

Archived [2021] version of the NYS Statewide GHG Emissions Report

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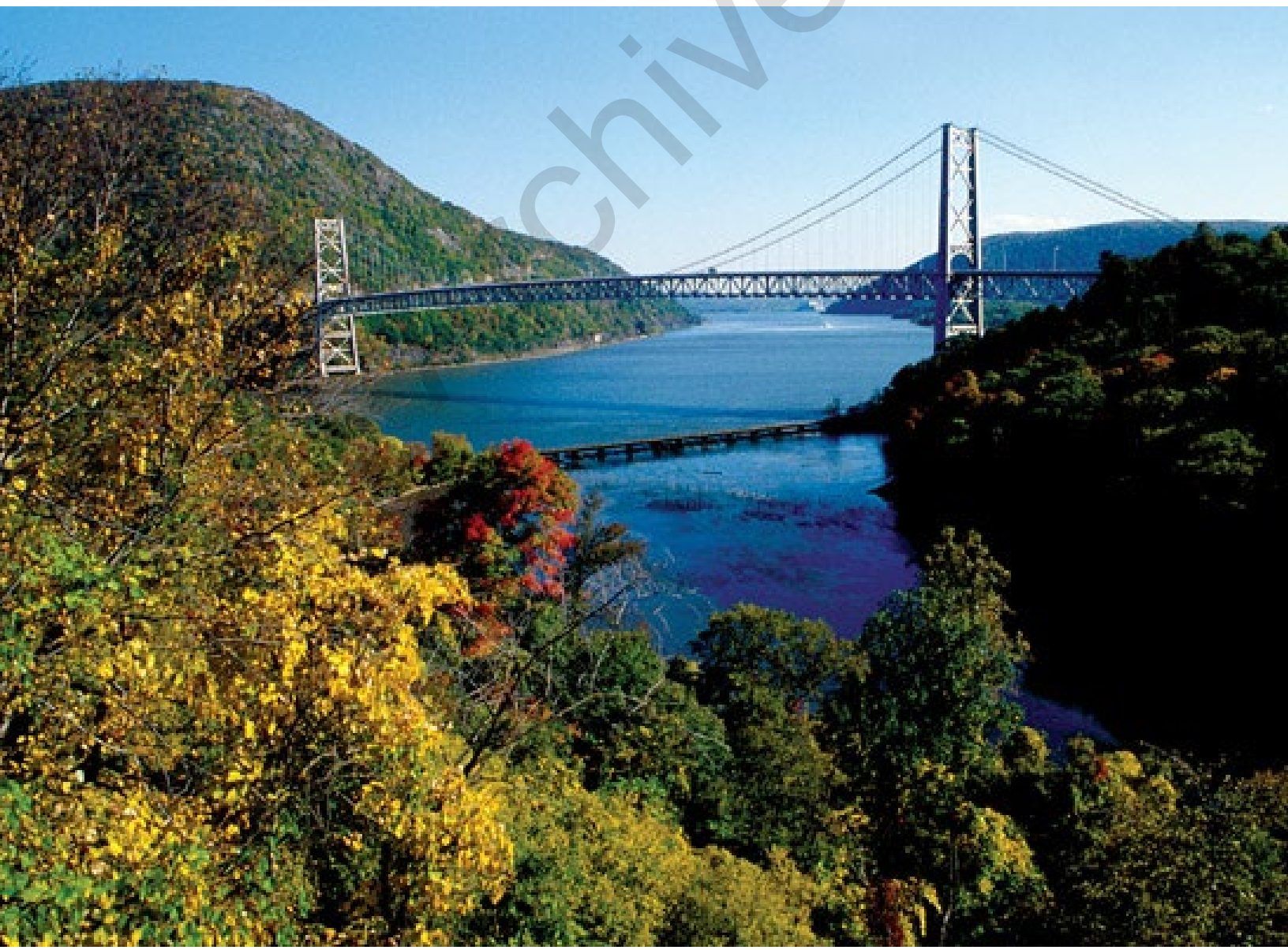


Department of
Environmental
Conservation

2021 Statewide GHG Emissions Report

SUMMARY REPORT

Kathy Hochul, Governor | Basil Seggos, Commissioner



Archived

Acknowledgements.....	i
Figures and Tables.....	ii
Executive Summary.....	iii
Format of This Report.....	iii
Current New York State Greenhouse Gas Emissions	iii
Trends in Greenhouse Gas Emissions, 1990-2019	vi
Trends in IPCC Emission Sectors, 1990-2019	vi
Emission Trends by Economic Sectors and CLCPA Scoping Plan	vii
2021 Statewide Greenhouse Gas Emissions Report	1
I. Introduction to the Report	1
Organization of the Report.....	1
Annual Inventory Process	1
Greenhouse Gas Accounting Used in This Report	3
Greenhouse Gases and Other Pollutants	5
II. Trends in New York State Greenhouse Gas Emissions, 1990-2019.....	8
III. Trends in Greenhouse Gas Emission Sectors, 1990-2019	9
Energy.....	10
Industrial Processes and Product Use (IPPU)	11
Agriculture, Forests, and Other Land Use (AFOLU).....	12
Waste.....	13
Emissions by Economic Sector and CLCPA Scoping Plan	14
IV. Additional Information	15
Comparison with 1990 Baseline in Part 496	15
CLCPA Informational Items.....	16
Appendix A. Emission Factors for Use by State Agencies and Applicants.....	17
Appendix B: Abbreviations	19
Appendix C: References	20

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- DEC's Division of Air Resources
- DEC's Division of Materials Management
- DEC's Division of Mineral Resources
- DEC's Division of Lands and Forests
- Department of Agriculture and Markets
- Department of Public Service

We also thank the Secretariat and fellow State Members of the U.S. Climate Alliance for our ongoing collaboration and the U.S. Environmental Protection Agency Climate Change Division for their support of State programs.

DEC's GHG Inventory Team

Office of Climate Change: Suzanne Hagell, Greg Mumby, Caitlin Frame
Division of Air Resources: Nathan Putnam

Figures and Tables

Table ES.1: Comparison of GHG Emission Accounting Formats Used in This Report	iii
Table ES.2: 2019 New York State GHG Emissions, by IPCC Sector	iv
Table ES.3: 2019 New York State GHG Emissions, by Economic Sector	v
Figure ES.1: NYS Statewide Greenhouse Gas Emissions by Gas, 1990-2019 (mmt CO ₂ e GWP20)	vi
Figure ES.2: NYS Statewide Greenhouse Gas Emissions by Sector, 1990-2019 (mmt CO ₂ e GWP20)	vii
Figure ES.3: NYS Statewide Emissions by Economic Sector, 1990-2019 (mmt CO ₂ e GWP20)	vii
Figure 1: New York State Greenhouse Gas Inventory Process Diagram	2
Table 1: Example Resources Used in This Report	2
Table 2: Global Warming Potential Values	5
Figure 2: NYS Statewide Greenhouse Gas Emissions by Gas, 1990-2019 (mmt CO ₂ e GWP20)	9
Figure 3: Comparison of 2019 Emissions, CLCPA and Standard Format	9
Figure 4: NYS Statewide Greenhouse Gas Emissions by Sector, 1990-2019 (mmt CO ₂ e GWP20)	10
Figure 5: Trends in Energy Sector Emissions	11
Figure 6: Trends in Industrial Process and Product Use Sector Emissions	12
Figure 7: Trends in AFOLU Agriculture Sector Emissions	13
Figure 8: Trends in AFOLU Net Emission Removals	13
Figure 9: Trends in Waste Sector Emissions	14
Figure 10: NYS Greenhouse Gas Emissions by Economic Sector (mmt CO ₂ e GWP20)	15
Table 3: Comparison of 1990 Statewide Greenhouse Gas Emission Totals	15
Table 8: Location of CLCPA Informational Items	16
Table A1: 2019 Emission Rates for Upstream Out-of-State Sources (g/mmbtu)	17
Table A2: 2019 Emission Rates for Fossil Fuel Products (g/mmbtu)	18
Table A3: 2019 Emission Rates for Downstream In-State Sources (g/mmbtu)	18
Table A4: High Heating Value of Select Fuels (mmbtu)	18

Executive Summary

The New York State Statewide Greenhouse Gas Emissions Report is a foundational component of the State's strategy for addressing climate change. This emission inventory is designed to meet the requirements of the Climate Leadership and Community Protection Act (CLCPA),¹ measure progress at reducing greenhouse gas (GHG) emissions, and to make greenhouse gas information accessible to a broad audience. This report provides the most up-to-date estimation of annual emissions from 1990 through 2019. The structure and content of this report is aligned with guidelines from the Intergovernmental Panel on Climate Change (IPCC) for governmental greenhouse gas accounting as used in the U.S. national greenhouse gas emissions report (EPA 2021a). Any deviations from these guidelines reflect available datasets and the requirements of New York State law.

Format of This Report

This report includes five stand-alone documents: one summary report and four sectoral reports. This *Summary Report* provides general background and economy-wide trends. The *Sectoral Reports* each review the data, methods, and results of analysis for specific sectors. The default format used throughout this report meets the requirements of the CLCPA, but this Summary Report also presents results in a conventional format developed for national parties to the United National Framework Convention on Climate Change (UNFCCC). The conventional format is comparable to emission information issued by other governments and organizations and is provided for informational purposes. As outlined in Table ES.1, the differences between the CLCPA and conventional accounting relate to the scope of emissions, the use of gross as well as net emission totals, and Global Warming Potential (GWP).

Table ES.1: Comparison of GHG Emission Accounting Formats Used in This Report

	CLCPA Format	Conventional Format*
Emissions Scope	In-state sources, imported electricity and fossil fuels, exported waste	In-state sources only
Gross versus Net	Gross and Net totals*	Net totals are used, but gross emissions are also reported
Global Warming Potential	20-Year GWP from IPCC's Fifth Assessment Report (AR5)	100-Year GWP from IPCC's Fourth Assessment Report (AR4)

*The Statewide GHG Emission Limits established by ECL § 75-0107 and reflected in 6 NYCRR Part 496 are measured in gross emissions and the CLCPA's zero emission goal established by ECL § 75-0103(11) refers to net emissions.

Current New York State Greenhouse Gas Emissions

In 2019, statewide gross emissions were 379.43 million metric tons of carbon dioxide equivalent (mmt CO₂e) using CLCPA accounting (Table ES.2). Carbon dioxide (CO₂) and methane (CH₄) comprised the largest portion of emissions, or 58% and 35% respectively. Energy was the largest source of emissions (76%), primarily from fuel combustion and fugitive emissions from imported fossil fuels. When comparing economic sectors (Table ES.3), the largest sources are Buildings (32%) and Transportation (28%). Approximately 8% (29.11mmt CO₂e) of 2019 emissions were removed, primarily via carbon sequestration in forests, resulting in a net emission total of 338.53mmt CO₂e.

¹ Environmental Conservation Law (ECL) Article 75 and as adopted in 6 NYCRR Part 496

Table ES.2: 2019 New York State GHG Emissions, by IPCC Sector

CLCPA Format (mmtCO₂e GWP20)	CO₂*	CH₄	N₂O	PFC	HFC	SF₆	NF₃	Total	% of Total	UNFCCC Total**
Energy	216.07	72.46	0.92	-	-	0.13	-	289.58	76%	164.75
Fuel Combustion	168.67	2.02	0.76	-	-	-	-	171.45	45%	159.31
<i>Electric Power</i>	22.03	0.04	0.05	-	-	-	-	22.12	6%	21.51
<i>Residential</i>	39.38	1.27	0.07	-	-	-	-	40.72	11%	36.18
<i>Commercial</i>	22.35	0.33	0.02	-	-	-	-	22.70	6%	21.94
<i>Industrial</i>	9.08	0.07	0.03	-	-	-	-	9.18	2%	7.38
<i>Transportation</i>	75.84	0.31	0.59	-	-	-	-	76.73	20%	72.29
Fugitive Emissions	0.17	14.05	+	-	-	-	-	14.22	4%	4.35
Electricity T&D	-	-	-	-	-	0.13	-	0.13	0%	0.17
Other Use of Fuels	0.93	-	-	-	-	-	-	0.93	0%	0.93
Out of State Emissions	46.30	56.39	0.16	-	-	-	-	102.85	27%	-
<i>Imported Electricity</i>	7.81	0.01	0.02	-	-	-	-	7.84	2%	-
<i>Imported Fossil Fuels</i>	38.49	56.37	0.15	-	-	-	-	95.01	25%	-
Industrial Processes and Product Use	2.08	+	0.02	0.10	20.89	+	+	23.10	6%	11.59
Metals	0.37	+	-	0.02	-	-	-	0.40	0%	0.40
Minerals	1.71	-	-	-	-	-	-	1.71	0%	1.71
Electronics	-	-	0.02	0.08	+	+	+	0.12	0%	0.16
Product Use	-	-	+	-	20.89	-	-	20.89	6%	9.32
Agriculture, Forestry, and Other Land Use	0.15	19.20	1.86	-	-	-	-	21.21	6%	7.77
Livestock	-	19.20	0.36	-	-	-	-	19.55	5%	6.11
Soil Management	0.15	-	1.5	-	-	-	-	1.65	0%	1.65
Waste	3.59	41.41	0.54	-	-	-	-	45.54	12%	10.45
Solid Waste Management	0.52	19.44	-	-	-	-	-	19.96	5%	5.79
Waste Combustion	2.49	0.07	0.03	-	-	-	-	2.60	1%	2.18
Wastewater	-	6.43	0.50	-	-	-	-	6.93	2%	2.48
Exported Waste†	0.05	15.94	+	-	-	-	-	16.05	4%	-
Gross Total	221.89	133.07	3.35	0.10	20.89	0.13	+	379.43		194.56
<i>% Gross Total</i>	58%	35%	1%	+	6%	+	+			
Net Emission Removals	(29.11)							(29.11)		(29.11)
Net Total*	180.98	133.07	3.35	0.10	20.89	0.13	+	338.53		165.46
<i>% Net Total</i>	53%	39%	1%	+	6%	+	+			

NA Not Applicable. "+" less than 0.01mmt or less than 0.1%. Totals may not sum due to independent rounding.

*Gross CO₂ emissions include biogenic CO₂. The Net total and UNFCCC total omit 11.79mmt of biogenic CO₂.

**UNFCCC Total refers to conventional accounting used by other governments, applies a 100-year GWP (IPCC 2007), omits biogenic CO₂, and does not include emissions outside of New York State.

† Exported waste refers to emissions generated from waste sent to landfills and combustors outside of New York State.

Table ES.3: 2019 New York State GHG Emissions, by Economic Sector

CLCPA Format (mmtCO_{2e} GWP20)	CO₂*	CH₄	N₂O	PFC	HFC	SF₆	NF₃	Total	% of Total	UNFCCC Format**
Electricity	35.65	14.99	0.08			0.13		50.85	13%	21.68
Fuel Combustion	22.03	0.04	0.05	-	-	-	-	22.12	6%	21.51
Electricity T&D	-	-	-	-	-	0.13	-	0.13	0%	0.17
Imported Fuels	5.80	14.94	0.02	-	-	-	-	20.76	5%	NA
Imported Electricity	7.81	0.01	0.02	-	-	-	-	7.84	2%	NA
Transportation	91.14	11.40	0.66		3.71			106.92	28%	72.36
Fuel Combustion	74.46	0.31	0.59	-	-	-	-	75.36	20%	70.91
Product Use	-	-	-	-	3.71	-	-	3.71	1%	1.44
Imported Fuels	17.47	10.31	0.08	-	-	-	-	27.86	8%	NA
Buildings	74.70	28.22	0.14		17.18			120.25	32%	66.00
Residential Fuel Comb.	39.38	1.27	0.07	-	-	-	-	40.72	11%	36.18
Commercial Fuel Comb.	22.35	0.33	0.02	-	-	-	-	22.70	6%	21.94
Product Use	-	-	-	-	17.18	-	-	17.18	5%	7.88
Imported Fuels	12.99	26.62	0.04	-	-	-	-	39.65	10%	NA
Industry	16.64	17.85	0.06	0.10	+	+	+	34.67	9%	16.31
Industrial Processes [†]	2.08	+	0.02	0.10	+	+	+	2.21	1%	2.27
Oil and Gas Industry ^{††}	1.55	14.05	+	-	-	-	-	15.60	4%	5.73
Fuel Combustion	9.08	0.07	0.03	-	-	-	-	9.18	2%	7.38
Other Uses of Fuels	0.93	-	-	-	-	-	-	0.93	0%	0.93
Imported Fuels	2.13	2.41	+	-	-	-	-	6.75	2%	NA
Waste [†]	3.59	41.40	0.54	-	-	-	-	45.54	12%	10.45
Waste	3.02	25.94	0.53	-	-	-	-	29.49	8%	10.45
Exported Waste	0.58	15.47	+	-	-	-	-	16.05	4%	NA
Agriculture [†]	0.15	19.20	1.86	-	-	-	-	21.21	6%	7.77
Gross Total	221.89	133.07	3.35	0.10	20.89	0.13	+	379.43		194.56
% Gross	58%	35%	1%	+	6%	+	+			
Net Emission Removals	(29.11)							(29.11)		(29.11)
Net Total	180.98	133.07	3.35	0.10	20.89	0.13	+	338.53		165.46
% Net	53%	39%	1%	+	6%	+	+			

NA Not Applicable. "+" less than 0.01mmt or less than 0.1%. Totals may not sum due to independent rounding.

*Gross CO₂ emissions include biogenic CO₂. The Net total and UNFCCC total omit 11.79mmt of biogenic CO₂.

**UNFCCC Total refers to conventional accounting used by other governments, applies a 100-year GWP (IPCC 2007), omits biogenic CO₂, and does not include emissions outside of New York State.

[†]See previous table for sources within these emission categories.

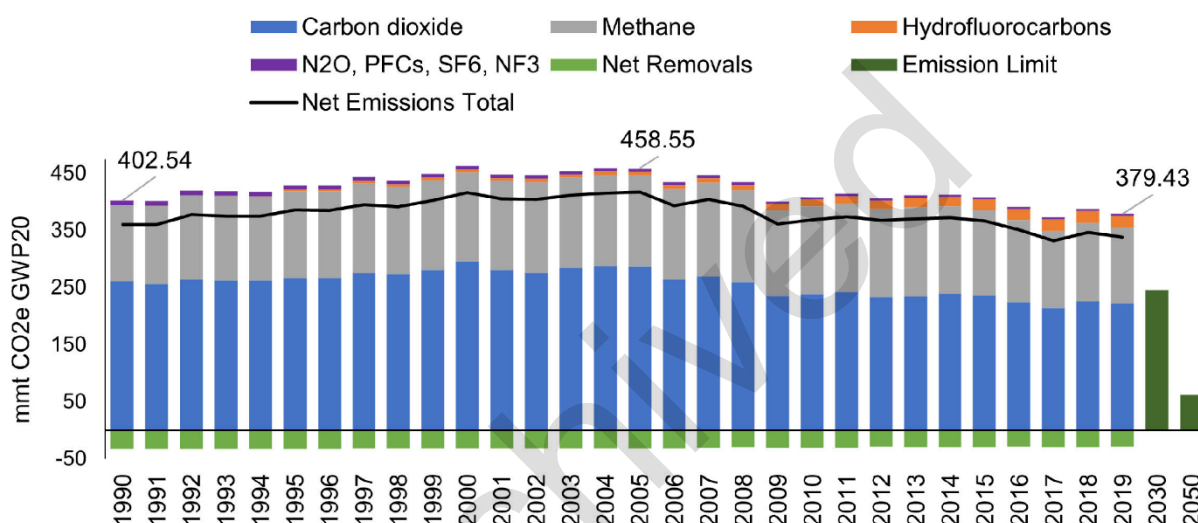
^{††}Oil and Gas Industry includes fuel use in pipelines and fugitive emissions within New York.

Trends in Greenhouse Gas Emissions, 1990-2019

Total statewide gross emissions in 2019 were 6% below 1990 and 17% below 2005 levels, when assessed using CLCPA accounting. Figure ES.1 shows overall trends in statewide emissions by gas on an annual basis, including gross and net emission totals, as well as the emission limits for 2030 and 2050 pursuant to ECL § 75-0107 and 6 NYCRR Part 496.

Annual emissions of CO₂ declined 15%, or 39mmt CO₂e, from 1990 to 2019, but this was coupled with an increase in hydrofluorocarbon emissions of over 20mmt CO₂e. Methane emission rates were approximately the same in 1990 and 2019. Emission rates for remaining gases declined 58% since 1990, or 5.03mmt CO₂e, and remain at relatively low rates in terms of carbon dioxide equivalence. Annual, net emission removals of CO₂ declined 11% or from -32.69mmt to -29.11mmt.

Figure ES.1: NYS Statewide Greenhouse Gas Emissions by Gas, 1990-2019 (mmt CO₂e GWP20)



As a point of comparison, when applying the conventional, or UNFCCC, format for governmental accounting, emissions declined 21% percent from 1990 to 2019, or from a net emission rate of 210.43mmt to 165.46mmt CO₂e GWP100. This format does not meet CLCPA accounting requirements.

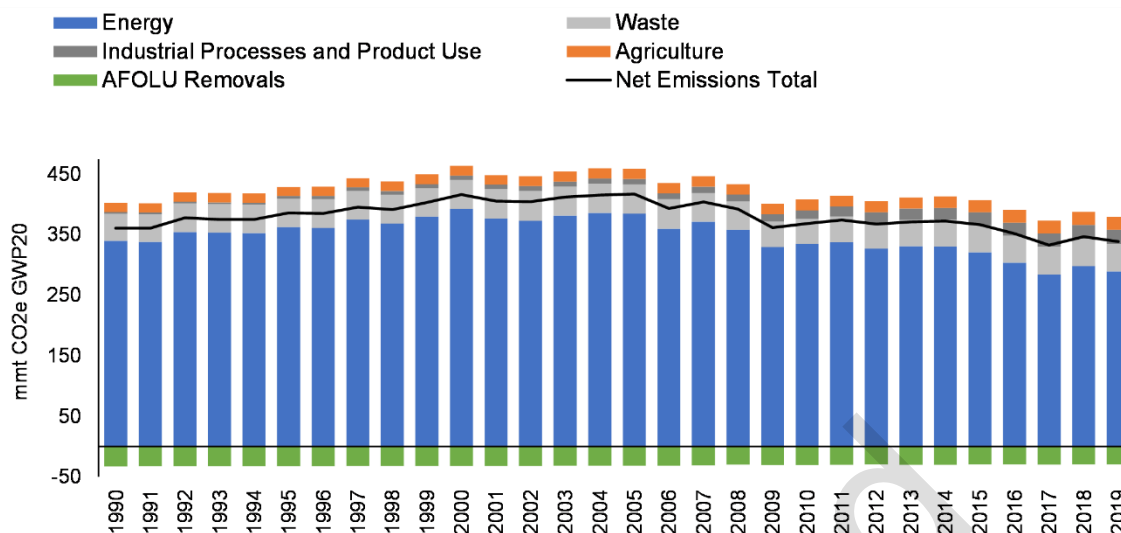
Trends in IPCC Emission Sectors, 1990-2019

In Figure ES.2, emissions are organized into the sectors described in IPCC guidelines (IPCC 2006). The Energy sector encompasses emissions associated with the energy system, including electricity, transportation, and building/industrial heating. The Industrial Process and Product Use (or IPPU) sector covers emissions associated with manufacturing and manufactured products. The Waste sector encompasses any activities to manage human wastes. Finally, the Agriculture, Forest, and Other Land Use (or AFOLU) sector encompasses emissions from the management of lands and livestock as well as net emission removals from land management and the long-term storage of carbon in durable goods.

The Energy sector represents the majority of emissions and energy emissions in 2019 were 15% lower than in 1990 (Figure ES.2). However, not all energy emissions were reduced over this time period. Additionally, the overall reduction in energy emissions was offset by increases in all other sectors and by a 11% decline in net emission removals. The largest increases occurred in IPPU due to the increasing

use of hydrofluorocarbons (20mmt CO₂e) and in AFOLU resulting from changes in agricultural practices (6mmt CO₂e). Waste sector emissions increased slightly over 1mmt CO₂e.

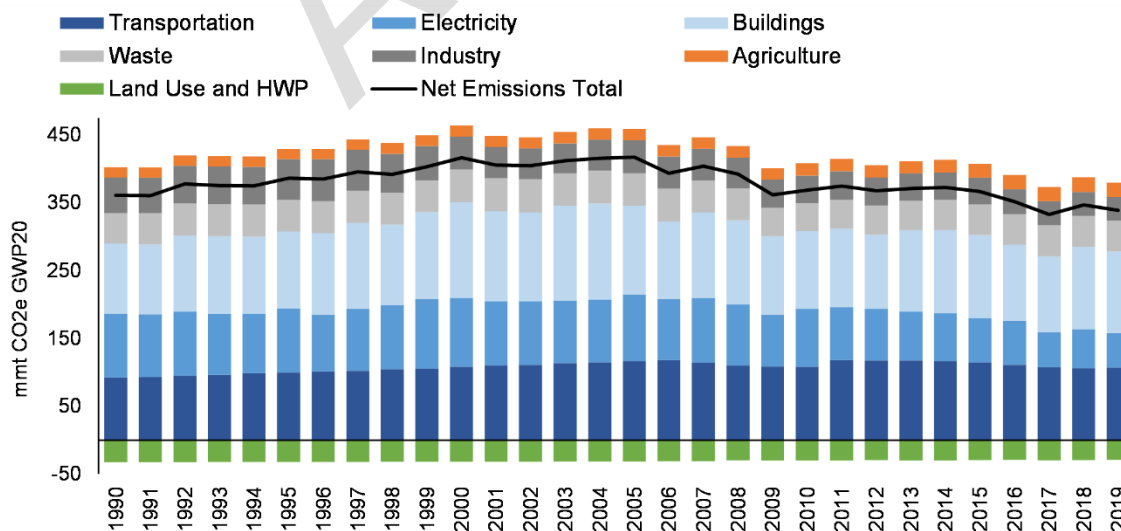
Figure ES.2: NYS Statewide Greenhouse Gas Emissions by Sector, 1990-2019 (mmt CO₂e GWP20)



Emission Trends by Economic Sectors and CLCPA Scoping Plan

Emissions can also be organized into sectors that reflect economic drivers and policy. Table ES.3 and Figure ES.3 organizes emissions according to the New York State Climate Action Council Draft Scoping Plan. For example, energy fuels were assigned to the sector where those fuels were used, such as in the transportation system or for electricity generation. Similarly, products that contain hydrofluorocarbons, such as air-conditioning equipment, were assigned to the transportation or buildings sectors. The most significant trends show a 46% decrease in electricity emissions and a 34% decrease in industrial emissions (15mmt and 18mmt CO₂e, respectively). These reductions were offset by a 16% increase in emissions from buildings and transportation (17mmt and 15mmt, respectively). Agricultural and waste emission increased by 6mmt and 1mmt CO₂e, respectively.

Figure ES.3: NYS Statewide Emissions by Economic Sector, 1990-2019 (mmt CO₂e GWP20)



2021 Statewide Greenhouse Gas Emissions Report

I. Introduction to the Report

This annual report on statewide greenhouse gas (GHG) emissions provides a summary of emissions for the years 1990-2019 and includes information on the relative contribution of each gas and emission source specified in the Climate Leadership and Community Protection Act.² This includes all anthropogenic greenhouse gas emissions from each sector of the economy for each year.

In producing this report, DEC used the guidelines provided by the International Panel on Climate Change (IPCC) Taskforce on National Inventories, referred to here as the “IPCC guidelines” (IPCC 2006, 2019). The IPCC guidelines are intended for use by national parties to the United Nations Framework Convention on Climate Change (UNFCCC) and represent a rigorous set of procedures for producing a full assessment of anthropogenic emission sources within a jurisdiction. The U.S. national greenhouse gas inventory applies these guidelines and is the primary model used for this state report (EPA 2021a).

The emission information provided in this report is intended to provide information in a way that is useful to the public and to policymakers. This includes summaries by gas, by IPCC sectors, and by the economic sectors used in the New York State Climate Action Council Draft Scoping Plan. DEC welcomes feedback on additional ways to present this information in future reports. DEC also intends to make the emission estimates available on Open Data NY so that users can produce their own summaries.

Organization of the Report

The annual report is provided in five stand-alone documents to enable users to locate the information most relevant to their needs. This *Summary Report* compares trends among all emission sectors and provides general information about the reporting process and the legal requirements of this report. The four *Sectoral Reports* provide more technical detail and a review of data, methods, and results for each of the IPCC sectors: Energy, Industrial Processes and Product Use (IPPU), Agriculture Forestry and Other Land Use (AFOLU), and Waste. The Sectoral Reports also provide information on subcategories of emission sources that are not described in the Summary Report. Finally, for informational purposes, the Summary Report provides emission results in a conventional format for ease of comparison to reports by other governments (see “Greenhouse Gas Accounting Used in This Report” below).

