default.

2.2.1.2 Sources of CH_4 Emissions

Natural gas leakage: The EPA published estimates[34] of national CO_2e emissions for natural gas systems for 1990 through 2011.[35] These estimates are reported for four processes:

- Production.
- Processing.
- Transmission and storage.
- Distribution.

Natural gas leakage in New York State was analyzed for the last two processes given the limited production and processing that occurs in the state. Emissions from natural gas transmission, storage, and distribution were estimated by scaling the U.S. GHG emissions from these processes based on the ratio of New York's natural gas consumption to national natural gas consumption. New York State's natural gas consumption estimates were obtained from a June 2013 NYSERDA publication[36] and national consumption estimates were compiled from Energy Information Administration (EIA) State Energy Data System (SEDS) data.[37]

---

32 U.S. and New York State population data from U.S. Census Bureau (http://www.census.gov/2010census/) and http://www.census.gov//census2000/states/us.html)

33 USGS Minerals Yearbook, Soda Ash Statistics and Information, various years (http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/)

34 In a recent study it was found that measured emissions of methane are approximately 1.5 times great than those published in the U.S. Environmental Protection Agency national GHG inventory. A commensurate scaling of this analysis would increase the emissions from natural gas leakage to 5.4 MMTonsCO2e or 2.5% of total emissions. Source: *Brandt, et al. "Methane Leaks from North American Natural Gas Systems." Science 343, February 2014.*

35 U.S. EPA. 2013. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2011.*April. (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf)

36 NYSERDA. 2013. "Patterns and Trends, New York State Energy Profiles: 1997-2011," June.

37 U.S. Department of Energy, EIA, 2013. State Energy Data System 1960-2011. June. (http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US)

2.2.1.3 Sources of PFC Emissions

Aluminum production: Emissions from aluminum production are calculated in the SIT Industrial Processes module based on the annual quantity of aluminum production. Data on the metric tons of aluminum produced in New York were derived from the aluminum statistics in United States Geological Survey's (USGS) Minerals Yearbook.[38]

Semiconductor manufacturing: Historical emissions associated with semiconductor manufacturing were estimated using the SIT default data. 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 U.S. EPA national GHG inventory.

2.2.1.4 Sources of HFC Emissions

ODS substitutes: Historical emissions from ODS substitutes are calculated within SIT by scaling national emissions from EPA's GHG inventory[39] based on the ratio of state to national population.[40]

2.2.2 Forecast Data and Methodology

Because available forecast information is generally for economic sectors that are too broad to reflect trends in the specific emissions-producing processes, the majority of forecasts are based on historical activity trends. In most cases, the forecasting method held the production/ consumption levels (or New York's market share) constant at the average value of the last three years of available historical data.

2.2.2.1 Sources of CO_2 Emissions

Cement production: For the forecast, the current inventory year emission level was kept constant through 2030. The amount of cement produced in the current inventory year was estimated to be the average of the previous three years.

Iron and steel production: The current inventory year emissions estimate was held constant through 2030. The current inventory year emissions value was estimated to be the average of the previous three years.

---

38 USGS Minerals Yearbook, Aluminum Statistics and Information, various years (http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/).

39 National emissions from U.S. EPA. 2013. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*, April (http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2013-Main-Text.pdf)

40 U.S. and New York State population data from U.S. Census Bureau (http://www.census.gov/2010census/) and (http://www.census.gov//census2000/states/us.html)

Limestone use: For the forecast, the current inventory year emission level was kept constant through 2030. The amount of limestone use in the current inventory year was estimated to be the average of the previous three years.

Soda Ash Use: The forecasted emissions through 2030 were estimated to remain constant at the level of the most recent year available data.

2.2.2.2 Sources of CH_4 Emissions

Natural gas leakage: Forecasted New York State natural gas consumption values for 2012 through 2030 were taken from mid-Atlantic region Annual Energy Outlook (AEO) data scaled to New York State. An emission factor for leaks for the natural gas transmission and distribution emissions per billion cubic feet of New York's natural gas consumption was used to estimate emissions forecasts. This emission factor was based on scaling the 2011 EPA-estimated U.S. natural gas transmission and distribution emissions to the state level using New York's percentage of national consumption.

2.2.2.3 Sources of PFC Emissions

Aluminum production: For the forecast, the current inventory year emission level was kept constant through 2030. The amount of aluminum production in the current inventory year was estimated to be the average of the previous three years.

Semiconductor manufacturing: For the forecast, the current inventory year emission level was kept constant through 2030. The amount of semiconductor manufacturing in the current inventory year was estimated to be the average of the previous three years.

2.2.2.4 Sources of HFC Emissions

ODS substitutes: Forecasted New York emissions from ODS substitutes were pro-rated from forecasted U.S. emissions for 2010, 2015, and 2020 obtained from the U.S. Department of State.[41] The rate of growth between the 2010 and 2020 U.S. values was calculated. This rate of growth was applied to the 2010 SIT default value for HFC, PFC, and SF_6 emissions to calculate the yearly ODS substitute emissions through 2020. From 2021 through 2030, the 2020 value was held constant.

---

41 U.S. Department of State. 2010. U.S. Climate Action Report 2010, Washington: Global Publishing Services (http://www.state.gov/documents/organization/140636.pdf)

2.3 Results

The historical and forecast emissions based on existing state policies and economic conditions for industrial non-fuel combustion processes from 1990 to 2030 are shown in Figure 2-1, and Table 2-1 shows the historical and forecasted emission values upon which Figure 2-1 is based. Total New York GHG emissions for these sources totaled approximately 7.40 MMtCO_2e in 1990 and grew to 13.50 MMtCO_2e in 2011. The emissions from industrial non-fuel combustion processes are expected to grow to approximately 20.03 MMtCO_2e by 2030. Emissions growth is primarily associated with the increasing use of ozone-depleting substances (ODS) substitutes, as shown in Figure 2-1.

Figure 2-1. GHG Emissions from Industrial Non-Fuel Combustion Processes by Source, 1990 – 2030

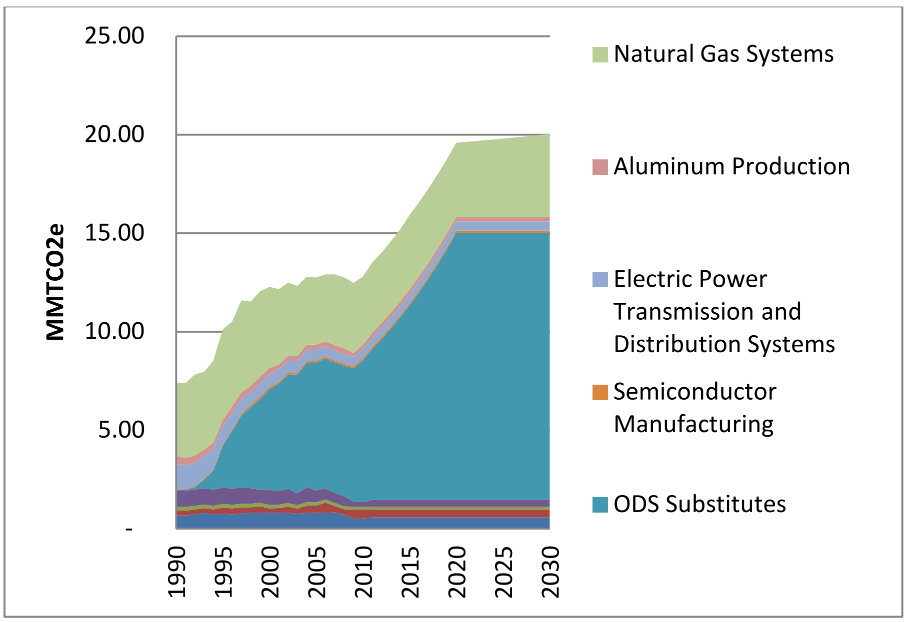


Table 2-1. Emissions Inventory and Forecast for Industrial Non Fuel Combustion Processes, 1990 – 2030 ($MMtCO_2e$)

Industrial Process	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
CO_2 Emissions										
Cement Manufacturing	0.67	0.83	0.80	0.79	0.51	0.57	0.57	0.57	0.57	0.57
Iron & Steel Production	0.83	0.83	0.75	0.60	0.24	0.34	0.34	0.34	0.34	0.34
Limestone & Dolomite Use	0.25	0.30	0.22	0.37	0.45	0.40	0.40	0.40	0.40	0.40
Soda Ash Use	0.20	0.19	0.18	0.17	0.14	0.14	0.14	0.14	0.14	0.14
CH_4 Emissions										
Natural Gas Leakage	3.74	4.60	4.12	3.40	3.48	3.58	3.78	3.76	3.98	4.22
PFC Emissions										
Aluminum Production	0.38	0.31	0.33	0.27	0.21	0.24	0.24	0.24	0.24	0.24
Semiconductor Manufacturing	0.04	0.07	0.11	0.09	0.11	0.11	0.11	0.11	0.11	0.11
HFC Emissions										
ODS Substitutes	0.02	2.12	5.12	6.47	7.19	7.66	9.87	13.56	13.56	13.56
Electric Power Transmission and Distribution Systems	1.27	0.93	0.63	0.57	0.45	0.46	0.46	0.46	0.46	0.46
TOTAL	**7.40**	**10.17**	**12.27**	**12.74**	**12.79**	**13.50**	**15.91**	**19.58**	**19.79**	**20.03**

2.4 Sources of CO_2 Emissions

Cement manufacturing: Emissions from this source were estimated to be about 0.67 $MMtCO_2e$ in 1990 and are forecasted to decrease slightly to 0.57 $MMtCO_2e$ by 2030, as shown in Figure 2-1 and Table 2-1.

