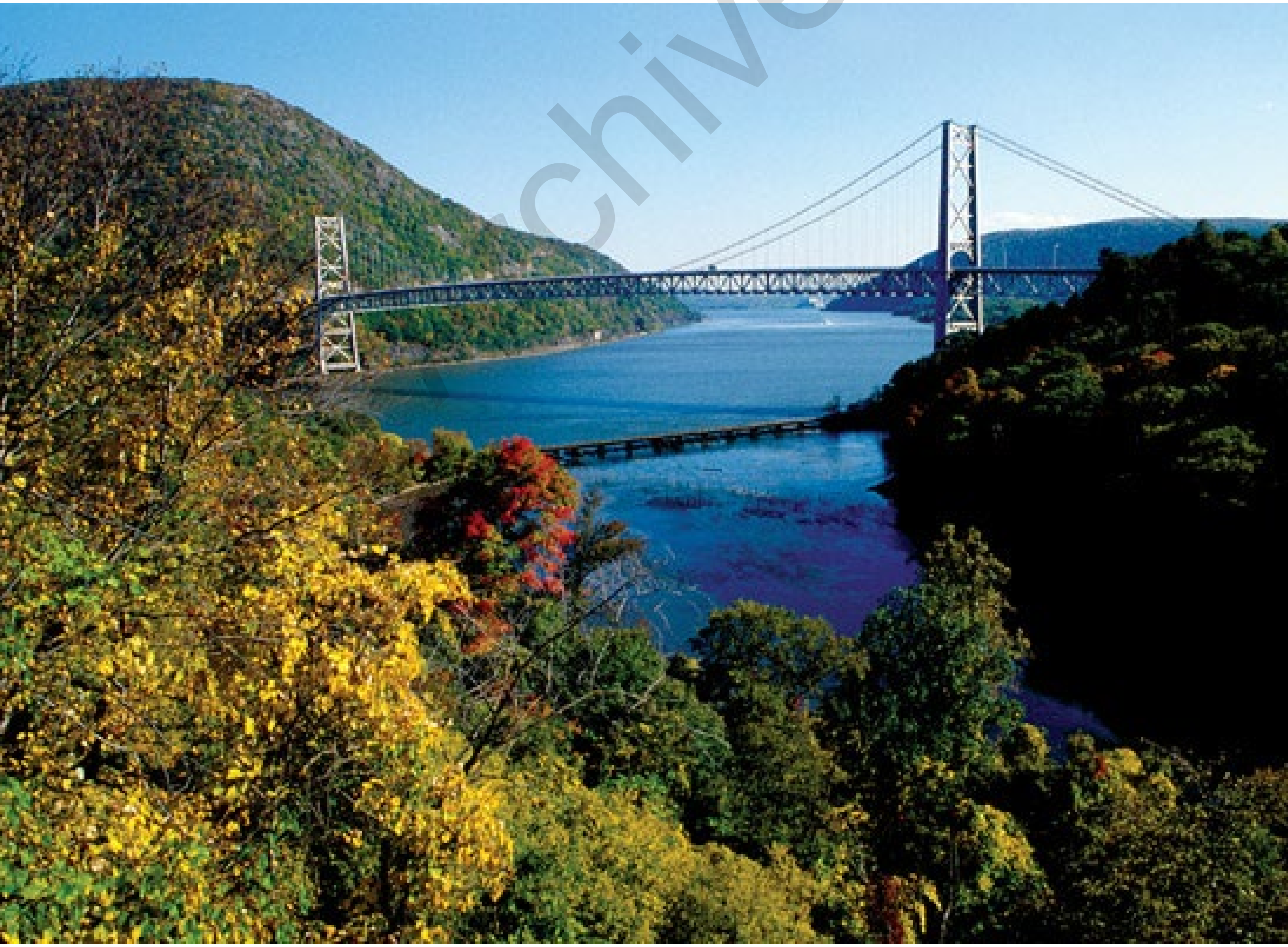
New York State Department of Environmental Conservation

2022 Statewide GHG Emissions Report

SUMMARY REPORT

Kathy Hochul, Governor | Basil Seggos, Commissioner



Acknowledgements

Many individuals provided the State with information, feedback, and expertise that has been incorporated into this report. This includes input on past greenhouse gas and related reporting initiatives and to support implementation of the Climate Leadership and Community Protection Act. Many of the concepts, data, and methods described here were informed by the comments received during the rulemaking for 6 NYCRR Part 496, "Statewide GHG Emission Limits".

Thanks go specifically to James Wilcox and Macy Testani of the New York State Energy Research and Development Authority (NYSERDA) Energy and Environmental Analysis office who managed much of the analytic work conducted for this report. The Department of Environmental Conservation (DEC) Office of Climate Change also worked with many other NYS agencies and offices to compile the information presented here. We also thank these partners:

- 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
- DEC's Division of Water
- 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.

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Figures and Tables

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 2020. The structure and content of this report is aligned with methodology 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 2022b). Any deviations from these methodologies reflect available datasets and the requirements of New York State law.

Format of This Report

In total, this report includes one summary report, four sectoral reports, and an Appendix with emission factors based on the CLCPA GHG emission accounting requirements. The *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.

[1] Chapter 106 of the Laws of 2019; Environmental Conservation Law (ECL) Article 75 and as adopted in 6 NYCRR Part 496.

Current New York State Greenhouse Gas Emissions

In 2020, statewide gross GHG emissions were 344.85 million metric tons of carbon dioxide equivalent (mmt CO_2e) using CLCPA accounting. Total gross emissions in 2020 were 15% lower than 1990 and 8% lower than in 2019. Carbon dioxide (CO_2) and methane (CH_4) comprised the largest portion of emissions by gas, 56% and 36% respectively, and energy was the largest source of emissions (75%). Net emissions were 306 mmt CO_2e in 2020, which includes a net 28.04 mmt CO_2e removed.

As in the case of national emissions, the sharp decline from 2019 to 2020 is likely anomalous and reflects the economic impacts of the COVID19 global pandemic (EPA 2022b). In New York, this decline was almost entirely driven by an 11% reduction in energy emissions (or 32.66mmt CO_2e), primarily due to a 20% drop in transportation emissions (a 15.28mmt CO_2e reduction) and an overall reduction in emissions associated with imported fuels (8.79mmt CO_2e). The other notable reductions were in fuel combustion categories, including a decline of 5.23mmt CO_2e in residential, 2.65mmt CO_2e in commercial, and 1mmt CO_2e in industrial fuel combustion. However, some of these reductions are also affected by seasonal weather patterns and demand for heating or cooling. Finally, emissions from fuel combustion for electricity generation in the state increased 2mmt CO_2e in 2020 while emissions from imported electricity decreased 1.31mmt CO_2e.

Importantly, 2020 emissions are not representative of current conditions and energy emissions are expected to normalize in future reports for 2021 and 2022, reflecting economic recovery following the pandemic. Therefore, this report is focused on trends observed from 2016 through 2019. Table ES.2 provides an updated assessment of 2019 emissions as the year for which the most up-to-date information is available that is also representative of current emission levels in New York State. Minor differences in the emission values included in this report as compared to the 2021 Statewide GHG Emissions report are the result of continual updates and improvements to the methodology and data used to calculate emissions. Based on the current analysis, 2019 statewide gross GHG emissions were 376.18 million metric tons of carbon dioxide equivalent (mmt CO2e) using CLCPA accounting. Total gross emissions in 2019 were 7% lower than 1990. Carbon dioxide (CO_2) and methane (CH_4) comprised the largest portion of emissions, or 59% and 34% respectively. Energy was the largest source of emissions (77%), primarily from fuel combustion and fugitive emissions from imported fossil fuels. When comparing economic sectors (Table ES.3), the largest sources were Buildings (32%) and Transportation (29%). Approximately 7.5% (28.12mmt CO_2e) of 2019 emissions were removed, primarily via carbon sequestration in forests, resulting in a net emission total of 335.54mmt CO_2e.