- Summary Report (this document)
- Sectoral Report #1: Energy
- Sectoral Report #2: Industrial Processes and Product Use
- Sectoral Report #3: Agriculture, Forestry, and Other Land Use
- Sectoral Report #4: Waste

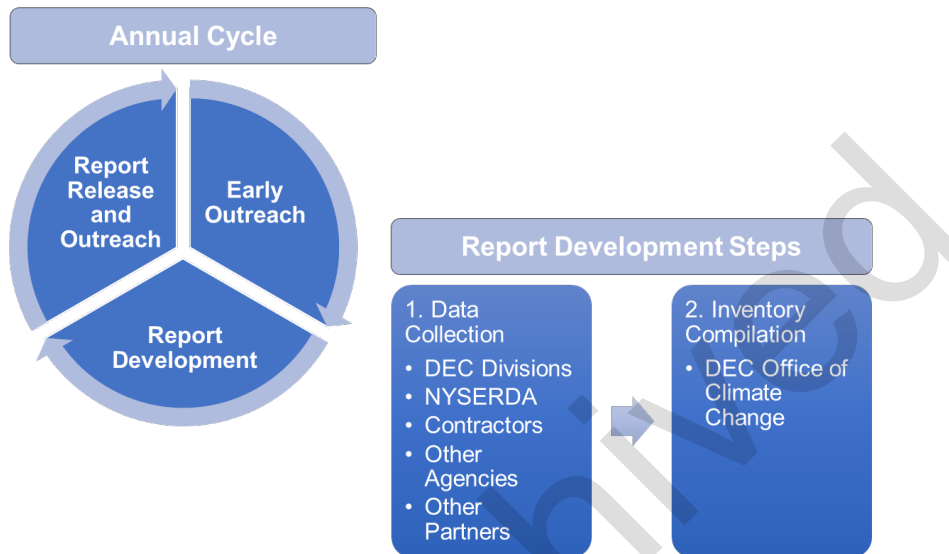
Annual Inventory Process

This report will be updated annually, as required by the CLCPA, following the release of the U.S. national greenhouse gas inventory and related datasets. DEC will update the emission estimation methodology as appropriate in order to incorporate the most recent data and best available methods. Wherever possible, the new methods will be applied to the full historical timeseries. DEC applied the following process for this

² ECL § 75-0105(1).

initial report, consistent with the requirements of the CLCPA (Figure 1). First, DEC invited early input on the scope of emissions to be covered in the report, the organization of the report, and the data and methods used to develop the emission estimates. As part of early outreach and as required by the CLCPA, DEC held three public hearings to seek input. For this report, DEC also consulted early with partners such as the U.S. EPA. Once this phase was completed and the relevant national datasets were made available, DEC developed the written report in collaboration with other State entities, contractors, and partners. Feedback received after the release of this report may be considered in the development of the following year’s report. DEC will accept feedback on the annual reports on an ongoing basis in order to continually improve the data and methods.

Figure 1: New York State Greenhouse Gas Inventory Process Diagram



This report collates information from many sources including national datasets, published academic research, and analyses conducted by private and public entities on behalf of New York State. Certain sources are indicated below (Table 1); details on these and other sources are provided in the Sectoral Reports. While this report uses the best information available at the time of development, DEC will continue to seek improvements wherever possible as it develops future reports. DEC welcomes input on how best to integrate new data into this report as well as other State policies and programs.

Table 1: Example Resources Used in This Report

Energy	Industrial Processes and Product Use	Waste	Agriculture, Forests, and Other Land Use
USEIA State Energy Data System	EPA Greenhouse Gas Reporting Program	DEC Solid Waste Information Management System	USDA Forest Service Inventory and Analysis
Motor Vehicle Emission Simulator (MOVES)	USGS Minerals Information Center		USDA National Agricultural Statistics Service
NYSERDA Oil and Gas Methane Inventory	NYSERDA HFC Inventory		NOAA Coastal Change Analysis Program
USEPA US National Greenhouse Gas Inventory (EPA 2021a) and submissions to the UNFCCC USEPA State Inventory Tool (EPA 2020)			

Greenhouse Gas Accounting Used in This Report

This report uses metrics and an organizational scheme that balances the requirements of the CLCPA against other goals, including alignment with the accounting used by other governments, consistency with other State policies, and to provide a familiar format to the public and stakeholders.

Bottom-up versus Top-down Accounting

As with all governmental emission accounting, this inventory is largely based on “bottom-up” estimates of greenhouse gas emission sources and sinks. Bottom-up methods attempt to estimate emissions from the individual source level, whereas “top-down” methods measure total emissions from multiple potential sources. Governmental emission inventories must look at the individual source level in order to identify and address emission sources. Fortunately, bottom-up estimates can be refined by comparing them to top-down measurements (see the *Sectoral Report #1: Energy* for an example). As the IPCC (2021) describes it, bottom-up emission inventories use empirical upscaling of point measurements, emission inventories and dynamical model simulations and the summation across these to provide total emissions estimates for a region. In contrast, top-down estimates are those constrained by atmospheric measurements and chemistry-transport models in inversion systems. Intercomparison of top-down and bottom-up estimates is useful because discrepancies can point to emission sources that might be unidentified or as yet unaccounted for in bottom-up inventories. Top-down measurements can also provide a cross-check on how closely the scaling and models used in bottom-up estimates actually reflect the atmospheric reality. On the other hand, bottom-up estimate can help break down the total regional emissions provided by top-down measurements by providing local and sector-specific information about emitting activities and nearby facilities.

Emission Scope: In-state, Out-of-state, and Lifecycle Emissions

Governmental greenhouse gas emission inventories that follow the IPCC guidelines are intended to monitor activities that occurred within that government’s jurisdictional boundaries. Unlike other governmental inventories, due to the requirements of the CLCPA, this report includes certain emission sources that are outside of New York State’s borders. Specifically, this report follows the definition of “statewide greenhouse gas emissions” provided in the CLCPA and includes sources within the state plus emissions associated with imported electricity and fossil fuels.³ It also includes emissions associated with wastes that have been exported outside of New York. In this report, these emissions may be referred to as imported, exported, or out-of-state. There are other types of accounting that go beyond jurisdictional boundaries, such as consumption and lifecycle accounting. As described in *Sectoral Report #1: Energy*, lifecycle models were used in the analysis of imported fuels. However, lifecycle accounting is not intended to produce annualized or historical inventories as is needed for this report.

Gross versus Net Greenhouse Gas Emissions

Governmental greenhouse gas inventories that follow the IPCC guidelines typically report emissions and emission removals (otherwise known as sources and sinks) that occurred within the government’s jurisdictional borders over the course of a year. Removals refer to CO₂ taken out of the atmosphere, such as by plants that absorb and store carbon during growth. A net emission total refers to emissions minus removals. Gross emission totals refer to emissions only, with no consideration of carbon removal from the atmosphere. In other words, “gross” emissions are actual emissions and “net” emissions are a component of the IPCC guidelines that also considers emission removals.

³ ECL § 75-0101(13). See also ECL § 75-0105(3).

Unless stated otherwise, emission totals in this report are provided as gross emissions and include all sources of emissions except from the Land Use sector. The Land Use sector is reported in terms of net emission removals over the annual period. For example, total CO₂ associated with forests in a given year could include all of the CO₂ sequestered by trees as well as any gases emitted during forest fires. Consistent with the IPCC guidelines, biogenic CO₂ is a form of gross emissions, but it is treated as zero net emissions in net emission totals. This is a simplified assumption used in the IPCC guidelines that considers the balance of emissions (such as from plant-based fuels) with removals (from the growth of such fuel feedstocks on croplands or forest). Ultimately, this assumes that the annual, net amount of CO₂ in the atmosphere from biogenic sources will be reflected in the global accounting of the Land Use sector.⁴ Put another way, this report follows IPCC guidelines and treats biogenic CO₂ as an anthropogenic emission source that is omitted from net emission totals to avoid double counting CO₂ sources across the Energy and Land Use sectors.

Global Warming Potentials

Greenhouse gases warm the atmosphere as a function of their atmospheric abundances, atmospheric lifetimes, specific warming power per molecule, and their influence on the physical and chemical dynamics of the atmosphere. The impact of a specific greenhouse gas emission on the current and future climate is dependent on this combination of factors as well as the response of the earth system to the emission. The IPCC developed the Global Warming Potential (GWP) metric as one method to compare the impact of a pulse emission of a particular greenhouse gas to a pulse emission of an equal amount of CO₂, integrated over a time horizon that is chosen based on the specific goals that policy makers are trying to achieve. The GWP is reported in units of carbon dioxide equivalence, or “CO₂e”. National governments that report emissions to the UNFCCC apply a GWP integrated over a 100-year time horizon from IPCC’s Fourth Assessment Report (IPCC 2007) and this has become the conventional approach.

The CLCPA requires that this report apply a GWP that is integrated over a 20-year time horizon. Shortening the time horizon over which the GWP is integrated increases the GWP of gases that are shorter-lived than CO₂, such as methane (CH₄; Table 2). In 2020, DEC adopted 20-year GWP values from the IPCC Fifth Assessment Report into the Part 496 regulation, which were the most up-to-date values at the time (IPCC 2013).⁵ For the purposes of this report, greenhouse gas emissions are reported according to that regulation, unless otherwise noted. Newer GWP values are now available and may be adopted in future updates (IPCC 2021). Because different gases have different atmospheric lifetimes, and GWP is integrated over a finite time horizon, there is a range of possible temperature responses to apparently equivalent emissions as quantified by CO₂e (Tanaka and O’Neill 2018). The raw, unweighted tonnage of each emission estimate provided in this report can be determined by dividing by the GWP.

⁴ E.g., IPCC Taskforce on National GHG Inventories (2021) Frequently Asked Questions #Q2-10, available at: <https://www.ipcc-nggip.iges.or.jp/faq/faq.html> (last visited November 4, 2021).

⁵ 6 NYCCR Part 496.

Table 2: Global Warming Potential Values

Gas	CLCPA GWP20 (IPCC AR5)	UNFCCC GWP100 (IPCC AR4)
CO ₂	1	1
CH ₄	84	25
N ₂ O	264	298
HFC-23	10,800	14,800
HFC-32	2430	675
HFC-41	427	92
HFC-125	6090	3500
HFC-134a	3580	1430
HFC-143a	6940	4470
HFC-152a	506	124
HFC-227ea	5360	3220
HFC-236fa	6940	9810
HFC-43-10mee	4310	1640
HFC-245fa	2920	1030
HFC-365mfc	2660	794
PFC-14	4880	7390
PFC-116	8210	12,200
PFC-218	6640	8830
PFC-318	7110	10,300
PFC-3-1-10	6850	8860
PFC-5-1-14	5890	9300
SF ₆	17,500	22,800
NF ₃	12,800	17,200

Source: IPCC (2007, 2013)

Greenhouse Gases and Other Pollutants

Many of the references cited in this report provide additional information on the pollutants that are driving climate change, including the IPCC Assessment Report (IPCC 2021) and the U.S. national greenhouse gas inventory (EPA 2021a). This report provides information on seven types of well-mixed greenhouse gases subject to the CLCPA and that are commonly reported by governments. However, there are other types of pollutants that also affect climate change as well as pollutants that may be associated with greenhouse gas sources that are harmful for human health and the environment.

Carbon dioxide

Carbon dioxide (CO₂) is the major anthropogenic climate forcer. The current atmospheric abundance of CO₂ has risen to 413.2 +/- 0.2 ppm from a preindustrial abundance of 278 ppm (WMO 2021), mainly due to fossil fuel combustion. Carbon cycle processes redistribute the CO₂ that is emitted to the atmosphere to terrestrial ecosystems and ocean carbon reservoirs. These CO₂ sinks take up roughly half of anthropogenic CO₂ emissions annually. But these sinks are responsive to changes in the atmospheric abundance of CO₂, and any deliberate net removal of CO₂ in the future will be partially offset by outgassing of CO₂ from the ocean and land sinks (IPCC 2021). The processes that remove CO₂ from the atmosphere act over different timescales that range from decades (e.g., incorporation into forest biomass,

afforestation and reforestation processes) to centuries (dissolution and circulation in the deep ocean) to millennia (uplift and weathering of silicate minerals). These timescales mean that CO₂ is a long-lived greenhouse gas, and its present-day emissions will impact the climate long into the future (IPCC 2018).

Methane

Like CO₂, the atmospheric abundance of methane (CH₄) has been driven upwards by anthropogenic emissions, from a preindustrial value of 722 ppb to over 1889 +/-2 ppb today (WMO 2020, 2021). For this reason, CH₄ is often grouped with CO₂ and other long-lived greenhouse gases, but its atmospheric lifetime is actually only 9 years (IPCC 2021). In contrast to CO₂, whose long atmospheric lifetime and high atmospheric abundance drive its climate impact, it is CH₄'s radiative efficiency, or heat-trapping ability, that makes it an important climate forcer over the short term. CH₄ that is emitted now will cause warming that peaks and largely dissipates after about a decade, because atmospheric reactions remove it relatively quickly. As a consequence, the GWP20 of CH₄ is much higher than its GWP100 (Table 2). It also means that a steady ongoing release of CH₄, rather than a pulse emission, is most similar to a pulse CO₂ emission in terms of their respective long-term climate impacts.

Nitrous oxide

Nitrous oxide (N₂O) is long-lived like CO₂, and like CH₄, it is also particularly effective at trapping heat in the atmosphere. Its atmospheric lifetime is estimated to be 116 +/- 9 years (IPCC 2021) and the only major removal processes are stratospheric chemical reactions. N₂O takes centuries to achieve equilibrium between emissions and removals and therefore, like CO₂, N₂O emissions impact climate cumulatively (IPCC 2021). N₂O sources are natural (60%) and anthropogenic (40%). Like CH₄, N₂O is produced both biologically through the activity of microorganisms, and through combustion. Biological N₂O is produced by microbial action on certain nitrogen compounds in soil and water. Anthropogenic activity in the agricultural and waste management sectors enhance biological N₂O emission rates. Combustion sources of N₂O include motor vehicles and point sources. The global atmospheric abundance of N₂O has risen to 333.2 +/- 0.1 ppb from a preindustrial value of 270 ppb (WMO 2021). Even after global emissions of N₂O are stabilized, its long atmospheric lifetime means that it will take more than a century before atmospheric abundances stabilize. N₂O is also of concern because it is the most significant anthropogenic destroyer of stratospheric ozone (Ravishankara, Daniel, and Portmann 2009).

Fluorinated or High GWP Gases

In addition to the naturally occurring greenhouse gases above, certain human-made compounds also contribute to climate change. Following IPCC guidelines, the following types of gases should be included in greenhouse gas accounting. These gases all contain fluorine and are emitted at a lower rate globally than the other well-mixed greenhouse gases but have much higher global warming potentials.

Hydrofluorocarbons (HFCs) are a group of different compounds primarily manufactured as replacements for ozone-depleting substances in a variety of end-uses such as refrigeration and foam blowing. The growth of HFCs corresponds to the adoption of the Montreal Protocol in 1987, which called for the phase down in the production and trade of chlorofluorocarbons (CFCs) and other ozone-depleting substances. Use of HFCs had therefore just begun around 1990, the UNFCCC's baseline year for reporting GHG emissions. Over the past thirty years, HFC use grew to replace the ozone-depleting substances and to meet an accelerated, global demand for refrigeration equipment. For this reason, HFC emissions started very close to zero in 1990 but have continued to grow exponentially through today. For example, HFC-134a was introduced early in the 1990's, reached an atmospheric abundance of 57.5 ppt by 2010, and doubled to 107.6 ppt by 2019 (IPCC 2021, Annex III). Some, but not all, HFCs are relatively short-lived;

estimated atmospheric lifetimes are 14.0 +/- 2.8 years for HFC-134a, 5.4 +/- 1.1 years for rapidly increasing HFC-32, and 228 years for the high-GWP HFC-23 (IPCC 2021; Hodnebrog et al. 2020).

Perfluorocarbons (PFCs) are a group of compounds used in refrigerants, electronics manufacturing, and aluminum smelting that are chemically stable and long-lived in the atmosphere. For example, PFC-14 (perfluoromethane or CF₄) has an estimated atmospheric lifetime of 50,000 years. The atmospheric abundance of PFCs has risen steadily since the 1970s, though not at the accelerating rate seen among HFCs. Certain PFCs like CF₄ also have natural sources that contribute significantly to their atmospheric abundance (IPCC 2021).

Sulfur hexafluoride (SF₆) is a synthetic fluorinated compound that is the most potent greenhouse gas currently known, with a GWP₂₀ of 17,500 (Table 2). It is also an extremely stable, long-lived molecule, with an atmospheric lifetime estimated to be 1,000 years (IPCC 2021). It therefore has a cumulative impact on climate, like CO₂ and N₂O, and a relatively small amount of SF₆ can have a significant long-term impact. The atmospheric SF₆ abundance was estimated to be 10.0 ppt in 2019, up from 7.0 ppt in 2011 (IPCC 2021). SF₆ has been used in a variety of applications, including electronics manufacturing and in medical applications. Electric utilities rely on SF₆ in electric power systems for voltage electrical insulation, current interruption, and arc quenching in the transmission and distribution of electricity.

Nitrogen trifluoride (NF₃) is emitted during electronics manufacturing. Its atmospheric abundance is still low but steadily increasing, rising from 0.7 ppt in 2010 to 2.1 ppt in 2019 (IPCC 2021, Annex III). Its high GWP (Table ES1.2) is second only to that of SF₆, and its long atmospheric lifetime of 569 years (Hodnebrog et al. 2020) means that today's NF₃ emissions will have a long-lasting impact on climate.

Other Pollutants

The sources of greenhouse gas emissions are often also sources of co-pollutants that impact air quality and public health in ways that are highly variable in space and time. These co-pollutants tend to have short atmospheric lifetimes and highly heterogeneous sources and sinks. Examples include tropospheric ozone, carbon monoxide, particulate matter less than 2.5 microns in width (PM 2.5), and nitrogen oxides (or NO_x) such as nitrogen dioxide. Both vehicles and stationary sources of greenhouse gases emit these co-pollutants. Under the Clean Air Act, states are required to meet national emission standards for co-pollutants. DEC collects information on emissions from sources that include power plants and vehicles, among others, and submits them to EPA to be incorporated into the U.S. National Emissions Inventory (NEI), which is updated every three years (EPA 2021b). The CLCPA addresses greenhouse gases and co-pollutants to ensure reductions of both particularly in disadvantaged communities.

DEC seeks feedback on how to specifically integrate reporting on black carbon into this annual statewide greenhouse gas emissions report. Black carbon is a component of PM 2.5 and a type of carbonaceous aerosol, or soot that is mostly made of carbon. Although it is already monitored as part of air quality reporting, it is also an important climate pollutant that absorbs solar radiation and emits heat, contributing radiative forcing that warms the atmosphere. However, it is not a greenhouse gas and it has a very short atmospheric lifetime (an estimated 5.5 +/-2.0 days; IPCC 2021), so that it cannot be easily compared to the well-mixed greenhouse gases using a Global Warming Potential metric. The major sources of black carbon in New York State include diesel engine emissions and residential wood stoves.

Finally, other pollutants of concern are greenhouse gases that are ozone-depleting substances. Under the UNFCCC, emissions of stratospheric ozone-depleting substances are not reported in national greenhouse gas inventories because they are already controlled under the 1987 Montreal Protocol (IPCC 2006). For example, the production and trade in chlorofluorocarbons (CFCs) was phased down under this

international agreement. As a result, estimated atmospheric abundances of CFC-12 and CFC-11 have declined from their respective peak concentrations of 542.3 ppt (c. 2000) and 259.3 ppt (c. 1995), to 2019 abundances of 503.1 ppt and 226.2 ppt, respectively (WMO 2020; IPCC 2021, Annex III). However, both chemicals have relatively long atmospheric lifetimes; 102 years for CFC-12 and 52 years for CFC-11. Although reported production of CFC-11 has stopped, emissions are still occurring (IPCC 2021).

II. Trends in New York State Greenhouse Gas Emissions, 1990-2019

In 2019, statewide gross emissions were 379.44 million metric tons of carbon dioxide equivalent emissions (mmtCO₂e GWP20), which is 6% lower than 1990 levels. The decrease in emissions reflects large-scale and long-term trends in population, economic factors including changes in the types of industries that are active in the state, and land-cover changes including those that affect forests. One key trend has been a reduction in CO₂ emissions associated with the electricity system. There is a national as well as strong New York-specific trend in the reduction of electricity emissions associated with various regulations, increased application of energy efficiency measures, and fuel switching. As the U.S. Environmental Protection Agency reports in the 2021 national inventory report (EPA 2021a):

Between 2018 and 2019, the decrease in total greenhouse gas emissions was driven largely by a decrease in CO₂ emissions from fossil fuel combustion. The decrease in CO₂ emissions from fossil fuel combustion was a result of a 1 percent decrease in total energy use and reflects a continued shift from coal to less carbon intensive natural gas and renewables in the electric power sector.

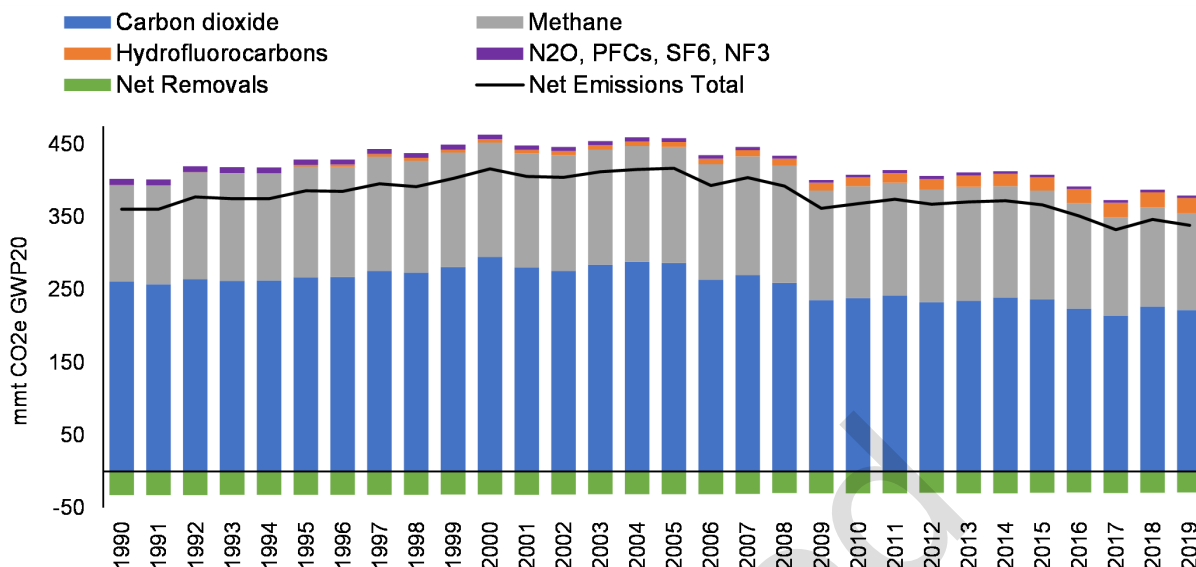
Figure 2 shows the relative contribution of each greenhouse gas to total statewide gross emissions and net removals over 1990-2019 in terms of carbon dioxide equivalence integrated over the 20-year timeframe. In New York State, CO₂ remains the primary greenhouse gas emitted by human activity (or 58% of emissions in 2019) and fossil fuel combustion is the primary source of CO₂. The land-use sector is an important CO₂ sink, removing roughly 8% of the State's total annual greenhouse gas emissions, primarily into forest biomass and soil organic carbon. Over time, there has been a significant reduction in CO₂ emissions, as discussed above, but also a reduction in CO₂ removals.

The second most important greenhouse gas in New York State, in terms of carbon dioxide equivalent emissions, is methane (35% of emissions; Figure 2). Major anthropogenic sources of CH₄ are fossil fuel infrastructure, waste, and agriculture. This includes CH₄ emissions from fuel infrastructure and waste management facilities outside of New York State. The majority of methane emissions are the result of leaks or other irregular releases from equipment or facilities, often referred to as fugitive emissions. Fugitive emissions often contain poorly understood release pathways which can make it difficult to estimate such emissions. One area of ongoing research is to reconcile bottom-up and top-down estimates of methane from the natural gas system, which may result in both a higher emission factor (Appendix A) and higher statewide emission estimate in future reports. For example, CH₄ emitted through incomplete natural gas combustion at the appliance level is an area of planned improvements discussed in *Sectoral Report #1: Energy*. Finally, DEC is evaluating data on CH₄ emissions from freshwater wetlands and other water bodies to better understand the carbon storage potential of these land use types and how they factor into net emission calculations. As with all aspects of net accounting, DEC seeks feedback on this approach (*Sectoral Report #3: AFOLU*).

Almost all of the remaining statewide greenhouse gas emissions in 2019 are HFCs (6%), an emission source that was almost nonexistent in 1990. While the emissions of N₂O, PFCs, and SF₆ all declined as a

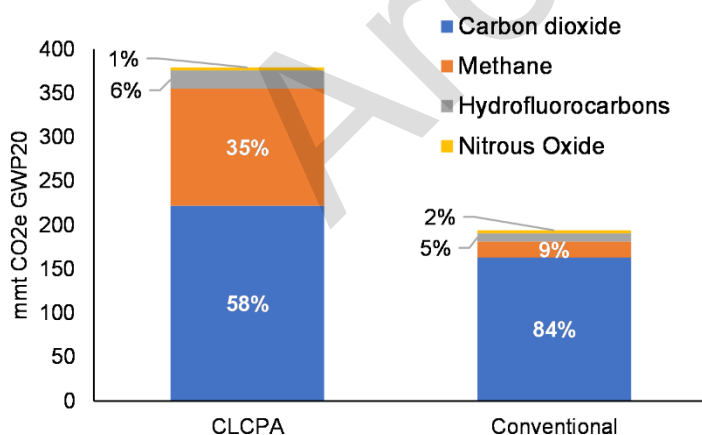
result of technological and economic change in New York State, HFC emissions continue to grow. Importantly, all pollutants are more powerful than CO₂ per ton and most are much longer lived.

Figure 2: NYS Statewide Greenhouse Gas Emissions by Gas, 1990-2019 (mmt CO₂e GWP20)



When considering emission sources only within New York State and using a GWP100, CO₂ is a much greater component of total emissions (Figure 3). The main difference is the CLCPA’s focus on shorter-lived methane and HFCs, which appear much larger using the 20-year GWP, although the actual mass of these emissions has not changed. The other key difference between the accounting frameworks is out-of-state emissions. Over time, New York State has imported more natural gas and has exported more waste and methane is a major source of emissions for both the natural gas system and waste management.

Figure 3: Comparison of 2019 Emissions, CLCPA and Standard Format

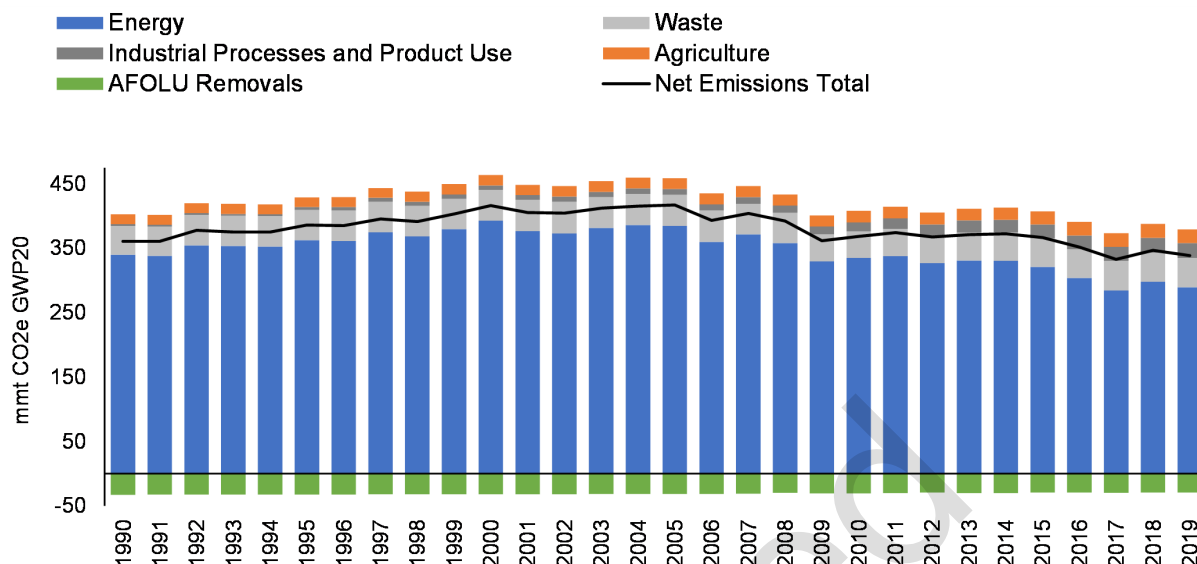


III. Trends in Greenhouse Gas Emission Sectors, 1990-2019

Figure 4 organizes emissions and removals into the sectors used by the IPCC and all national governments: “Energy,” “Industrial Processes and Product Use,” “Waste,” and “Agriculture, Forestry, and

Other Land Use” (or AFOLU). A condensed explanation of each sector is provided below, and a detailed explanation of data sources, methods, and trends are provided in the sectoral reports.