Iron and steel production: Emissions in 1990 were 0.83 $MMtCO_2e$ and are forecasted to decrease to about 0.34 $MMtCO_2e$ by 2030, as shown in Figure 2-1and Table 2-1.

Limestone and Dolomite use: Relative to total industrial non-fuel combustion process emissions, CO_2 emissions from limestone consumption are consistently low, estimated at about 0.25$MMtCO_2e$ in 1990, 0.45 $MMtCO_2e$ in 2010, and 0.40 $MMtCO_2e$ in 2030.

Soda ash use: CO_2 emissions from soda ash consumption are also consistently low, estimated at about 0.20 $MMtCO_2e$ in 1990, 0.14 $MMtCO_2e$ in 2010, and 0.14$MMtCO_2e$ in 2030.

2.4.1 Sources of CH_4 Emissions

Natural gas leakage: Natural gas leakage is currently the highest contributor to GHG emissions from industrial non- fuel combustion processes in New York. Emissions from this source were estimated at 3.74 $MMtCO_2e$ in 1990, 3.58 $MMtCO_2e$ in 2011, and are under existing state policies and economic conditions, are forecasted to grow to 4.22 $MMtCO_2e$ in 2030.[42] This modest increase in methane emissions is due to increased use of natural gas in the electricity generation sector and fuel switching to natural gas from higher carbon fuel sources for on-site uses. While non-fuel combustion emissions from natural gas are forecasted to represent only 2% of statewide emissions in 2030, policy approaches may be adoptable to further control such emissions

2.4.2 Sources of PFC Emissions

Semiconductor manufacturing: Emissions from this source are fairly low in New York throughout the analytic period, as shown in Figure 2-1 and Table 2-1. They are estimated to have increased from 0.04 $MMtCO_2e$ in 1990 to about 0.11$MMtCO_2e$ in 2011, and are expected to remain at 0.11$MMtCO_2e$ through 2030.

Aluminum production: GHG emissions from aluminum production in New York were estimated at 0.38 $MMtCO_2e$ in 1990, 0.24$MMtCO_2e$ in 2011, and are forecasted to increase slightly to 0.24 $MMtCO_2e$ in 2030.

2.4.3 Sources of HFC Emissions

ODS substitutes: Emissions in New York from this source are estimated to have increased from 0.02 $MMtCO_2e$ in 1990 to about 7.66$MMtCO_2e$ in 2011, and are forecasted to further increase to 13.56 $MMtCO_2e$ in 2020, which would make them the highest contributor to GHG emissions from industrial non- fuel combustion processes in New York. After 2020, the rate of emissions growth for this source is assumed to slow down, with emissions remaining at 13.56 $MMtCO_2e$ in 2030. ODS substitutes (and as a result, HFCs) are increasing due to the provisions of the Montreal Protocol. While the protocol has been effective at protecting the ozone layer by phasing ODSs, it has led to an increase in HFCs which are a potent greenhouse gas. Given the risk HFCs pose to the climate, the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) has launched an initiative to promote HFC alternative technologies and standards with a goal to reduce their use and emissions going forward.[43] These types of initiatives could help to mitigate the impact of HFCs in the future.

42 In a recent study it was found that measured emissions of methane are approximately 1.5 times great than those published in the U.S. Environmental Protection Agency national GHG inventory. A commensurate scaling of this analysis would increase the emissions from natural gas leakage to 5.4 MMTonsCO2e or 2.5% of total emissions. Source: *Brandt, et al.2014. "Methane Leaks from North American Natural Gas Systems." Science 343, February.*

43 Refrigeration and Air Conditioning Magazine, April 1, 2014. http://www.racplus.com/news/us-climate-body-launches-low-gwp-case-studies-for-developing-countries/8660997.article

3 Transportation Energy Use

3.1 Overview

The transportation sector is one of the largest sources of greenhouse gas (GHG) emissions in New York. Carbon dioxide (CO_2) accounts for the majority of the transportation GHG emissions from fuel use. Most of the remaining GHG emissions from the transportation sector are due to nitrous oxide (N_2O) emissions from on-road gasoline-fueled vehicles.

3.2 On-Road Vehicle Fuels

Gasoline: CO_2, N_2O, and CH_4 emissions are produced from gasoline that is combusted by passenger cars, light-duty trucks, heavy-duty vehicles, and motorcycles. Although gasoline itself contains virtually no CH_4, this GHG is produced as a byproduct of gasoline combustion and is influenced by various factors such as emission control technologies, combustion conditions, and fuel composition. Gasoline contains up to 10% ethanol by volume; however, per the United States Environmental Protection Agency's (US EPA) Emission Inventory Improvement Program (EIIP) guidance documents[44] ethanol is considered a biofuel, so no CO_2 emissions associated with the combustion of ethanol that is blended into gasoline are included in the inventory.[45]

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 itself contains virtually no CH_4, it is produced as a byproduct of diesel combustion and is influenced by various factors such as emission control technologies, combustion conditions, and fuel composition.

Natural gas: CO_2, N_2O and CH_4 emissions are produced from natural gas that is combusted by light-duty and heavy-duty alternative fuel vehicles. [46]

---

44 Emission Inventory Improvement Program, Volume VIII: Chapter 1. "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels," December 2006.

45 Carbon dioxide emissions associated with fuels produced from sustainably grown biomass are not counted. For cases where biomass is not grown sustainably, the GHG impact would be captured as a land use change.

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

3.2.1 Off-Road Vehicle Fuels

Gasoline: CO_2, N_2O, and CH_4 emissions are produced from gasoline that is combusted by sources such as 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.[47]

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

3.2.2 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,[48] which represents the fraction of consumed product (on an energy-content basis) that is combusted and leads to GHG emissions.

---

[47] 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 off-road vehicles. See the EIA's *State Energy Data System Technical Notes and Documentation, Consumption, Section 4: Petroleum* for more details (http://www.eia.gov/state/seds/sep_use/notes/use_petrol.pdf)

[48] The oxidation factor for lubricants was derived from United States Environmental Protection Agency's State Inventory Tool CO2FFC Module, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 1. "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels," December 2006.

3.3 Emissions Inventory and Forecast

3.3.1 Inventory Data and Methodology

Historical GHG emissions were estimated using the SIT and the methods provided in the EIIP guidance document for the sector.[49,50]

The SIT module was used to determine emissions from the following sources: Highway vehicles, aviation, boat and marine vessels, alternative fuel vehicles. Options for locomotives and "other non-highway sources" were not utilized. Default emissions factors were used.

3.3.1.1 On-Road Vehicle Fuels

The SIT CO_2 Fossil Fuel Combustion Module was used to calculate CO_2 emissions based on the energy content, in British thermal units (Btu), of fuel and lubricants consumed, with the default SIT fuel consumption values for New York replaced with New York specific information calculated from annual vehicle miles of travel (VMT) data provided by NYS DOT and fuel economy data provided by ORNL and FHWA for historical and AEO for forecast (see the details below for an explanation of the methodology used in this analysis). The SIT Mobile Combustion Module was used to calculate N_2O and CH_4 emissions based VMT for on-road vehicles, with the SIT default data for VMT replaced with NYS DOT data for New York State.[51]

Gasoline and diesel: New York 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 3-1.[52] The fraction of VMT by vehicle type for years 1991 through 2001 and 2002 through 2007 were calculated by interpolation and the fractions for years after 2007 were held constant at the 2007 levels. These fractions were applied to the corresponding annual statewide total VMT value to produce annual VMT by vehicle type, which were input into the SIT Mobile Combustion Module to calculate emissions of N_2O and CH_4.

---

49 CO_2 emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 1. "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels," December 2006.

50 CH_4 and N_2O emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 3. "Methods for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion," December 2006.

51 While NYS DOT forecasts show that VMT are projected to continue to grow from 2012-2030, the latest growth rates show a much lower rate of increase. This lower growth rate, when coupled with a forecasted increase in vehicle fuel economy across all vehicle categories, results in a decrease in transportation fuel consumption, which lowers the emission forecast.

52 New York State Department of Transportation VMT modeling.

Table 3-1. New York State VMT by Vehicle Type

Vehicle Type	1990	2000	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**

Annual fuel efficiency data were applied to the annual VMT by vehicle type to calculate the quantity of on-road fuel consumption. Historical fuel efficiency data were provided by the Oak Ridge National Laboratory and the Federal Highway Association, forecasted efficiency data were provided by AEO. Consumption of biofuel within blended fuels was estimated by applying ethanol fractions of motor gasoline and biodiesel fractions of diesel sold to the calculated consumption numbers. The biofuel fractions were obtained from EIA's State Energy Data System (SEDS) for New York, The estimated consumption of the biofuels was then subtracted from the gasoline and diesel totals and the resultant consumption data were input into the SIT CO_2FFC Module to calculate emissions of CO_2.

Natural Gas: Historical transportation natural gas consumption data were obtained from EIA's SEDS and input into the CO_2FFC Module to calculate CO_2 emissions.