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

New York State 2022 Statewide GHG Emissions Report

CLCPA Format (mmtCO2e GWP20)	CO_2[(a)]	CH_4	N_2O	PFC	HFC	SF_6	NF_3	Total	*% of Total*	UNFCCC Total[(b)]
Energy	216.74	72.43	0.80	-	-	0.13	-	290.10	*77%*	165.78
Fuel Combustion	169.75	2.21	0.64	-	-	-	-	172.60	*46%*	160.21
Electric Power	*22.03*	*0.04*	*0.05*	-	-	-	-	*22.12*	*6%*	*21.51*
Residential	*39.38*	*1.27*	*0.07*	-	-	-	-	*40.73*	*11%*	*36.18*
Commercial	*22.35*	*0.33*	*0.02*	-	-	-	-	*22.70*	*6%*	*21.94*
Industrial	*8.91*	*0.07*	*0.03*	-	-	-	-	*9.01*	*2%*	*7.21*
Transportation	*77.08*	*0.50*	*0.47*	-	-	-	-	*78.04*	*21%*	*73.36*
Fugitive Emissions	0.23	14.34	+	-	-	-	-	14.57	*4%*	4.50
Electricity T&D	-	-	-	-	-	0.13	-	0.13	+	0.17
Other Use of Fuels	0.90	-	-	-	-	-	-	0.90	+	0.90
Out of State Emissions	45.86	55.88	0.16	-	-	-	-	101.90	*27%*	-
Imported Electricity	*7.79*	*0.01*	*0.02*	-	-	-	-	*7.81*	*2%*	-
Imported Fossil Fuels	*38.07*	*55.87*	*0.14*	-	-	-	-	*94.08*	*25%*	-
Industrial Processes and Product Use	2.19	+	0.02	0.10	20.89	+	+	23.21	*6%*	11.70
Metals	0.37	+	-	0.02	-	-	-	0.39	+	0.40
Minerals	1.82	-	-	-	-	-	-	1.82	+	1.82
Electronics	-	-	0.02	0.08	+	+	+	0.12	+	0.16
Product Use	-	-	+	-	20.89	-	-	20.89	*6%*	9.32
Agriculture, Forestry, and Other Land Use	0.15	19.29	1.80	-	-	-	-	21.25	*6%*	7.75
Livestock	-	19.29	0.36	-	-	-	-	19.65	*5%*	6.15
Soil Management	0.15	-	1.45	-	-	-	-	1.60	+	1.60
Waste	3.59	37.48	0.54	-	-	-	-	41.62	*11%*	8.66
Solid Waste Management	0.52	19.44	-	-	-	-	-	19.96	*5%*	5.79
Waste Combustion	2.49	0.07	0.03	-	-	-	-	2.60	*1%*	1.56
Wastewater	-	2.50	0.50	-	-	-	-	3.00	*1%*	1.31
Exported Waste [(c)]	0.58	15.47	+	-	-	-	-	16.05	*4%*	-
Gross Total	**222.68**	**129.21**	**3.22**	**0.10**	**20.89**	**0.13**	**+**	**376.18**		**193.89**
% Gross Total	*59%*	*34%*	*1%*	+	*6%*	+	+			
Net Emission Removals [(d)]	(28.12)							(28.12)		(28.85)
Net Total	180.99	129.21	3.22	0.10	20.89	0.13	+	335.54		165.03
% Net Total	*54%*	*39%*	*1%*	+	*6%*	+	+			

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

(a) Gross CO_2 emission estimates include biogenic CO_2.

(b) UNFCCC Total refers to conventional accounting used by other governments, applies a 100-year GWP (IPCC 2007), omits biogenic CO_2, and does not include emissions outside of New York State.

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

(d) Net Emission Removals include a small amount of methane and nitrous oxide from forest fire.

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

New York State 2022 Statewide GHG Emissions Report

CLCPA Format (mmtCO_2e GWP20)	CO_2[(a)]	CH_4	N_2O	PFC	HFC	SF_6	NF_3	Total	% of Total	UNFCCC Total[(b)]
Electricity	35.63	14.81	0.08			0.13		50.66	13%	21.68
Fuel Combustion	22.03	0.04	0.05	-	-	-	-	22.12	6%	21.51
Electricity T&D	-	-	-	-	-	0.13	-	0.13	+	0.17
Imported Fuels	5.81	14.76	0.02	-	-	-	-	20.59	5%	-
Imported Electricity	7.79	0.01	0.02	-	-	-	-	7.81	2%	-
Transportation	93.09	12.57	0.54		3.71			109.92	29%	74.81
Fuel Combustion	75.44	0.49	0.47	-	-	-	-	76.40	20%	73.36
Product Use	-	-	-	-	3.71	-	-	3.71	1%	1.39
Imported Fuels	17.66	12.08	0.08	-	-	-	-	29.81	8%	-
Buildings	74.63	27.88	0.14		17.74			119.82	32%	66.00
Residential Fuel Comb.	39.38	1.27	0.07	-	-	-	-	40.73	11%	36.18
Commercial Fuel Comb.	22.35	0.33	0.02	-	-	-	-	22.70	6%	21.94
Product Use	-	-	-	-	17.74	-	-	17.74	5%	8.24
Imported Fuels	12.90	26.28	0.04	-	-	-	-	39.22	10%	-
Industry	15.59	18.37	0.05	0.10	+	+	+	34.11	9%	28.00
Industrial Processes[†]	2.19	+	0.02	0.10	+	+	+	2.31	+	2.38
Oil and Gas Industry[††]	2.25	15.26	+	-	-	-	-	17.51	5%	17.51
Fuel Combustion	8.91	0.07	0.03	-	-	-	-	9.01	2%	7.21
Other Uses of Fuels	0.90	-	-	-	-	-	-	0.90	+	0.90
Imported Fuels	1.34	3.04	+	-	-	-	-	4.39	1%	-
Waste[†]	3.59	37.48	0.54	-	-	-	-	41.62	11%	8.66
Waste	3.02	22.01	0.53	-	-	-	-	25.56	7%	8.66
Exported Waste [(c)]	0.58	15.47	+	-	-	-	-	16.05	4%	-
Agriculture[†]	0.15	19.29	1.80	-	-	-	-	21.25	6%	7.75
Gross Total	**222.68**	**129.21**	**3.22**	**0.10**	**20.89**	**0.13**	**+**	**376.18**		**193.89**
% Gross	*59%*	*34%*	*1%*	+	*6%*	+	+			
Net Emission Removals [(d)]	(28.12)							(28.12)		(28.85)
Net Total	180.99	129.21	3.22	0.10	20.89	0.13	+	335.54		165.03
% Net	*54%*	*39%*	*1%*	+	*6%*	+	+			

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

(a) Gross CO_2 emission estimates include biogenic CO_2.

(b) UNFCCC Total refers to conventional accounting used by other governments, applies a 100-year GWP (IPCC 2007), omits biogenic CO_2, and does not include emissions outside of New York State.

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

(d) Net Emission Removals include a small amount of methane and nitrous oxide from forest fire.