Figure 4: NYS Statewide Greenhouse Gas Emissions by Sector, 1990-2019 (mmt CO₂e GWP20)



New York State’s report makes slight changes to the IPCC guidelines as it is used in the national greenhouse gas inventory (EPA 2021). There are two additional sources of emissions associated with the Energy sector (imported electricity and imported fossil fuels) as well as new sources added to the Waste sector (for out-of-state or exported waste management). Waste combustion emissions have also been included in Waste sector emissions, rather than treated as a source of Energy sector emissions. Conversely, emissions associated with the electricity system and the oil and gas industry have been assigned to the Energy sector, rather than being assigned fully or partially to Industrial Process and Product Use. Finally, this report refers to the AFOLU sector, but the national inventory reports some emission removals as “Land Use, Land Use Change, and Forestry” (LULUCF).

Energy

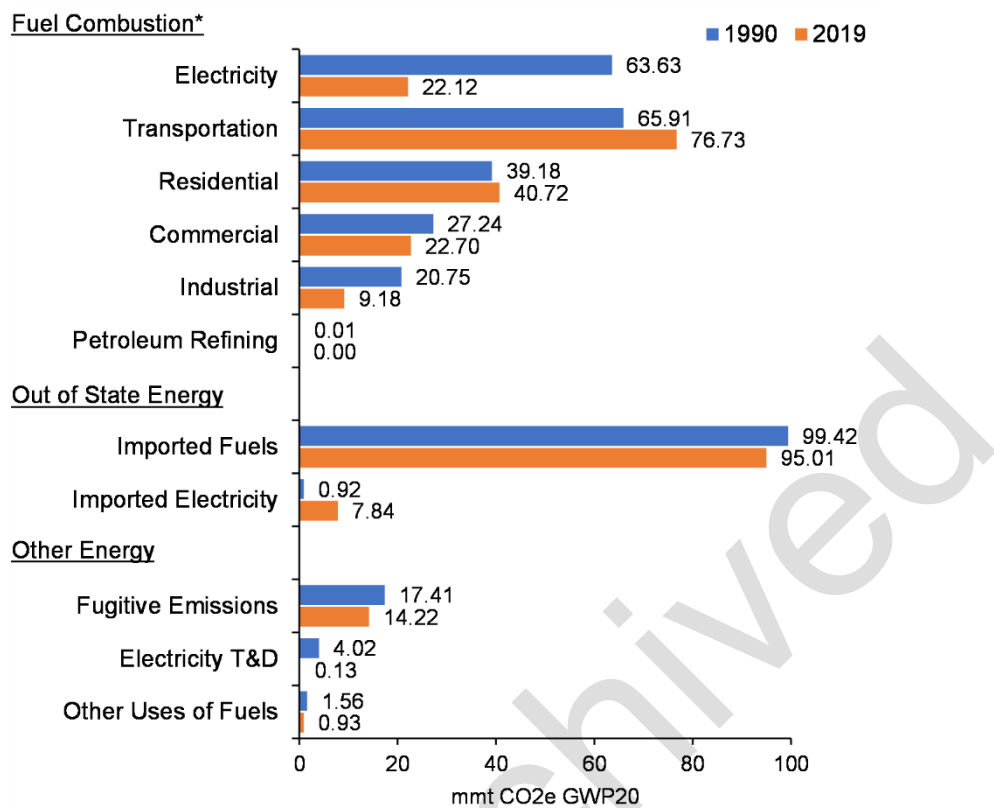
The Energy sector includes all emissions associated with the generation and use of energy, including for electricity, on-road transportation, non-road transportation (aviation, boating, and lawn and garden equipment), and on-site fuel use in buildings such as to heat buildings or for manufacturing. The Energy sector encompassed the largest portion of emissions every year from 1990 through 2019. These emissions are explained in detail in *Sectoral Report #1: Energy*.

The Energy sector is a major source of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and sulfur hexafluoride (SF₆) emissions. SF₆ in the Energy sector is exclusively associated with equipment used in electricity transmission. The remaining gases are associated with the production, transport, and combustion of fuels. For fossil fuels, this includes intentional and unintentional emissions at the point of extraction, during processing, in the transmission and distribution system, and during combustion.

Since 1990, there has been a substantial decrease in emissions associated with fuel combustion for electricity generation as well as a decrease in fuels combusted for industrial purposes (Figure 5). Emissions in all other energy sources saw minor declines and two sources saw minor increases (transportation and residential buildings). The largest source of emissions under CLCPA accounting is the

imported fossil fuel system, or emissions associated with the extraction, processing, transmission, and distribution of the fossil fuels used in New York. If the overall decline in fuel combustion was the result of lower energy demand alone, then the emissions associated with imported fuels would have also declined. However, this would be offset by a transition to fuels with higher out-of-state emission rates.

Figure 5: Trends in Energy Sector Emissions



For plant and waste-based fuels, Energy emissions are associated only with the combustion of the fuels, and this includes biogenic CO₂. There may be additional emissions associated with these fuels, such as from the growing of fuel feedstocks in New York State (*Sectoral Report #3: AFOLU*).

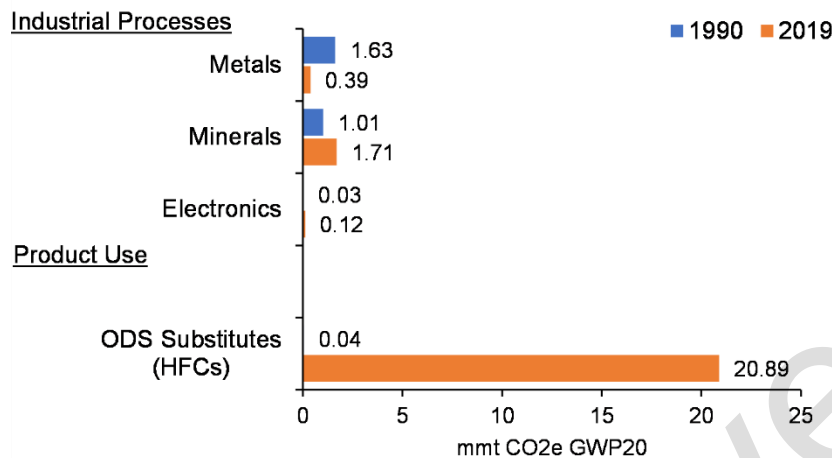
Industrial Processes and Product Use (IPPU)

The Industrial Processes and Product Use sector, or IPPU, encompasses emissions associated with manufacturing as well as the use of manufactured products. The majority of IPPU emissions in New York relate to the use of products rather than process emissions from industrial facilities. These emissions are explained in detail in the IPPU report (see *Sectoral Report #2: Industrial Processes and Product Use*).

Many industrial processes have the potential to produce greenhouse gases, and these are in addition to emissions associated with fuel use (fuel combustion is captured in the Energy sector). Industrial processes are a large source of emissions globally, but they are a relatively small portion of emissions in New York State. Industrial process emissions in New York are primarily CO₂ associated with the manufacturing of cement, metals such as iron and steel, or the various products made with limestone or dolomite (carbonates) such as glass. This report also includes sources associated with aluminum (PFCs) and electronics manufacturing (N₂O, PFCs, HFCs, and SF₆).

The types of industrial products that are emission sources are almost entirely imported into New York State and will release emissions while in use or after disposal. Globally and in New York, the majority of product use emissions are associated with hydrofluorocarbons (HFCs) used as a replacement for ozone-depleting substances in refrigeration equipment, aerosol products, and foam insulation. An insignificant amount of PFCs and SF₆ may also have been used in products historically but in too small of a quantity to be estimated. Finally, the IPPU sectoral report also reports on nitrous oxide product use, such as in medical applications, but it is also at too small of a quantity to be comparable to other emission sources.

Figure 6: Trends in Industrial Process and Product Use Sector Emissions

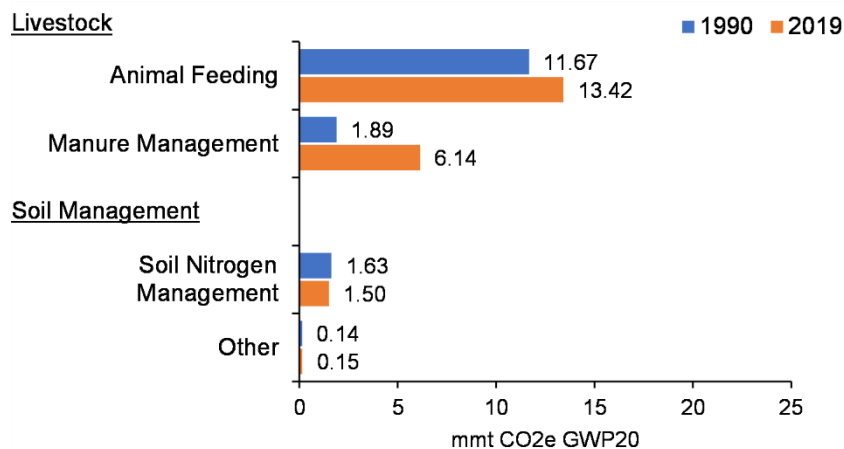


Agriculture, Forests, and Other Land Use (AFOLU)

The AFOLU sector captures emissions from agricultural operations as well as net emission removals, or carbon storage, in harvested wood products and from land management. The federal government considers all lands in the continental U.S. to be “managed” by humans and all emissions that result from the use of these lands as anthropogenic. This includes cropland and grasslands, forests, “wetlands” (which includes all modified water bodies), as well as emissions and removals associated with developed or “settlement” lands such as urban trees.

Agricultural livestock emissions are measured in much the same way as the sectors above and the largest source of emissions is methane (CH₄) from animal feeding (Figure 7). However, the largest growth in emissions is related to manure management (CH₄ and N₂O) as New York State policies regarding water quality went into effect and required certain livestock operations to store and manage manure in anaerobic, methane-generating systems. Finally, the use of different soil amendments is a consistent source of greenhouse gas emissions, particularly N₂O from nitrogen fertilizers.

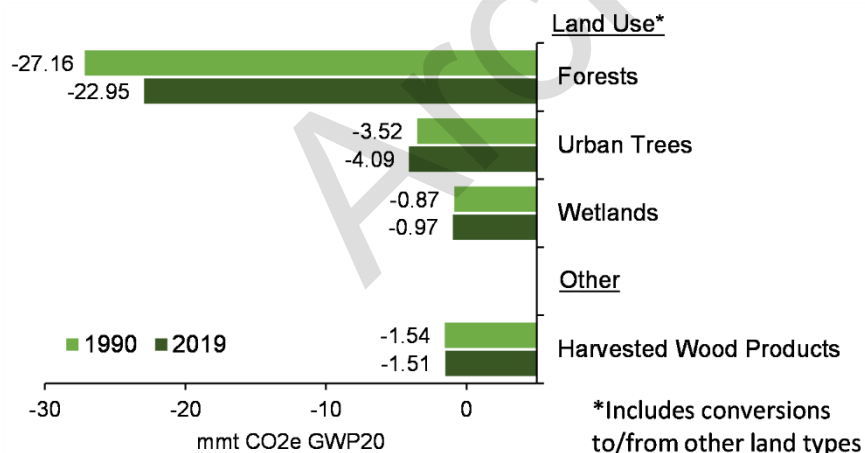
Figure 7: Trends in AFOLU Agriculture Sector Emissions



Unlike the rest of the emission sectors described in this report, the AFOLU sector also includes emission sinks, or net emission removals (Figure 8). One consistent source of emission removals for the past 30 years has been the long-term storage of carbon in Harvested Wood Products (under “Other” in Figure 8). However, the major source of net emission removals comes from New York’s nearly 19 million acres of forest land.

Land Use accounting reflects both how much net CO₂e is taken up on a given type of land as well as how much of that land type may have been converted to or from another land type. For example, net emission removals from forests have declined in part because some portion of forest area has been converted to croplands or settlement lands. In addition, a large amount of forest is forested wetlands. As a result, the forest values shown in Figure 8 reflect changes in croplands, settlement lands, and wetlands.

Figure 8: Trends in AFOLU Net Emission Removals



Waste

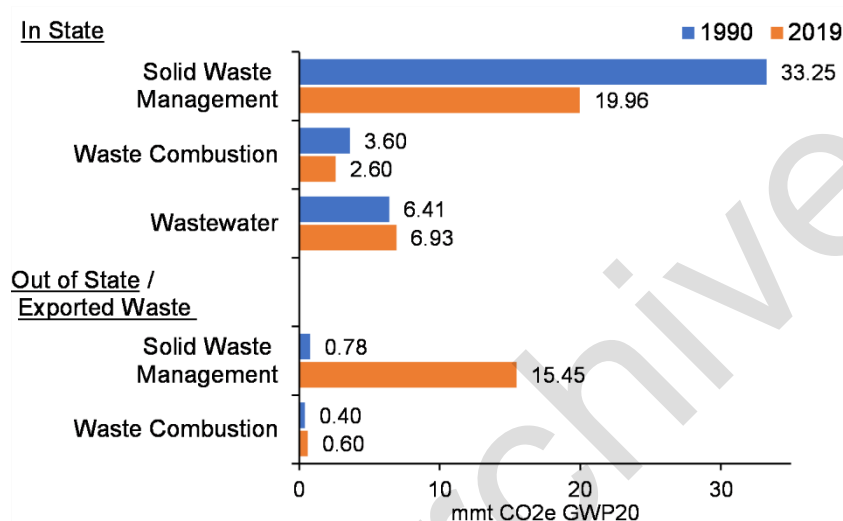
The IPCC’s Waste sector specifically encompasses emissions associated with human-generated waste. The majority of waste emissions globally are associated with solid, organic wastes deposited in landfills (or “solid waste management”, per the IPCC guidelines). Other sources of emissions include waste

combustion, wastewater managed in septic systems or centralized systems, and the use of anaerobic digestion for either solid or liquid wastes.

The primary gas associated with the Waste Sector is methane (CH₄) because it is generated when organic materials decay in the type of anaerobic environment found in landfills. CO₂ is also a product of waste decay and the main component of waste combustion. Consistent with the Part 496 regulation, CO₂ emissions associated with composting or natural decay are not included in the State's greenhouse gas emissions reporting.⁶

From 1990 to 2019, emissions from solid waste facilities in New York declined while an increasing volume of waste was exported, which resulted in emissions from facilities in other states (Figure 9). Meanwhile, emissions from waste combustion declined at essentially the same level that emissions from wastewater increased. As a result, the total rate of emissions from the waste sector increased by roughly 1mmt CO₂e over this time period.

Figure 9: Trends in Waste Sector Emissions

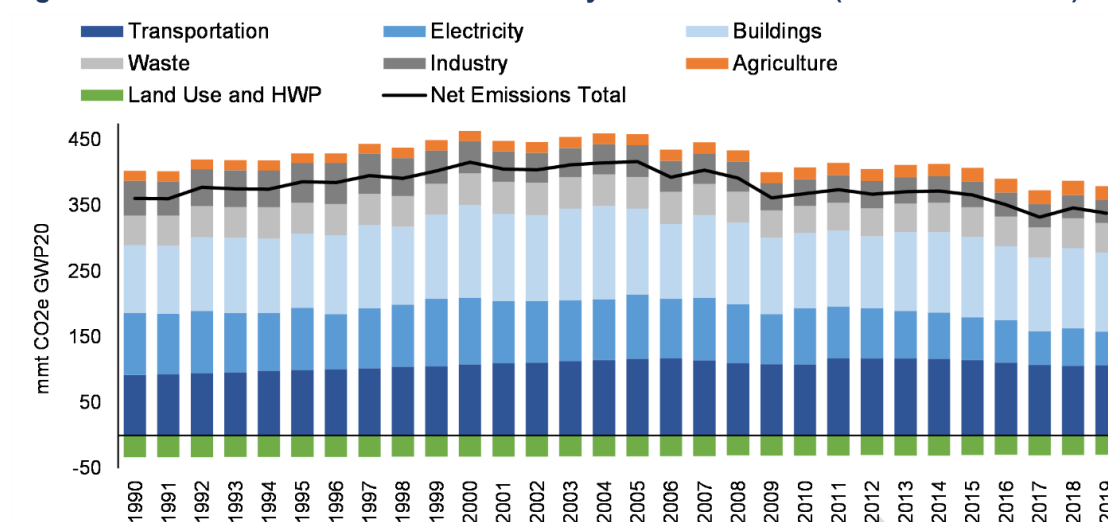


Emissions by Economic Sector and CLCPA Scoping Plan

Emissions can also be organized according to economic sectors and the U.S. national greenhouse gas inventory provides such a breakdown into residential, commercial, industry, transportation, electric power, and agriculture sectors (EPA 2021a). Figure 10 and Table ES.3 assigns emissions and removals to the economic sectors as organized in the New York State Climate Action Council Draft Scoping Plan. For example, HFC emissions from vehicle air-conditioning systems are assigned to the transportation sector as this is where the relevant equipment was used. Similarly, the emissions associated with imported fuels are also assigned based on the economic sector where these fuels were used. When using this organizational structure, the reduction in emissions from the electricity and industrial sectors in the state were offset by increasing emissions in buildings and transportation sectors, which are now the two largest emission sectors. The organization of agricultural and waste emission sources are the same as in the IPCC guidelines, these increased 6mmt and 1mmt respectively.

⁶ 6 NYCRR Part 496, as explained in the Regulatory Impact Statement.

Figure 10: NYS Greenhouse Gas Emissions by Economic Sector (mmt CO₂e GWP20)



IV. Additional Information

The following information is provided to aid stakeholders and to address questions that are frequently received by DEC. DEC seeks feedback on what other sources of information related to statewide greenhouse gas accounting under the CLCPA may be useful and could be added to future reports.

Comparison with 1990 Baseline in Part 496

Prior to this report, DEC and NYSERDA conducted an analysis of statewide emissions in 1990 to establish a baseline for the “Statewide GHG Emission Limits” established by ECL 75-0107 and reflected in 6 NYCRR Part 496. The data and methods used in the current report are an improvement over those used for 6 NYCRR Part 496 and DEC will continue to make improvements in future annual reports. The 6 NYCRR Part 496 regulation may be revised at a later date using updated information. The table below provides a comparison and explanation of the differences between the estimate of gross statewide emissions in 1990 from the 6 NYCRR Part 496 rulemaking and in this report.

Table 3: Comparison of 1990 Statewide Greenhouse Gas Emission Totals

Emission Sector	Part 496*	This Report	Example Improvement
Energy	337.04	340.05	Refinement of imported fuels and fugitive emissions methods.
Industrial Processes and Product Use (IPPU)	2.72	2.72	Inclusion of N ₂ O product use. Total change less than 0.01mmt CO ₂ e
Agriculture Forestry and Other Land Use (AFOLU)	17.13	15.32	Refinement of EPA SIT model inputs with NYS datasets
Waste	52.88	44.44	Use of historical waste data rather than EPA SIT model estimates of waste tonnage
Gross Total	409.78	402.98	

* As provided in the 6 NYCRR Part 496 Regulatory Impact Statement

CLCPA Informational Items

The CLCPA includes a list of informational items that are required to be included in this report.⁷ These represent particular emission sources that are found in the IPCC guidelines and are commonly included in governmental greenhouse gas accounting, if relevant. The following table provides a list of these informational items along with the names of the corresponding IPCC sectoral category as it is found in this report. These sectoral categories largely match the organization of the IPCC guidelines and any deviations are explained in the text. For example, the IPCC guidelines place waste combustion emissions in the Energy sector, rather than in the Waste sector.

Table 8: Location of CLCPA Informational Items

Informational Item		Sectoral Report: Sections
a	The use of fossil fuels by sector, including for electricity generation, transportation, heating, and other combustion purposes	SR1. Energy: Fuel Combustion
b	Fugitive and vented emissions from systems associated with the production, processing, transport, distribution, storage, and consumption of fossil fuels, including natural gas	SR1. Energy: Fugitive Emissions, Imported Fossil Fuels
c	Emissions from non-fossil fuel sources, including but not limited to garbage incinerators, biomass combustion, landfills and landfill gas generators, and anaerobic digesters	SR1. Energy: Fuel Combustion SR4. Waste: All Sections
d	Emissions associated with manufacturing, chemical production, cement plants, and other processes that produce non-combustion emissions	SR2. Industrial Processes and Product Use: All Sections

⁷ ECL § 75.0105(2).

Appendix A. Emission Factors for Use by State Agencies and Applicants

The following tables provide information on the greenhouse gas emissions associated with different types of fuels. This information can be used by any entity to estimate emissions that result from the use of fuels following the same CLCPA-compliant accounting used in this report and in the adoption of 6 NYCRR Part 496. These emission factors can be applied to generic (not source-specific) fossil fuels at the high heating content (see High Heating Values). The emission factors included in this document are derived from the same analyses described in the accompanying “*Sectoral Report #1: Energy*” for calculating Imported Fossil Fuels and Fugitive Emissions. The emission factors presented in this document are a work in progress, subject to future stakeholder comment, and will be subject to a continual improvement process as additional information becomes available. These factors do not include the direct emissions resulting from the combustion of the fuel.

Current Upstream and Out-of-State Emission Factors for Imported Fossil Fuels

Emission factors in Table A1 reflect greenhouse gas emissions associated with the extraction, production, and transmission of fossil fuels imported into New York State for the most recent year available, or 2019. This does not include extraction, production, or transmission of fuels within New York State (see below). Users may wish to adjust the specified emission factors for blended fuels. The gasoline emission factors represent 100% fossil fuel content gasoline, equivalent to gasoline blend stock, if evaluating blends with oxygenates (e.g., ethanol) these blends can be apportioned to the fraction of emissions associated with the energy fraction of the blend that is from fossil fuels (e.g., E85 is a blend of ethanol and gasoline estimated here to have the energy content of approximately 28% gasoline and 72% ethanol). Finally, units in grams can be converted to pounds by dividing by 453.6.

Table A1: 2019 Emission Rates for Upstream Out-of-State Sources (g/mmbtu)

Fuel Type	CO₂	CH₄	N₂O	Total CO₂e
Natural Gas	12,131	357	0.14	42,147
Diesel/ Distillate Fuel	15,164	121	0.26	25,375
Coal	3,300	364	0.10	33,891
Kerosene/Jet Fuel	10,071	109	0.17	19,270
Gasoline (E85)	5,097	33	0.08	7,905
Gasoline	19,604	128	0.33	30,405
LPG	17,295	121	0.27	27,553
Petroleum Coke	11,612	112	0.20	21,096
Residual Fuel	11,799	111	0.19	21,184

Note: Total CO₂e conversion uses GWP20 per 6 NYCRR Part 496

Current Emission Factors for Non-Energy Fuel Use

Emission factors in Table A2 reflect the upstream out of state emissions associated with fossil fuel derived products that are not primary combustion fuels but have other consumption uses within the state.

Table A2: 2019 Emission Rates for Fossil Fuel Products (g/mmbtu)

Fuel Type	CO ₂	CH ₄	N ₂ O	Total CO ₂ e
Asphalt and Road Oil	8,487	105	0.13	17,325
Lubricants	20,190	116	0.37	30,009
Waxes	19,518	115	0.36	29,261
Miscellaneous Petroleum Products	10,691	109	0.17	19,904
Special Naphthas	14,313	117	0.26	24,193

Note: Total CO₂e conversion uses GWP20 per 6 NYCRR Part 496

Current Downstream and In-State Emission Factors for Fossil Fuels

Emission factors in Table A3 reflect fugitive emissions within New York State associated with fuel throughput for the most recent year available, or 2019. Emission factors were generated by summing emissions from natural gas distribution, or downstream infrastructure and dividing by the instate consumption of natural gas in industry, commercial, residential, transportation sectors.

Table A3: 2019 Emission Rates for Downstream In-State Sources (g/mmbtu)

Fuel Type	CO ₂	CH ₄	N ₂ O	Total CO ₂ e
Natural Gas and Renewable Natural Gas (RNG/biogas)	2.0	68	n/a	5,714

Note: Total CO₂e conversion uses GWP20 per 6 NYCRR Part 496

High Heating Value

The following table is reproduced from the Energy Information Administration (EIA) State Energy Data System (SEDS), with btu values divided by physical units. Renewable Natural Gas is assumed to be pipeline quality with equivalent energy content. Raw landfill gas has substantially different energy content per standard cubic foot. E85 is assumed to have the energy content of 28% gasoline and 72% ethanol.

Table A4: High Heating Value of Select Fuels (mmbtu)

Fuel Type	High Heating Value	Unit of volume or mass
Natural Gas/RNG	0.001033	Standard cubic foot
Diesel/Distillate Fuel	0.137	U.S. gallon
Coal	25.36	Short Ton
Kerosene/Jet Fuel	0.135	U.S. gallon
Gasoline E85	0.097	U.S. gallon
Gasoline	0.124	U.S. gallon
LPG	0.091	U.S. gallon
Petroleum Coke	0.136	U.S. gallon
Residual Fuel	0.150	U.S. gallon
Asphalt and Road Oil	0.158	U.S. gallon
Lubricants	0.144	U.S. gallon
Waxes	0.132	U.S. gallon
Misc. Petroleum Products	0.138	U.S. gallon
Special Naphthas	0.125	U.S. gallon

Appendix B: Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
AR6	IPCC Sixth Assessment Report
btu	British thermal unit
CCAP	Coastal Change Analysis Program
CH ₄	Methane
CLCPA	NYS Climate Leadership and Community Protection Act
CO	Carbon monoxide
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
DEC	NYS Department of Environmental Conservation
EIA	Energy Information Administration, U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GWP	Global Warming Potential
GWP100	100-Year Global Warming Potential
GWP20	20-Year Global Warming Potential
HFC	Hydrofluorocarbon
HWP	Harvested Wood Products
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
LPG	Liquefied petroleum gas
LULUCF	Land Use, Land-Use Change, and Forestry
mmt	Million metric tons
mmbtu	Metric million british thermal unit
N ₂ O	Nitrous oxide
NA	Not applicable
NE	Not estimated
NEI	National Emissions Inventory
NF ₃	Nitrogen trifluoride
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen oxides
NYCRR	New York Codes, Rules and Regulations
NYSERDA	NYS Energy Research and Development Authority
ODS	Ozone depleting substances
PFC	Perfluorocarbon
ppm	Parts per million
ppb	Parts per billion
ppt	Parts per trillion
RNG	Renewable natural gas
SF ₆	Sulfur hexafluoride
SIT	EPA State Inventory Tool
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WMO	World Meteorological Organization

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Department of
Environmental
Conservation

Energy

2021 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #1

Kathy Hochul, Governor | Basil Seggos, Commissioner



Table of Contents

Format of This Report	1
Figures and Tables	1
Energy	2
Fuel Combustion	3
Electricity Generation	4
Residential, Commercial, and Industrial Fuel Combustion	5
Transportation	7
Petroleum Refining	9
Other Fossil Fuel Use	9
Fugitive Emissions from Fossil Fuels	10
Electricity Transmission	11
Out of State Energy Emissions	12
Imported Electricity	12
Imported Fossil Fuels	13
Planned Improvements	14
Abbreviations	16
References	17

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Format of This Report

This sectoral report provides a detailed explanation of methods, data, and trends for the energy sector. The accounting used in this sectoral report follows the requirements of the Climate Leadership and Community Protection Act (CLCPA) and is in alignment with the 6 NYCRR Part 496 regulation, “Statewide GHG Emission Limits.” This includes the use of a 20-Year Global Warming Potential metric provided in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC 2013). The organization of this report and specific methodologies are based on guidelines from the IPCC Taskforce on National Greenhouse Gas Inventories (or “IPCC guidelines”) as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2021a). The accompanying *Summary Report* provides a comparison with other accounting methods, including by economic sector or using conventional accounting formats. DEC also intends to provide emission values for all years via the Open Data NY platform.