New York State annual natural gas historical VMT data by vehicle type were calculated based on consumption data from EIA's SEDS and fuel efficiency data from the Oak Ridge National Laboratory and FHWA. The resultant VMT values were then input into the SIT Mobile Combustion Module to calculate emissions of N_2O and CH_4.

3.3.1.2 Off-Road Vehicle Fuels

Gasoline: Historical off-road motor gasoline consumption was estimated based on FHWA marine vehicle gasoline sales data for New York. These data were divided by the FHWA national motor gasoline sales data to calculate the fraction of sales that are associated with New York marine vehicles. These factions were then used to scale the national motor gasoline consumption data from SEDS to estimate the New York off-road motor gasoline consumption. Gasoline consumption data in Btu were subsequently input into the SIT CO_2FFC and Mobile Combustion Modules to produce GHG emissions estimates.

Diesel: For historical analysis, off-road diesel sales data from SEDS were used to estimate off-road diesel consumption. The diesel sales data were adjusted using national data on the ratio of diesel consumption to diesel sales in the U.S. in order to approximate off-road diesel consumption. Diesel consumption data in Btu were subsequently input into the SIT CO_2FFC and Mobile Combustion Modules to produce GHG emissions estimates.

Residual oil, liquefied petroleum gas, and jet fuel (kerosene): For these other off-road fuels, emissions estimates were calculated within the SIT CO_2FFC and Mobile Combustion modules using fuel consumption data in Btu from NYSERDA's *Patterns and Trends.*

3.3.1.3 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 within the SIT CO_2FFC module.

3.3.2 Forecast Data and Methodology

To project CO_2 emission rates, emission factors by fuel type were calculated from the most recent historical activity data (such as fuel consumption) along with emissions estimates generated by the appropriate SIT module. To project CH_4 and N_2O emission rates, emission factors by fuel type were calculated from the activity data and emissions for the final year of emission factors from the SIT modules. All of these emission factors were then held constant through the end of the study period and multiplied by the corresponding projected fuel consumption or VMT data.

3.3.2.1 On-Road Vehicle Fuels

Gasoline and diesel: To calculate forecasted emissions of N_2O and CH_4, NYS DOT annual VMT projections for gasoline and diesel on-road vehicles were allocated to differing vehicle types based on the percentages for 2007 that are reflected in the VMT data shown in Table 3-1. The resulting annual projections of VMT by vehicle type through 2020 were input into the SIT Mobile Combustion Module to calculate emissions of N_2O and CH_4. Annual projections of VMT by vehicle type for 2021 through 2030 were multiplied by the 2020 fuel- and vehicle-specific emission factors derived from the Mobile Combustion Module to produce annual emissions projections for the remainder of the forecast period.

To calculate CO_2 emissions from on-road gasoline and diesel vehicles, annual AEO fuel efficiency projections were applied to the annual VMT projections to estimate annual values of Btu of on-road fuel consumption. The AEO projected biofuel fractions were used to estimate how much biofuel will be consumed in New York State through 2030. The energy content of this biofuel projection was subtracted from the total fuel consumption projection to estimate the amount of gasoline and diesel that will be consumed. The projections for gasoline and diesel consumption were subsequently multiplied by the fuel-specific emission factors derived from the CO_2FFC Module to produce emission projections. The projected fuel efficiency values include the effects of the revisions to the national Corporate Average Fuel Economy (CAFE) standards and EPA's proposed CO_2 emission standards.

Natural gas: Annual projected natural gas consumption was based on forecasted Mid-Atlantic regional natural gas consumption. The regional forecasts were multiplied by the New York fraction to estimate New York's future consumption of natural gas. The consumption forecasts were subsequently multiplied by the natural gas emission factor derived from the CO_2FFC Module to produce CO_2 emission projections.

Natural gas VMT was estimated using AEO fuel efficiency projections. The natural gas VMT projections by vehicle type through 2020 were input into the SIT Mobile Combustion Module to calculate emissions of N_2O and CH_4. Annual projections of VMT for natural gas VMT for 2021 through 2030 were multiplied by the 2020 vehicle-specific emission factors derived from the Mobile Combustion Module to produce annual emissions projections for the remainder of the forecast period.

3.3.2.2 Off-Road Vehicle Fuels

Gasoline and diesel: New York State off-road motor gasoline and diesel consumption was projected using national annual growth factors based on the AEO annual projected growth in national non-highway gasoline and diesel consumption. The projections for gasoline and diesel consumption were subsequently multiplied by the fuel-specific emission factors derived from the CO_2FFC Module to produce CO_2 emission forecasts. The projections for gasoline and diesel consumption through 2020 were input into the SIT Mobile Combustion Module to calculate emissions of N_2O and CH_4. Annual projections of diesel and gasoline consumption for 2021 through 2030 were multiplied by the 2020 fuel-specific emission factors derived from the Mobile Combustion Module to produce annual emissions projections for the remainder of the forecast period.

Residual oil, liquefied petroleum gas, and jet fuel (kerosene): Forecasts of New York's off-road consumption of these fuels was estimated based on fuel consumption forecasts developed based on EIA's Annual Energy Outlook and the 2014 draft New York State Energy Plan. The forecasts were subsequently multiplied by the fuel-specific emission factors derived from the CO_2FFC Module to produce CO_2 emission forecasts. The forecasts for residual oil and jet fuel consumption through 2020 were input into the SIT Mobile Combustion Module to calculate emissions of N_2O and CH_4. Annual forecasts of residual oil and jet fuel consumption for 2021 through 2030 were multiplied by the 2020 fuel-specific emission factors derived from the Mobile Combustion Module to produce annual emissions projections for the remainder of the forecast period.

3.3.2.3 Lubricants

The CO_2 emissions for lubricants were estimated to remain constant at the current inventory level.

3.4 Results

Gasoline consumption accounts for the largest share of transportation GHG emissions, as shown in Table 3-2 and Figure 3-1,. From 1990 to 2011, emissions from gasoline decreased by about 3% to account for approximately 73% of total transportation emissions. GHG emissions from diesel fuel consumption increased by about 68% from 1990 to 2011, and by 2011 accounted for approximately 17% of GHG emissions from the transportation sector. Emissions from jet fuel also accounted for approximately 6% of transportation emissions in 2011. Emissions from residual oil accounted for about 3% of total transportation emissions in 2011, while emissions from all other categories combined (natural gas, LPG, and lubricants) contributed approximately 1% of total transportation emissions in 2011.

Emissions from the transportation sector are projected to decrease from 2011 to 2030, by about 25%. GHG emissions from diesel fuel are expected to decrease by approximately 31% from 2011 to 2030, while emissions from gasoline are expected to decrease by 32% over the projection period. This decrease in emissions levels, which is projected to occur while total statewide VMT is increasing, is primarily due to the anticipated increased use of more fuel efficient on-road vehicles as they come into compliance with the new CAFE requirements and GHG emission standards, as well as a slower growth forecast for VMT.

Figure 3-1. Transportation GHG Emissions by Fuel, 1990 – 2030

LPG is liquefied petroleum gas.

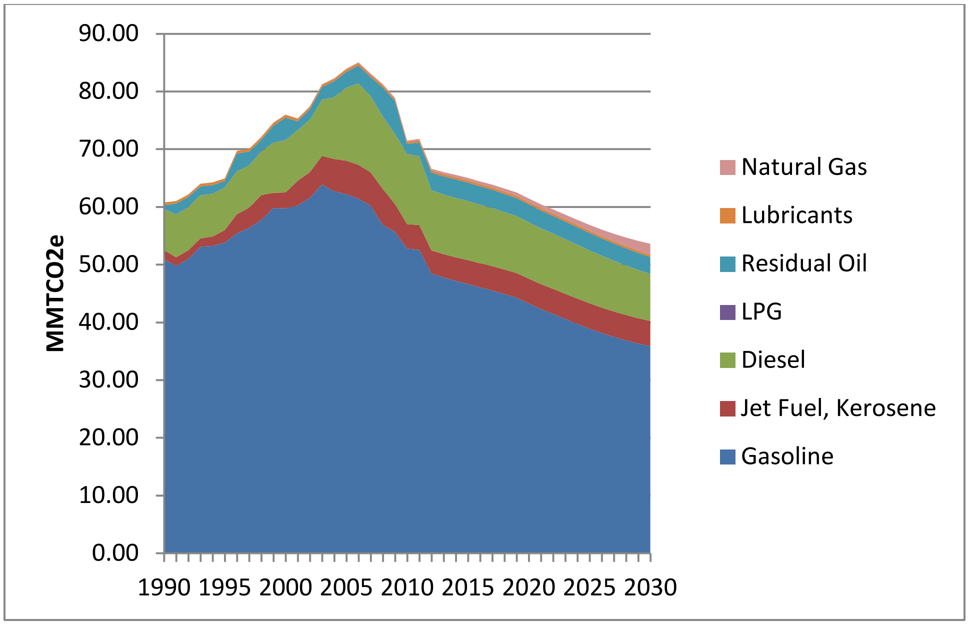


Table 3-2. Transportation Sector Emissions Inventory and Forecast, 1990 – 2030 ($MMtCO_2e$)

Fuel Type	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Gasoline	50.97	53.78	59.73	62.17	52.75	52.55	46.62	43.27	38.88	35.86
Jet Fuel (Kerosene)	1.54	2.19	2.75	5.81	4.24	4.28	4.13	4.28	4.40	4.37
Diesel	7.07	7.36	9.03	12.66	12.13	11.91	10.22	9.76	9.16	8.11
Residual Oil	0.65	1.09	3.87	2.70	1.70	2.37	3.19	3.09	3.00	2.93
Lubricants	0.48	0.46	0.49	0.42	0.39	0.39	0.39	0.39	0.39	0.39
LPG	0.04	0.03	0.06	0.02	0.04	0.04	0.03	0.03	0.03	0.03
Natural Gas	0.00	0.02	0.05	0.15	0.21	0.24	0.43	0.63	1.01	1.91
Total	60.74	64.92	75.98	83.93	71.47	71.78	65.01	61.45	56.86	53.60

4 Power Supply and Delivery

4.1 Overview

Emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulfur hexafluoride (SF_6) are produced from the generation of electricity used to meet electricity demand in New York State as well as with the transmission and distribution of electricity throughout the State. The power supply and delivery sector greenhouse gas (GHG) emission sources and sinks can be subdivided into three primary categories: fuel combustion, electricity distribution, and municipal waste combustion.