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

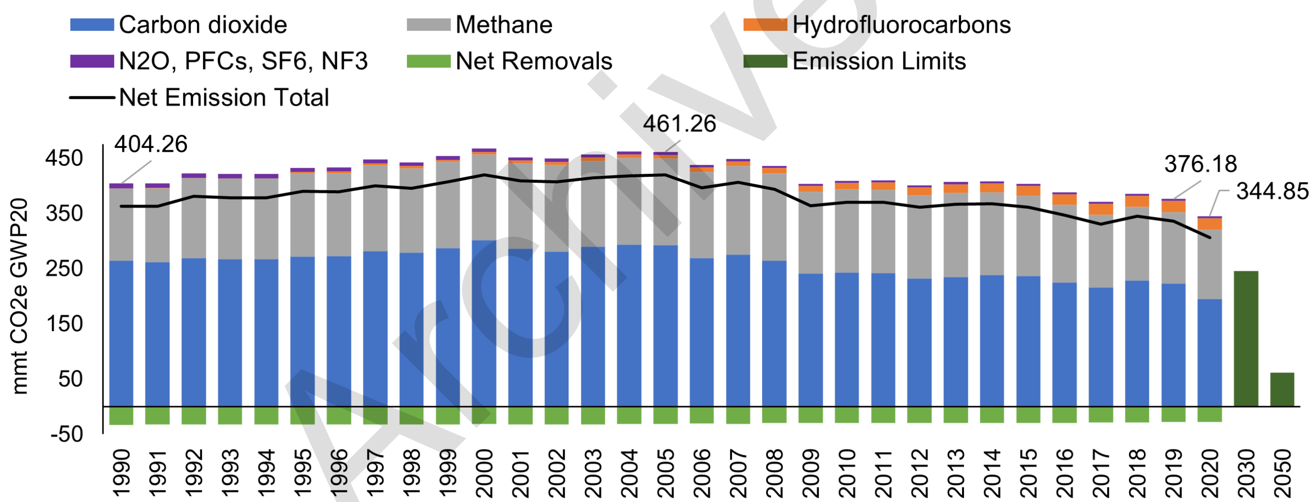
[††]Oil and Gas Industry includes fuel use in pipelines and fugitive emissions within New York.

Trends in Greenhouse Gas Emissions, 1990-2020

Given the anomalous nature of emissions in 2020, emission trends are described for 1990-2019 as the most recent year for which data are available and that is representative of current emission levels. Total statewide gross emissions in 2019 were 7% below 1990 and 18% 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. Statewide emissions for 2020 are also described in this report but are not representative of current conditions due to the impacts of the COVID19 global pandemic.

Annual emissions of CO_2 declined 16%, or 42.24mmt CO_2e, from 1990 to 2019, but this was coupled with an increase in hydrofluorocarbon emissions of over 20mmt CO_2e. Methane emission rates were approximately the same in 1990 and 2019. Emission rates for the other gases remain at relatively low rates in terms of carbon dioxide equivalence and declined 60% since 1990, or 5.23mmt CO_2e. Annual, net emission removals of CO_2 declined 15% 1990 to 2019, or from -33.11mmt to -28.12mmt CO_2e.

Figure ES.1: NYS Statewide Greenhouse Gas Emissions by Gas, 1990-2020 (mmt CO_2e GWP20)



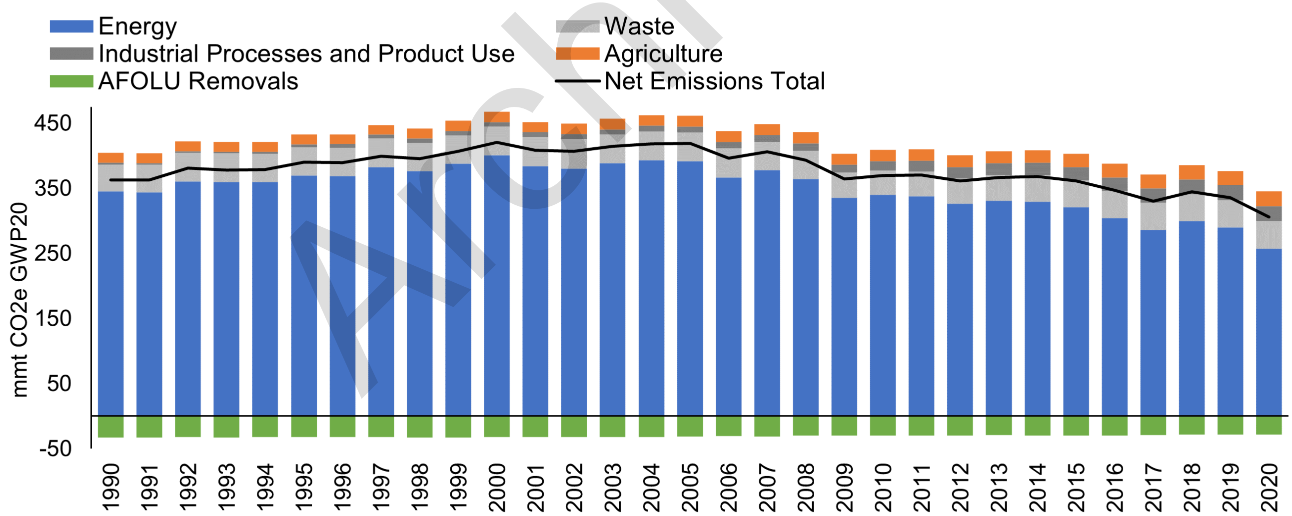
As a point of comparison, when applying the conventional, or UNFCCC, format for governmental accounting, emissions declined 32% percent from 1990 to 2020 in New York State. However, this steep decline is largely due to the economic impacts of the COVID19 global pandemic in 2020. Emissions were 12% lower in 2020 compared to 2019 using the conventional UNFCCC accounting. A more representative trend may be the 22% reduction in emissions from 1990 to 2019. Importantly, this accounting format does not meet CLCPA requirements.

Trends in IPCC Emission Sectors, 1990-2020

In Figure ES.2, emissions are organized into the sectors described in IPCC approach (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 (77-79%, 2016-2019), but energy emissions in 2019 were 16% lower than in 1990 (Figure ES.2). The overall reduction in energy emissions was offset by increases in all other sectors and by a 15% 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. In 2020, energy emissions steeply declined due to the impacts of the COVID19 global pandemic. Energy emissions in 2020 were 11% lower than in 2019 and agricultural emissions 4% lower. All other sectors were relatively unchanged between 2019 and 2020 (reduced by 0.06mmt CO2e). Net emission removals were not affected, and net forest carbon sequestration continued to decline.

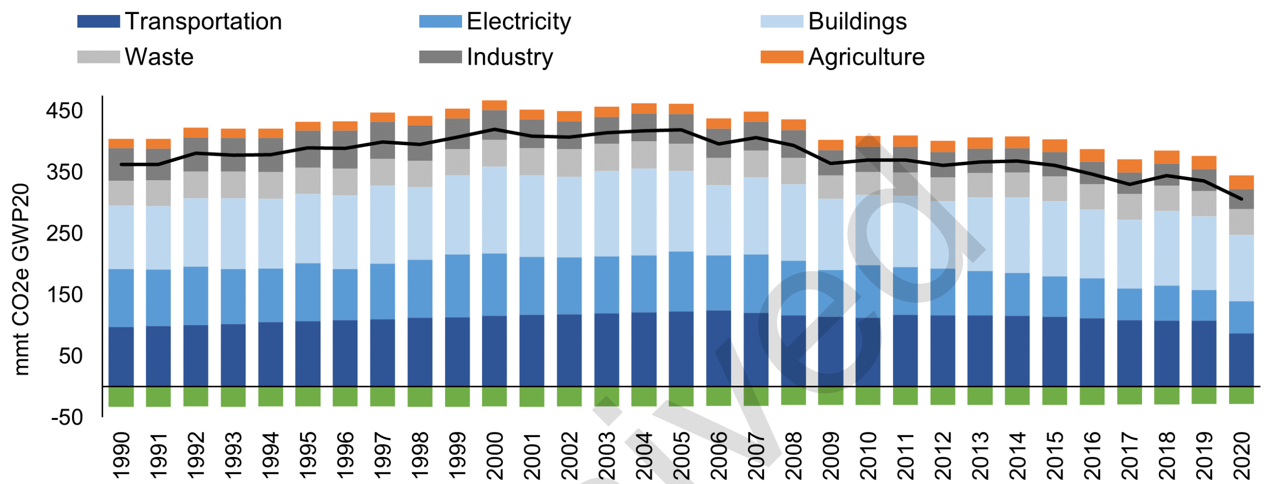
Figure ES.2: NYS Statewide Greenhouse Gas Emissions by Sector, 1990-2020 (mmt CO_2e GWP20)



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 as sectors described in the New York State Climate Action Council 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 from 1990 to 2019 show a 46% decrease in electricity emissions and a 33% decrease in industrial emissions (43.85mmt and 17.38mmt CO_2e reduction, respectively). These reductions were offset by a 16% increase in emissions from buildings and 10% in transportation (16.3mmt and 10.07mmt increase, respectively). Agricultural and waste emission increased by about 6mmt and 1mmt CO_2e, respectively. The primary impacts of the COVID19 global pandemic in 2020 were to lower emissions in the Transportation and Buildings sectors, but this impact is expected to be temporary in nature.