Figures and Tables

Table SR1.1 Energy Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	2
Table SR1.2 2019 Energy Emissions by Gas (mmt CO ₂ e GWP20).....	3
Table SR1.3 Fuel Combustion Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	4
Table SR1.4 Fuel Combustion Emissions by Fuel Category, 1990-2019 (mmt CO ₂ e GWP20).....	4
Table SR1.5 Electricity Emissions by Fuel Type, 1990-2019 (mmt CO ₂ e GWP20).....	5
Figure SR1.1 Heating Degree Days and Fuel Combustion.....	6
Table SR1.6 RCI Fuel Combustion Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	6
Table SR1.7 RCI Fuel Combustion Emissions by Fuel Type, 1990-2019 (mmt CO ₂ e GWP20).....	7
Table SR1.8 Transportation Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	8
Table SR1.9 Transportation Emissions by Fuel Type, 1990-2019 (mmt CO ₂ e GWP20).....	9
Table SR1.10 Excluded Transportation Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	9
Table SR1.11 Emissions from Other Uses by Fuel Type, 1990-2019 (mmt CO ₂ e GWP20).....	10
Table SR1.12 Oil and Gas Fugitive Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	11
Table SR1.13 Electricity Transmission SF ₆ Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	12
Table SR1.14 Out of State Energy Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	12
Table SR1.15 Imported Fossil Fuel Emissions by Fuel Type, 1990-2019 (mmt CO ₂ e GWP20).....	14
Table SR1.16 Excluded Emissions by Fuel Type, 1990-2019 (mmt CO ₂ e GWP20).....	14

Energy

This sectoral report provides information on greenhouse gas emissions associated with the energy system. Most emissions in the energy sector are from the combustion of fuels (Table SR1.1). This report also describes emissions within New York State from other uses of fossil fuels (such as for asphalt), the leakage of emissions in the oil and gas system (or fugitive emissions), and the use of greenhouse gases in electricity transmission. The CLCPA also requires that this report include emissions that occur outside of the state that are associated with imported electricity and imported fossil fuels. These emissions are not typically included in governmental greenhouse gas emission reports or the IPCC guidelines. Finally, one additional source of emissions is provided as an informational item. Per IPCC guidelines, the portion of transportation fuels used for international transport, or bunker fuels, has been excluded from emission totals (“Excluded Transportation”, Table SR1.1).

The energy system is the primary source of greenhouse gas emissions in New York (Table SR1.1). In 2019, total energy emissions were 289.58mmt CO₂e or 76% of statewide gross emissions and over 80% of net emissions, when measured using CLCPA accounting. This represents a 15% reduction in gross emissions since 1990. The majority of emissions were from either fuel combustion (59% of energy and 45% of total emissions) or were associated with the importing of those fuels or electricity (36% of energy and 27% of total emissions). The trend in Energy emissions over time is the same as that seen in nationally, with an initial increase in emission from 1990 through the mid-2000’s and then a decline thereafter (EPA, 2021a). Further information on the relative contribution of the different emission sources within the energy sector are described in the sections below. The accompanying *Summary Report* provides a breakdown of these sources by economic sector as was used for the New York State Climate Action Council Draft Scoping Plan.

Table SR1.1 Energy Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Fuel Combustion	216.73	227.80	183.78	172.98	165.36	174.84	171.45
Other Fossil Fuel Use	1.56	2.26	1.46	1.33	1.29	1.19	0.93
Fugitive Emissions	17.41	20.68	15.83	15.11	14.64	14.19	14.22
Electricity Transmission	4.02	1.61	0.17	0.15	0.14	0.13	0.13
Out of State Energy Emissions*	100.33	132.20	119.77	114.09	102.83	107.50	102.85
Gross Total	340.05	384.56	321.01	303.66	284.25	297.84	289.58
<i>% of Statewide Gross Total</i>	<i>84.5%</i>	<i>83.9%</i>	<i>78.7%</i>	<i>77.5%</i>	<i>76.2%</i>	<i>76.8%</i>	<i>76.3%</i>
Net Total	333.23	375.82	309.92	293.38	274.15	287.17	278.76
<i>% of Statewide Net Total</i>	<i>92.4%</i>	<i>90.1%</i>	<i>84.5%</i>	<i>83.4%</i>	<i>82.4%</i>	<i>82.8%</i>	<i>82.3%</i>
Excluded Transportation Emissions	15.37	13.89	21.25	21.08	21.02	20.13	19.31

*Not an IPCC Category; Note: Totals may not sum due to independent rounding.

The primary greenhouse gas emitted by the energy sector is carbon dioxide (CO₂) for 75% of energy emissions (Table SR1.2). Under the IPCC guidelines for national governments, the CO₂ produced by burning biogenic or plant-based fuels is reported but treated separately from other anthropogenic

emissions. The same practice is applied in this report.¹ In this report, biogenic sources of CO₂ are included in gross emission totals but omitted in net totals. A small fraction of the fuels used in New York are currently biogenic, so biogenic fuel emissions are much lower than fossil fuel emissions.

The second most common greenhouse gas is methane (CH₄; 25% of energy emissions), primarily from leakage or intentional venting in the oil and gas system in New York and through the fuel system. Notably, 78% of energy sector methane is associated with out-of-state sources. Nitrous oxide (N₂O) is also a byproduct of fuel combustion, but at a lower emission rate than the gases above. Finally, the major source of sulfur hexafluoride (SF₆) globally is as an insulating gas in electricity transmission and distribution equipment, but its leakage rate in New York declined significantly since the 1990's.

Table SR1.2 2019 Energy Emissions by Gas (mmt CO₂e GWP20)

Emission Category	CO₂	Biogenic CO₂	CH₄	N₂O	SF₆
Fuel Combustion	157.85	10.82	2.02	0.76	na
Other Fossil Fuel Use	0.93	na	na	na	na
Fugitive Emissions	0.17	na	14.05	+	na
Electricity Transmission	na	na	na	na	0.13
Out of State Energy Emissions*	46.31	+	56.39	0.16	na
Gross Total	205.25	10.82	72.46	0.92	0.13

* Not an IPCC Category; "+" less than 0.01mmt; "na" not applicable; Note: Totals may not sum due to independent rounding.

Fuel Combustion

This IPCC category represents emissions associated with the burning of fossil and biogenic fuels. Fuel combustion is the largest source of greenhouse gas emissions in the state. This includes fuels combusted for electricity, transportation, and heating in residential, commercial, and industrial buildings in New York (Table SR1.3). Petroleum refining, which existed in the state until 1991, represented a source of fuel combustion emissions in the 1990 baseline year, but it is not an emission source currently.

NYSERDA (2021a) is a technical supplement that is cited throughout this report and provides additional information on data and methods used in this section. Unless otherwise noted, the Energy Information Administration State Energy Data System (EIA SEDS) was used as the primary data source for the fuel combustion analysis and this section of the report is organized to align with that dataset. The EIA SEDS is the authoritative source of information on the nationwide transmission of fuels, and it aligns with the EPA's national greenhouse gas emissions report (EPA 2021a). However, there are minor differences in how emission sources are organized in the IPCC guidelines. For example, industrial fuel combustion includes emission sources from industries that the IPCC guidelines split across multiple subcategories.

The most significant trend in fuel combustion emissions since 1990 was a 65% reduction from the electricity sector (Table SR1.3). However, another major source of emissions is the transportation sector, in which emissions grew 16% from 1990 to 2019 and represented 45% of fuel combustion emissions in

¹ Per 6 NYCRR Part 496

2019. The second largest source of emissions is the use of fuels in residential buildings, such as for heating and cooking, followed by commercial fuel use and electricity generation.

Table SR1.3 Fuel Combustion Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Electric Power	63.63	56.22	29.90	28.58	22.94	25.17	22.12
Residential	39.18	46.44	40.54	34.90	35.42	41.31	40.72
Commercial	27.24	29.93	22.66	21.53	21.86	23.01	22.70
Industrial	20.75	13.71	9.42	9.27	8.90	9.17	9.18
Transportation	65.91	81.51	81.26	78.70	76.24	76.18	76.73
Petroleum Refining	0.01	no	no	no	no	no	no
Gross Total	216.73	227.80	183.78	172.98	165.36	174.84	171.45

“no” not occurring; Note: Totals may not sum due to independent rounding.

The majority of fuel combustion emissions in 2019 were from the burning of petroleum fuels, which is unsurprising as these are the main fuels used in transportation (Table SR1.4, SR1.9). However, emissions from the combustion of petroleum fuels had declined 28% since 1990, while emissions from natural gas increased nearly 50%. Emissions from the combustion of coal declined 96%.

Table SR1.4 Fuel Combustion Emissions by Fuel Category, 1990-2019 (mmt CO₂e GWP20)

Fuel Category	1990	2005	2015	2016	2017	2018	2019
Petroleum Fuels	127.44	135.13	97.91	92.20	88.85	91.68	91.54
Natural Gas	47.59	58.98	74.27	71.06	67.88	74.09	70.87
Coal	33.60	23.95	3.54	2.54	1.56	1.37	1.30
Wood	8.09	9.75	8.06	7.19	7.06	7.70	7.73
Gross Total	216.73	227.80	183.78	172.98	165.36	174.84	171.45

Note: Totals may not sum due to independent rounding.

Electricity Generation

This category addresses emissions from facilities whose primary activity is to generate electricity that will be transmitted via the electricity grid. Per IPCC guidelines, this category does not include electricity generated for local use, or distributed sources of generation such as industrial facilities or combined heat and power (CHP) facilities (a form of industrial fuel combustion). Although some excess portion of electricity may be shared with the electricity grid, that is not the main function of these emission sources. Instead, all emissions associated with on-site combustion of fuels is covered in the Residential, Commercial, and Industrial Fuel Combustion section below. Additionally, this section focuses on emission sources located within New York. Emissions resulting from Imported Electricity are described in a separate section below.

The mix of fuels used to generate electricity in New York has changed over time. For the 1990-2019 timeseries, these fuels included coal, distillate fuel oil, natural gas, petroleum coke, residual fuel oil, and wood. Additional information on the sources of fuels used in New York can be found in the annual

NYSERDA “Patterns and Trends” report and NYISO “Gold Book” and “Power Grid” reports (e.g., NYSERDA 2021c, NYISO 2021a and b).

Methodology

Emissions from fuel combustion are generally estimated by applying standard emission factors to the volume or energy content (BTUs) of fuels used in each sector. An alternative approach would be to summarize data that may be reported by facilities as part of state or federal air pollution regulations, however these data sources do not cover all sources or gases for the full 1990-2019 timeseries. For this report, annual BTUs of fuel consumed were taken from the EIA SEDs dataset and emission factors for CO₂, CH₄, and N₂O were from the EPA (NYSERDA 2021a, EPA 2021a Table A-32).

Results

The most significant emission reduction in this report was the decrease in fuel combustion emissions in the electricity sector, by 65% (Table SR1.3). This is related to the transition away from fuels with higher combustion emissions to those with lower combustion emissions; as natural gas usage has increased, the use of coal and petroleum fuels such as residual fuel oil has declined (Table SR1.5). As described in NYSERDA (2021a), the emissions from the extraction, processing, transmission, and distribution of these fuels have not followed the same pattern. Note, according to the SEDS dataset, petroleum coke was not a source of fuel prior to 1996 or after 2011.

Table SR1.5 Electricity Emissions by Fuel Type, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Coal	25.04	20.60	2.12	1.51	0.61	0.68	0.46
Distillate Fuel	0.47	0.69	0.36	0.15	0.11	0.34	0.16
Natural Gas	12.59	16.52	25.80	25.82	21.09	22.72	20.73
Petroleum Coke	no	1.33	no	no	no	no	no
Residual Fuel	25.45	16.59	0.92	0.30	0.30	0.76	0.17
Wood	0.07	0.49	0.70	0.80	0.83	0.67	0.60
Gross Total	63.63	56.22	29.90	28.58	22.94	25.17	22.12

“+” less than 0.01mmt; “no” not applicable; Note: Totals may not sum due to independent rounding.

Residential, Commercial, and Industrial Fuel Combustion

This sectoral category includes emissions from the combustion of fuels in residential, commercial, and industrial buildings such as for space heating, cooking, and industrial processes. Based on the EIA SEDS data, the types of fuels used from 1990 to 2019 in residential and commercial buildings in New York included coal, distillate fuel oil, kerosene, liquefied petroleum gas (LPG), natural gas, residual fuel oil, and wood. Industrial fuels included coal, distillate fuel oil, kerosene, LPG, natural gas, petroleum coke, residual fuel oil, special naphthas, and wood. Additional information on the sources of fuels used in New York can be found in the annual NYSERDA “Patterns and Trends” report (e.g., NYSERDA 2021c).

Methodology

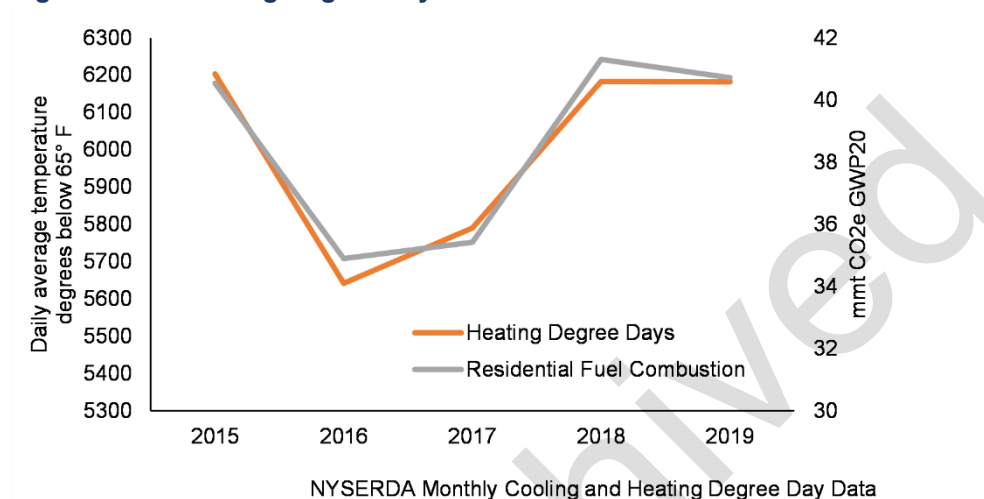
The method used to estimate emissions from fuel combustion in buildings is the same as that used for electricity generation. Annual BTUs of fuel consumed were gathered from the EIA SEDs dataset and emission factors for CO₂, CH₄, and N₂O were from the EPA (NYSERDA 2021a). Distillate fuel oil emission factors were applied to kerosene and natural gas emission factors were applied to LPG. One notable

aspect of this analysis is that when using the EIA SEDS dataset, states must also consider the volume of fuels that were not combusted but used for other purposes, as described in the Other Uses of Fossil Fuels section below.

Results

It is important to review long term trends when considering changes in fuel combustion emissions associated with space heating because interannual changes are heavily influenced by seasonal weather patterns in addition to economic trends and technological change. In particular, residential fuel combustion in a given year is affected by the severity of weather in the cold seasons. Figure SR1.1 compares residential fuel combustion emissions to the number of heating degree days in New York State, or the total number of degrees that the daily average temperature fell below 65° F in that year.²

Figure SR1.1 Heating Degree Days and Fuel Combustion



When comparing 1990 emission levels to emissions in recent years (or 2015-2019), fuel combustion emissions in the Residential Commercial and Industrial (RCI) sources were 17-25% lower overall (Table SR1.6). However, the largest portion of emissions is from residential fuel combustion, which was up to 5% higher in recent years compared to 1990. Commercial fuel combustion levels were 16% below 1990 and industrial fuel combustion levels were 56% below 1990 levels, likely in part to the decline in manufacturing over this time period.

Table SR1.6 RCI Fuel Combustion Emissions, 1990-2019 (mmt CO₂e GWP₂₀)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Residential	39.18	46.44	40.54	34.90	35.42	41.31	40.72
Commercial	27.24	29.93	22.66	21.53	21.86	23.01	22.70
Industrial	20.75	13.71	9.42	9.27	8.90	9.17	9.18
Gross Total	87.18	90.08	72.63	65.70	66.18	73.48	72.60

Note: Totals may not sum due to independent rounding.

² Available at <https://www.nysed.gov/about/publications/ea-reports-and-studies/weather-data/monthly-cooling-and-heating-degree-day-data>

As in the case of the electricity sector, there has been a transition in the RCI energy sectors away from fuels with higher combustion emissions (Table SR1.7). While combustion emissions from natural gas increased 40%, emissions of all other fuels decreased 54%.

Table SR1.7 RCI Fuel Combustion Emissions by Fuel Type, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Coal	8.56	3.35	1.42	1.03	0.96	0.69	0.84
Distillate	21.79	24.52	13.96	10.78	10.28	12.19	12.20
Natural Gas	34.73	41.73	46.49	43.67	45.34	49.85	48.69
Wood	8.02	9.25	7.35	6.38	6.23	7.03	7.13
Other	14.07	11.23	3.40	3.84	3.37	3.73	3.73
Gross Total	87.18	90.08	72.63	65.70	66.18	73.48	72.60

Note: Totals may not sum due to independent rounding.

Transportation

Emissions from the transportation sector are distinguished from other sources of fuel combustion emissions in that they are predominantly emitted by mobile sources (sources that can be moved). Road transportation comprises the largest subcategory of emissions and includes passenger cars and trucks, commercial light-duty trucks, motorcycles, buses, and heavy-duty trucks. Non-road transportation sources include aviation, marine, and rail as well as equipment used in agriculture, construction, landscaping, or recreation. The IPCC guidelines also include emissions associated with the operation of oil and natural gas pipelines and distribution. In this report, the leakage of emissions in this infrastructure is described below in the Fugitive Emissions section.

Transportation fuels used in New York for 1990-2019 included motor gasoline, diesel, compressed natural gas (CNG), and blended biofuels (ethanol and biodiesel). Emissions of gasoline and diesel blended with biofuels are reported together with the fossil fuel, and the biogenic CO₂ accounted for separately. One key aspect of transportation emissions accounting relates to the treatment of fuels used for international transport, or bunker fuels (Table SR1.10). The current report follows the IPCC guidance and focuses on fuels used for domestic transportation and so only considers fuels used for trips that start in New York and whose destination is within the United States.

Methodology

Non-Road Transportation: Non-road emission sources were estimated using fuel volume data from EIA SEDS and emission factors from the EPA, with minor adjustments as described in NYSERDA (2021a). A key exception is the analysis of aviation emissions which is based on a combination of SEDS fuel volumes and information from the Bureau of Transportation Statistics. This approach enables New York to include fuel volumes that the EIA SEDS dataset allocates to neighboring states as well as distinguish between domestic and international flights. As described above, emissions from international flights were excluded from emission totals, but were provided as an informational item. Additionally, it is not possible at this time to determine the portion of marine residual and distillate fuels that are not bunker fuels, i.e., not used for ocean-going trips. So, these fuels were all treated as bunker fuels and excluded from the analysis (a total of 0.73mmt CO₂e). This may be reassessed in future reports if new data are made available (see Planned Improvements).

Road Transportation: Road transportation emissions include two additional layers of complexity compared to other types of fuel combustion. The first is that the actual tailpipe emissions of methane and nitrous oxide from vehicles depends on the control technology used in those vehicles, which varies widely among vehicle makes and model years. Secondly, motor vehicles move easily across state borders and may contain fuels purchased in other states. The EIA SEDS dataset provides an estimate of fuels sold in New York, but not fuels purchased elsewhere that were combusted in New York. Given these complexities, it is not appropriate to use the EIA SEDS fuel volumes alone to estimate emissions from road transportation.

The U.S. EPA requires states to use the Motor Vehicle Emissions Simulator (MOVES) model for estimating air pollution emissions from “on-road” transportation. This model is also ideal for estimating statewide greenhouse gas emissions as it estimates tailpipe emissions based on total vehicle miles travelled (VMT), rather than fuel sales. DEC’s MOVES modeling inputs are provided to the EPA’s National Emissions Inventory (or “NEI”, EPA 2021b). EPA then publishes emission estimates based on these inputs. These published emissions were used as the emission estimates for 2011 and 2014 while the emissions for 2017 were from DEC modeling of inputs submitted to EPA. 2017 is the most recent year of MOVES modeling by DEC. Emissions from 2017 were copied for 2018 and 2019, updated DEC modeling of these emissions is planned. Emission estimates for 1990 through 2010 were conducted by the NYSDERA contractor, ERG, and are further described in NYSERDA (2021a).

Results

Transportation is the largest source of fuel combustion emissions, which increased substantially since 1990. Road transportation emissions increased nearly 7mmt CO₂e since 1990 or 12% (Table SR1.8) and represented 82% of transportation fuel combustion emissions and 17% of statewide total emissions in 2019. Non-road source emissions increased 4mmt or 41% since 1990. A little over half of non-road emissions are from aviation (56% in 2019). However, this does not include the additional 14.6mmt of emissions associated with international aviation (Table SR1.10) that were excluded from this analysis.

Table SR1.8 Transportation Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Road	55.98	69.80	67.50	65.13	62.75	62.75	62.75
Non-Road	9.93	11.71	13.75	13.57	13.49	13.43	13.98
Aviation	5.90	6.69	7.45	7.70	7.82	7.60	7.82
Rail	0.12	0.85	0.79	0.66	0.37	0.50	0.58
Marine	0.45	0.61	0.73	0.84	0.84	0.75	0.81
Other Transportation	3.20	3.00	3.06	3.07	3.10	3.13	3.40
Pipeline	0.26	0.56	1.73	1.31	1.36	1.45	1.38
Gross Total	65.91	81.51	81.26	78.70	76.24	76.18	76.73

Note: Totals may not sum due to independent rounding.

Given that the largest source of emissions is road transportation, it is not surprising that gasoline is also the fuel type associated with the highest level of emissions, or 69% of transportation fuel combustion emissions in 2019 (Table SR1.9). However, the growth of gasoline emissions is approximately the same as jet fuel (roughly 2mmt between 1990 and 2019, a 5% growth in gasoline, 33% growth in jet fuel), while diesel emissions grew by over 5mmt, almost 60% increase.

Table SR1.9 Transportation Emissions by Fuel Type, 1990-2019 (mmt CO₂e GWP20)

Fuel Type	1990	2005	2015	2016	2017	2018	2019
Aviation Gasoline	0.06	0.10	0.03	0.03	0.03	0.03	0.03
CNG	+	0.16	0.25	0.26	0.08	0.08	0.08
Diesel	9.21	14.41	15.05	15.21	14.85	15.17	14.65
Gasoline	50.42	59.68	56.78	54.23	52.12	51.88	52.81
Jet Fuel	5.84	6.59	7.42	7.67	7.79	7.57	7.78
Natural Gas	0.26	0.56	1.73	1.31	1.36	1.45	1.38
Residual Fuel	0.12	na	na	na	na	na	na
Gross Total	65.91	81.51	81.26	78.70	76.24	76.18	76.73

“+” less than 0.01mmt; “na” not applicable; Note: Totals may not sum due to independent rounding.

As described above, IPCC guidelines omit fuels used for international transport and these emissions were excluded from this analysis as well (Table SR1.10). As New York State receives a significant volume of the United States international travel and shipping, these emissions are significant.

Table SR1.10 Excluded Transportation Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Bunker (Aircraft)	11.58	8.25	13.68	14.52	15.15	14.57	14.55
Bunker (Marine Vessel)	0.60	2.63	2.91	1.97	1.32	1.33	0.71
Excluded Total	12.18	10.89	16.58	16.49	16.46	15.90	15.26

Note: Totals may not sum due to independent rounding.

Petroleum Refining

The EIA SEDS dataset suggests that one refinery operated in New York in 1990 and ceased operations in 1991. Emissions for this facility were calculated for 1990 and 1991 by scaling national refinery emissions for those years to New York based on the state’s crude oil distillation capacity. Emissions were estimated as 0.01mmt CO₂e for both 1990 and 1991.

Other Fossil Fuel Use

While the majority of emissions from fossil fuels are the result of fuel combustion or leakage, there are also emissions associated with other non-energy uses of fossil fuels. This includes emissions that might occur during the manufacturing or use of plastics, asphalt, or lubricants. Some of these uses result in longer term storage of carbon, rather than emissions. Nationwide, the EPA estimates that 38% of the carbon consumed in these uses is emitted as CO₂.³ The IPCC guidelines include these other uses of fossil fuels in the Industrial Process and Product Use sector. This report follows the national greenhouse gas inventory, which includes these emissions in the energy sector (EPA 2021a).

³ EPA (2021a) 3.2 Carbon Emitted from Non-Energy Uses of Fossil Fuels (CRF Source Category 1A)

Methodology

The EIA SEDS dataset provides total fuel volumes, but an additional step is needed to determine how much fuel was likely to be used in New York for different products. The U.S. national inventory was used to determine the percentage of each type of fuel that was either combusted, used for other reasons that resulted in emissions, or not associated with emissions (i.e., stored) for each year in the time series (NYSERDA 2021a). For those fuel volumes that were determined to be used for other reasons that resulted in emissions, it is assumed that 100% of the carbon content was oxidized and released as CO₂, and no CH₄ or N₂O emissions were produced.

Results

Although these non-combustion activities are not a major source of annual emissions, emissions declined 40% from 1990 to 2019, suggesting a reduction in the use of these fuels in New York State.

Table SR1.11 Emissions from Other Uses by Fuel Type, 1990-2019 (mmt CO₂e GWP20)

Fuel Type	1990	2005	2015	2016	2017	2018	2019
Lubricants	0.88	0.75	0.61	0.59	0.54	0.52	0.48
Special Naphthas	0.22	0.10	0.18	0.17	0.16	0.15	0.15
Miscellaneous Petroleum Products	0.23	0.12	0.12	0.13	0.16	0.16	0.15
Natural Gas	0.08	0.06	0.06	0.06	0.06	0.06	0.06
Coal	0.02	0.77	0.39	0.29	0.29	0.22	0.02
Other Fuels	0.13	0.47	0.09	0.09	0.07	0.08	0.08
Gross Total	1.56	2.26	1.46	1.33	1.29	1.19	0.93

Note: Totals may not sum due to independent rounding.

Fugitive Emissions from Fossil Fuels

This IPCC category represents emissions associated with the intentional venting or unintentional leakage of emissions from oil and natural gas infrastructure in New York. This includes many individual sources from extraction, through the transmission and distribution system, and at the “customer side” or the final delivery location. As described in the *Summary Report*, governmental greenhouse gas inventories are “bottom-up” and attempt to catalogue annual emissions from all sources across a wide geographic area. The analysis of fugitive emissions in this section and in the Imported Fossil Fuels section below also considers “top-down” information, or data collected from sensors that are not associated with any specific emission source. Top-down information can complement bottom-up inventories and provide valuable points of comparison. Notably, the primary source of information for this report is NYSEDA (2021b), which is an updated version of the NYS Oil and Gas Methane Inventory from 2019. The estimate of current CH₄ emissions increased 44% as that analysis was updated to reflect improved methodologies. This report applies a further consideration of potential fugitive emissions and higher emission rates for in-state natural gas wells, as described in NYSEDA (2021a).

Methodology

The underlying data and methodology used in this report are described in the NYS Oil and Gas Methane Inventory (NYSEDA 2021b) as supplemented by methods described in NYSEDA (2021a). These analyses will continue to be updated as new information is made available, which is likely to result in higher estimates of fugitive CH₄ (see Planned Improvements). For these analyses, NYSEDA contracted

with researchers at Abt Associates Inc. and Eastern Research Group and received technical support from DEC and other State agencies as well as from outside experts. DEC also hosted a public hearing in March 2021 to describe the analyses and take feedback on data sources and methodology. DEC continues to welcome feedback on this and any part of the current analyses.

Results

Based on the analysis provided by NYSERDA (2021a, b) emissions in the oil and gas industry within New York has declined 18% since 1990 (Table SR1.12). However, emissions from this industry remain high, and were 3.6% of total emissions in 2019 despite providing a very small portion of fuel used in the state. This analysis was also used to generate upstream and downstream emission factors by fuel type for use by State agencies, as provided in the accompanying *Summary Report*.

Table SR1.12 Oil and Gas Fugitive Emissions, 1990-2019 (mmt CO₂e GWP20)

Gas	1990	2005	2015	2016	2017	2018	2019
Carbon dioxide	0.02	0.04	0.04	0.05	0.07	0.09	0.17
Methane	17.39	20.65	15.78	15.07	14.57	14.10	14.05
Nitrous oxide	+	+	+	+	+	+	+
Gross Total	17.41	20.68	15.83	15.11	14.64	14.19	14.22

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

Electricity Transmission

This IPCC category is typically included in the Industrial Process and Product Use sector but represents an emission source associated with energy systems. Emissions of sulfur hexafluoride (SF₆) are primarily the result of leaks emitted from electric system substations and switchgear. In addition to leaks, SF₆ can also be emitted during installation, servicing, and disposal of substations and switchgear. To address the high rate of SF₆ emissions in the 1990's, EPA established the Electric Power Systems Partnership, which resulted in a significant decline in annual emission rates nationwide.⁴ However, these systems are still the industry standard and new SF₆ equipment continues to be installed. SF₆ is one of the strongest known greenhouse gases and has an extremely stable molecular structure. This stability also means that SF₆ degrades slowly in the atmosphere, potentially affecting the earth's climate for thousands of years.