4.1.1 Fuel Combustion

Electricity generation: This source category captures CO_2, CH_4, and N_2O emissions that result from the burning of various fuels by in-state power plants.

Net imports of electricity: New York State has historically imported more electricity than it has exported. Net imports are the difference between total in-state imports and exports. This source category includes CO_2, CH_4, and N_2O emissions that are associated with this net imported electricity.

4.1.2 Electricity Distribution

This source category captures SF_6 emissions associated with the transmission and distribution (T&D) of electricity. SF_6 is used as an electrical insulator and interrupter in the electric power T&D system. Because of its high dielectric strength and arc-quenching abilities, the largest use for SF_6 is as an insulator in T&D equipment such as gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines. Not all of the electric utilities in the U.S. use SF_6; use of the gas is more common in urban areas where the space occupied by electric power T&D facilities is more valuable.[53]

4.1.3 Municipal Waste Combustion

Some of New York State's municipal waste is combusted in facilities that are equipped to use the heat produced by the 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 waste-to-energy facilities. Emissions associated with other forms of waste management (i.e., those that are not associated with the production of electricity) are covered in Chapter 6.

---

[53] U.S. EPA, 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, February 2013.

4.2 Emissions Inventory and Forecast

4.2.1 Inventory Data and Methodology

GHG emissions related to the power supply represent emissions produced at the point of electric generation only. In addition, according to the US EPA emission inventory protocols and the methodologies prescribed in the eGRID2010 Technical Support Document,[54] the carbon dioxide emissions from the combustion of biogenic fuels (e.g. wood, landfill gas, and the biomass component of municipal waste) are also not included in estimates of GHG emissions.

4.2.1.1 Fuel Combustion

Emissions from direct fuel use were estimated using the SIT software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for electric sector fuel combustion.[55]

Electricity generation: The default historical fuel consumption data in SIT for New York, which came from the SEDS, were updated with fuel consumption data from NYSERDA's *Patterns and Trends.*[56]

Net imports of electricity: Emissions from net imports of electricity were based on output from the Integrated Planning Model (IPM®), an electricity sector modeling software prepared by ICF International to support the development of New York's State Energy Plan. For imports, the emission factor was estimated based on modeled emissions from neighboring electric service territories.

---

54 U.S. EPA. 2014. *The Emissions & Generation Resource Integrated Database for 2007 (eGRID2007) Technical Support Document*, available at http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Technical_Support_Document.pdf

55 GHG emissions were calculated using SIT, with reference to *EIIP, Volume VIII*: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", December 2006, and Chapter 2 "Methods for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion", December 2006.

56 *Patterns and Trends, New York State Energy Profiles: 1997-2011*, New York State Energy Research and Development Authority, June, available at https://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/EA-Reports-and-Studies/Patterns-and-Trends.aspx

4.2.1.2 Electricity Distribution

Emissions from T&D were estimated using the SIT and the methods provided in the EIIP guidance document for industrial process emissions.[57] The default data that were used were derived using the assumption that SF_6 consumption is equivalent to SF_6 sales. The default historical SF_6 data in SIT came from the U.S. DOE EIA's Electric Power Annual report.[58]

4.2.1.3 Municipal Waste Combustion

Emissions from waste combustion were based on waste-to-energy facility-specific tonnage data from the New York State Department of Environmental Conservation's (NYSDEC) Solid Waste Information Management System (SWIMS) for 1998 through 2010.[59] Linear extrapolation was used to back-cast waste tonnage data for 1990 through 1997. The actual and derived data were input into the SIT, and the methods provided in the EIIP guidance document for municipal solid waste emissions were used to estimate the CO_2 and N_2O produced.[60]

4.2.2 Forecast Data and Methodology

4.2.2.1 Fuel Combustion

The forecast of emissions from fuel combustion for electricity generation and net imports of electricity were derived from the Reference Case forecast presented in the 2014 New York draft State Energy Plan developed by NYSERDA staff, working closely with the New York Independent System Operator (NYISO).[61]

The analysis was performed using the Integrated Planning Model (IPM), developed by ICF International. IPM is a linear programming model that incorporates the New York State electricity system, the systems managed by the New England Independent System Operator (ISO-NE) and the PJM Interconnection (PJM), covering Pennsylvania, New Jersey, and Maryland, as well as the systems extending throughout the rest of the United States and Canada. Key input data include existing and planned generation units, annual electricity demand by zone, load shapes,

---

57 GHG emissions were calculated using SIT, with reference to *EIIP, Volume VIII*: Chapter 6 "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes", December 2006.

58 *Electric Power Annual 2011 Volume I*, U.S. DOE Energy Information Administration, 2013, available at http://www.eia.gov/electricity/annual/archive/2011/.

59 NYSDEC Division of Solid & Hazardous Materials, *SWIMS Capacity Data for Landfills and Waste-to-Energy Facilities*, annual reports for 1998 – 2010.

60 GHG emissions were calculated using SIT, with reference to *EIIP, Volume VIII*: Chapter 13 "Methods for Estimating Greenhouse Gas Emissions from Municipal Solid Waste", December 2006.

61 The Reference Case is based as closely as possible on the system planning assumptions used by the NYISO for its system and reliability planning activities, including the continued operation of the Indian Point nuclear units.

transmission system capacities and transfer limits, generation unit level operation and maintenance costs and performance characteristics, fuel prices, new capacity and emission control technology costs and performance characteristics, zonal reliability requirements, national and state environmental regulations, and financial market assumptions.

The Reference Case is based on the "Gold Book" electricity load forecast used by the NYISO for its system planning activities.[62] The NYISO load forecast extends from 2012 to 2022, and projects electricity load to grow at an annual rate of 0.59 percent over these years. Load forecast values for 2022 through 2030 are projected based on the average growth rate over the last five years of the NYISO load forecast, resulting in an annual growth rate of 0.77 %.

In 2014, after the draft State Energy Plan modeling was complete, the Regional Greenhouse Gas Initiative (RGGI)[63] regional emission cap was lowered from 165 million short tons to 91 million short tons. A comparison between the draft State Energy Plan reference case modeling results and the results from modeling conducted by the RGGI Inc. for the new emission cap are shown in the text box entitled RGGI Comparison in Section 4.3.

4.2.2.2 Electricity Distribution

Forecast emissions from T&D were estimated by holding constant the most recent three-year average historical estimates.

4.2.2.3 Municipal Waste Combustion

Forecast emissions from waste combustion were estimated by holding constant the most recent three-year average historical estimates.

---

62 NYISO, 2012 Gold Book Load and Capacity Data, April 2012. The NYISO uses moderately risk adverse assumptions that have been widely vetted among market participants with respect to their use in analysis of system reliability. The NYISO load forecast assumes only currently authorized funding levels for energy efficiency programs, which translates into the assumption that approximately 64% of the Program Administrator goal (per "*Order Establish Energy Efficiency Portfolio Standard and Approving Programs*," issued and effective June 23, 2008) for energy efficiency is achieved by 2015 and 93% are achieved by 2022. (http://www.nyiso.com/public/webdocs/markets_operations/services/planning/Documents_and_Resources/Planning_Data_and_Reference_Docs/Data_and_Reference_Docs/2012_GoldBook_V3.pdf).