Figure ES.3: NYS Statewide Emissions by Economic Sector, 1990-2020 (mmt CO_2e GWP20)



2022 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 1990-2020 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 approach provided by the International Panel on Climate Change (IPCC) Taskforce on National Inventories, referred to here as the "IPCC approach" (IPCC 2006, 2019). The IPCC approach 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 this approach and is the primary model used for this state report (EPA 2022b).

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 Scoping Plan. DEC welcomes feedback on additional ways to present this information in future reports. DEC also makes 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 a set of 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. 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"). 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, a separate Appendix is provided by DEC with emission factors that align with the data and methods used in this report.

- Summary Report (this document)
- Sectoral Report #1: Energy
- Sectoral Report #2: Industrial Processes and Product Use

[2] ECL § 75-0105(1).

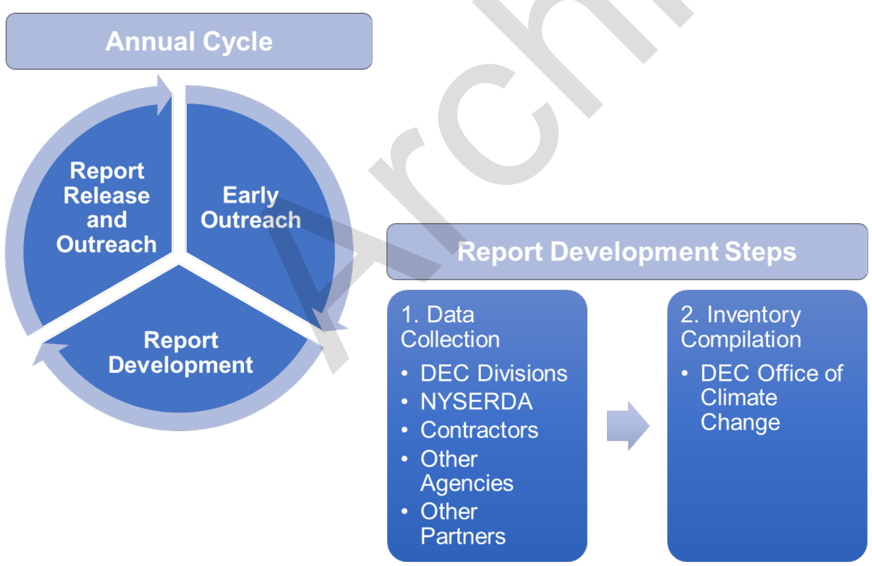
- Sectoral Report #3: Agriculture, Forestry, and Other Land Use
- Sectoral Report #4: Waste
- Appendix: Emission Factors for Use by State Agencies and Applicants

Annual Inventory Process

This report is updated annually as required by the CLCPA, following the release of the U.S. national greenhouse gas inventory and related datasets. DEC updates 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. As such, results provided in the 2021 report for 1990-2019 have been updated in this report.

DEC applies the same general process for each annual report, consistent with the requirements of the CLCPA (Figure 1). First, DEC invites 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. Where needed, DEC may hold public meetings to collect feedback. DEC also consults early with partners such as the U.S. EPA. Once this phase is completed and the relevant national datasets are made available, DEC develops the written report in collaboration with other State entities, contractors, and partners. Feedback received after the release of each report may be considered in the development of the following year's report. DEC accepts 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 2022b), submissions to the UNFCCC, and Inventory of U.S. Greenhouse Gas Emissions and Sinks by State			
USEPA State Inventory Tool (EPA 2022a)			

Greenhouse Gas Accounting Used in This Report

This report uses metrics and an organizational scheme that meets the requirements of the CLCPA while also considering other goals, including alignment with the accounting used by other governments, consistency with other State policies, and providing 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, along with 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 estimates 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 approach 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] This report also includes emissions associated with wastes that have been exported outside of New York, per regulation. 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 approach 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 CO_2 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 approach that also considers emission removals.

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 CO_2 associated with forests in a given year could include all of the CO_2 sequestered by trees as well as any gases emitted during forest fires. Consistent with the IPCC approach, biogenic CO_2 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 approach 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 CO_2 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 approach and treats biogenic CO_2 as an anthropogenic emission source that is omitted from net emission totals to avoid double counting CO_2 sources across the Energy and Land Use sectors.

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

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 CO_2, 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 "CO_2e". 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 CO_2, such as methane (CH_4; 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 CO_2e (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.

[5] 6 NYCCR Part 496.

Table 2: Global Warming Potential Values

Gas	**Conventional** AR4 GWP100 (IPCC 2007)	**CLCPA**[(a)] AR5 GWP20 (IPCC 2013)	AR6 GWP 100 (IPCC 2021)	AR6 GWP 20 (IPCC 2021)
CO_2	1	1	1	1
CH_4	25	84	27.9	81.2
N_2O	298	264	273	273
HFC-23	14,800	10,800	14,600	12,400
HFC-32	675	2430	771	2690
HFC-41	92	427	135	485
HFC-125	3500	6090	3740	6740
HFC-134a	1430	3580	1530	4140
HFC-143a	4470	6940	5810	7840
HFC-152a	124	506	164	591
HFC-227ea	3220	5360	3600	5850
HFC-236fa	9810	6940	8690	7450
HFC-43-10mee	1640	4310	1600	3960
HFC-245fa	1030	2920	962	3170
HFC-365mfc	794	2660	914	2920
PFC-14	7390	4880	7380	5300
PFC-116	12,200	8210	12,400	8940
PFC-218	8830	6640	9290	6770
PFC-318	10,300	7110	10,200	7400
PFC-3-1-10	8860	6850	10,000	7300
PFC-5-1-14	9300	5890	8620	6260
SF_6	22,800	17,500	25,200	18,300
NF_3	17,200	12,800	17,400	13,400

(a) 6 NYCRR Part 496; Source: IPCC (2007, 2013, 2021)

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 2022b). 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 (CO_2) is the major anthropogenic climate forcer. The current atmospheric abundance of CO_2 has risen to 415.7 +/- 0.2 ppm from a preindustrial abundance of 278.3 ppm (WMO 2022), mainly due to fossil fuel combustion. Carbon cycle processes redistribute the CO_2

that is emitted to the atmosphere to terrestrial ecosystems and ocean carbon reservoirs. These CO_2 sinks take up roughly half of anthropogenic CO_2 emissions annually. But these sinks are responsive to changes in the atmospheric abundance of CO_2, and any deliberate net removal of CO_2 in the future will be partially offset by outgassing of CO_2 from the ocean and land sinks (IPCC 2021). The processes that remove CO_2 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 CO_2 is a long-lived greenhouse gas, and its present-day emissions will impact the climate long into the future (IPCC 2018).