Methodology

Per the U.S. EPA SIT, national emissions estimates were scaled to New York State using the ratio of New York State to U.S. electricity sales (MWh) with one notable adjustment. Based on feedback from EPA, SF₆ emissions were calculated separately for Consolidated Edison Inc. (ConEd), which historically represented a large share of U.S. emissions. Electricity sales attributable to ConEd were deducted from national and state totals and SF₆ was estimated separately for ConEd. Publicly reported ConEd SF₆ emissions were used, where available. For the earlier years of 1990-1995, the 1996 ratio of ConEd to total national emissions was applied to the annual U.S. emissions estimate.

⁴ <https://www.epa.gov/eps-partnership/eps-partnership-accomplishments>

Results

Based on this assessment, emissions of SF₆ were greatest in the early years of the time series and declined substantially. The emission rate has remained relatively flat in recent years, likely due to the servicing of existing equipment and the continuing installation of new SF₆ equipment across the state.

Table SR1.13 Electricity Transmission SF₆ Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Electricity Transmission	4.02	1.61	0.17	0.15	0.14	0.13	0.13
Gross Total	4.02	1.61	0.17	0.15	0.14	0.13	0.13

Out of State Energy Emissions

The CLCPA requires that this emissions report include two categories of emissions that occur outside of the State's jurisdictional boundaries and that are not typically included in governmental greenhouse gas accounting. These are emissions associated with imported electricity and with the "extraction and transmission" of imported fossil fuels (Table SR1.14). The IPCC guidelines do not include these emission categories and DEC is unaware of similar analyses in any governmental greenhouse gas report. However, the emission sources covered here may be included in reporting by the states in which they are located. National emission reports will not attribute these emissions to New York State or to facilities located in New York.

The data and methods used for these two analyses are described at a high level below and in greater detail in NYSEDA (2021a). In general, this analysis seeks to calculate the "upstream", out-of-state emissions associated with imported electricity and the fossil fuel volumes described in other sections of this report.

This report follows IPCC guidelines and excludes emissions from bunker fuels, or fuels used for international transport ("Excluded Transportation Emissions", Table SR1.14). This is explained in more detail in the Fuel Combustion section above. For this section, this means that this report excludes the upstream, out-of-state emissions for the volume of fuel that was used as a bunker fuel in New York.

Table SR1.14 Out of State Energy Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Imported Electricity	0.92	7.86	6.55	7.22	6.67	8.27	7.84
Imported Fossil Fuels	99.42	124.34	113.22	106.87	96.16	99.22	95.01
Gross Total	100.33	132.20	119.77	114.09	102.83	107.50	102.85
Excluded Transportation Emissions	3.19	3.00	4.67	4.60	4.56	4.23	4.05

Note: Totals may not sum due to independent rounding.

Imported Electricity

This emission category relates to the importing of electricity into New York that was generated at facilities outside of New York. The amount of power imported into New York in any given year is determined by a variety of factors that are beyond the scope of this report. Additionally, the types of technologies used to

generate electricity in other states and the emissions that result from that generation are also not subject to New York State's jurisdiction.

Methodology

The data and methodology used in this report are described in the accompanying report from NYSERDA (2021a). For this analysis, NYSERDA contracted with researchers at Eastern Research Group Inc. (ERG) and received technical support from DEC and other State agencies as well as from outside experts. DEC continues to welcome feedback on this and any part of the current analysis. This analysis included both net electricity imports from the surrounding regional electricity grids as well as imports from specific electricity generation units in New Jersey that are directly connected to New York's electricity grid.

Results

Emissions of CO₂, CH₄, and N₂O from imported electricity were very low in 1990 but have been greater than 6.5mmt per year since 2002. In other words, although emissions were higher in 2019 compared to 1990, this is not a new trend. Instead, emissions from imported electricity have stayed between 6.5 and 10.52mmt CO₂e for almost twenty years, and below 8.3mmt CO₂e for the last five years.

Imported Fossil Fuels

This category of emissions encompasses a wide variety of individual emission sources including those associated with the extraction of fuels, transport to refineries, the processing and blending of finished fuels, and then the transport of those fuels to the New York State border. This category does not include emission sources within New York State, as these are described in the other sections of this report. For comparison, the Fuel Combustion section above assessed the emissions resulting from the combustion of a certain volume of fuel. This Imported Fuels analysis estimated the emissions that occurred during extraction, production, and transmission or distribution of those fuels to New York. Just as the Fuel Combustion analysis applied a combustion emission factor to fuel volumes, this analysis calculated and then applied emission factors related to the upstream fuel cycle.

Methodology

The data and methodology used in this section of the report are described in the accompanying technical documentation from NYSERDA (2021a). For that analysis, NYSERDA contracted with ERG and received technical support from DEC and other State agencies as well as from outside experts. DEC also hosted a public hearing in March 2021 to describe the analysis and take feedback on data sources and methodology. DEC continues to welcome feedback on this and any part of the current analysis.

The methodology used in this section of the report is unique because it encompasses a large, complex set of infrastructures that are not located in New York and are not subject to New York State laws or reporting requirements. There is also no comprehensive federal data source that can provide all of the necessary information. The closest source of information are lifecycle models, which attempt to estimate emissions associated with a product across all stages, from the extraction of raw materials through the final end-use of the product. However, lifecycle models are not updated annually and they may utilize information collected across multiple years. There is also no lifecycle analysis tool that will provide information specific to New York State. Instead, the research team used a combination of lifecycle models, historical emission and fuel data, and spatial information to reconstruct the full time series. NYSERDA (2021a) also describes approaches to assess sensitivities and address specific sources of uncertainty. For this report, DEC uses emission outputs from the "high sensitivity" approach, which represented the most precautionary approach and applies the highest emission factors.

Results

Emissions of CO₂, CH₄, and N₂O from imported fossil fuels declined 4% since 1990 (Table SR1.15). The previous sections of this report described a trend away from fuels with higher combustion emissions such as coal towards those with lower combustion emissions such as natural gas. That trend in fuel use is also apparent in the emissions associated with imported fossil fuels, as upstream, out-of-state emissions associated with coal were reduced 95% while natural gas increased 29%. NYSERDA (2021a) provides additional background and supplemental information, including comparisons of aggregate emission rates associated with different fuel basins that provided fuel to New York. This analysis was also used to generate upstream emission factors by fuel type for use by State agencies, as provided in the accompanying *Summary Report*.

Table SR1.15 Imported Fossil Fuel Emissions by Fuel Type, 1990-2019 (mmt CO₂e GWP20)

Fuel Type	1990	2005	2015	2016	2017	2018	2019
CNG	+	0.16	0.21	0.22	0.05	0.04	0.04
Coal	9.24	5.97	2.31	2.17	1.68	1.80	1.41
Diesel/Distillate	10.83	10.83	10.83	10.83	10.83	10.83	10.83
Gasoline	21.65	26.32	23.58	22.34	21.37	20.67	21.04
Jet Fuel	1.52	1.78	2.06	2.12	2.14	2.00	2.06
Natural Gas	43.66	66.24	72.13	68.45	59.87	62.97	59.18
Other Fuels	12.52	13.03	2.08	0.74	0.22	0.90	0.45
Gross Total	99.42	124.34	113.22	106.87	96.16	99.22	95.01

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

As discussed in the sections above, the IPCC guidelines omit fuels used for international transport, so the associated upstream, out of state emissions from those fuels has also been excluded from this analysis (Table SR1.16).

Table SR1.16 Excluded Emissions by Fuel Type, 1990-2019 (mmt CO₂e GWP20)
Informational Purposes Only

Emission Category	1990	2005	2015	2016	2017	2018	2019
Diesel/Distillate	0.03	0.03	0.12	0.09	0.09	0.09	0.09
Jet Fuel	3.01	2.23	3.80	4.01	4.17	3.85	3.84
Residual Fuel	0.14	0.74	0.75	0.49	0.30	0.29	0.12
Gross Total	3.19	3.00	4.67	4.60	4.56	4.23	4.05

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

Planned Improvements

Fuel Combustion

The apportionment of SEDS fuel data to excluded bunker fuels is an area for future improvement. Fuel combustion emissions were estimated using SEDS data, but these data do not provide the share of fuels for international (bunker) trip use. Two areas of specific interest for improvement are marine

diesel/distillate and airline jet fuel. Due to lack of information, marine diesel/distillate use is currently assigned entirely to bunker fuels. Information will be sought to determine the share of this fuel use being used domestically and include these emissions in the State gross total. Additional approaches to the apportionment of aviation jet fuel use will be evaluated. One of these approaches is the use Bureau of Transportation Statistics T-100 segment data to estimate emissions and fuel use.

Fugitive Emissions from Fossil Fuels

DEC and partners will continue to research and evaluate methods for reconciling bottom-up and top-down estimates of fugitive emissions. Some of the areas of potential future analysis are summarized in NYSERDA (2021b), including further evaluations of top-down measurements taken in New York State, as they become available, and expanding the scope of potential emission sources in commercial and industrial buildings. Further refinements to the analyses conducted in NYSERDA (2021a) may also result in improvements to the estimate of in-state fugitive emissions (Out of State Emissions, below).

Electricity Transmission

Current methodology relies on apportioning national electricity transmission SF₆ emissions to New York State. DEC may seek additional data on SF₆ use in electricity transmission equipment in New York State. Improved data will help refine emissions estimates for this category, as well as be more reactive to actions or policies designed to mitigate emissions.

Out of State Emissions

DEC will continue to refine the methodologies used to estimate upstream energy emissions, particularly from imported fossil fuels. This report represents the best available data and methods that could be used to produce an annualized inventory of sources relevant to New York State for the 1990-2019 time period. However, the measurement of emissions from the fuel system is an active area of research and any new and relevant information will be incorporated whenever possible. DEC welcomes feedback on alternative data and methods that may improve the accuracy of this assessment and the ability to identify and characterize emission sources outside of New York.

Abbreviations

btu	British thermal unit
CH ₄	Methane
CHP	Combined heat and power
CLCPA	NYS Climate Leadership and Community Protection Act
CNG	Compressed natural gas
CO ₂	Carbon dioxide
CO _{2e}	Carbon dioxide equivalent
DEC	NYS Department of Environmental Conservation
EIA	Energy Information Administration, U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GWP	Global Warming Potential
GWP100	100-Year Global Warming Potential
GWP20	20-Year Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LPG	Liquefied petroleum gas(es)
mmt	Million metric tons
MOVES	Motor Vehicle Emission Simulator model
N ₂ O	Nitrous oxide
NA	Not applicable
NEI	National Emissions Inventory
NYCRR	New York Codes, Rules and Regulations
NYISO	New York Independent System Operator
NYS	New York State
NYSERDA	NYS Energy Research and Development Authority
RCI	Residential, Commercial, Industrial
SEDS	EIA State Energy Data System
SF ₆	Sulfur hexafluoride
SIT	EPA State Inventory Tool

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2021 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #2

Kathy Hochul, Governor | Basil Seggos, Commissioner



Table of Contents

Format of This Report	1
Figures and Tables	1
Industrial Processes and Product Use	2
Industrial Processes	2
Metals	3
Aluminum	4
Ferroalloys	4
Iron and Steel	5
Lead	5
Minerals	5
Cement	6
Other Process Use of Carbonates	6
Soda Ash	6
Electronics	7
Industrial Products	8
N ₂ O Product Use	8
Hydrofluorocarbons / Substitutes for Ozone Depleting Substances	9
Planned Improvements	11
Abbreviations	12
References	13

Archived

Format of This Report

This sectoral report provides a detailed explanation of methods, data, and trends for the Industrial Processes and Product Use (IPPU) sector. The accounting used in this sectoral report follows the requirements of the Climate Leadership and Community Protection Act (CLCPA) and is in alignment with the 6 NYCRR Part 496 regulation, “Statewide GHG Emission Limits.” This includes the use of a 20-Year Global Warming Potential metric provided in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC 2013). The organization of this report and specific methodologies are based on guidelines from the IPCC Taskforce on National Greenhouse Gas Inventories (or “IPCC guidelines”) as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2021a). The accompanying *Summary Report* provides a comparison with other accounting methods, including by economic sector or using conventional accounting formats. DEC also intends to provide emission values for all years via the Open Data NY platform.

Figures and Tables

Table SR2.1 Industrial Process and Product Use Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	2
Table SR2.2 Industrial Process Emissions 1990-2019 (mmt CO ₂ e GWP20).....	3
Table SR2.3 Metal Industry Process Emissions 1990-2019 (mmt CO ₂ e GWP20).....	3
Table SR2.4 Mineral Industry Process CO ₂ Emissions, 1990-2019 (mmt CO ₂).....	5
Table SR2.5 Semiconductor Industry Emissions by Gas, 1990-2019 (mmt CO ₂ e GWP20).....	8
Table SR2.6 Industrial Product Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	8
Table SR2.8 ODS Substitute Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	10
Table SR2.9 Refrigerant Emissions by End Use, 1990-2019 (mmt CO ₂ e GWP20).....	10
Table SR2.10 ODS Substitutes Included in This Report.....	11

Industrial Processes and Product Use

This IPCC category encompasses emissions from industrial activities and includes industrial processes, such as those conducted in manufacturing facilities, as well as emissions that result when products are used, such as during the operation of equipment used in homes or businesses. Energy emissions, including the combustion of fuels at industrial facilities are summarized in *Sectoral Report #1: Energy*. The accompanying *Summary Report* also provides an alternative breakdown of emission sources, such as to combine industrial energy and process emissions.

In New York, industrial process emissions are a relatively small portion of overall statewide emissions and have declined over the thirty-year period from 1990 to 2019 (Table SR2.1). This trend reflects both the nationwide reduction in manufacturing and changes in the technologies used in some industries. At the same time, emissions associated with the usage of industrial products have grown and greatly outweigh those associated with industrial processes. This trend reflects the use of hydrofluorocarbons (HFCs) as replacements for ozone depleting substances in many applications globally and in the U.S.; HFCs from industrial product use were 45.6% of national IPPU emissions in 2019 (EPA 2021).

Table SR2.1 Industrial Process and Product Use Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Processes	2.68	2.17	2.72	1.75	1.94	2.36	2.21
Product Use	0.04	6.79	18.12	19.23	19.86	20.42	20.89
Gross Total	2.72	8.97	20.84	20.98	21.80	22.78	23.10
<i>% of statewide gross total</i>	<i>0.7%</i>	<i>2.0%</i>	<i>5.1%</i>	<i>5.4%</i>	<i>5.8%</i>	<i>5.9%</i>	<i>6.1%</i>
Net Total	2.72	8.97	20.84	20.98	21.80	22.78	23.10
<i>% of statewide net total</i>	<i>0.8%</i>	<i>2.2%</i>	<i>5.7%</i>	<i>6.0%</i>	<i>6.6%</i>	<i>6.6%</i>	<i>6.8%</i>

Note: Totals may not sum due to independent rounding.

Industrial Processes

Industrial processes contribute anthropogenic emissions of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and the fluorinated greenhouse gases: perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃). The emissions characterized in this section occur within industries that operated in New York State from 1990 through 2019. This accounts for emissions generated during production processes, whereas fuel combustion emissions from these industries are accounted for under industrial fuel combustion in *Sectoral Report #1: Energy*.

In 2019, industrial process emissions were 2.21mmt CO₂e GWP20, or approximately 0.6% of statewide emissions. Overall industrial process emissions declined 18% since 1990, due to an 76% reduction in the metals industry as a result of technological change and the closing of multiple facilities in New York. The other sources of industrial process emissions, including mineral industries like cement manufacturing as well as electronics industries such as semiconductor manufacturing, have increased since 1990 but remain relatively small emission sources compared to the energy sector (*Sectoral Report #1: Energy*).

Table SR2.2 Industrial Process Emissions 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Metals	1.63	0.78	0.59	0.58	0.57	0.53	0.39
Minerals	1.01	1.32	2.07	1.11	1.29	1.73	1.71
Electronics	0.03	0.07	0.06	0.06	0.07	0.10	0.12
Chemicals	ne	ne	ie	ie	ie	ie	ie
Gross Total	2.68	2.17	2.72	1.75	1.94	2.36	2.21

“ne” not estimated; “ie” included elsewhere; Totals may not sum due to independent rounding.

Further details on each industrial sector are provided below except for the chemicals industry. For the purposes of the current report, emissions associated with the chemicals industry in NY are captured in the Energy sector. Currently, the only available information on greenhouse gas emissions from chemical industry processes that are not fuel combustion emissions are from hydrogen production.¹ However, these emissions are already captured as fuel combustion in the Energy sector and cannot be separated at this time. The EPA does not include hydrogen production in the national greenhouse gas inventory, possibly because hydrogen is most commonly a by-product of Energy sector processes. Additionally, the U.S. Energy Information Administration (EIA) does not disaggregate fuel volumes used for hydrogen production from energy generation.

Metals

New York has a long history of metal manufacturing that includes some of the oldest facilities in the nation. However, overall emissions are lower than in other states reflecting the relative size of the industry and economic changes in the industry. The industry includes the production of aluminum, iron and steel, ferroalloy, and secondary lead.

Table SR2.3 Metal Industry Process Emissions 1990-2019 (mmt CO₂e GWP20)

Gas/Source	1990	2005	2015	2016	2017	2018	2019
CO₂	0.75	0.62	0.57	0.56	0.55	0.51	0.37
Aluminum	0.41	0.28	0.22	0.22	0.22	0.21	0.22
Ferroalloys	0.20	0.20	0.21	0.21	0.18	0.18	NA
Iron and Steel	0.09	0.09	0.09	0.09	0.10	0.07	0.07
Lead	0.05	0.05	0.05	0.05	0.06	0.05	0.08
CH₄	+	+	+	+	+	+	+
Ferroalloys	+	+	+	+	+	+	na
Iron and Steel	+	+	+	+	+	+	+
PFCs	0.88	0.16	0.01	0.01	0.02	0.02	0.02
Aluminum	0.88	0.16	0.01	0.01	0.02	0.02	0.02
Gross Total	1.63	0.78	0.59	0.58	0.57	0.53	0.39

“+” less than 0.01mmt; “na” not applicable; Totals may not sum due to independent rounding.

¹ The U.S. GHGRP lists one chemical facility in NY with process emissions (i.e., emissions not related to stationary combustion). The facility reported 0.025-0.034mmt of CO₂ per year for “hydrogen production”, 2015-2019.

Aluminum

Aluminum production results in process emissions of CO₂ and PFCs. CO₂ emissions occur during the smelting process when alumina is reduced to aluminum. The electrolysis used during this reduction consumes carbon-containing anodes and cathodes and releases CO₂. Emissions of the PFCs perfluoromethane (CF₄) and perfluoroethane (C₂F₆), also occur during the smelting process as anode effects. PFC emissions can be reduced through operational controls that reduce the frequency and duration of anode effects. The EPA notes that PFC emissions have been reduced since 1990 due to both decreased aluminum production and mitigation actions taken by aluminum smelters (EPA 2021a).

Methodology

For 1990 through 2010, emissions were estimated by applying the IPCC production method-specific (e.g., prebake or Soderberg) CO₂ emission factors to an estimate of New York State aluminum production. State aluminum production was estimated by applying the ratio of national production by capacity to New York state capacity by facility, using data from the USGS National Minerals Information Center. PFC (C₂F₆, CF₄) emissions were estimated by scaling national PFC aluminum emissions using the ratio of NYS production to national production. For 2011 and later years, emission values reflect facility reporting to the U.S. EPA Greenhouse Gas Reporting Program (GHGRP) by aluminum production facilities located in New York (EPA 2021b).

Results

Emissions have declined 81% since 1990 to 0.24mmt CO₂e. A majority of this reduction, 82%, was from the decline in PFCs emissions from changes in operational controls that are a reflection of national trends. A secondary factor was the decline in New York State aluminum production levels. This trend is largely reflective of economic factors.

Ferroalloys

Ferroalloys are iron alloys that contain significant quantities of other elements and are often used in the production of steel and other alloys. The production of ferroalloys generates emissions of CO₂ and CH₄ as metallurgical coke is oxidized during the manufacturing process. No ferroalloy manufacturers currently operate within New York State as the sole facility closed in 2018.

Methodology

Due to a lack of state-level ferroalloy production data prior to 2010, it is not possible to estimate emissions prior to 2009. However, the number and capacity of facilities in New York was consistent from 1990-2018. As such, the values for 1990-2009 represent the nine-year average of ferroalloy production emissions from facilities in New York, as reported to the GHGRP for 2010-2018. Values for years after 2009 reflect reporting to the GHGRP by individual ferroalloy production facilities (EPA 2021b).

Results

New York State has no currently operating ferroalloy production facilities, resulting in zero emissions for this category in 2019. Based on its reporting to the EPA GHGRP, the only facility operating in the period covered by this report maintained relatively stable annual emissions until its closure in 2018.

Iron and Steel

The production of iron and steel generates process-related emissions of CO₂ and CH₄. Multiple steps in the steel making process produce emissions. The majority of CO₂ emissions are generated by the use of metallurgical coke to remove oxygen from iron ore during the production of pig iron. One of the two operating facilities was shuttered in 2018.

Methodology

The eight-year (2010-2017) average of iron and steel emissions from facilities in New York, as reported to the GHGRP, was applied as a static value to 1990-2009 (EPA 2021b). The number of New York facilities was consistent between the 2010-2017 and 1990-2009 periods. For 2010 and later years, emission values represent data reported to the GHGRP by iron and steel production facilities (EPA 2021b).

Results

The closure of one of the two operating iron and steel production facilities in 2018 resulted in the largest decline in emissions over the period. Emissions declined 34% in 2018 compared to 2017 and remained stable in 2019. Overall, iron and steel emissions declined 27% as compared to 1990.

Lead

In New York State, the only form of lead production since 1990 has been secondary lead production. Secondary production primarily deals with the recycling of lead acid batteries and other scrap lead products. CO₂ emissions occur during production as metallurgical coke is used in the reduction process.

Methodology

The ten-year (2010-2019) average of secondary lead production emissions from facilities in New York, as reported to the GHGRP, was applied as a static value to 1990-2009 (EPA 2021b). One facility has operated in New York for the entirety of the time period covered. For 2010 and later years, emission values represent data reported to the GHGRP by secondary lead production facilities (EPA 2021b).

Results

After relatively stable emissions from 2010-2018, emissions rose 54% in 2019 compared to the year prior. This increase led to emissions increasing 71% in 2019 as compared to 1990.

Minerals

The minerals category refers to the production of cement, and the uses of carbonates and soda ash. In each of these categories CO₂ is released as the input mineral is heated, creating a process called calcination. Cement is the largest contributor of emissions in the Minerals subcategory in New York.

Table SR2.4 Mineral Industry Process CO₂ Emissions, 1990-2019 (mmt CO₂)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Cement	0.67	0.80	1.42	0.62	0.83	1.28	1.26
Other Process Use of Carbonates	0.15	0.36	0.52	0.36	0.34	0.33	0.33
Soda Ash	0.20	0.17	0.13	0.13	0.12	0.12	0.12
Gross Total	1.01	1.32	2.07	1.11	1.29	1.73	1.71

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

Cement

Greenhouse gas 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 CO₂ when calcium carbonate is heated in a cement kiln to form lime (calcium oxide) and CO₂.

Methodology

For 1990 through 2009, cement emissions were calculated by applying an EPA clinker emission factor to annual state clinker production estimates, with a cement kiln dust correction factor applied to the total to account for these additional emissions. State-level clinker production data is not publicly available, but district-level data is published annually via the USGS National Minerals Information Center and incorporated into the EPA SIT (EPA 2020). State clinker production was estimated by applying the SIT default share (50%) to the New York and Maine district totals. For 2010 and later years, emission values represent data reported to the GHGRP by cement facilities located in New York (EPA 2021b).

Results

Although this analysis suggest that emissions increased in recent years, the pre-2010 analysis may underestimate emissions because it is based on a simplified apportionment of the USGS data. Facility data reported to EPA suggest a slight decline in emissions since 2010.

Other Process Use of Carbonates

Carbonates, such as limestone, dolomite, and soda ash, are used in a wide variety of applications. Examples of these applications include cement production, flue gas desulphurization, glass production, as a flux in metallurgy, mine dusting or acid water treatment, sugar refining, and agricultural soil management. This section refers specifically to industrial process uses of limestone and dolomite not covered in agricultural emission analysis elsewhere in this report. Carbonates in these processes are heated to the point where CO₂ is generated and emitted as a byproduct.

Methodology

The EPA SIT method was used to estimate emissions related to industrial processes for this source, using default emission factors (EPA 2020). Following this method, New York's total annual limestone and dolomite consumption (as reported by the USGS National Minerals Information Center) was multiplied by the ratio of national consumption for industrial uses to total national consumption. The quantities were then applied to limestone and dolomite specific emission factors.

Results

Emissions in this category roughly doubled from 1990 to 2005, doubled again by 2015, and then returned to 2005 levels. As this analysis is based on consumption levels in New York, this directionality may reflect economic activity in the state, but the use of these commodities also reflects national trends. National trends, including emission increases 1990 to 2015 and subsequent decreases, were predominately the result of limestone usage in flue gas desulfurization systems (EPA 2021a).

Soda Ash

Soda ash (sodium carbonate) is used in, and in the production of, many consumer products such as glass, soap and detergents, paper, textiles, and food. The largest use of soda ash is in the glass manufacturing industry. CO₂ is released when soda ash is heated and consumed in industrial processes.

Methodology

Soda ash emissions were estimated by applying an IPCC emission factor (IPCC 2006) to estimated state consumption. State consumption estimates were derived by scaling national consumption from the USGS National Minerals Information Center according to population size (EPA 2021a).

Results

The analysis conducted here reflects national trends in soda ash use and state population size, which may not portray actual trends in New York soda ash use emissions. National soda ash use has declined 28% since 1990, while soda ash emissions have declined 41% since 1990.

Electronics

The electronics manufacturing industry employs numerous greenhouse gases in production processes. These processes include plasma etching, reactor chamber cleaning, and temperature control. The electronics industry includes semiconductor, photovoltaic cells, thin-film-transistor flat panel display, and micro-electro-mechanical system manufacturing. The only electronics industry that DEC has identified as operating in New York is semiconductor manufacturing, discussed below.

Semiconductor manufacturing uses and emits a variety of greenhouse gases in its production process. Greenhouse gasses emitted include nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃). Manufacturers of semiconductors use fluorinated greenhouse gases in the plasma etching and plasma enhanced chemical vapor deposition processes. Some fluorinated compounds can also be transformed in the plasma processes into other compounds (e.g., CF₄ generated from C₂F₆). Abatement systems reduce emissions of these gases, but those that are not captured are released into the atmosphere. The production of semiconductors is highly complex, with different steps requiring varying amounts of these chemicals for specific purposes. Technological changes and manufacturing improvements impact the relative annual contribution of greenhouse gases over the covered time period.

Methodology

Emissions associated with semiconductor manufacturing for 1990 through 2010 were estimated by applying the ratio of New York to national shipments value (for semiconductors and related device manufacturing) to national semiconductor manufacturing emissions. Shipment values were retrieved from the U.S Census Bureau's quinquennial Economic Census (i.e., 1992, 1997, 2002, and 2007), with ratios held constant between censuses and the 1992 value applied to the preceding two years. For 2011 and later years, emission values represent data reported to the GHGRP by semiconductor manufacturing facilities located in New York (EPA 2021b).

Results

Based on this analysis, greenhouse gases associated with semiconductor manufacturing may have increased since 1990 and the facilities that report annually to EPA continue to emit these substances in stable or increasing levels. Although the relative emission level is low compared to other sources and gases covered in this report, PFCs and SF₆ are incredibly powerful and long-lived greenhouse gases. In some cases, emissions will persist in the atmosphere for hundreds of thousands of years.