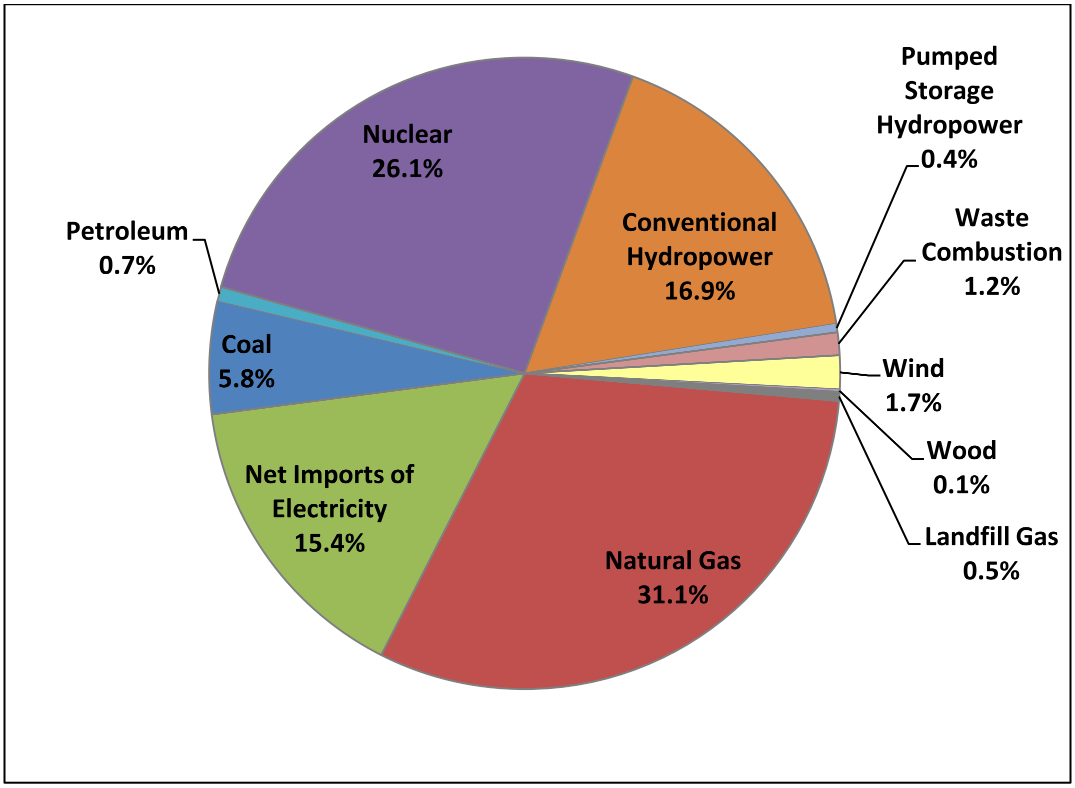
63 RGGI is the first market-based regulatory program in the United States to reduce greenhouse gas emissions. RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont to cap and reduce CO_2 emissions from the power sector. www.rggi.org.

4.3 Results

A 2011 percentage-wise breakdown of electricity generation and net imports of electricity for New York by source category is provided in Figure 4-1. The primary energy sources for the majority of electricity generation were natural gas (31%) and nuclear power (26%) followed by conventional hydropower (17%) and net imports of electricity (15%). Figure 4-1 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 4-1. Proportion of New York Electricity Generation and Net Imports by Source Category, 2011

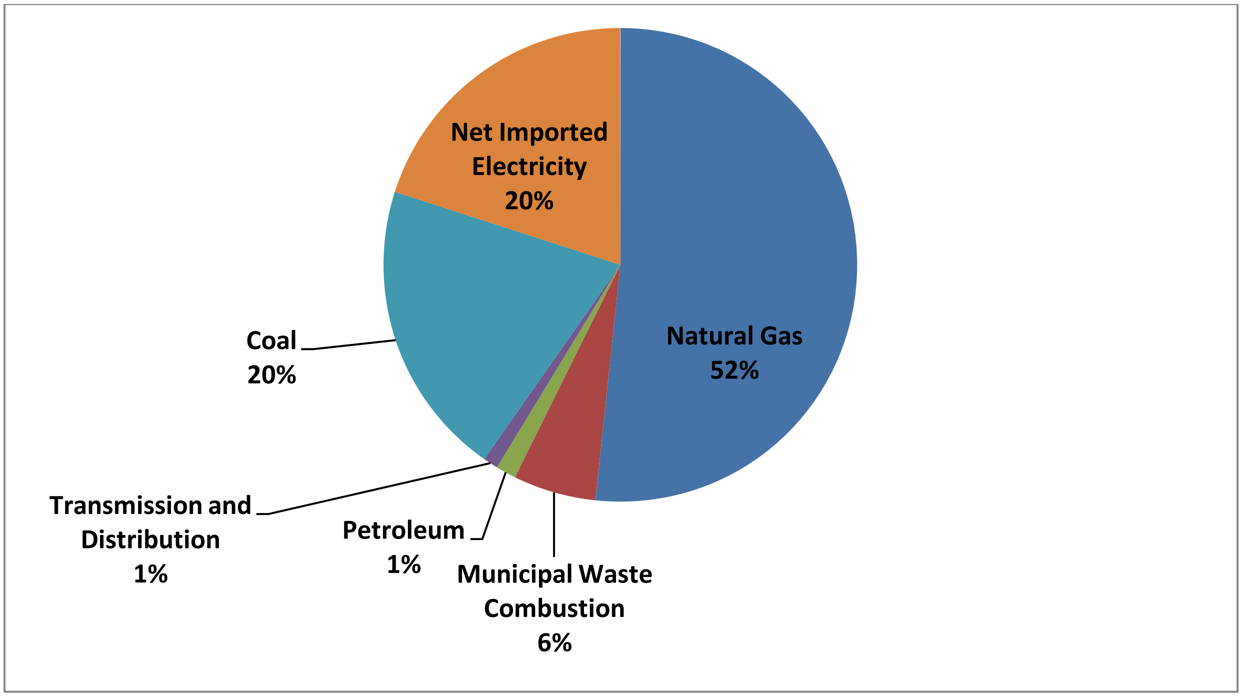
The Wood category includes wood waste.



A 2011 breakdown by percentage of emissions from power supply and delivery within New York State by source category is provided in Figure 4-2. While the majority of emissions come from natural gas combustion (52%), coal is the second-highest source of emissions percentage-wise (20%), though it only provides a relatively small proportion of New York State's electricity generation (5.8%). Net imports of electricity also contribute approximately 20% of GHG emissions, however there is some uncertainty associated with the estimation of emissions from this out-of-state source category. SF_6 emissions from the transmission and distribution of electricity and petroleum emissions are the smallest sources at only 1% each of total emissions.

Figure 4-2. Proportion of GHG Emissions from Power Supply and Delivery by Source Category, 2011

CO_2 emissions from Municipal Waste Combustion are assumed to come from the non-biogenic portions of the waste only. In accordance with EPA guidelines, the biogenic portions of the waste are assumed to have no net CO_2 emissions.

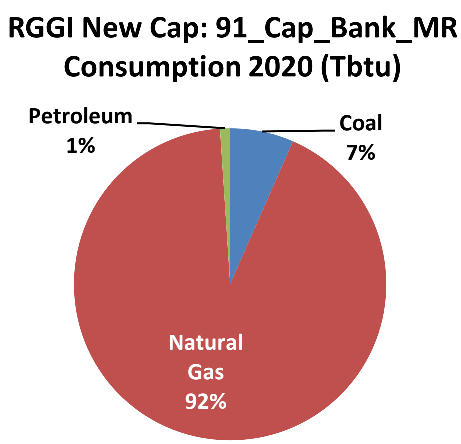


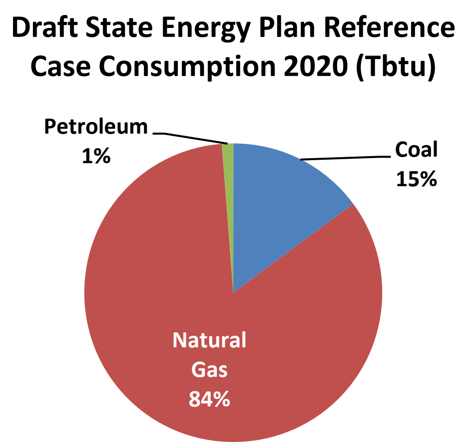
RGGI Comparison

Future CO_2 emissions associated with in-state power generation have been projected as part of two separate modeling exercises:

- **Draft SEP Reference Case**: To support the development of the 2014 draft State Energy Plan, the New York electricity system was modeled assuming that the original regional CO_2 emission cap reduction schedule through 2030 remained in-force given the uncertain outcome of the regulatory process at the time the modeling work was completed.
- **RGGI New Cap 91_Cap_Bank_MR**: As part of the scheduled review of the regional CO_2 cap, modeling scenarios were developed by RGGI Inc to forecast the combined impact of a lower regional cap and the future unavailability of the Indian Point Energy Center nuclear units.[a,b] Modeling results show that regional CO_2 emission levels will be 5 percent lower in 2020 than regional emission levels in 2013.

A comparison between the draft SEP Reference Case and the RGGI New Cap 91_Cap_Bank_MR scenario shows that New York's emissions would remain unchanged in 2015 and would be approximately 10 percent higher in 2020 in the event that the Indian Point Energy Center nuclear units no longer generate electricity, and as the region adopts a lower regional CO_2 cap. The use of primary fossil fuel in New York also differs between the two scenarios, with natural gas use increasing by 128 Tbtu and coal use decreasing by 37 Tbtu in the RGGI New Cap 91_Cap_Bank_MR scenario.





Notes:

a Modeling results from RGGI Inc. for scenario RGGI New Cap: 91_Cap_Bank_MR can be found at the Data: 2013 IPM Modeling Results link here: http://www.rggi.org/design/program-review

b The Indian Point Energy Center (IPEC) operates two nuclear power reactors in the lower Hudson Valley (IPEC Unit 2 and IPEC Unit 3). Applications to relicense the original operating licenses are pending before the US Nuclear Regulatory Commission's (NRC) Atomic Safety Licensing Board (ASLB) due to license expiration in 2013 (Unit 2) and 2015 (Unit 3). The ASLB is conducting a series of hearings and administrative proceedings on the license renewal applications. The State of New York has petitioned the NRC in opposition to relicensing and contributed contentions that will be reviewed by the ASLB. As described in the NYS Public Service Commission Order accepting IPEC reliability contingency plans (CASE 12-E-0503 - Proceeding on Motion of the Commission to Review Generation Retirement Contingency Plans), if the IPEC units were to become unavailable in 2016, replacement capacity of approximately 1,450 MW would be needed that year to maintain the reliable operation of the New York bulk power system.