Methane

Like CO_2, the atmospheric abundance of methane (CH_4) has been driven upwards by anthropogenic emissions. Atmospheric CH_4 is now 262% higher than preindustrial levels, and the rate of annual increase is higher now than any other period; CH_4 increased 18ppb to reach 1908 +/- 0.2 ppb in 2021 (WMO 2022). Due to its abundance, CH_4 is often grouped with CO_2 and other long-lived greenhouse gases, but its atmospheric lifetime is actually only 9 years (IPCC 2021). In contrast to CO_2, whose long atmospheric lifetime and high atmospheric abundance drive its climate impact, it is CH_4's radiative efficiency, or heat-trapping ability, that makes it an important climate forcer over the short term. CH_4 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 CH_4 is much higher than its GWP100 (Table 2). It also means that a steady ongoing release of CH_4, rather than a pulse emission, is most similar to a pulse CO_2 emission in terms of their respective long-term climate impacts.

Nitrous oxide

Nitrous oxide (N_2O) is long-lived like CO_2, and like CH_4, 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. N_2O takes centuries to achieve equilibrium between emissions and removals and therefore, like CO_2, N_2O emissions impact climate cumulatively (IPCC 2021). N_2O sources are natural (60%) and anthropogenic (40%). Like CH_4, N_2O is produced both biologically through the activity of microorganisms, and through combustion. Biological N_2O is produced by microbial action on certain nitrogen compounds in soil and water. Anthropogenic activity in the agricultural and waste management sectors enhance biological N_2O emission rates. Combustion sources of N_2O include motor vehicles and point sources. The global atmospheric abundance of N_2O has risen to 334.5+/-0.1 ppb from a preindustrial value of 270.1 ppb (WMO 2022). Even after global emissions of N_2O are stabilized, its long atmospheric lifetime means that it will take more than a century before atmospheric abundances stabilize. N_2O 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 approach, 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 CF_4) 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 CF_4 also have natural sources that contribute significantly to their atmospheric abundance (IPCC 2021).

Sulfur hexafluoride (SF_6) 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 CO_2 and N_2O, and a relatively small amount of SF_6 can have a significant long-term impact. The atmospheric SF_6 abundance was estimated to be 10.0 ppt in 2019, up from 7.0 ppt in 2011 (IPCC 2021). The current abundance of SF6 in the atmosphere is more than twice that in the mid-1990's (WMO 2022). SF_6 has been used in a variety of applications, including electronics manufacturing and in medical applications. Electric utilities rely on SF_6 in electric power systems for voltage electrical insulation, current interruption, and arc quenching in the transmission and distribution of electricity.

Nitrogen trifluoride (NF_3) 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 SF_6, and its long atmospheric lifetime of 569 years (Hodnebrog et al. 2020) means that today's NF_3 emissions will have a long-lasting impact on climate.

Sulfuryl fluoride (SO_2F_2) is another well-mixed GHG of potential concern that is not within the statutory definition of GHGs and not currently subject to the CLCPA accounting requirements per 6 NYCRR Part 496. Emissions of this pollutant are not currently included in this report but may be included in future reporting. Sulfuryl fluoride is primarily used in pest control and is a New York State registered pesticide subject to environmental control and reporting requirements.

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 NOx) 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 be incorporated into the U.S. National Emissions Inventory (NEI), which is updated every three years (EPA 2021). 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 (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, 1990-2020

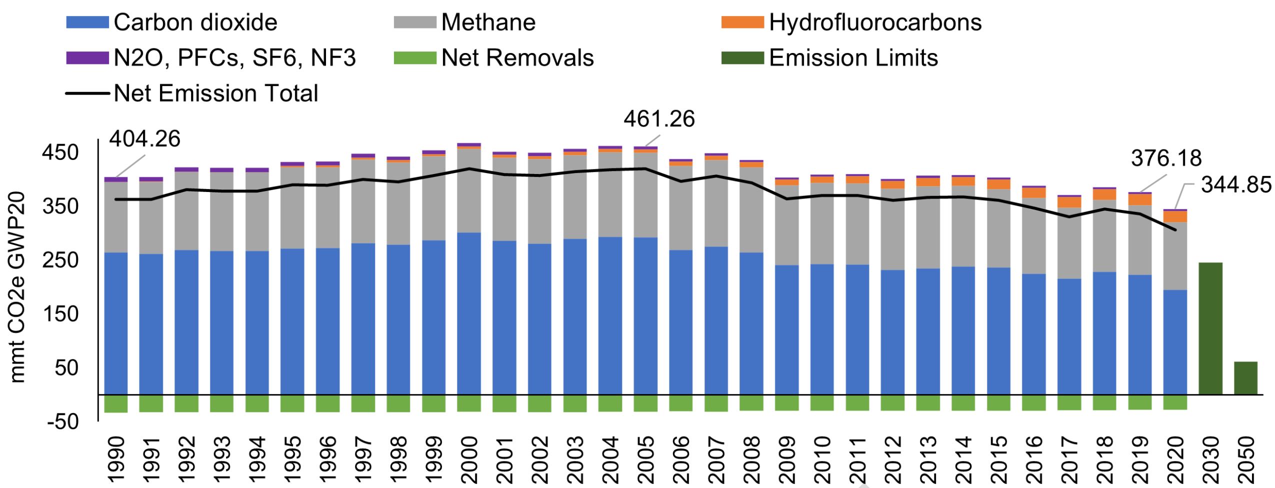
In 2020, statewide gross GHG emissions were 344.85 million metric tons of carbon dioxide equivalent (mmt CO2e) using CLCPA accounting and net emissions were 306 mmt CO2e. Total gross emissions in 2020 were 15% lower than 1990 and 8% lower than in 2019. As in the case of national emissions, the sharp decline from 2019 to 2020 is likely anomalous and reflects the economic impacts of the COVID19 pandemic (EPA 2022b). This decline is almost entirely driven by an 11% reduction in energy emissions (or 32.66mmt CO2e), primarily due to a 20% drop in transportation emissions (a 15.28 mmt CO2e reduction) and an overall reduction in emissions associated with imported fuels (8.79mmt CO2e). The other notable reductions were in the other uses of fuels, or 5.23mmt CO2e in residential, 2.65mmt CO2e in commercial, and 1mmt CO2e in industrial fuel combustion. However, fuel combustion for electricity generation in the state increased 2mmt CO2e.

Importantly, annual emission levels are expected to increase from 2020 levels in future reports for 2021 and 2022, reflecting economic recovery following the COVID19 global pandemic. In this report, 2019 rather than 2020 is therefore considered to be representative of current conditions and 2016 through 2019 as representative of recent trends.

Based on the current analysis, 2019, statewide gross emissions were 376.18 mmtCO_2e, which is 7% 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 CO_2 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. Nationally, emissions from the electric power industry declined 11% from 2016-2019 (EPA, 2022b).

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, CO_2 remains the primary greenhouse gas emitted by human activity (or 59% of emissions in 2019) and fossil fuel combustion is the primary source of CO_2. The land-use sector is an important CO_2 sink and removed roughly 7.5% 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 CO_2 emissions, as discussed above, but also a reduction in CO_2 removals.