Table SR2.5 Semiconductor Industry Emissions by Gas, 1990-2019 (mmt CO₂e GWP20)

Gas	1990	2005	2015	2016	2017	2018	2019
N ₂ O	+	+	0.02	0.02	0.02	0.02	0.02
HFCs	+	+	+	+	+	+	+
PFCs	0.03	0.05	0.03	0.04	0.05	0.07	0.08
SF ₆	0.01	0.01	+	+	+	+	+
NF ₃	+	+	+	+	+	+	0.01
Gross Total	0.03	0.07	0.06	0.06	0.07	0.10	0.12

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

Industrial Products

The IPCC’s IPPU sector includes various emission sources associated with the use of manufactured or packaged goods (Table SR2.6). The largest source of product use emissions is hydrofluorocarbons (HFCs) and other substances used as substitutes for ozone depleting substances (or “ODS substitutes”). ODS are subject to long-standing international phase-down described below. Another category is the use of nitrous oxide in the medical and food industries. Two additional IPCC IPPU categories, non-energy fuel use and electricity transmission equipment emissions have been assigned to the energy sector (*Sectoral Report #1: Energy*). The EPA does not differentiate fuels used for energy from those used for non-energy purposes, this report follows the same convention.²

Table SR2.6 Industrial Product Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Ozone-Depleting Substance Substitutes	0.04	6.79	18.12	19.23	19.86	20.42	20.89
N ₂ O Products	+	+	+	+	+	+	+
Non-Energy Fuel Use	ie	ie	ie	ie	ie	ie	ie
Electricity Transmission	ie	ie	ie	ie	ie	ie	ie
Gross Total	0.04	6.79	18.12	19.23	19.86	20.42	20.89

“+” less than 0.01mmt; “ie” included elsewhere

N₂O Product Use

Nitrous oxide (N₂O) is used in a variety of applications, including some covered in other areas of this report, such as in semiconductor manufacturing. This category covers emissions associated with the use of N₂O outside of manufacturing processes. These uses cannot be measured directly at the state-level but are based on the analysis provided by the EPA in the national greenhouse gas inventory (EPA 2021a). As EPA describes it, the N₂O produced in the U.S. is primarily used in medical or dental anesthetics (89.5% of national usage in 2019), followed by propellants used in food applications such as pressure-packaged whipped cream (6.5%). The remaining uses for N₂O are either covered in other sections of the national inventory or are non-emissive.

² EPA (2021) page 4-7

Methods

To estimate emissions at the state-level, annual U.S. emissions for 1990-2019 were collected from the national emission data (EPA's submission to the UNFCCC) and scaled to New York based on population size. The EPA's national greenhouse gas inventory report describes the analysis conducted. This analysis focused on N₂O emissions from medical/dental uses and food propellants, which are assumed to be emitted at 100% when the product is used based on the IPCC guidelines (IPCC 2006). For 1990-2003, the EPA used a combination of industry data and expert interviews. From 2004-2019, the EPA used the 2003 estimated value. EPA (2021a) also describes planned improvement for their analysis.

Results

The EPA (2021a) analysis found that N₂O product use emissions remained flat 1990-2003 because substitutes have been introduced to meet increasing demand.

Hydrofluorocarbons / Substitutes for Ozone Depleting Substances

The largest category of emissions in the IPPU sector in New York are ODS substitutes. Unlike other IPCC categories, the emission sources covered in this section are not related to any specific type of activity or product. Instead, these emissions reflect the use of certain gases across many parts of the economy including refrigeration, heating and air-conditioning (or HVAC), insulation foam, consumer products, and fire retardants.

Starting around the baseline year of 1990 and just prior to the formation of the UNFCCC and the IPCC, the Montreal Protocol was adopted to address chemicals responsible for degrading the ozone layer. This global phasedown in ODS led to a corresponding increase in the emissions from new substitute compounds. The most common ODS substitutes are HFCs or blends that contain HFCs. PFCs and SF₆ have also been used in ODS substitutes but at a much lower level.

Importantly, most ODS are also greenhouse gases, and some are more harmful to the climate than the substances that have replaced them. This report does not provide information on ODS because ODS are not included in the IPCC guidelines for national reporting on greenhouse gases. This may be the same reason ODS were not explicitly included in the definition of greenhouse gas in the CLCPA. The IPCC accounting does not include greenhouse gases that were already subject to the Montreal Protocol prior to the development of the UNFCCC international climate agreements. However, ODS are still in use today, even if the global phasedown under the Montreal Protocol has been largely successful. Future reports may provide an estimate of ODS emissions once there is sufficient information to estimate emissions at the state level.

Methods

The standard approach for estimating ODS substitute emissions is to develop a vintaging model that considers the stock of equipment and other products along with the turnover time for these products, the substances contained in the products, and the time period over which those substances are lost to the environment. In some cases, these substances are intentionally emitted, such as when they are used as an aerosol propellant (e.g., personal defense sprays or medical inhalers). In other cases, the substances are leaked during the operation of certain equipment, such as supermarket refrigeration systems, or lost when equipment is improperly disposed of, such as home appliances like refrigerators or air conditioning units. The model used for this report is described in detail in NYSERDA (2021), which includes an additional description and explanation of trends in these emissions.

Results

The majority of emissions today are from HFCs used as refrigerants in food refrigeration and HVAC equipment (Table SR2.8). The growth in HFCs in these applications reflects the use of HFCs as ODS substitutes as well as the increasing adoption of air conditioning and other appliances. HFCs were also increasingly used in recent years as ODS substitutes in foam insulation. The growth of HFCs in aerosols was relatively small due to the adoption of not-in-kind replacements, such as pump dispensers.

Table SR2.8 ODS Substitute Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Refrigerants	+	3.50	10.80	11.70	12.59	13.47	14.24
Foam Blowing Agents	no	0.72	2.21	2.38	2.44	2.43	2.43
Aerosols	0.04	2.15	4.57	4.59	4.27	3.93	3.63
Solvents and Fire Suppression	no	0.42	0.54	0.56	0.56	0.59	0.59
Gross Total	0.04	6.79	18.12	19.23	19.86	20.42	20.89

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding; no ‘not occurring’

Refrigerant emissions can be divided into multiple end-uses (Table SR2.9) based on the type of equipment and user. The largest source of emissions in 2019 was commercial refrigeration, which is mainly comprised of equipment used in supermarkets and other food stores. The second largest source of emissions is air-conditioning (or HVAC) in motor vehicles. Finally, the remaining large sources of HFCs are from the use of refrigerants for space cooling, specifically air-conditioning equipment used in residential and commercial buildings.

Table SR2.9 Refrigerant Emissions by End Use, 1990-2019 (mmt CO₂e GWP20)

Category/End-Use	1990	2005	2015	2016	2017	2018	2019
Refrigeration	0.01	1.21	4.57	4.93	5.30	5.65	5.98
Commercial	0.01	1.03	3.98	4.34	4.69	5.04	5.37
Residential	no	0.05	0.41	0.41	0.42	0.42	0.42
Transportation	no	0.13	0.18	0.18	0.19	0.19	0.19
HVAC	no	2.28	6.18	6.71	7.24	7.75	8.17
Commercial	no	0.02	1.40	1.68	1.97	2.25	2.55
Residential	no	0.03	1.16	1.40	1.64	1.88	2.10
Transportation	no	2.23	3.62	3.63	3.63	3.62	3.52
Other*	no	no	0.02	0.03	0.03	0.04	0.05
Residential	no	no	0.02	0.03	0.03	0.04	0.05
Commercial	no	no	+	+	+	+	+
Industrial Processes	no	0.01	0.03	0.03	0.03	0.03	0.04
Gross Total	0.01	3.50	10.80	11.70	12.59	13.47	14.24

*Includes dehumidifiers and clothes dryers; “no” not occurring.

The substances used in this IPCC category represent individual HFC gases, blends of HFCs, and blends that include other non-HFC substances (Table SR2.10). In recent years, there has been a transition to

compounds with lower overall GWPs, which should reduce total emission levels. However, this trend will continue to be offset by the growth in the end-use applications described above including air conditioning and heat pumps.

**Table SR2.10 ODS Substitutes Included in This Report
GWP and 2019 Emissions by ASHRAE Code**

ASHRAE #	GWP20	2019 Emissions (mmt CO ₂ e GWP20)
R-125	6090	
R-134a	3710	4.54
R-143a	6940	
R-152a	506	
R-227ea	5360	
R-236fa	6940	0.01
R-245fa	2920	
R-32	2430	0.01
R-365mfc	2660	
R-404A	6437	3.26
R-407A	4406	0.20
R-407C	4011	0.11
R-410A	4260	4.50
R-4310mee	4310	
R-466A	1891	
R-507	6515	1.61
R-507A	6515	

Note: Emissions for pure HFCs do not include emissions from blends of which they are a component.

Planned Improvements

DEC will continue to make improvements wherever possible to the analyses provided in this report. A few specific areas are considered to be priorities, or equivalent to IPCC “key categories”, that can have a significant influence on this emissions inventory.

Industrial Processes

DEC will continue to seek historical data to fill gaps and to improve the accuracy of this report. The methodologies used in this report are based on those provided in the EPA SIT (EPA 2020), facility reporting to the EPA (EPA 2021b), or a combination of both. These methods follow IPCC guidelines in that they use a bottom-up method to estimate all emissions whenever possible, rather than rely on facility reporting that may not cover all emissions. However, it is ideal to align both types of estimation so that emissions from such facilities are effectively monitored and controlled.

Ozone Depleting Substances

Ozone depleting substances such as CFCs and HCFCs are not included in the scope of emissions that are the focus of this report and are being phased down under international agreements. However, they are greenhouse gases and they may still be emitted in sufficient quantities in New York to warrant additional policy. There is no information at this time on these emissions, but DEC plans to expand the analysis of HFCs to further investigate ODS as well.

Abbreviations

AC	Air conditioner
CFC	Chlorofluorocarbon
CF ₄	Perfluoromethane
C ₂ F ₆	Perfluoroethane
CH ₄	Methane
CLCPA	NYS Climate Leadership and Community Protection Act
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
DEC	NYS Department of Environmental Conservation
EIA	Energy Information Administration, U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GHGRP	EPA Greenhouse Gas Reporting Program
GWP	Global Warming Potential
GWP100	100-Year Global Warming Potential
GWP20	20-Year Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HVAC	Heating, ventilation, and air conditioning
HVAC-R	Heating, ventilation, air conditioning, and refrigeration
IE	Included elsewhere
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
MMT	Million metric tons
N ₂ O	Nitrous oxide
NE	Not estimated
NF ₃	Nitrogen trifluoride
NO	Not occurring
NYCRR	New York Codes, Rules and Regulations
ODS	Ozone depleting substances
PFC	Perfluorocarbon
SF ₆	Sulfur hexafluoride
SIT	EPA State Inventory Tool
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey

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Department of
Environmental
Conservation

Agriculture, Forestry, and Other Land Use

2021 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #3

Kathy Hochul, Governor | Basil Seggos, Commissioner



Table of Contents

Format of This Report	1
Figures and Tables	1
Agriculture, Forestry, and Other Land Use	2
Agricultural Emissions.....	3
Livestock.....	3
Animal Feeding	3
Manure Management.....	4
Soil Management.....	6
Liming	7
Urea Application.....	7
Soil Nitrogen Management	8
Net Emission Removals	9
Harvested Wood Products.....	10
Land Use	11
Forest Lands	12
Wetlands	14
Croplands and Grasslands	17
Settlements	17
Planned Improvements	17
Abbreviations	19
References.....	20

Archived

Format of This Report

This sectoral report provides a detailed explanation of methods, data, and trends for the Agriculture, Forestry and Other Lands Use (AFOLU) sector. The accounting used in this sectoral report follows the requirements of the Climate Leadership and Community Protection Act (CLCPA) and is in alignment with the 6 NYCRR Part 496 regulation, “Statewide GHG Emission Limits.” This includes the use of a 20-Year Global Warming Potential metric provided in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC 2013). The organization of this report and specific methodologies are based on guidelines from the IPCC Taskforce on National Greenhouse Gas Inventories (or “IPCC guidelines”) as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2021a). The accompanying Summary Report provides a comparison with other accounting methods, including by economic sector or using conventional accounting formats. DEC also intends to provide emission values for all years via the Open Data NY platform.

Figures and Tables

Table SR3.1 AFOLU Agriculture Emissions, 1990-2019 (mmt CO ₂ e GWP20)	2
Table SR3.2 AFOLU Net Emission Removals, 1990-2019 (mmt CO ₂ e GWP20)	2
Table SR3.3 Livestock Emissions, 1990-2019 (mmt CO ₂ e GWP20)	3
Table SR3.4 Animal Feeding Methane Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	4
Table SR3.5 Manure Management Emissions, 1990-2019 (mmt CO ₂ e GWP20)	6
Table SR3.6 Soil Management Emissions, 1990-2019 (mmt CO ₂ e GWP20)	7
Table SR3.7 Soil Nitrogen Management N ₂ O Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	9
Table SR3.8 Net CO ₂ Removals, 1990-2019 (mmt CO ₂ e GWP20).....	9
Table SR3.9 Harvested Wood Products CO ₂ Removals, 1990-2019 (mmt CO ₂).....	11
Table SR3.10 Land Use Net Emission Removals, 1990-2019 (mmt CO ₂ e GWP20).....	12
Table SR3.11 Forest Land Net Emission Removals, 1990-2019 (mmt CO ₂ e GWP20)	13
Table SR3.12 Wetland Net CO ₂ Removals, 1990-2019 (mmt CO ₂).....	16
Table SR3.13 Excluded Wetland CH ₄ Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	17

Agriculture, Forestry, and Other Land Use

This sectoral report provides information on greenhouse gas emissions and emission removals following the organizational structure of the Intergovernmental Panel on Climate Change guidance for governmental greenhouse gas inventories (e.g., IPCC 2006). For the purposes of the Climate Leadership and Community Protection Act (CLCPA), an additional distinction is made between sources covered by the statewide gross versus net emission totals, as described in the accompanying *Summary Report*.

In 2019, total agricultural emissions were 21.21mmt CO₂e or approximately 6% of statewide emissions, when measured using CLCPA accounting (Table SR3.1). This represents a 38% increase in gross emissions since 1990. The majority of agricultural emissions are from livestock (92%). Further information on the relative contribution of the agricultural emission sources is described in the sections below. Agricultural practices also contribute to the removal of carbon dioxide from the atmosphere. These emission removals are considered a part of Land Use in the IPCC guidelines and are captured as “net emission removals” (Table SR3.2).

Table SR3.1 AFOLU Agriculture Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Livestock	13.56	15.11	18.82	19.53	19.51	20.05	19.55
Soil Management	1.77	1.67	1.67	1.67	1.68	1.67	1.65
Gross Total	15.32	16.78	20.49	21.20	21.19	21.72	21.21
<i>% of statewide gross total</i>	3.8%	3.7%	5.0%	5.4%	5.7%	5.6%	5.6%
Net Total	15.32	16.78	20.49	21.20	21.19	21.72	21.21
<i>% of statewide net total</i>	4.2%	4.0%	5.6%	6.0%	6.4%	6.3%	6.3%

Note: Totals may not sum due to independent rounding.

The two forms of net emission removals in New York State today are via the long-term storage of carbon in Harvested Wood Products (HWPs) and the annual carbon uptake and storage on various land types particularly forests (Table SR3.2). Overall annual rates of emission removals have declined 11% since 1990 primarily due to changes in land use, which is the largest source of net emission removals (95%).

Table SR3.2 AFOLU Net Emission Removals, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Harvested Wood Products	-1.54	-1.86	-1.58	-1.64	-1.56	-1.51	-1.51
Land Use	-31.14	-29.50	-27.78	-27.42	-28.09	-27.85	-27.60
Net Emission Removals	-32.68	-31.36	-29.36	-29.05	-29.65	-29.36	-29.11
Excluded Wetland Emissions	13.50	13.42	13.42	13.44	13.46	13.48	13.50

“+” less than 0.01mmt; “na” not applicable; Note: Totals may not sum due to independent rounding.

This report is novel in that it reports annual CH₄ emissions as well as CO₂ sequestration by freshwater wetlands. The IPCC guidelines are intended to capture anthropogenic emissions and sequestration by ‘managed lands,’ not non-anthropogenic emissions from unmanaged, naturally functioning ecosystems. In the U.S., the EPA interprets coastal wetlands as managed lands, and therefore includes the CH₄

emissions and CO₂ sequestration fluxes attributed to these ecosystems in the national greenhouse gas inventory (EPA 2021). However, freshwater wetlands that are upland of coastal areas have not yet been included in the national inventory. DEC seeks feedback on whether freshwater wetlands in New York should be considered managed lands in a similar manner to coastal wetlands, and therefore whether their CH₄ emissions and CO₂ sequestration should be included in net emission totals. In the interim, annual CH₄ emissions are provided for informational purposes only (“Excluded Wetland Emissions” Table SR3.2). These land use emissions affect accounting for the CLCPA net goal, not the statewide GHG emission limits promulgated as 6 NYCRR Part 496. An important consideration is that the IPCC guidelines do not apply a 20-year Global Warming Potential (GWP), which is a requirement for this report. Using a 20-year rather than a 100-year GWP weights CH₄ emissions more heavily compared to CO₂ sequestration. However, over longer timescales, greenhouse gas fluxes into and out of wetland ecosystems have a net-cooling effect on climate because CO₂ is longer-lived (Neubauer 2014).

Agricultural Emissions

Agriculture contributes to anthropogenic emissions of carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). These emissions are related to livestock and soil nutrient management practices (Table SR3.1). Livestock sources include animal feeding (enteric fermentation) and manure storage systems. Soil nutrient management practices include liming, urea application, and soil nitrogen (N) management. Emission estimates for this section of the report were developed by Peter Woodbury and Jenifer Wightman (Cornell University) using IPCC (2019). As an economic sector, the agricultural industry also contributes other emissions and emission removals that are not captured in this section. For example, agriculture is a source of Energy sector emissions related to the use of fuels (*Sectoral Report #1: Energy*). Agricultural practices also affect carbon sequestration rates on croplands and can affect land conversion, including conversions to or from forest. Although this report includes an estimate of N₂O emissions from croplands additional work is needed to estimate CO₂ removals from these same areas (see Net Emission Removals).

Livestock

Livestock management practices are the largest source of emissions in the agricultural sector, and they have increased 44% since 1990 (Table SR3.3). Although animal feeding is the larger source of emissions, the greatest increase in emissions is related to manure management. This trend reflects a change in policies regarding the collection and storage of manure to improve and protect water quality.

Table SR3.3 Livestock Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Animal Feeding	11.67	11.34	13.06	13.38	13.63	13.52	13.42
Manure Management	1.89	3.77	5.77	6.15	5.88	6.53	6.14
Gross Total	13.56	15.11	18.82	19.53	19.51	20.05	19.55

“+” less than 0.01mmt; “na” not applicable; Note: Totals may not sum due to independent rounding.

Animal Feeding

Ruminant animals produce methane as they digest the organic carbon in their feed. Specifically, anaerobic microbes present in the animals’ digestive systems convert some of the feed into methane that is then exhaled or belched by the animals.

Methodology

This analysis includes the historic and current methane contribution of NY dairy cattle and non-dairy ruminant animal herds including non-dairy cattle, sheep, swine, horses, mules and asses, goats, American bison, llamas, alpacas, and deer and elk in captivity. Separate methodologies were used to estimate emissions from dairy and non-dairy animals. For non-dairy animals, herd population data were from the U.S. Department of Agriculture National Agricultural Statistics Service (NASS 2020) and methane emissions were estimated using IPCC emission factors (Table 10.10 and 10.11, IPCC 2019). For dairy cattle, the dry matter intake (DMI) of the New York dairy herd was estimated using the number and size of cows (to calculate the energy required for maintaining body mass), milk production, and percent milkfat (to calculate the energy required to produce the milk). NASS provided historical data on percent milkfat, animal number, and milk production (NASS 2020). The DMI values were used to calculate an emission factor (kg CH₄ per head per year; equation 10.21A, IPCC 2019).

Results

From 1990 to 2019, methane emissions from animal feeding (enteric fermentation) increased 15% (Table SR3.4). The largest annual contributions to emissions were made by dairy cattle (Table SR3.4). Emission trends primarily reflect herd size, with the exception of dairy cattle, whose herd sizes have decreased but whose milk production has increased over time. Annual emissions by beef cattle, for example, follow the population trends, where herd sizes were lowest in 1990 at 436,000 head, peaked at 525,000 head in 2017, and fell to 490,000 head in 2019.

Table SR3.4 Animal Feeding Methane Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Source	1990	2005	2015	2016	2017	2018	2019
Dairy Cattle	9.41	8.94	10.15	10.42	10.46	10.46	10.44
Beef Cattle	1.90	1.99	2.55	2.61	2.82	2.72	2.63
Horses	0.27	0.29	0.24	0.23	0.23	0.23	0.23
Sheep	0.07	0.06	0.06	0.06	0.06	0.06	0.06
Swine	0.01	+	+	+	+	+	+
Goats	+	0.03	0.02	0.02	0.02	0.02	0.02
Deer/Elk in Captivity	ne	0.02	0.01	0.01	0.01	0.01	0.01
Bison	ne	+	+	+	+	+	+
Alpacas/Llamas	ne	+	+	+	+	+	+
Mules/Asses	+	+	+	+	+	+	+
Gross Total	11.67	11.34	13.06	13.38	13.63	13.52	13.42

“+” less than 0.01mmt; “ne” not estimated; Note: Totals may not sum due to independent rounding.

Manure Management

Manure management systems (MMS) that are used to treat and store livestock and poultry waste also emit CH₄ and N₂O. Manure stored in conditions that promote anaerobiosis will produce CH₄ (e.g., as liquid/slurry, in lagoons, ponds, tanks, or pits). Specifically, the volatile solids or organic carbon component of the manure is converted to CH₄ by certain microorganisms. In contrast, if manure is handled as a solid (e.g., in stacks or dry lots) or deposited on pasture, range, or paddock lands, it can decompose aerobically and will produce little or no CH₄. Microorganisms also produce N₂O as they act on the N compounds present in livestock and poultry waste. The series of microbial reactions that yield N₂O

are known as nitrification and denitrification. They may occur directly where the waste is stored or deposited, and indirectly when the N compounds in the waste mobilize and stimulate nitrification and denitrification in another location. Two pathways produce indirect N₂O emissions. In the first, volatile manure N (mainly NH₃ and NO_x) moves through the air and is deposited on soils and the surfaces of lakes and other waterbodies where it stimulates N₂O emission. In the second pathway, water in runoff and manure leachate carries N compounds into groundwater, riparian zones, ditches, streams, rivers, and estuaries that have hydrological connections to farmland. Direct and indirect N₂O emissions that are associated with manure application to soils are accounted for in the soil N management section below.

Methodology

Animal number and body weight data were gathered from the USDA-NASS. Cattle farm MMS data were gathered on DEC-regulated concentrated animal feeding operations (CAFOs) from notices of intent, change of operation, and annual compliance reports. Note that CAFOs in New York are smaller than CAFOs in other parts of the US where number of animals are in the tens of thousands. Livestock farms in New York are required to be permitted based on livestock numbers alone, regardless of discharge status. Since 1999, all CAFOs are in the ECL CAFO General Permit, a no-discharge permit, and must follow a Comprehensive Nutrient Management Plan (CNMP). Data on smaller cattle farms were gathered from the NYS Agricultural Non-Point Source Abatement and Control Grant Program (AgNPS) as well as other State data sources. Data on non-cattle MMS were gathered from livestock specialists and from annual compliance reports for non-cattle, CAFO-regulated farms.

Methane emissions from dairy cattle and non-dairy animals were estimated separately. IPCC emission factors were applied to each type of animal: CH₄ emissions for non-dairy animal MMS emissions were estimated using equation 10.22; dairy cattle MMS emissions were estimated using equation 10.23 (IPCC 2019). Animal waste N content was estimated using equation 10.30 and IPCC default N₂O emissions factors were applied to the fraction of manure in each type of MMS (Table 10.21, IPCC 2019).

Results

Total N₂O emissions from manure management doubled between 1990 and 2019 and CH₄ emissions more than tripled (Table SR3.3, SR3.5). In 2019, total N₂O emissions from manure management were estimated to be 0.35mmt CO₂e; in 1990 while emissions were 0.19mmt CO₂e. These values include both direct and indirect N₂O emissions from manure management. Dairy accounted for 82% and 87% of N₂O emissions from the entire 1990 and 2019 livestock herds, respectively. To avoid double counting, these tables do not include emissions of N₂O from field applied manure at any time (see the Soil Nitrogen Management section). CH₄ emissions from manure management increased from 1.70mmt CO₂e in 1990 to 5.78mmt CO₂e in 2019 as a result of increased liquid storage of dairy manure.

Table SR3.5 Manure Management Emissions, 1990-2019 (mmt CO₂e GWP20)

Gas/Source	1990	2005	2015	2016	2017	2018	2019
CH₄	1.70	3.52	5.44	5.82	5.54	6.18	5.78
Dairy Cattle	1.51	3.31	5.07	5.48	5.18	5.86	5.46
Other Cattle	0.01	0.03	0.06	0.06	0.05	0.05	0.05
Swine	0.05	0.04	0.04	0.02	0.02	0.02	0.03
Chickens	0.10	0.12	0.25	0.23	0.26	0.22	0.22
Other Poultry	+	+	+	+	+	+	+
Horses	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Sheep	+	+	+	+	+	+	+
Goats	+	+	+	+	+	+	+
Mules/Asses	+	+	+	+	+	+	+
N₂O	0.19	0.25	0.32	0.34	0.34	0.35	0.35
Dairy Herd	0.16	0.21	0.28	0.29	0.30	0.31	0.31
Other Cattle	+	+	+	+	+	+	+
Swine	+	+	+	+	+	+	+
Poultry	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Sheep	+	+	+	+	+	+	+
Goat	+	+	+	+	+	+	+
Horse(mule/ass)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gross Total	1.89	3.77	5.77	6.15	5.88	6.53	6.14

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

Soil Management

The IPCC guidelines include multiple emission sources under the AFOLU subcategory, “aggregated sources and non-CO₂ emissions on land.” Since the relevant sources in New York are all associated with soil amendments, we refer to this as “soil management” in this report (Table SR3.6). Other sources of emissions that are not considered relevant in New York are related to the burning of biomass as a land management practice and rice cultivation. The IPCC guidelines also include Harvested Wood Products in the aggregated sources subcategory but are treated as a component of net emission removals in this report (see next section).

Soil management emissions in New York decreased by just over 100,000 tons per year since 1990, or roughly 7% (Table SR3.6). The majority of these emissions today are associated with soil nitrogen management (91%) or from application practices that result in excess N₂O emissions.

Table SR3.6 Soil Management Emissions, 1990-2019 (mmt CO₂e GWP20)

Gas/Source	1990	2005	2015	2016	2017	2018	2019
CO₂	0.14	0.15	0.16	0.15	0.15	0.15	0.15
Liming	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Urea Application	0.02	0.02	0.04	0.04	0.04	0.04	0.04
N₂O	1.63	1.52	1.51	1.52	1.52	1.52	1.50
Soil Nitrogen Management	1.63	1.52	1.51	1.52	1.52	1.52	1.50
Gross Total	1.77	1.67	1.67	1.67	1.68	1.67	1.65

Note: Totals may not sum due to independent rounding.

Liming

Crushed limestone and dolomite are added to soils by land managers to increase soil pH. CO₂ emissions occur when these minerals react with soil acidity. Reaction rates of limestone and dolomite applications depend on soil conditions, soil type, and climate. Emissions associated with use of these minerals in industrial processes (e.g., cement production) are accounted for in *Sectoral Report #2: Industrial Processes and Product Use*.

Methodology

The average lime use over time was calculated using data from USGS (2018) and adjusted for cropland area in New York using the EPA State Inventory Tool (SIT, EPA 2020) as well as older data from the Census of Agriculture (Bureau of the Census 1989). The CO₂ emissions for each census year were calculated using the emission factors from West & McBride (2005) for limestone and dolomite and summed to estimate total CO₂ emissions due to agricultural liming.

Results

Emissions from liming of soils have fluctuated very little over the past 25 years in New York with a total of 0.12 or 0.13mmt CO₂e for each year since 1990 (Table SR3.6). This lack of change is not surprising because the area of cropland changes slowly, if at all, and use of lime is expected to be similar from one year to the next.

Urea Application

Adding urea fertilizer to soils causes emission of CO₂ when the organic carbon that is integral to urea molecules is oxidized by soil microorganisms. An industrial fertilizer production process uses pressure and heat to fix CO₂ and NH₃ into urea molecules. This fixation and emission cycle is rapid, and accurately accounting for its net impact on CO₂ emissions is difficult. However, the CO₂ emitted by urea is included here to assure complete accounting for urea across sectors.

Methodology

Calendar year data on the amount of urea fertilizer applied were extracted from the SIT tool (EPA 2020). The SIT uses information on state-level fertilizer sales provided by The Tennessee Valley Authority (1991 through 1994) and the Association of American Plant Food Control Officials. Complete conversion of all carbon in urea to CO₂ was assumed.

Results

CO₂ emissions from field application of synthetic urea increased from 0.02mmt CO₂e in 1990 to 0.04mmt CO₂e in 2019 (Table SR3.6), following increased use of urea fertilizers.

Soil Nitrogen Management

Emission sources from soil nitrogen management practices include direct and indirect N₂O emissions from managed soils, and indirect N₂O emissions from field application and management of manure. Agricultural activities that lead to direct N₂O emissions include the application of N fertilizer, the application of managed livestock manure or other organic materials such as biosolids (i.e., treated sewage sludge), the deposition of manure on soils by domesticated animals in pastures, range, and paddocks, retention of crop residues (both N-fixing legumes and non-legume crops and forages), and drainage of organic soils. Agricultural soil management activities such as irrigation, drainage, tillage, cover cropping, and fallowing of land can also influence the rates at which microorganisms produce N₂O through nitrification and denitrification and add N to soil through N fixation.