Electricity generation and net imports of electricity for New York by source category for 1990 through 2030 are shown in Figure 4-3. During that time period, under existing state policies and economic conditions, the largest absolute increase in electricity generation is forecasted to come from natural gas, which would rise from approximately 26,000 GWh of generation in 1990 to approximately 73,000 GWh of generation by 2030. As indicated by Table 4-1, the Other category, which includes renewable energy sources such as solar, wood and wind as well as other sources such as landfill gas and waste, is forecasted to have the greatest percentage-wise growth in the future with an estimated average annual growth rate of 4% between 2011 and 2030. This anticipated increase in generation from the Other category is expected to be largely driven by policies that promote renewable energy. Net imports of electricity are expected to decrease by 2030, although this could be expected to change from year to year depending on a number of market forces.

Figure 4-3. New York Electricity Generation and Net Imports of Electricity by Source Category, 1990 – 2030, Status Quo Forecast

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

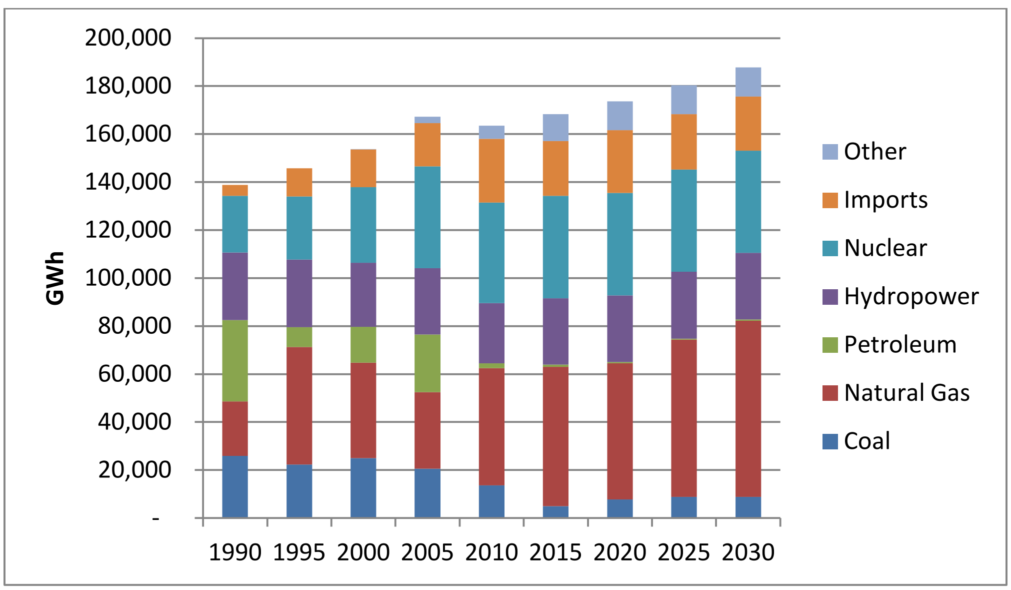


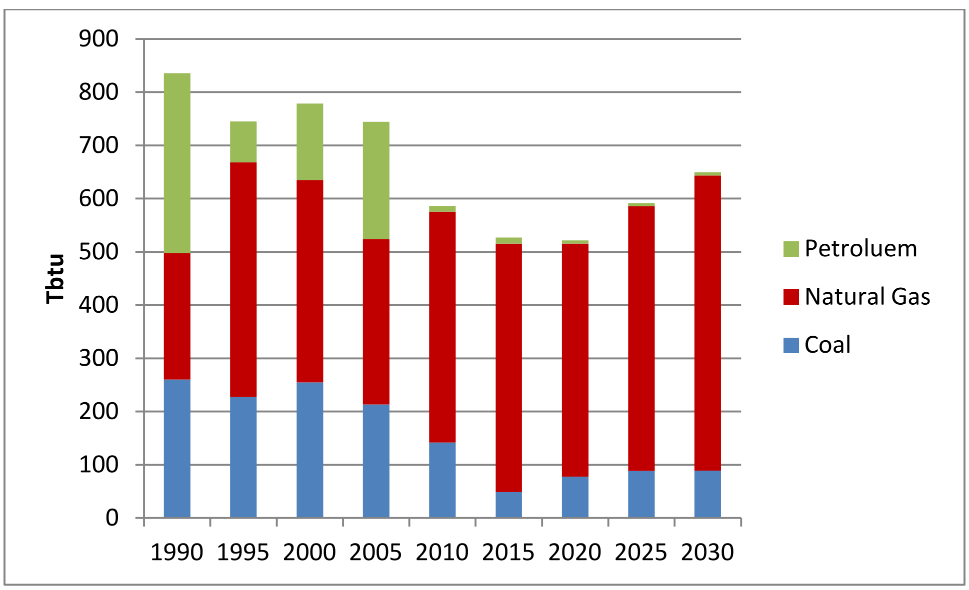
Table 4-1. Electric Generation (GWh) and Annual Average Growth Rates by Fuel Type

The Other category includes solar, wind, wood, landfill gas, and waste. The Hydropower category includes both conventional and pumped storage hydropower.

Energy Source	1990	2010	2030	Average % Annual Growth 1990 – 2011	Average % Annual Growth 2011 – 2030
Coal	25,913	9,426	8,864	-4.70	-0.32
Natural Gas	22,724	50,805	73,391	3.91	1.95
Petroleum	33,885	1,189	502	-14.74	-4.44
Hydropower	28,188	28,355	27,750	0.03	-0.11
Nuclear	23,623	42,695	42,622	2.86	-0.01
Net Imports of Electricity	4,519	25,202	22,523	8.53	-0.59
Other	0	5,651	12,083	NA	4.08
Total	**138,853**	**163,323**	**187,735**	1.49	0.74

The primary fossil fuel energy use at in-state power stations for natural gas, coal, and petroleum for 1990 through 2030 is shown in Figure 4-4. The data indicates that, under existing state policies and economic conditions, New York State is expected to increase its consumption of natural gas in order to meet the State's electricity demand in future years.

Figure 4-4. Primary Fossil Fuel Energy Use at New York Power Stations by Fuel Type



GHG emissions from power supply and delivery within New York State by source category for 1990 through 2030 are shown in Figure 4-5. Between 1990 and 2011, total GHG emission from power supply and delivery (including imports) decreased by approximately 22 million metric tons of carbon dioxide equivalent (MMtCO_2e) to reach approximately 46 MMtCO_2e. Total GHG emissions including imports are forecasted to remain relatively stable in the near future, rising by only approximately 4 MMtCO_2e from 2011 to 2030. Emissions of SF_6 from electrical equipment have experienced declines since the mid nineties, mostly due to voluntary action by industry. SF_6 emissions from electric power T&D were approximately 1.3 MMtCO_2e in 1990 and decreased to approximately 0.5 MMtCO_2e in 2011. Emissions are forecasted to remain at approximately 0.5 MMtCO_2e through 2030.

The largest absolute increase in GHG emissions between 1990 levels and 2030 status quo levels comes from natural gas, with emissions rising from approximately 13 MMtCO_2e in 1990 to approximately 29 MMtCO_2e in 2030, as indicated by Table 4-2. While emissions associated with natural gas combustion more approximately doubled over that timeframe, the electricity generated from that fuel source tripled. During the same time period emissions associated with coal combustion decreased by approximately 66% from approximately 25MMtCO_2e in 1990 to approximately 8 MMtCO_2e in 2030. Because coal is a more carbon-intensive fuel than natural gas, the 66% decrease in emissions from coal was associated with a decrease in electricity generation of approximately 61%.

Figure 4-5. GHG Emissions from Power Supply and Delivery by Source Category, 1990 – 2030, Status Quo Forecast

CO_2 emissions from municipal waste combustion are assumed to come from the non-biogenic portions of the waste only. In accordance with EPA guidelines, the biogenic portions of the waste are assumed to have no net CO_2 emissions.