Figure 2: NYS Statewide Greenhouse Gas Emissions by Gas, 1990-2020 (mmt CO_2e GWP20)

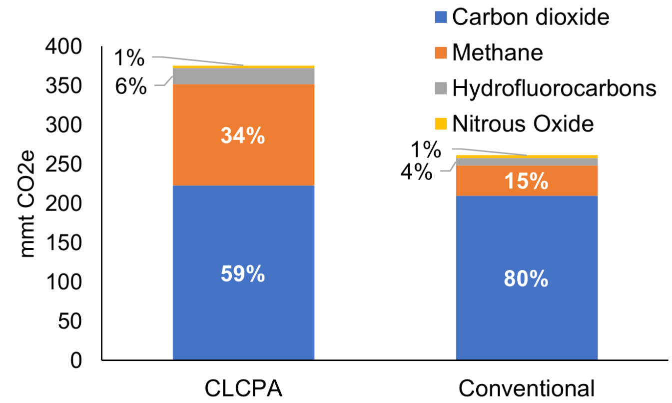


The second most important greenhouse gas in New York State, in terms of carbon dioxide equivalent emissions, is methane (34% of emissions; Figure 2). Major anthropogenic sources of CH_4 are fossil fuel infrastructure, waste, and agriculture. This includes CH_4 emissions from fuel infrastructure and waste 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, CH_4 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 CH_4 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 N_2O, PFCs, and SF_6 all declined as a result of technological and economic change in New York State, HFC emissions continue to grow. Importantly, all these pollutants are more powerful than CO_2 per ton and most are much longer lived.

When considering emission sources only within New York State and using a GWP100, CO_2 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.

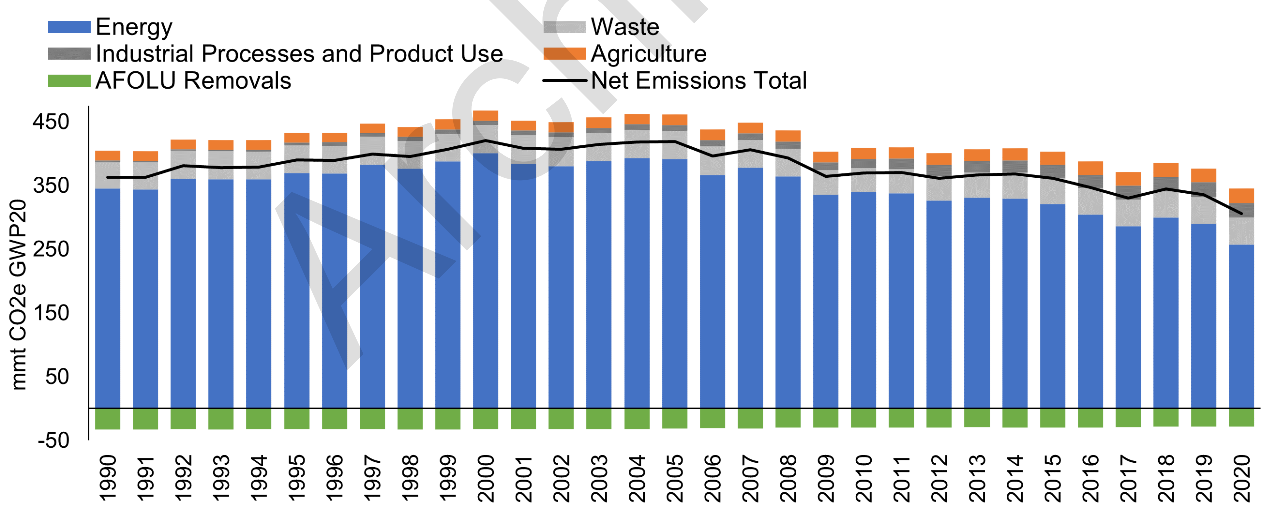
Figure 3: Comparison of 2019 Emissions, CLCPA and Standard Format



III. Trends in Greenhouse Gas Emission Sectors, 1990-2020

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, 1990-2020 (mmt CO_2e GWP20)



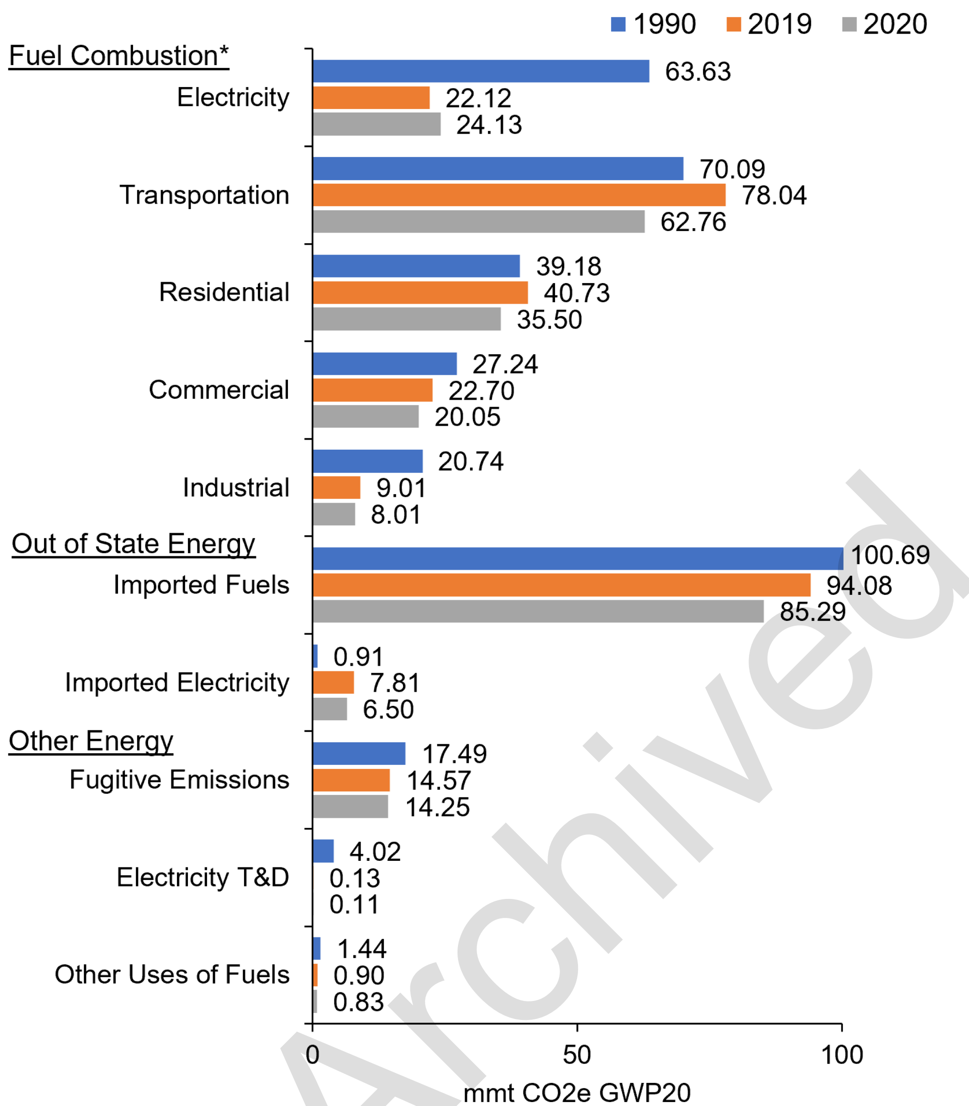
New York State's report makes slight changes to the IPCC approach as it is used in the national greenhouse gas inventory (EPA 2022b). There are two additional sources of emissions associated with the Energy sector (imported electricity and imported fossil fuels) as well as new sources added to the Waste 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 (CO_2), methane (CH_4), nitrous oxide (N_2O), and sulfur hexafluoride (SF_6) emissions. SF_6 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.

Figure 5: Trends in Energy Sector Emissions



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 reduction is partially offset by a transition to fuels with higher out-of-state emission rates.

For plant and waste-based fuels, Energy emissions are associated only with the combustion of the fuels, and this includes biogenic CO_2. 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*).