Methodology

N from a variety of sources can be added to soil. The IPCC provides default N₂O emission factors associated with each source of added soil N (IPCC 2019). Inventoried sources of added N included synthetic fertilizer, animal manure, biosolids, and crop residues. In addition, N₂O emissions from organic soils that have been drained for agricultural activity was estimated based on the area under this type of soil and land use, and an IPCC default emission factor per unit area (IPCC 2019).

Annual estimates of synthetic N fertilizer application were from the Association of Plant Food Control Officials and The Fertilizer Institute as reported in Brakebill and Gronberg (2017) for years up until 2012. Fertilizer application was assumed to remain at 2012 levels in subsequent years. An IPCC default emission factor of 0.016 kg N₂O per kg N was used for synthetic fertilizer (Table 11.1, IPCC 2019).

Livestock manure N that was estimated for the manure management emission category (above) was assumed to be applied to soil, whether directly or after a storage period. A fraction of this applied manure N was assumed to be lost, and was subtracted from the total manure N. An IPCC default emission factor of 0.006 kg N₂O per kg N was assumed for the fraction of manure N remaining in the soil (IPCC 2019).

Data on biosolids (treated sewage sludge) applied to soil were from DEC (NYSDEC 1999 and 2018) and Baker (2016). An emission factor of 0.006 kg N₂O per kg N (IPCC 2019) was applied to an estimate of the N added to soil calculated with the total dry mass, fraction applied to soil, and the average N content of the biosolids.

The N added to soil by crop residues was estimated using crop-specific area and yields from the USDA NASS census of agriculture for barley, dry edible beans, buckwheat, corn grain, corn silage, non-alfalfa hay, alfalfa hay, non-alfalfa haylage, alfalfa haylage, hops, oats, rye, sorghum grain, sorghum silage, soybeans, sunflower, triticale, and wheat. The estimated N content of specific crop residues and the emission factor of 0.006 kg N₂O per kg N were the default values provided by the IPCC (2019).

The area of drained organic soil under agricultural production was estimated for the years 1998 and 2000 by Ropel and Smith (2001) and for 2008 by the New York State Crop Reporting Service (NASS 2008). Linear interpolation was used to extend these area estimates to other years. The IPCC's default emission factor of 13 kg N₂O-N per hectare per year was used to estimate the annual N₂O flux (IPCC 2014).

Results

Annual N₂O emissions from agricultural soils were 8% lower in 2019 compared to 1990 primarily due to a 16% decrease in synthetic fertilizer use and a 10% decrease in all manure sources. However, the interannual variation was much greater than the change from 1990 to 2019 and this variation was driven primarily by synthetic fertilizer use. Emissions from synthetic fertilizer application were derived from annual sales data up until 2012, and the interannual variation may not capture changes in synthetic fertilizer use after 2012 or in the actual amount of fertilizer applied to soils in a given year.

Changes in annual manure emissions reflect the net impact of a large decrease in emissions from daily spread and an increase in emissions from manure management systems as dairy manure management practices have changed over time. Total N₂O emissions from soils in 2019 were largely from cropland (87%), with grassland and non-agricultural lands accounting for 8% and 5%, respectively (data not shown). In 2019, 67% of total emissions were direct, and 33% were indirect (Table SR3.7).

Table SR3.7 Soil Nitrogen Management N₂O Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Type	1990	2005	2015	2016	2017	2018	2019
Direct	1.06	1.00	0.98	0.98	0.99	0.98	0.97
Indirect	0.52	0.49	0.48	0.48	0.49	0.48	0.47
Gross Total	1.58	1.49	1.46	1.46	1.47	1.46	1.45

Note: Totals may not sum due to independent rounding.

Net Emission Removals

The CLCPA sets three distinct emission reduction requirements, two of which relate to gross emissions to the atmosphere (Statewide GHG Emission Limits, Part 496) and a third that also relates to removals from the atmosphere, or net zero emissions. This section provides information on the two existing sources of emission removals: harvested wood products and land use. This information can be used to estimate net emission levels in the state.

Table SR3.8 illustrates the trend in net removals from 1990 through 2019 as described in more detail below. Overall net removals have decreased by 11% however net removals associated with harvested wood products and most types of land use have remained relatively stable through the time period. For reasons discussed below, annual carbon sequestration rates within NY forests have steadily declined since 1990. As described below, a portion of net emissions from wetlands are excluded from net totals.

Table SR3.8 Net CO₂ Removals, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Harvested Wood Products	-1.54	-1.86	-1.58	-1.64	-1.56	-1.51	-1.51
Land Use	-31.14	-29.50	-27.78	-27.42	-28.09	-27.85	-27.60
Net Emission Removals	-32.68	-31.36	-29.36	-29.05	-29.65	-29.36	-29.11
Excluded Net Emissions	13.50	13.42	13.42	13.44	13.46	13.48	13.50

Note: Totals may not sum due to independent rounding.

Harvested Wood Products

Most timber harvested from forest land in New York is used to produce harvested wood products (HWP), which include, for example, sawn wood used in housing construction and paper. HWPs sequester CO₂ for a duration that depends on the lifespan of the product and the rate at which it is converted back to CO₂ through decay in landfills or waste combustion.

Emission estimates for this section of the report were developed in conjunction with Robert Malmshemer, HakSoo Ha, Timothy Volk, Tristan Brown, Danielle Kloster, Jenny Frank, Theodore Koch, Nehan Naim, and Obste Therasme (State University of New York, College of Environmental Science and Forestry) and the DEC Division of Lands and Forests Forest Utilization Program.

Methodology

The accounting approach taken includes carbon storage by sawtimber-based HWPs but does not include pulp logs used to produce paper or HWPs used to produce other products with shorter useful lives. Sourcing includes trees that are (1) grown in New York and consumed outside New York (NY/Out), (2) grown outside New York and consumed in New York (Out/NY), or (3) grown and consumed within NY (NY/NY). This approach captures out-of-state trees that are imported for use within New York, as well as trees that are grown within New York and exported for out-of-state for use.

Mill survey data collected by DEC, known as the Timber Products Output data, were used to estimate annual board feet of sawtimber-based HWPs used between 1999 and 2018, and were then converted to carbon storage. Trends from this data were extrapolated back through time to produce an estimate of the carbon stored in wood products harvested from 1990 to 1998, a period before the data collection program had started. This method converted board feet of lumber to carbon storage assuming a density (oven-dry mass / air-dry volume) of 0.56 metric tonnes per cubic meter for hardwood and 0.49 metric tonnes per cubic meter for softwood, and carbon fractions of 0.5 for both types of wood. Using this dataset as a proxy for HWPs may overestimate carbon storage in HWPs because conversion of sawtimber to HWPs is not complete and does not account for mill residuals that may be burned to produce energy. The dataset may underestimate carbon storage by non-lumber HWPs such as paper and cardboard that are produced from pulpwood and chips. Finally, this component of the inventory does not explicitly model the decay or combustion of HWPs in landfills and other solid waste facilities, although the solid waste sector's analysis in the Waste sector report does include a decay model for organic carbon in landfills.

There may be other emissions associated with production of timber including from fertilizer application or the energy used to harvest, process, and transport the harvested materials. These emissions are captured in relevant agriculture and energy emission sectors. The impact of timber harvesting on carbon sequestration by forested lands is captured in the land use section below.

Results

Trends in HWP carbon storage roughly correspond with those in new housing construction in the Northeast, peaking in 2001 at -1.97mmt CO₂, declining to a minimum of -1.17mmt CO₂ per year in 2009, and recovering to an average of -1.57 from 2015 to 2018. For 2019, 2018 values are used but these will be updated when data are available.

Table SR3.9 Harvested Wood Products CO₂ Removals, 1990-2019 (mmt CO₂)

Origin/Destination	1990	2005	2015	2016	2017	2018	2019
NY/NY	-1.09	-1.21	-1.10	-1.07	-1.07	-1.05	-1.05
NY/Out	-0.42	-0.56	-0.37	-0.37	-0.32	-0.29	-0.29
Out/NY	-0.03	-0.09	-0.11	-0.20	-0.17	-0.17	-0.17
Net Emission Removals	-1.54	-1.86	-1.58	-1.64	-1.56	-1.51	-1.51

Note: Totals may not sum due to independent rounding.

Land Use

The analysis of net emission removals by land in New York included an assessment of both land use and land use change for each year between 1990 and 2019. The annual fluxes of greenhouse gases into and out of natural and managed lands depends mainly on the growth and decay of trees, plants, and other organisms that can remove CO₂ from the atmosphere and sequester it as organic carbon. Certain landscapes, such as forests, sequester and store more organic carbon per unit area than other lands.

The six categories of land use that were considered here are forest land, wetlands, cropland, grassland, settlement, and other lands, following the IPCC's 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019). Quantifying the net emission removals through land use and land-use change requires accounting for the differences in carbon sequestration and storage per unit area among land use types and surveying the changes in areal extent of land-use types over time.

Data are not yet available to estimate net emission removals associated with all types of land use in New York from 1990 through 2019 (Table SR3.10). However, conversions to and from forest land and wetlands are available, reflect the majority of emission removals, and encompass other land use types. For example, the forest land estimate includes emissions associated with conversion of forest land to settlement lands (3.47mmt CO₂ emitted in 2019). It should be noted that this categorization aligns with greenhouse gas accounting by the U.S. federal government but differs from the IPCC's guidance. In this instance, the IPCC guidelines for forest land would only include the conversions to forest land (-2.08mmt CO₂, or 2.08mmt CO₂ sequestered in 2019). Additional research is underway to fill information gaps following IPCC guidance (see Planned Improvements).

Finally, the EPA has provided a state-level estimate of a little over -1mmt CO₂ sequestration in soil organic carbon in cropland and grassland for the year 2015 (e.g., EPA 2021, Table SR3.10). These values are not included in the total net CO₂ sequestration associated with land use in New York as there is only one year available (see Planned Improvements).

Table SR3.10 Land Use Net Emission Removals, 1990-2019 (mmt CO₂e GWP20)

Land Type	1990	2005	2015	2016	2017	2018	2019
Forest land	-26.76	-24.80	-22.74	-22.39	-23.05	-22.80	-22.54
Wetlands	-0.87	-0.79	-0.93	-0.93	-0.95	-0.96	-0.97
Cropland	nd	nd	nd*	nd	nd	nd	nd
Grassland	nd	nd	nd*	nd	nd	nd	nd
Settlement (Urban Trees)	-3.52	-3.91	-4.11	-4.09	-4.09	-4.09	-4.09
Net Emission Removals	-31.14	-29.50	-28.20	-27.78	-28.42	-27.85	-27.60

“nd” no data; “*” EPA estimated 2015 net CO₂ as -0.91mmt for croplands and -0.13mmt for grasslands

Forest Lands

New York is among the most forested states in the nation with roughly 19 million acres of forest land, covering over 60% of the land area. This is in large part why lands in New York remove more CO₂e than they emit on an annual basis. Specifically, forest land that has remained forest land is removing additional CO₂ as organic carbon every year on the order of -23.93mmt CO₂ in 2019. The conversion of other land use types to forest land contributed an additional -2.08mmt CO₂ in 2019 because forest lands remove more CO₂ per unit area than any other land-use type.

Methodology

This report uses data from the U.S. Forest Service on annual forest CO₂e emissions and sequestration (Domke et al. 2021; Walter et al. 2021). Additional input on this analysis was received from Colin Beier (State University of New York, College of Environmental Science and Forestry) as part of ongoing work (Planned Improvements). The annual Forest Service analysis assesses the sequestration of CO₂ as organic carbon in five reservoirs: aboveground biomass, belowground biomass, dead wood, litter, and soil organic carbon. The rate of change in the organic carbon density of these reservoirs is assessed by sampling specific field plots over time and measuring biomass, dead wood, and litter. Soil organic carbon is modeled using latitude, elevation, precipitation, temperature, and moisture index data (Domke et al. 2017) as well as remote sensing information from the National Agriculture Imagery Program (NAIP). The assessment implicitly incorporates any losses of organic carbon density and greenhouse gas emissions through fires, forest cutting, insects, disease, and weather events (Coulston et al. 2015). The impact of land-use change on forest land is evaluated using measured annual rates of transitions among cropland, grassland, settlement, forest land, wetlands, and other land use types. Observed conversions of field plots from one land-use type to another are used to quantify the impact of the conversion on organic carbon storage in the absence of other data. Conversions that involve forest land currently do not include the contribution of trees located on the other land-use types (wetlands, cropland, grassland, settlement, other land). However, trees located in settlements that remain settlements are reported as “urban trees.”

Achieving a wall-to-wall assessment of carbon sequestration and emissions by the different land-use types will require additional work to reconcile the area considered “forest” according to the Forest Service’s inventory, and the areas that may be mapped as forest by satellite-based land-cover products (such as those used to assess wetlands and the other land-use types in this report). The land-use definition of forest land that is used here may include some harvested areas that are replanted or left to regenerate and forested areas that lose biomass through forest fires or other disturbances. Land-cover maps may classify these areas into categories other than forest (Coulston et al. 2015), causing overlaps in coverage. Furthermore, some forested areas that do not meet the Forest Service’s definition of forest

are not counted in this inventory, including areas that are too small (less than 120 feet wide and 1 acre in area with at least 10% cover; Oswalt et al. 2019) and agroforestry systems (EPA 2021).

A subset of land defined as forest land in the Forest Service’s inventory is also wetland. These lands were excluded from the wetlands component of this report to avoid double-counting (an average of - 3.93mmt CO₂ sequestered per year from 1990 to 2019). However, forested wetlands have the unique potential to produce CH₄ and N₂O emissions as well as sequester CO₂. The Forest Service inventory does not currently include these emissions, so they are also omitted in the forest land estimates in this report, but they are discussed in the wetlands section (below).

Results

The forest land category is broken into three types of land use change, described below (Table SR3.11). The largest source of net emission removals is on lands that remained forested year-to-year, but an additional 2mmt per year is also added by the conversion of agricultural and other lands to forest. However, approximately 3mmt of sequestration was lost as lands were converted away from forests. Finally, the Forest Service also reported methane emissions from forest fires in 2015 and 2016.

Table SR3.11 Forest Land Net Emission Removals, 1990-2019 (mmt CO₂e GWP20)

Land Use Change	1990	2005	2015	2016	2017	2018	2019
Forest Remaining Forest	-27.91	-26.08	-24.98	-24.72	-24.45	-24.19	-23.93
Land Converted to Forest	-2.16	-2.13	-2.08	-2.08	-2.08	-2.08	-2.08
Forest Converted to Land	3.31	3.41	3.46	3.48	3.48	3.47	3.47
Forest Fire	nd	nd	0.86	0.93	nd	nd	nd
Net Emission Removals	-26.76	-24.80	-22.74	-22.39	-23.05	-22.80	-22.54

“nd” no data

Forest Remaining Forest

Forest land remaining forest land sequestered far more CO₂ than any other land use category (-26.08mmt CO₂ sequestered in 2005 and -23.93mmt CO₂ sequestered in 2019). The declining trend in annual CO₂ sequestration is due in part to the conversion of forest land to other land (3.47mmt CO₂ emitted in 2019 and an average of 3.45mmt CO₂ emitted per year between 2005 and 2019), which was not matched by the rate at which conversion of other land-use types to forest land sequestered CO₂ (-2.08mmt CO₂ sequestered in 2019 and an average of -2.10mmt CO₂ per year sequestered between 2005 and 2019). Future inventories will include an assessment of the impact of interannual changes in the rate at which forest land that remains forest land sequesters CO₂ and stores it as organic carbon.

Land Converted to Forest

Cropland conversion to forest land sequestered an average of -0.61mmt CO₂ per year from 2005 to 2019. Settlement conversions to forest land sequestered an average of -1.02mmt CO₂ per year from 2005 to 2019. Wetlands converted to forest land sequestered an average of -0.28mmt CO₂ per year from 2005 to 2019. Other lands converted to forest land sequestered -0.20mmt CO₂ per year from 2005 to 2019. Grassland converted to forest sequestered an average of -0.02mmt CO₂ per year from 2005 to 2019.

Forest Converted to Land

IPCC methods break down emissions so that those that are due to the conversion of one land use type (e.g., forest) to another (e.g., wetlands) are included with the land use category to which the land is

converted. Here these conversions are included under forests because we do not yet have a full inventory of all of the other land use types to which forests can be converted.

Conversion of forest land to cropland resulted in an average of 1.32mmt CO₂ emitted per year between 2005 and 2019. Conversion to settlements resulted in an average of 1.37mmt CO₂ emitted per year between 2005 and 2019. Smaller emissions were caused by conversion to wetlands (an average of 0.41mmt CO₂ emitted per year between 2005 and 2019) and other land (an average of 0.34mmt CO₂ emitted per year between 2005 and 2019). There were no emissions attributed to grassland conversions.

Wetlands

Emissions and emission removals from both ecological wetlands and other types of water bodies are reported under the wetlands category. The other water bodies reported in this inventory include lakes and ponds that are captured in the USGS National Hydrography Dataset (NHD). Emissions from rivers, canals, ditches, and New York's coastal waters also belong in this category but additional method development is required before any anthropogenic emissions and removals can be reported. Wetlands contribute the majority of emissions and emission removals discussed in this section. Wetlands, like forest land, sequester CO₂ and store it as organic carbon in plant biomass and soils. Unlike forests, the areal extent of wetlands is estimated here using land cover observations, rather than defined areas of land use. All New York wetlands are inventoried here, even those that do not directly undergo anthropogenic activities, such as peat harvesting. New York has both coastal wetlands, which are exposed to tidal cycles and are often adapted to brackish and saltwater inundation, and upland wetlands, which are not tidal and whose soils are saturated with freshwater.

Vegetated wetlands are particularly effective at sequestering CO₂ as organic carbon and storing it in their soils. This is because water-saturated soils tend to be low-oxygen soils, and the absence of oxygen slows the rate of decay that would normally convert organic carbon back into CO₂ (IPCC, 2014). Wetland soils can also be important sources of CH₄ and N₂O. Freshwater wetlands are the main source of CH₄ whereas CH₄ production is suppressed in tidal wetlands that are inundated by brackish and salt water above a certain salinity threshold (Holmquist et al 2019; IPCC 2014). As noted above, CH₄ emissions from freshwater wetlands are provided for informational purposes and are not included in net totals. N₂O production may occur in either type of wetland and is stimulated by the discharge of nitrogen (e.g., nitrate and ammonium) from the watershed, as well as atmospheric deposition of nitrogen compounds generated by fossil fuel combustion or released when nitrogen fertilizers are applied to soil.

Methodology

The distinction between wetlands that are inundated by freshwater versus brackish to saltwater is made here using land-cover maps from satellite images that are produced by the Coastal Change Analysis Program (CCAP) within NOAA. These maps classify wetlands as either estuarine or palustrine, where palustrine wetlands are inundated by water with a nominal salinity that is less than 0.5 parts per thousand (ppt). Estuarine wetlands are assumed to produce no CH₄, whereas the flux of methane from palustrine wetlands is assumed to be 157 kg CH₄ per hectare per year (see Section 4.3.1.2 and Annex 3A.3 in IPCC, 2014). The CCAP maps further classify estuarine and palustrine wetlands as forested, scrub and shrub, or emergent vegetation, for a total of six wetlands land-cover categories. Annual changes in the areal extent of the six wetlands categories were estimated by comparing consecutive updates of the CCAP land cover maps. Beginning in 1996, the maps have been issued approximately every 5 years, with the most recent update issued in 2016. The areas of wetlands that remain wetlands as well as conversions of other land-cover types to and from wetlands has been interpolated to cover years between

map updates. Trends observed between the 2010 and 2016 maps are extrapolated to 2019 but will be replaced with appropriate interpolations once the next CCAP land-cover map is available.

Carbon sequestration by wetlands is assessed in the following organic carbon reservoirs: soil carbon, aboveground biomass, and belowground biomass. Annual CO₂ fluxes into soil carbon are geometric means of measurements made using lead-210 and retrieved from publications and public databases by the Smithsonian's Environmental Research Center.¹ The carbon sequestration by aboveground biomass and belowground biomass are the same values used in the national greenhouse gas inventory (EPA 2021). Aboveground wetland biomass is assumed to sequester -3.05 to -3.17 mt of carbon per hectare per year. Belowground biomass sequesters -6.44 to -6.54 mt carbon per hectare per year in estuarine wetlands, and -3.57 to -3.65 mt carbon per hectare per year in palustrine wetlands. For conversions of other land-cover types to and from wetlands, the impact of biomass in the other land-cover types is captured here; changes in CO₂ sequestration by soil carbon and soil carbon storage are not captured.

Areas that are classified as palustrine forested wetlands in the CCAP land-cover maps are assumed to have been counted as forest land in the Forest Service's national inventory report data (Domke et al. 2021, Walter et al. 2021). Therefore, they have not been included in the CO₂ sequestration calculations for palustrine wetlands, but their CH₄ emissions are included here. No land area classified as estuarine forested wetlands by CCAP are included in the Forest Service's inventory because data are needed to quantify the impacts of forestry activity on soil carbon stocks in forested coastal wetlands (Crooks et al. 2018, Lisa Schile-Beers personal communication). Therefore, these areas are included in calculations of CO₂ sequestration by estuarine wetlands. The CCAP maps also resolve 19 other classes of land cover that are grouped to approximate the other five IPCC land-use categories in order to quantify conversions of wetlands to and from other types of land cover (IPCC 2019).

Seagrass is included in the calculation of CO₂ sequestration by estuarine wetlands. The areal extent of seagrass in NY waters is assumed to reflect a value reported in the 2009 Final Report of the New York State Seagrass Task Force.² In the absence of regular, state-wide survey data, this area is held constant from 1990 to 2019 and multiplied by the seagrass soil carbon sequestration fluxes reported by Salinas et al. (2020).

The USGS NHD water body maps are used to estimate the total area of lakes and ponds in New York. Lake Erie, Lake Ontario, and Lake Champlain were excluded from these estimates because they are shared with Canada and other US states. Mapped stream and river features are also not included in this estimate pending further method development. There is some overlap between waterbodies mapped by NHD and the emergent wetlands areas mapped by CCAP. There are also areas of open water mapped by CCAP that are not mapped by NHD. Additional work is necessary to determine the extent and impact of these coverage differences between the two types of map. The waterbodies are assumed to have both CO₂ and CH₄ fluxes associated with them. This report assumes a CH₄ flux of 54 kg per hectare per year (see Table 7.9 in IPCC 2019) from these waterbodies. CO₂ fluxes from these waterbodies are not included here because additional research is needed.

Results

The wetland category is broken into five types of land use change, as described above. Overall net emission removals increased by approximately 0.1mmt CO₂ or 10% (Table SR3.12). Palustrine wetlands

¹ <https://github.com/Smithsonian/Coastal-Wetland-NGGI-Data-Public>

² https://www.dec.ny.gov/docs/fish_marine_pdf/finalseagrassreport.pdf

were responsible for 94% of annual removals by wetlands in 2019. However, this accounting does not include methane emissions from palustrine wetlands (Table SR3.13).

Table SR3.12 Wetland Net CO₂ Removals, 1990-2019 (mmt CO₂)

Land Use Change	1990	2005	2015	2016	2017	2018	2019
Estuarine Wetlands Remaining Estuarine Wetlands	-0.09	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
Palustrine Wetlands Remaining Palustrine Wetlands	-1.18	-1.17	-1.26	-1.28	-1.29	-1.30	-1.31
Land Converted to Wetlands	0.40	0.41	0.41	0.42	0.42	0.42	0.42
Wetlands Converted to Land	+	+	+	+	+	+	+
Wetlands Converted to Water	+	0.06	+	+	+	+	+
Net Emission Removals	-0.87	-0.79	-0.93	-0.93	-0.95	-0.96	-0.97

“+” positive values less than 0.01mmt

Wetlands remaining wetlands

CO₂ sequestration by palustrine wetlands (-1.31mmt CO₂ in 2019) is greater than that of estuarine wetlands (-0.08mmt CO₂ in 2019), mainly because palustrine wetlands occupy more land in NY. Although CO₂ sequestration by forested palustrine wetlands is already counted in the forest land section of the inventory (Table SR3.11), it should be noted that these wetlands sequester more CO₂ (-3.87mmt CO₂ in 2019) than any other type of wetlands due to their larger area and capacity to form biomass. Estuarine wetlands include -0.02mmt CO₂ sequestered per year as soil carbon accumulated by seagrass meadows in NY waters and -0.06mmt CO₂ sequestered per year by estuarine wetlands as biomass and soil carbon (Table SR3.12).

Estimated CH₄ emissions from palustrine wetlands and waterbodies are 0.14mmt CH₄ per year (12.04mmt CO₂e) per year and 0.02mmt CH₄ (1.45mmt CO₂e) per year, respectively (Table SR3.12). Forested palustrine wetlands contribute 0.11mmt CH₄ (9.22mmt CO₂e) per year to the palustrine wetlands total, and this is reported here because the Forest Service does not currently include this CH₄ source in its forest inventory (Grant Domke, personal communication). The CH₄ emissions reported in this section are for informational purposes only, as discussed above.

Wetlands Converted to Water

Sea level rise, coastal subsidence and erosion can convert vegetated coastal wetlands to open water. When this happens, some of the organic carbon stored in wetland biomass and soil can be converted back to CO₂. Catastrophic coastal erosion can cause the release of many years of accumulated soil carbon stock (Crooks et al. 2018, Holmquist et al. 2018). In New York, conversion of wetlands to water resulted in the emission of 0.06mmt CO₂ per year between 2002 and 2010 but was negligible from 1990 to 2001 and from 2011 to 2019.

Lands converted to wetlands

Conversion of forest land to wetlands emitted 0.42mmt CO₂ in 2019 (Domke et al. 2021). Conversion of other lands to wetlands contributed an average of 300mt of CO₂ per year from 1990 to 2019.

Excluded wetland emissions

As indicated in the introduction to this report, this assessment omits methane emissions from total net removals by freshwater wetlands (Table SR3.13). If these emissions were included, they would be subtracted from net emission removals in the land use categories above (Table SR3.12). These estimates are also preliminary, and these emissions are not yet included in the U.S. national greenhouse gas inventory (EPA 2021).

**Table SR3.13 Excluded Wetland CH₄ Emissions, 1990-2019 (mmt CO₂e GWP20)
Informational Purposes Only**

Emission Source	1990	2005	2015	2016	2017	2018	2019
Palustrine Wetlands	12.05	11.95	11.97	11.99	12.01	12.03	12.04
Waterbodies	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Excluded Net Emissions	13.50	13.42	13.42	13.44	13.46	13.48	13.50

Croplands and Grasslands

Conversion of forest land to cropland emitted 1.3mmt CO₂ per year from 2005 to 2019. Conversion of forest land to grassland emitted less than 0.05mmt CO₂ per year from 2005 to 2019 (Domke et al. 2021). In 2015, sequestration of CO₂ as soil carbon on cropland removed -0.91mmt CO₂ and grassland removed -0.13mmt CO₂ (EPA 2021). These 2015 estimates provided by EPA are reported here for informational purposes only. They will be replaced as additional research becomes available.

Settlements

Urban trees are located in settlements that remain settlements and other lands that are converted to settlements. They contributed a significant amount to annual carbon sequestration (-4.09mmt CO₂ in 2019, Domke et al. 2021, Walters et al. 2021). However, conversion of forest land to settlements is also a large source of CO₂ emissions as stored forest carbon is released to the atmosphere (3.47mmt CO₂ in 2019).

Planned Improvements

Improvements to the AFOLU sector inventory are ongoing. Like the “key categories” prioritized by the IPCC, certain areas of improvement will be prioritized here because they are expected to have a significant influence on statewide emission calculations.

Forest lands, Settlement trees, and Harvested Wood Products

Future inventory reports may incorporate forest land-cover maps based on satellite images that are available from the National Land Cover Dataset (NLCD). The NLCD land-cover maps incorporate CCAP land-cover data and should therefore reduce any overlap or gaps that currently exist between the inventoried forest land and mapped wetlands land cover. LiDAR data may be used when and where they are available to estimate aboveground biomass in forest land. Comparisons between lidar-based biomass estimates and the Forest Service’s field plot measurements may be used to extrapolate coverage.

Expanded collection of survey data from sawtimber producers and manufacturing data for other wood products (for example, paper and particle board), as well as analyses of recent historical trends may be incorporated into future inventories. Product-specific models of emissions as HWPs decay in landfills may also be developed to account for the impact that these products have once they have exceeded their useful lives.