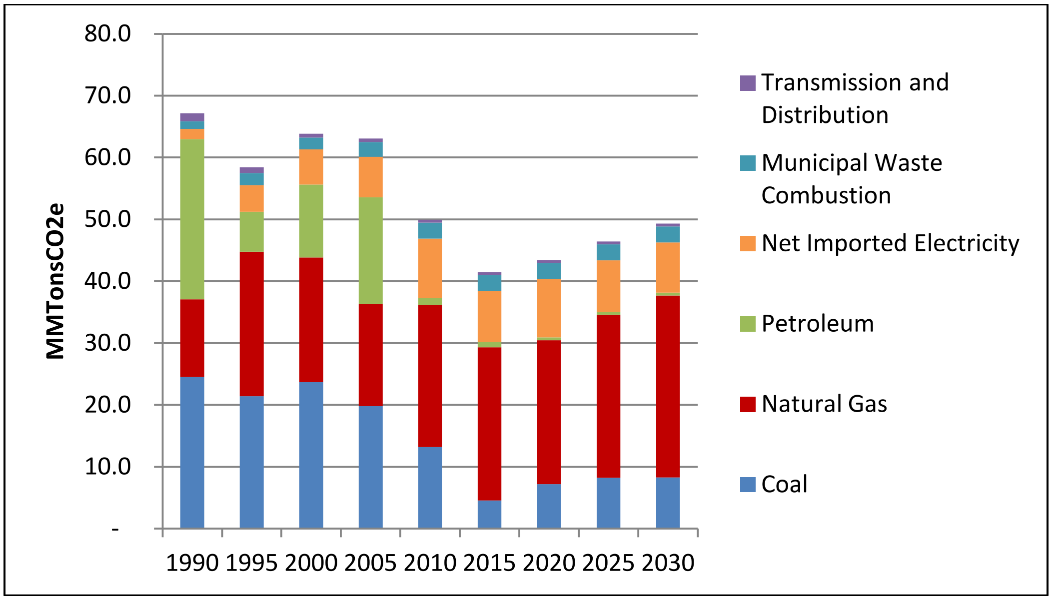


Table 4-2. GHG Emissions from Power Supply and Delivery by Source Category, 1990 – 2030 ($MMtCO_2e$)

CO_2 emissions from municipal waste combustion are assumed to come from the non-biogenic portions of the waste only. In accordance with EPA guidelines, the biogenic portions of the waste are assumed to have no net CO_2 emissions.

Source Category	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Natural Gas	12.6	23.4	20.2	16.5	23.0	23.5	24.8	23.2	26.4	29.4
Coal	24.5	21.4	23.7	19.8	13.2	9.2	4.5	7.2	8.2	8.3
Petroleum	25.9	6.5	11.8	17.3	1.1	0.6	0.9	0.5	0.5	0.5
Municipal Waste Combustion	1.3	2.0	1.9	2.4	2.6	2.6	2.6	2.6	2.6	2.6
Electricity T&D	1.3	0.9	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Net Imports of Electricity	1.6	4.3	5.7	6.6	9.6	9.1	8.3	9.5	8.3	8.1
Electric Power including Imports	**67.2**	**58.4**	**63.9**	**63.1**	**49.9**	**45.5**	**41.5**	**43.4**	**46.4**	**49.3**
Electric Power excluding Imports	**65.5**	**54.1**	**58.2**	**56.5**	**40.3**	**36.4**	**33.2**	**33.9**	**38.1**	**41.2**

5 Agriculture

5.1 Overview

The emissions discussed in this chapter refer to non-energy methane (CH_4) and nitrous oxide (N_2O) emissions from both livestock and crop production. Energy emissions related to agricultural practices (combustion of fossil fuels to power agricultural equipment) are included in the residential, commercial, and industrial (RCI) fuel consumption sector estimates (see Chapter 1).

The inventory and forecast account for both direct and indirect emissions of N_2O-related to livestock and crop production. Direct emissions occur at the site of application of manure, fertilizer, and sewage sludge 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 be re-deposited, enter the nitrification/denitrification cycle, and 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 off-site and then be emitted as N_2O.

The primary agricultural GHG sources—livestock and agricultural soils—are further subdivided as described in the following sections.

5.1.1 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 fore-stomach.

Manure management: CH_4 and N_2O emissions from the storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons) occur as a result of manure 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 operations). 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.

5.1.2 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: This source category covers N_2O emissions from the decomposition of crop residues and the production of nitrogen fixing crops.

Animal production: This source category covers N_2O emissions resulting from animal excretions directly on agricultural soils (e.g. pasture, paddock or range) or manure spreading on agricultural soils, including leaching and runoff.

5.2 Emissions Inventory and Forecast

5.2.1 Inventory Data and Methodology

Historical GHG emissions were estimated using the SIT software and the methods provided in the EIIP guidance document for the sector.[64] In general, the SIT methodology applies emission factors developed for the U.S. to activity data for the agriculture sector. Activity data include livestock population statistics, amounts of fertilizer applied to crops, and trends in manure management practices. This methodology is based on international guidelines developed by sector experts for preparing GHG emissions inventories.[65,66]

Historical data on crop production in New York and on the number of animals in the State were obtained from the United States Department of Agriculture (USDA), National Agriculture Statistical Service (NASS) and incorporated as defaults in SIT.[67] The default SIT manure management system assumptions for each livestock category were used for this inventory. SIT data on fertilizer usage came from *Commercial Fertilizers*, a report from the Fertilizer Institute and are also contained as defaults with the SIT module. Details for each of the livestock and crop production emission sources are provided below.

---

64 GHG emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter 8. "Methods for Estimating Greenhouse Gas Emissions from Livestock Manure Management", August 2004; and Chapter 10. "Methods for Estimating Greenhouse Gas Emissions from Agricultural Soil Management", December 2006.

65 Revised 1996 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, published by the National Greenhouse Gas Inventory Program of the IPCC, available at (http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm).

66 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, published in 2000 by the National Greenhouse Gas Inventory Program of the IPCC, available at http://www.ipcc-nggip.iges.or.jp/public/gp/english/.

67 USDA, NASS (http://www.nass.usda.gov/Statistics_by_State/New_York/index.asp).

5.2.2 Livestock

Agricultural animals: SIT default data on livestock populations are taken from the 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 SIT.

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 (VS) production rate to estimate the total VS produced. The VS 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.

Nitrous oxide emissions are derived using the same 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 unvolatilized portion 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.

5.2.3 Agricultural Soils

Fertilizers: Direct and indirect emissions from fertilization are calculated using data on the amount of nitrogen applied to the soil in the form of both synthetic and organic fertilizers along with factors on the fraction of nitrogen volatilized and an IPCC-based emission factor for N_2O emissions from the re-deposited nitrogen (0.01 kg N_2O-N/kg N re-deposited).

Crops: Default data on tonnage of crop production from the USDA NASS were used to calculate N_2O emissions from crop residues and crops that fix nitrogen.

Animal production: The calculation of emissions for this source category requires data on animal population, mass and nitrogen emitted per unit of animal mass, as well as the amount of manure left on the soil.

To calculate indirect emissions from this source category, data on nitrogen inputs from animals to crop soils are used along with factors on the fraction of nitrogen volatilized, and an IPCC-based emission factor for N_2O emissions from the re-deposited nitrogen (0.01 kg N_2O-N/kg N re-deposited).

5.3 Forecast Data and Methodology

5.3.1 Livestock

Agricultural animals: Future emissions for enteric fermentation were estimated using a 5 year average of historical emissions.

Manure management: Forecast emissions data for manure management were estimated using a five-year average of historical emissions.

5.3.2 Agricultural Soils

Fertilizers: Forecast emissions estimates for this source category were based on linear extrapolation of historical emissions data.

Crops: Forecast emissions estimates for this source category were based on linear extrapolation of historic emissions data.

Animal production: Forecast emissions estimates for this source category were based on linear extrapolation of historical emissions data.

5.4 Results

Annual GHG emissions from agricultural sources in New York State range between about 5.3 and 5.4 $MMtCO_2e$ during the time period between 1990 and 2030, generally staying stable over time, as shown in Figure 5-1,. Detailed information on GHG emissions from agricultural sources is provided in Table 5-1. Enteric fermentation accounted for about 54% (2.9 $MMtCO_2e$) of total agricultural emissions in both 1990 and 2030. The manure management category accounted for 14% (0.8 $MMtCO_2e$) of total agricultural emissions in 1990 and is estimated to account for about 18% (1.0 $MMtCO_2e$) of total agricultural emissions in 2030. The agricultural soils category shows 1990 emissions accounting for 32% (1.7 $MMtCO_2e$) of total agricultural emissions and 2030 emissions estimated to be about 28% (1.5 $MMtCO_2e$) of total agricultural emissions.

Figure 5-1. GHG Emissions from Agriculture, 1990 – 2030

The Agricultural Soil Management category includes emissions from fertilizers, crops (crop residues and nitrogen fixing crops), and animal production. Soil carbon sequestration is not shown (see Table 5-1).