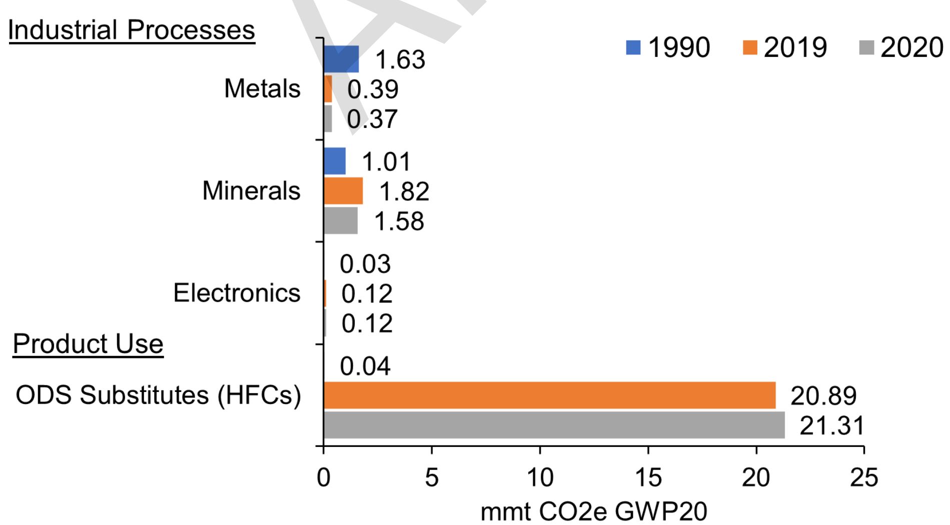
Industrial Processes and Product Use (IPPU)

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 CO_2 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 (N_2O, PFCs, HFCs, and SF_6).

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 SF_6 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



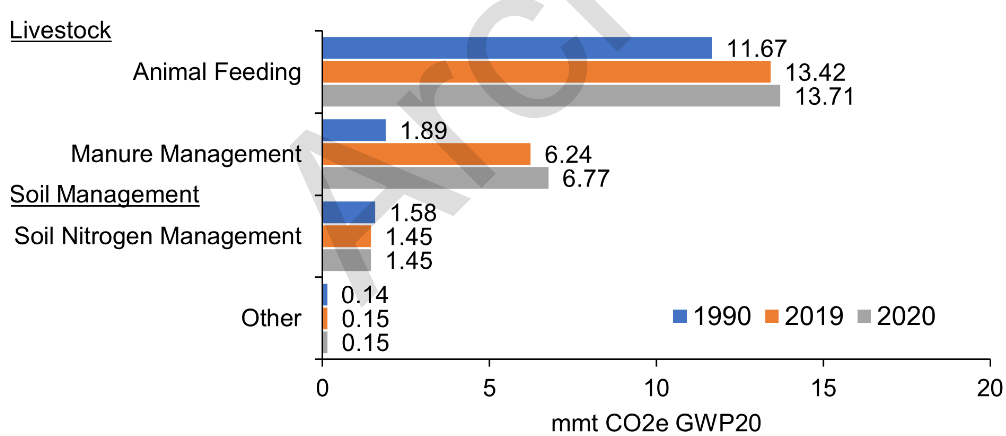
Agriculture, Forests, and Other Land Use (AFOLU)

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 (CH_4) from animal feeding (Figure 7). However, the largest growth in emissions is related to manure management (CH_4 and N_2O) 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 N_2O from nitrogen fertilizers.

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 durable goods, or "Harvested Wood Products" (Figure 8). However, the major source of net emission removals comes from the Land Use category and particularly New York's nearly 19 million acres of forest land.

Figure 7: Trends in AFOLU Agriculture Sector Emissions



Land Use accounting reflects both how much net CO_2e 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 development (referred to as "settlement lands"). In addition, a large amount of forest is forested wetlands. Figure 8a shows the difference between 1990, 2019, and 2020 emission removals in forested lands, wetlands, and as carbon stored in harvested wood products. Figure 8b focuses in on the "other lands", which represent net sources of carbon dioxide. Notably, this report introduces new data from the USEPA regarding annual removals and emissions in croplands and grasslands. Croplands were a net sink for CO_2 in 1990, but are now a significant source of emissions. This is primarily due to the conversion of forest land to cropland that results in both the loss of carbon stored in forests as well as annual sequestration by forests.

Figure 8a: Trends in AFOLU Net Emission Removals

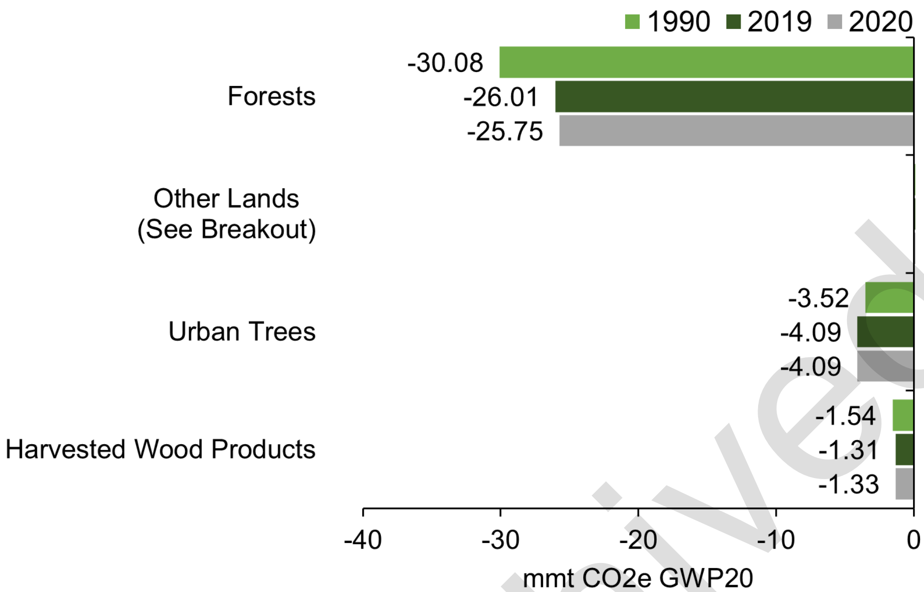
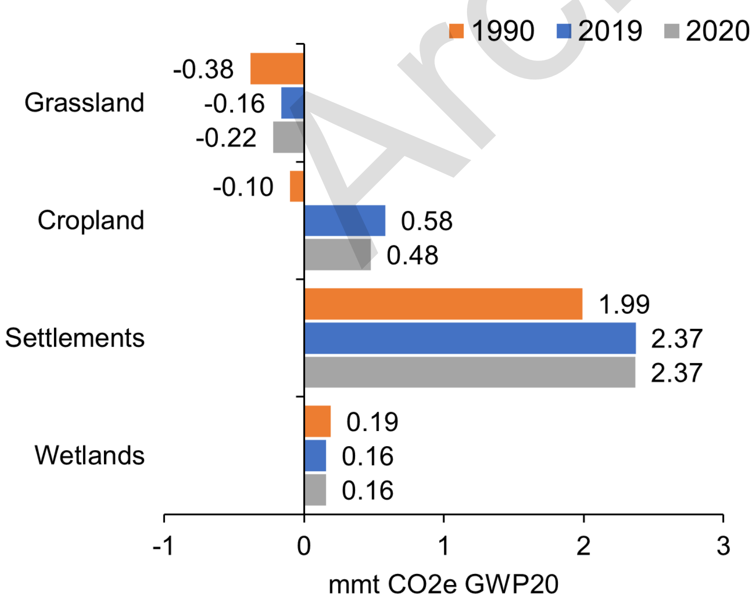