Croplands and Grasslands

Croplands have the potential to sequester CO₂ above and belowground and these net removals could be included in future assessments. Soil carbon storage on all types of cropland may also sequester CO₂ and should be accounted for in a way that considers impacts of tillage, crop types, and residue management. The impact of land-use conversions from other lands to cropland should also be quantified beyond the conversion of forest land to cropland that the Forest Service currently estimates. Changes in soil carbon stocks that result from these conversions are expected to contribute to greenhouse gas fluxes. Similarly, historically drained wetlands that have been converted to cropland should be identified and mapped so that any current emissions associated with conversion of their soil organic carbon to CO₂ can be estimated and/or measured. Over 3.7 million acres of land are classified as grassland or pasture and hay by the 2016 CCAP land-cover map. In assessing changes in soil carbon storage on these lands, the latest guidance offered by the IPCC considers practices such as irrigation, fertilization, liming, organic amendments, grass variety, and grazing status. These will be evaluated and included in future inventory reports.

Wetlands and Other Waterbodies

Refining the CH₄ emissions attributed to wetlands is an important benchmark for future inventories. Recent developments in quantifying wetland emissions means that future inventories will have access to CH₄ emission factors that are specific to the state's wetland ecosystem types, rather than IPCC default emission factors. Further methodological updates will consider whether a salinity threshold should be used to separate wetlands that emit CH₄ from those that do not. Although the IPCC default threshold is 18 ppt (Section 4.3.1.2 in IPCC 2014), a salinity threshold of 0.5 ppt is incorporated into the CCAP land-cover maps used here. The lower salinity threshold means that this inventory does not capture any CH₄ emissions from wetlands inundated by water with a salinity higher than 0.5 ppt. Future inventories may consider mapping salinity gradients wherever possible and using separate probability distributions for palustrine and estuarine wetlands to provide a more representative calculation of total CH₄ emissions, rather than relying on a single emission factor and salinity threshold (Holmquist et al. 2018).

Future reports may provide information on rivers, canals, ditches, farm ponds, and other waterbodies that may contribute anthropogenic emissions or removals. Wherever temperature, chlorophyll a, and total phosphorus data are available on specific waterbodies, this information will be used to inform emission factors. The impact of flooding and draining of flooded areas on emissions will also be considered. Flooding disrupts the rate at which organic carbon decays back into CO₂ and stimulates CH₄ production as submerged soils become anoxic (IPCC 2019). Land-cover data and other sources of current and historical flooding extent are currently being researched for this purpose. N₂O emissions from wetlands are stimulated by discharge of N from the watershed, as well as atmospheric deposition of N generated by fossil fuel combustion and released during nitrogen fertilizer application. These emissions are included in the agricultural and wastewater components of this inventory. However, future inventories may also include N₂O emissions driven by local sources of N to the wetlands. The contribution of seagrass soils to carbon sequestration that is estimated in this inventory is a maximum value. Future inventories should incorporate seagrass survey data and estimate changes in the areal extent of seagrass through time. All available region-specific measurements of seagrass soil carbon sequestration will be used to calculate sequestration fluxes. Loss of seagrass habitat is expected to contribute emissions to future inventories as their organic carbon is converted back to CO₂.

Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
CCAP	NOAA Coastal Change Analysis Program
CH ₄	Methane
CLCPA	NYS Climate Leadership and Community Protection Act
CO ₂	Carbon dioxide
CO _{2e}	Carbon dioxide equivalent
DEC	NYS Department of Environmental Conservation
DMI	Dry matter intake
EPA	U.S. Environmental Protection Agency
FIA	Forest Inventory and Analysis
GHG	Greenhouse gas
GWP	Global Warming Potential
GWP100	100-Year Global Warming Potential
GWP20	20-Year Global Warming Potential
HWP	Harvested wood product
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
MMS	Manure Management System
mmt	Million metric tons
N	Nitrogen
N ₂ O	Nitrous oxide
NA	Not applicable
NAIP	USDA National Agriculture Imagery Program
NASS	USDA National Agriculture Statistics Service
NE	Not estimated
NFI	National forest inventory
NH ₃	Ammonia
NHD	USGS National Hydrography Dataset
NLCD	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NO _x	Nitrogen oxides
NYCRS	New York State Crop Reporting Service
NYCRR	New York Codes, Rules and Regulations
ppt	Parts per thousand
SIT	EPA State Inventory Tool
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey

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Department of
Environmental
Conservation

Waste

2021 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #4

Kathy Hochul, Governor | Basil Seggos, Commissioner



Table of Contents

Format of This Report	1
Figures and Tables	1
Waste	2
Solid Waste Management	3
Biological Treatment of Solid Waste	5
Waste Combustion	6
Wastewater	7
Planned Improvements	8
Abbreviations	10
References	11

Archived

Format of This Report

This sectoral report provides a detailed explanation of methods, data, and trends for the Waste sector. The accounting used in this sectoral report follows the requirements of the Climate Leadership and Community Protection Act (CLCPA) and is in alignment with the 6 NYCRR Part 496 regulation, “Statewide GHG Emission Limits.” This includes the use of a 20-Year Global Warming Potential metric provided in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC 2013). The organization of this report and specific methodologies are based on guidelines from the IPCC Taskforce on National Greenhouse Gas Inventories (or “IPCC guidelines”) as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2021a). The accompanying Summary Report provides a comparison with other accounting methods, including by economic sector or using conventional accounting formats. DEC also intends to provide emission values for all years via the Open Data NY platform.

Figures and Tables

Table SR4.1 Waste Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	3
Table SR4.2 2019 Waste Emissions by Gas (mmt CO ₂ e GWP20)	3
Table SR4.3 Solid Waste Management Emissions by Gas, 1990-2019 (mmt CO ₂ e GWP20).....	5
Table SR4.4 Waste Combustion Emissions by Gas, 1990-2019 (mmt CO ₂ e GWP20).....	7
Table SR4.5 Wastewater Emissions, 1990-2019 (mmt CO ₂ e GWP20).....	8

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Waste

This sectoral report provides information on greenhouse gas emissions associated with the management and treatment of waste materials, broken into solid waste management, biological treatment of solid wastes, waste combustion, and wastewater (Table SR4.1). Most solid wastes are sent to solid waste management facilities (landfills) or combustion facilities. Organic wastes may also be treated through composting or anaerobic digestion, which the IPCC guidelines refers to as the “biological treatment of solid wastes”. Finally, wastewater is either treated on-site in septic systems or collected, treated, and discharged via a centralized wastewater system. Emissions associated with the production, transportation, use, or recycling of materials may be found in the other sectoral reports, such as *Sectoral Report #1: Energy* or *Sectoral Report #2: Industrial Processes and Product Use*.

The organization of information in this report deviates from the IPCC guidelines and U.S. national greenhouse gas inventory in three ways. First, the IPCC guidelines for national governments assign waste combustion emissions to the energy sector as “waste-to-energy”. Although waste combustion facilities produce energy, their primary role in New York is in waste management. Secondly, some of the solid wastes produced in New York are exported to facilities outside of the state for disposal. The IPCC guidelines only consider emissions that occur within the given jurisdiction. However, the exporting of waste represents a potentially large source of emission leakage¹ for New York State, so this report includes emissions from solid wastes sent to landfills and combustion facilities in other states in emission totals. Finally, under the IPCC guidelines for national net emission accounting, the carbon dioxide (CO₂) produced from waste is considered biogenic and reported separately from other anthropogenic emissions. The same practice is applied in this report in that biogenic CO₂ is also excluded from net emission totals. However, CO₂ emissions associated with the combustion of waste and landfill gas are included as part of gross emission totals (Table SR4.1, Table SR4.2), while emissions associated with natural decomposition are omitted entirely.²

An important consideration for the waste sector is that landfills are the dominant source of emissions and these emissions are generated over multiple decades. This means that current emissions are the result of waste deposited in landfills in the past and that waste deposited today will continue to produce emissions through 2050 and beyond. The “methane commitment” of landfilled waste is not quantified in this report. Methane commitment accounting quantifies the total lifetime amount of methane (CH₄) that could be generated from waste deposited in a landfill each year. The methodology employed in this report uses an emission factor for “CH₄ generation potential” of 100 m³ per ton MSW (EPA 2020). This is equivalent to 5.71 metric tons CO₂e per ton MSW using a 20-year Global Warming Potential. CH₄ generation potential does not account for oxidation of CH₄ in the cover layer, or CH₄ destruction via capture systems.

In 2019, total statewide emissions for the waste sector were 45.54mmt CO₂e GWP20 on a gross basis, which was 12% of all statewide gross emissions (Table SR4.1). Waste sector emissions increased 3 percent from 1990 to 2019. The largest source of emissions in all years was what the IPCC guidelines refer to as “solid waste management” (or landfills). As discussed below, non-CO₂ emissions from composting and solid waste anaerobic digesters (i.e., the biologic treatment of solid wastes) are not estimated in this report and are not expected to contribute emissions at this time. Biogenic CO₂ is omitted in net totals and this includes CO₂ from the combustion of waste and waste gas.

¹ For example, emission leakage might occur when emissions within a jurisdiction appear to be reduced, but the emission source has just been relocated outside of that jurisdiction.

² Per 6 NYCRR Part 496

Importantly, total emissions include those associated with the exporting of waste, which has increased from 1.18mmt CO₂e in 1990 to 16.05mmt CO₂e in 2019 (“Exported Waste”, Table SR4.1). DEC seeks comment on whether exported wastes should be excluded from emission totals in the future noting that this represents a form of emission leakage that cannot be legally controlled by New York State (see New York State Climate Action Council Draft Scoping Plan).

Table SR4.1 Waste Emissions, 1990-2019 (mmt CO₂e GWP20)

Emission Category	1990	2005	2015	2016	2017	2018	2019
Solid Waste Management*	34.03	37.97	35.02	35.23	35.82	35.18	35.42
Biological Treatment of Solid Waste	no	ne	ne	ne	ne	ne	ne
Waste Combustion*	4.00	3.46	2.80	2.87	3.22	3.20	3.20
Wastewater	6.41	6.81	7.00	6.99	6.98	6.96	6.93
Gross Total	44.44	48.25	44.82	45.09	46.01	45.33	45.54
<i>% of statewide gross total</i>	<i>11.0%</i>	<i>10.5%</i>	<i>11.0%</i>	<i>11.5%</i>	<i>12.3%</i>	<i>11.7%</i>	<i>12.0%</i>
Net Total	42.13	46.88	43.87	44.16	45.07	44.35	44.56
<i>% of statewide net total</i>	<i>11.7%</i>	<i>11.2%</i>	<i>12.0%</i>	<i>12.6%</i>	<i>13.6%</i>	<i>12.8%</i>	<i>13.2%</i>
Exported Waste	1.18	10.70	15.25	15.50	15.67	15.84	16.05

“no” not occurring; “ne” not estimated; “*” Includes in-state and out-of-state emission sources

The waste sector is responsible for emissions of CO₂, CH₄, and nitrous oxide (N₂O). CH₄ is the primary greenhouse gas and represented 91% of all waste emissions in 2019 (Table SR4.2). The relative amount of each gas reflects the types of waste management used in New York. CH₄ is primarily associated with solid waste management in landfills, which is the primary method used to manage waste. This is further emphasized when applying a 20-year GWP because CH₄ is shorter lived in the atmosphere than CO₂ and N₂O.

Table SR4.2 2019 Waste Emissions by Gas (mmt CO₂e GWP20)

Emission Category	CO₂	Biogenic CO₂	CH₄	N₂O
Solid Waste Management	na	0.52	34.89	na
Biological Treatment of Solid Waste	na	ne	ne	ne
Waste Combustion	2.62	0.45	0.09	0.04
Wastewater	na	na	6.43	0.50
Gross Total	2.62	0.98	41.41	0.54

“ne” not estimated; “na” not applicable

Solid Waste Management

This IPCC category represents emissions associated with the wastes deposited in landfills. Once deposited in a landfill, wastes are decomposed by aerobic and anaerobic microorganisms, the latter of which produce methane. There are three types of landfills included in this report, municipal solid waste

(MSW) landfills in the state, MSW landfills outside of the state (or exported waste), and industrial landfills. The majority of waste in the United States is managed in MSW landfills. Waste management in the U.S. underwent significant changes in the period leading up to the 1990 baseline year.³ One of the changes in New York was to replace hundreds of open, unlined waste “dumps” with managed MSW landfills that are subject to state and federal regulations to protect the environment and public health. Over time, landfills have also increasingly adopted technologies to collect and destroy methane such as through landfill-gas-to-energy (LFGTE) or flaring, which converts CH₄ to CO₂ through combustion.

MSW landfills produce significantly more greenhouse gas emissions than industrial landfills in part because industrial landfills contain less organic material. The organic carbon, or plant-based, component of waste is the primary source of emissions and the low-oxygen landfill environment promotes the generation of additional CH₄ as these wastes decay. Organic materials make up a large portion of waste collected from homes and businesses and deposited in MSW landfills.

Methodology

The EPA State Inventory Tool (or SIT, EPA 2020) was used to estimate emissions from waste placed in landfills either in New York or exported to landfills in other states. In keeping with IPCC guidelines, the SIT applies a First Order Decay (FOD) model to estimate emissions generated by a specified volume of waste in a landfill environment. The amount of CH₄ that was oxidized or destroyed was subtracted from the emission estimate. Currently, the SIT uses a FOD model and assumptions based on the EPA LandGEM model. DEC is currently evaluating alternative methods as well as ways to incorporate additional sampling (see Planned Improvements). Some portion of waste deposited in industrial landfills may be organic, but this would be a smaller overall percentage of waste compared to MSW landfills. The EPA SIT estimates the annual emissions of industrial landfill waste as 7% of annual MSW landfill emissions. The industrial landfill emissions were added to MSW landfill emissions to generate total solid waste landfill emissions.

For in-state solid waste management multiple data sources were compiled to generate a full time series. The SIT FOD model assumes that emissions are generated continuously for decades after waste was deposited in a landfill. Hence, annual waste data are needed as far back as 1960 to estimate emissions in 1990. Due to lack of state data, SIT default landfill disposal tonnage values were used for 1960-1985 that are derived from national per capita waste generation rates. Facility-reported tonnage values were used for the period 1986-2018, using interpolation to provide values for any years without data. Historical information was gathered from annual reports of the NY State Assembly (NYS Assembly 2002). SIT default LFGTE and flaring values were used for 1990-2008, and data reported to DEC were used for 2009-2018. A combustion efficiency percentage and CO₂ emission factor were applied to the CH₄ capture data and these emissions are included in the New York landfills totals. Data covering the 2019 period are currently under review. For the purposes of this report, 2018 data were used to fill in for 2019. These values will be updated when data are available.

For this report, additional information was used to estimate emissions from wastes exported out of the state to either landfills or combustion facilities. For example, historical NY State Assembly reports suggest that very little waste was exported prior to the widespread closure of local dumps around 1990 to meet federal standards. However, an increasing volume was exported after 1990. For 1986-2001, waste tonnages were used as reported by the NYS Assembly (NYS Assembly 2002). A combination of data sources was used to estimate the total amount of exported waste after this period, including information

³ As described in the New York State Solid Waste Management Plan

collected by DEC from waste transfer facilities, municipal offices, and as shared by other states. DEC has collated data for 2008-2018 and interpolation was used to provide values for 2002-2007. An unknown quantity of waste is exported without passing through a waste transfer facility, i.e., direct-hauled, and likely results in an underestimation of total exported waste tonnage. DEC will continue to seek new information sources to further refine this estimate.

Results

The estimated total emissions produced by landfills remained relatively stable between 1990 and 2018, when exported waste is included (Table SR4.3). However, if exported wastes are excluded, there would be an appearance of a reduction in total emissions of 60% (from 33.25 to 19.97mmt CO₂e). This reflects both the diversion of MSW to out of state landfills, and the enhanced adoption of CH₄ capture and destruction systems. Since the SIT method for estimating industrial waste is based on a ratio of MSW landfill emissions, they reflect the same trends as MSW landfills in this analysis.

CO₂ emissions from out-of-state landfills is not included in this report and listed as “na” in the table below. This is due to a lack of data on the CH₄ capture and destruction systems employed at out of state facilities.

Table SR4.3 Solid Waste Management Emissions by Gas, 1990-2019 (mmt CO₂e GWP20)

Gas/Location	1990	2005	2015	2016	2017	2018	2019
CO₂	0.05	0.33	0.51	0.51	0.49	0.52	0.52
New York landfills	0.05	0.33	0.51	0.51	0.49	0.52	0.52
Out of State landfills	na	na	na	na	na	na	na
CH₄	33.98	37.64	34.51	34.72	35.32	34.65	34.89
New York landfills	33.20	27.55	19.86	19.82	20.26	19.41	19.44
Out of State landfills	0.78	10.10	14.65	14.90	15.07	15.24	15.45
Gross Total	34.03	37.97	35.02	35.23	35.82	35.18	35.42
Exported Waste	0.78	10.10	14.65	14.90	15.07	15.24	15.45

“na” not applicable

Biological Treatment of Solid Waste

In addition to landfilling, organic solid waste can be treated through composting or anaerobic digestion.⁴ The types of solid waste management described in this IPCC category are not considered to be a large source of emissions in New York because they have not been widely adopted to date. However, if new State and federal policies promote adoption of these practices as alternatives to landfilling, their relative contribution to waste sector emissions are expected to increase. Hence, this sector will continue to be monitored (see Planned Improvements).

Like decomposition that naturally occurs in soils, the CO₂ generated from composting organic waste would not be included in greenhouse gas accounting. The emissions of CH₄ and N₂O are minimal and will

⁴ The IPCC guidelines also includes mechanical-biological treatment, but this is not used in New York.

depend on the management of the compost. Current State regulations require large composting facilities to manage organic waste in a way that minimizes these emissions.⁵

Anaerobic digestion is used to accelerate the decomposition of organic waste without oxygen (i.e., in an anaerobic environment), which promotes CH₄ production. The CH₄ may be captured and used for energy production but there is the potential for CH₄ leaks from piping and other sources. There are very few on-site, solid waste anaerobic digestors currently operating in New York. As the number of facilities increases and data become available, the CH₄ emissions from these digestors will be included in the Waste sector. The use of anaerobic digestion at wastewater facilities or farms would be reported elsewhere (i.e., as wastewater or agricultural emission sources). Any emissions resulting from the use of digester gas as an energy fuel, including leakage or “fugitive emissions”, will be reported in the Energy sector.

Waste Combustion

This category of emissions includes the CO₂, CH₄, and N₂O associated with the combustion of municipal wastes sent to regulated combustion facilities in the state or exported to such facilities outside of the state (Table SR4.4). Wastes combusted in other contexts were not included. As in the case of fuel combustion for energy, the primary greenhouse gas from the combustion of waste is CO₂. Due to the mixed compositional nature of MSW, the waste contains both organic and fossil-derived carbon (e.g., such as plastics). Emissions therefore include fossil CO₂ and biogenic-CO₂, the latter of which is deducted when calculating net emission totals. Unlike landfilling, municipal waste combustion was not associated with a large volume of CH₄ because there is no anaerobic decomposition.

Methodology

Emissions for this category were estimated by applying EPA MSW emission factors to the amount of waste combusted, both by in-state and out-of-state facilities (EPA 2021). The SIT was not used because it does not estimate biogenic CO₂, or emissions from the combustion of organic material. The remaining CO₂ comes from fossil-derived materials, such as plastics, rubbers, and synthetic fibers. For in-state combustion, state data were used for the period 1990-2018, using interpolation to provide values for any years without data. 2018 values were used for 2019 and will be updated when data become available. For out-of-state combustion, facility destination information is only available beginning in 2016. However, as waste disposal contracts with combustors are generally long-term and constant, recent waste tonnage information was used to estimate emissions going back to the year that a facility began operating.

The EPA emission factor for CO₂ includes fossil and biogenic CO₂, which are both anthropogenic. However, biogenic CO₂ is conventionally excluded, there is not sufficient information to determine their relative contribution. As a planned improvement, DEC is evaluating methods for apportioning CO₂ emissions, particularly for historic time periods in which there may not be a record of waste composition. For this report, the biogenic portion of annual total CO₂ was estimated by subtracting the portion of emissions that were non-biogenic (as estimated in the SIT) from total emissions as estimated using the EPA emission factor for waste combustion (EPA 2021b). The annual ratio of in-state biogenic to non-biogenic CO₂ emissions was applied to out-of-state waste combustion CO₂ emissions. The SIT estimated that in-state waste combustion resulted in 2.16mmt of fossil CO₂ in 2018, which was 87% of total in-state waste combustion CO₂ in that year. The remaining 0.66mmt CO₂ are of biogenic origin.

⁵ 6 NYCRR Part 361

Results

Waste combustion emissions in 2018, and reported here for 2019 until data becomes available, were 3.2mmt, a reduction of 20% since 1990 (Table SR4.4). The majority of emissions are CO₂ (96%), with some CH₄ and N₂O from incomplete combustion. Exported wastes are a small portion of total waste combustion emissions and this has not changed appreciably over the timeseries.

Table SR4.4 Waste Combustion Emissions by Gas, 1990-2019 (mmt CO₂e GWP20)

Gas/Location	1990	2005	2015	2016	2017	2018	2019
CO₂	1.58	2.29	2.25	2.33	2.63	2.62	2.62
New York facilities	1.42	1.89	1.77	1.84	2.14	2.13	2.13
Out of State facilities	0.16	0.40	0.48	0.49	0.49	0.49	0.49
Biogenic CO₂	2.26	1.04	0.44	0.42	0.46	0.45	0.45
New York facilities	2.03	0.86	0.35	0.33	0.37	0.37	0.37
Out of State facilities	0.22	0.18	0.09	0.09	0.09	0.09	0.09
CH₄	0.11	0.10	0.08	0.08	0.09	0.09	0.09
New York facilities	0.10	0.08	0.06	0.06	0.07	0.07	0.07
Out of State facilities	0.01	0.02	0.02	0.02	0.02	0.02	0.02
N₂O	0.05	0.04	0.03	0.03	0.04	0.04	0.04
New York facilities	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Out of State facilities	+	+	+	+	+	+	+
Gross Total	4.00	3.46	2.80	2.87	3.22	3.20	3.20
Exported Waste	0.40	0.60	0.60	0.60	0.60	0.60	0.60

“+” less than 0.01mmt; Note: Totals may not sum due to independent rounding.

Wastewater

Wastewater can contain liquid organic matter along with suspended solids that can produce greenhouse gases. There are two primary mechanisms for treating wastewater, in on-site septic systems or in a centralized system which accepts domestic and industrial wastewater through sewers, treats it, and then discharges it into aquatic systems. As with solid waste management, the anthropogenic component of wastewater emissions can be mitigated through management. The biogenic CO₂ associated with natural decomposition is not estimated here.

Wastewater treatment practices involve both aerobic and anaerobic decomposition. CH₄ is generated by microorganisms when the organic carbon in wastewater is allowed to decompose under anaerobic conditions. Septic systems treat the solid component of the wastewater anaerobically, producing additional CH₄. This is less common in centralized systems as the majority of wastewater treatment facilities in New York use aerobic treatment methods. However, anaerobic pockets can develop in these treatment facilities, depending on operational factors. N₂O production is stimulated by the action of microorganisms on nitrogen compounds that enter wastewater in human waste, kitchen waste, industrial wastewater, and other sources.

Methodology

The SIT was used with default emission factors to estimate CH₄ and N₂O production from wastewater (EPA 2020). Inputs used for both gases included the state population (U.S. Census Bureau 2020) and the

fraction of the population with septic wastewater treatment (0.186) based on a national average from the American Housing Survey (U.S. Census Bureau 2017). Septic system CH₄ emissions were calculated by applying a default emission factor of 10.7 g CH₄ per person per day (Leverenz et al. 2010) to the fraction of the state population using septic system wastewater treatment.

For centralized wastewater systems, CH₄ and N₂O emissions were calculated using the methodology and emission factors from the IPCC guidelines (IPCC 2019, Volume 5, chapters 2 and 6). CH₄ was estimated based on the maximum amount of CH₄ that can be produced from a given quantity of organic matter in wastewater (0.6 kg CH₄ per kg BOD), where biochemical oxygen demand (BOD) was used as a proxy for the amount of organic matter in wastewater. The average amount of organic matter generated per person in the U.S. was assumed to be 0.09 kg BOD per day. A correction factor of 0.1625 was applied to estimate the fraction of wastewater organic matter that was converted anaerobically (EPA 2020). Direct N₂O emissions from wastewater treatment facilities were estimated assuming production of 4 g N₂O per person per year. Another emission factor of 0.005 g N₂O-N generated per g wastewater nitrogen (N) was applied to an estimate of the total N present in both septic and non-septic wastewater. The emission factor was selected under the default assumption that effluent was discharged to an aerobic environment that was not nutrient-impacted or oxygen-impaired. The total N in wastewater was calculated based on the average U.S. protein consumption, the average N content of protein, and a scaling factor (1.75) to account for the presence of N derived from sources other than human waste in wastewater. The most recent national GHG inventory includes improved methods for assessing emissions from wastewater discharge (EPA 2021a). These have not yet been incorporated into the SIT but may be considered in future updates of this report (Planned Improvements).

Results

Based on this analysis, emissions from wastewater treatment have increased 8% over past 30 years in New York State (Table SR4.5). As this SIT-based analysis is fundamentally linked to census population data, this trend reflects demographic trends. These estimates will likely be refined in future years to reflect additional emission measurements (Planned Improvements).

Table SR4.5 Wastewater Emissions, 1990-2019 (mmt CO₂e GWP20)

	1990	2005	2015	2016	2017	2018	2019
Centralized Wastewater	5.23	5.56	5.71	5.70	5.69	5.67	5.65
Septic Systems	1.18	1.26	1.29	1.29	1.29	1.28	1.28
Gross Total	6.41	6.81	7.00	6.99	6.98	6.96	6.93

Planned Improvements

Improvements to the waste sector inventory are ongoing. Like the “key categories” prioritized by the IPCC, certain areas of improvement, such as solid waste management, will be prioritized in the near-term because they are expected to have a significant influence on the emission totals and State policy.

Solid Waste Management

This report uses the same methodologies used by the U.S. EPA and other governments as recommended by the IPCC guidelines. Future analyses will seek to refine the EPA SIT model and incorporate more information on local climatic conditions, such as precipitation and temperature, as well as sampling data from active landfills. Additionally, data on historic and current waste composition is

needed. Refining the model to incorporate this information will refine estimates and be responsive to potential declines in organic matter content in MSW. Over time, DEC would seek to develop a methodology that accurately portrays statewide emissions and that is consistent with facility-level measurements and top-down data, where available (see *Summary Report*). At this time, facility data are typically focused on gas collection systems and do not include measurements from the entire landfill.

Other areas of future improvements will include further refinements to the estimate of exported waste emissions, industrial landfill emissions, as well as information on the “methane commitment” of landfills.

Biological Treatment of Solid Waste

As discussed above, this report does not include emissions from this category because there were not sufficient data, the number of emission sources is small, and current regulations require these sources to be operated in a manner that would limit emissions. However, these emissions will be analyzed in future reports, particularly as more organic waste is diverted from landfills.

Waste Combustion

Of primary interest in this category is the composition of waste from organic/biogenic sources versus fossil sources such as plastics. However, this distinction would not affect the estimation of gross emissions. Additionally, the DEC will seek to improve estimates of the share of exported waste sent to out-of-state combustors.

Wastewater

Future inventories will incorporate state-specific data to determine the fraction of New Yorkers using septic versus non-septic wastewater management. The current methodology assumes aerobic treatment at centralized wastewater treatment facilities. Methods for separating and accounting aerobic versus anaerobic centralized wastewater treatment will be reviewed. The impact of the water quality (nutrient and eutrophic status) of water bodies that receive wastewater will be incorporated into N₂O emissions estimates. Finally, the contribution of industrial and commercial wastewater to CH₄ and N₂O emissions will also be included explicitly when such data are available.

Abbreviations

AR6	IPCC Sixth Assessment Report
BOD	Biological oxygen demand
CH ₄	Methane
CLCPA	NYS Climate Leadership and Community Protection Act
CO ₂	Carbon dioxide
CO ₂ e	Carbon dioxide equivalent
DEC	NYS Department of Environmental Conservation
EPA	U.S. Environmental Protection Agency
FOD	First order decay
GHG	Greenhouse gas
GWP	Global Warming Potential
GWP100	100-Year Global Warming Potential
GWP20	20-Year Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
LFGTE	Landfill gas-to-energy
mt	metric tons
mmt	million metric tons
MSW	Municipal solid waste
N	Nitrogen
N ₂ O	Nitrous oxide
NA	Not applicable
NE	Not estimated
NO	Not occurring
NYCRR	New York Codes, Rules and Regulations
NYS	New York State
SIT	EPA State Inventory Tool

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