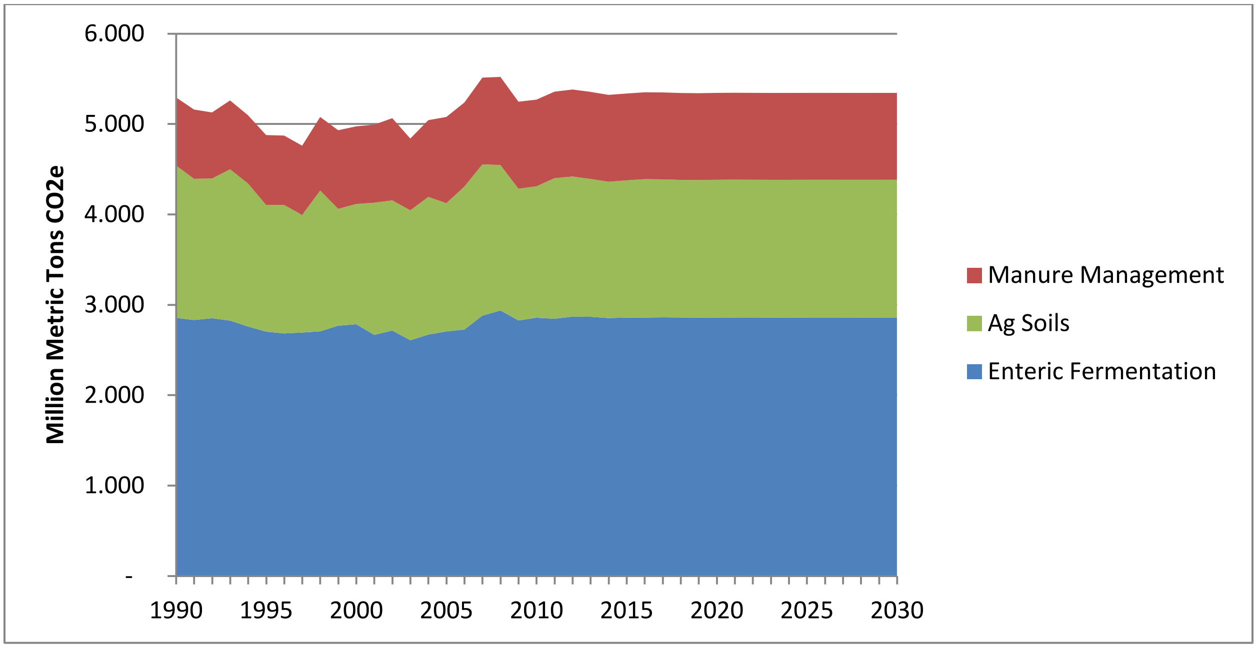


Table 5-1. GHG Emissions from Agriculture, 1990 – 2030 (MMtCO_2e)

Source Category	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Enteric Fermentation	2.9	2.7	2.8	2.7	2.9	2.8	2.9	2.9	2.9	2.9
Manure Management	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Agricultural Soil Management	1.7	1.4	1.3	1.4	1.5	1.6	1.5	1.5	1.5	1.5
Total	**5.3**	**4.9**	**5.0**	**5.1**	**5.3**	**5.4**	**5.3**	**5.3**	**5.3**	**5.3**

6 Waste Management

6.1 Overview

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

6.1.1 Landfills

Municipal solid waste landfills: Methane (CH_4) emissions are generated from the anaerobic decomposition of the organic matter present in landfilled waste by methanogenic bacteria. Some municipal solid waste (MSW) landfills employ control technologies, such as flares that convert the CH_4 portion of recovered landfill gas to carbon dioxide (CO_2), to reduce the emissions of GHGs to the atmosphere.

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

6.1.2 Municipal Wastewater Management

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

In addition to the sources outlined in previous sections, emissions can also result from industrial wastewater treatment, commercial/industrial waste incineration, and MSW combustion that results in energy production (waste-to-energy combustion). Only municipal wastewater treatment sources were considered based on the information presently available at the State level. There is no significant commercial/industrial waste incineration within the state, and waste-to-energy combustion emissions are accounted for in Chapter 4. Note that this inventory does not currently capture any other forms of waste combustion, including medical waste or hazardous waste incineration.

6.2 Emissions Inventory and Forecast

6.2.1 Data and Methodology

6.2.1.1 Landfills

Municipal solid waste landfills: The inventory data on municipal solid waste landfills for 1990 – 2006 was a combination of total waste emplacement data at landfills provided by New York State Department of Environmental Conservation (NYSDEC) and the United States Environmental Protection Agency (U.S. EPA) Landfill Methane Outreach Program (LMOP) database.[68] After 2006, SIT module default values and default emissions factors were selected. The landfill forecast through 2030 is based upon a three-year average of historical data.

6.2.1.2 Wastewater Management

For municipal wastewater treatment, emissions are calculated in the SIT based on state population, assumed biochemical oxygen demand (BOD) and protein consumption per capita, and emission factors for N_2O and CH_4. The key SIT default values are shown in Table 6-1. Municipal wastewater treatment emissions were therefore based on the population growth rate for 1990 – 2011, which was 0.37% per year on average over the timeframe.

Table 6-1. SIT Key Default Values for Municipal Wastewater Treatment

Source: U.S. EPA State Inventory Tool – Wastewater Module; methodology and factors taken from U.S. EPA, Emission Inventory Improvement Program, Volume 8, Chapter 12, December 2006.

Variable	Default Value
BOD	0.09 kg /day-person
Amount of BOD anaerobically treated	16.25%
CH_4 emission factor	0.6 kg/kg BOD
New York residents not on septic	79%
Water treatment N_2O emission factor	4.0 g N_2O/person-yr
Biosolids emission factor	0.005 kg N_2O-N/kg sewage-N

68 EPA LMOP Project Index. Available at http://www.epa.gov/lmop/projects-candidates/index.html

6.3 Results

The emission estimates for the waste management sector are shown in Figure 6-1 and Table 6-2. Overall, the sector accounts for 10.01 MMtCO$_2$e in emissions for 2011. The emission forecast was held constant at the 2011 value through 2030. In 2011, municipal landfills accounted for 81% of total waste management emissions. The emission forecast was held constant at the 2011 value through 2030. In 2011, about 19% of the waste management sector emissions were contributed by municipal wastewater treatment. Note that these estimates are based on the default parameters listed in Table 6-1. The contribution to the total waste sector emissions from the municipal wastewater treatment sector is expected to remain at approximately 19% through 2030.

Figure 6-1. GHG Emissions from Waste Management, 1990 – 2030

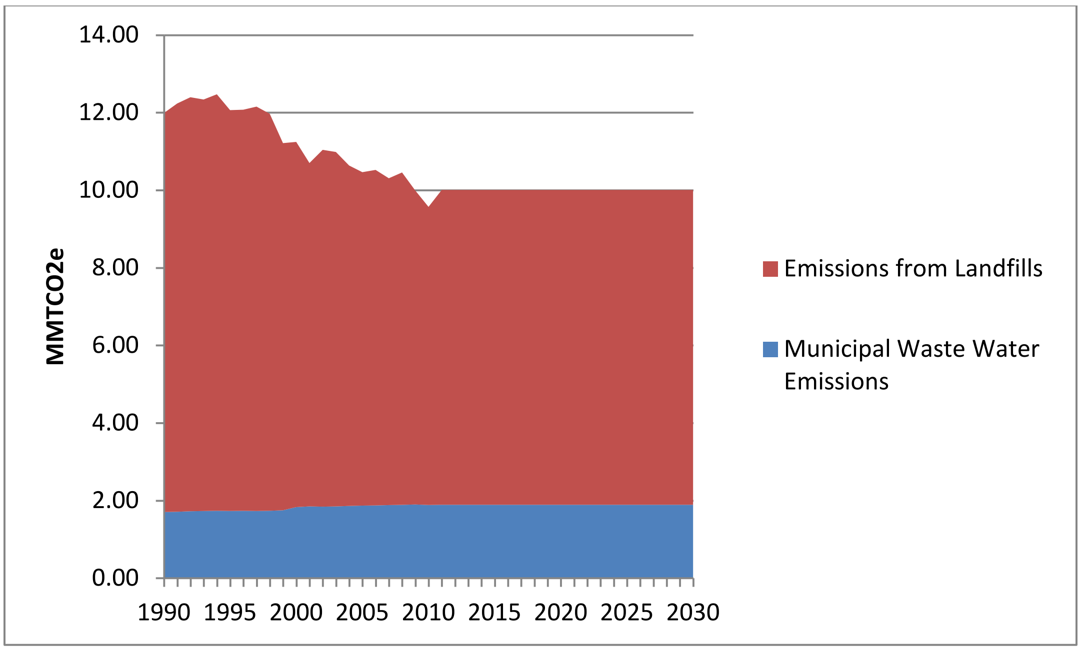


Table 6-2. GHG Emissions from Waste Management (MMtCO$_2$e), 1990 – 2030

Source Category	1990	1995	2000	2005	2010	2011	2015	2020	2025	2030
Municipal Wastewater	1.70	1.73	1.83	1.87	1.89	1.89	1.89	1.89	1.89	1.89
Landfills	10.28	10.33	9.41	8.59	7.68	8.11	8.11	8.11	8.11	8.11
Total	11.99	12.06	11.24	10.46	9.57	10.01	10.01	10.01	10.01	10.01

These results do not indicate the impact of two significant emissions sources that arise from waste management in New York State: export of MSW and embedded emissions within MSW. Because this inventory and forecast focuses only on emissions that take place within the borders of New York State, emissions from the exported MSW are not included.

Many of the materials that comprise MSW – aluminum cans, steel cans, glass, plastic, paper, etc. – represent significant embedded GHG emissions, which are also not included. 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 good or packaging to the marketplace.

Appendix A

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	159.3
Coal	204.9
Distillate Fuel Oil (No. 2)	163.8
Gasoline	155.0
Kerosene	162.1
Natural Gas	117.1
Propane/Liquefied Petroleum Gas	136.9
Residual Fuel Oil (No. 6)	166.3
Wood	15.8
Source: Emissions Factors were derived from the U.S. EPA's State Inventory Tool (release Feb, 2013)	

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)	

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and funding to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

New York State Energy Research and Development Authority

17 Columbia Circle
Albany, New York 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

New York State Greenhouse Gas Inventory and Forecast: Inventory 1990-2011 and Forecast 2012-2030

Final Report
April 2014
Revised June 2015

EA-2011 NYS GGI&F-r-1-v2
6/15