Figure 8b: Breakout Other Land Trends in AFOLU Net Emission Removals



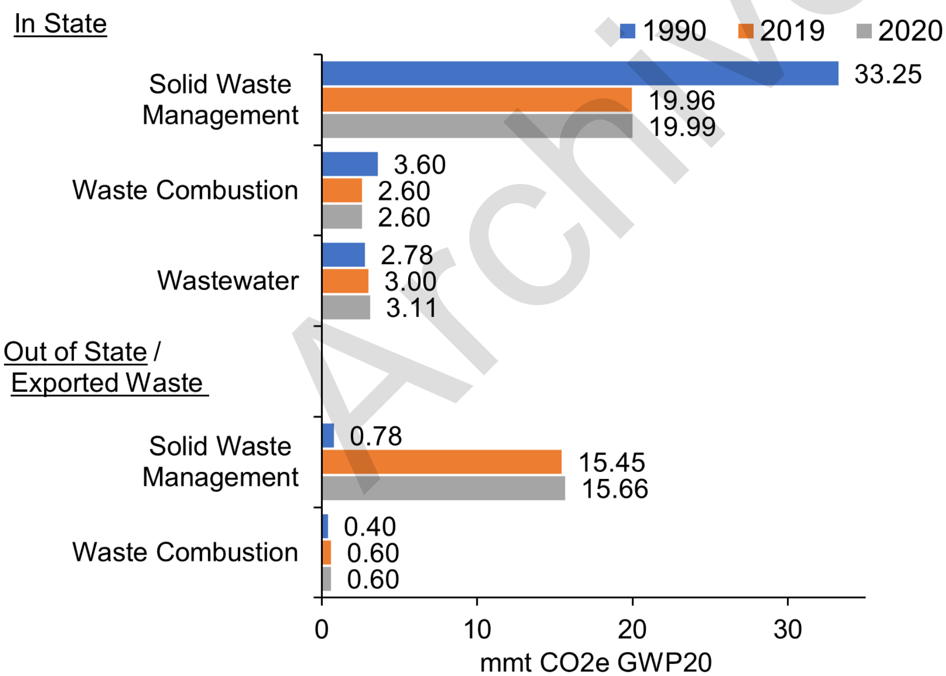
Waste

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 approach). 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 (CH_4) because it is generated when organic materials decay in the type of anaerobic environment found in landfills.CO_2 is also a product of waste decay and the main component of waste combustion. Consistent with the Part 496 regulation, CO_2 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 CO_2e over this time period.

Figure 9: Trends in Waste Sector Emissions



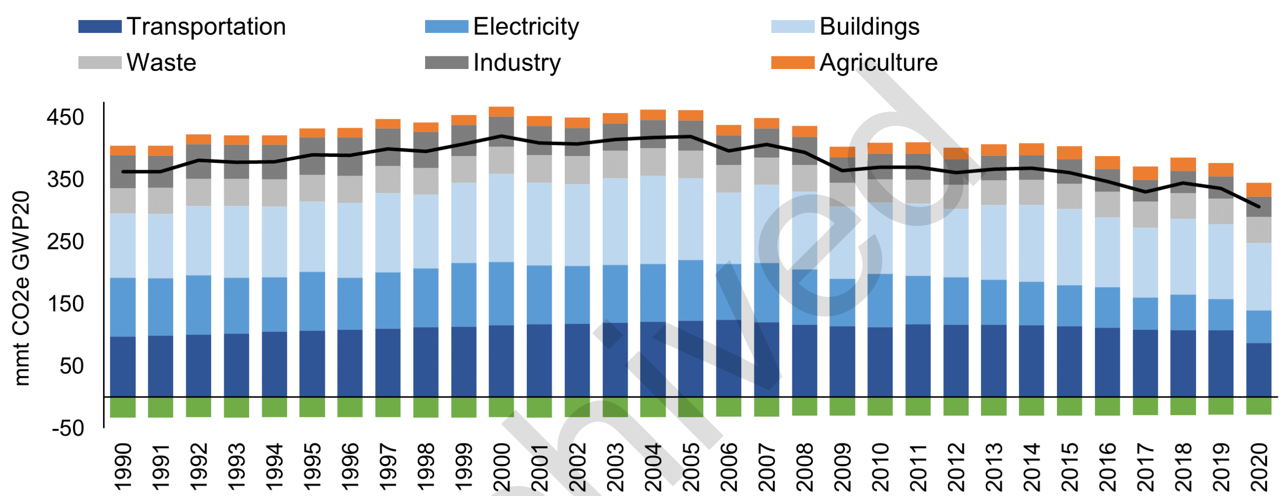
Emissions by Economic Sector and CLCPA Scoping Plan

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,

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

transportation, electric power, and agriculture sectors (EPA 2022b). Figure 10 and Table ES.3 assigns emissions and removals to the economic sectors as organized in the New York State Climate Action Council 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 where 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 approach.

Figure 10: NYS Greenhouse Gas Emissions by Economic Sector (mmt CO_2e 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	345.45	Refinement of imported fuels and fugitive emissions methods.
Industrial Processes and Product Use (IPPU)	2.72	2.72	Inclusion of N_2O product use. Total change less than 0.01mmt CO_2e.
Agriculture Forestry and Other Land Use (AFOLU)	17.13	15.29	Refinement of EPA SIT default inputs with NYS datasets.
Waste	52.88	40.81	Refinement of EPA SIT default inputs with NYS datasets and corrections to wastewater factors.
Gross Total	**409.78**	**404.26**	

* 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 approach 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 approach and any deviations are explained in the text. For example, the IPCC approach place waste combustion in the Energy rather than in the Waste sector.

Table 4: 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).

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_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
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_2O	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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NEW YORK STATE | Department of Environmental Conservation

Energy

2022 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #1

Kathy Hochul, Governor | Basil Seggos, Commissioner

Table of Contents

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 the IPCC Taskforce on National Greenhouse Gas Inventories approach (or "IPCC approach") as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2022a and 2022b). 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

Tables

Energy

This sectoral report provides information on greenhouse gas (GHG) emissions associated with the energy system. Most emissions in the energy sector are from the combustion of fuels (Table 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 approach. Finally, one additional source of emissions is provided as an informational item. Per IPCC approach, the portion of transportation fuels used for international transport, or bunker fuels, has been excluded from emission totals ("Excluded Transportation", Table 1).

The energy system is the primary source of greenhouse gas emissions in New York (Table 1). In 2020, total energy emissions were 257.44mmt CO_2e or 75% of statewide gross emissions and over 80% of net emissions, when measured using CLCPA accounting. This represents a 25% reduction in gross emissions compared to 1990 and an 11% reduction compared to 2019. The majority of Energy emissions in 2020 were from either fuel combustion (58% of energy and 44% of total emissions) or were associated with the importing of those fuels or electricity (36% of energy and 27% of total emissions).

The steep emissions reduction in 2020 matches the trend seen at the national level and represents the impact of the COVID19 global pandemic on economic activity (EPA 2022b). These impacts are most pronounced in the transportation sector, which saw a 20% drop in emissions (a 15.28mmt CO_2e reduction), and the related decline in emissions associated with imported fuels (8.79mmt CO_2e). Other emission categories with significant changes include electric power, and residential, commercial and industrial (RCI) fuel combustion. Emissions from fuel combustion for electricity generation in the state increased 2mmt CO_2e in 2020 and is representative of increased fossil-fueled energy generation as compared to 2019 (4,606.2 GWh). Overall, annual in-state electricity generation declined 2.3% and total use declined 3.6% (NYISO 2021). RCI emission declines include 5.23mmt CO_2e in residential, 2.65mmt CO_2e in commercial, and 1mmt CO_2e in industrial fuel combustion. Much of these declines can be attributed to fewer heating degree days (Figure 1) and is discussed in more detail in that section of the report.

The trend in Energy emissions over time, or from 1990-2019, is also the same as that seen nationally, with an initial increase in emission from 1990 through the mid-2000's and then a decline thereafter (EPA 2022b). Importantly, 2020 emissions are not representative of current conditions and energy emissions are expected to increase in future reports for 2021 and 2022, reflecting economic recovery following the pandemic. Minor differences in the emission values included in this report as compared to the 2021 Statewide GHG Emissions report are the result of continual updates and improvements to the methodology and data used to calculate emissions.

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 1. Energy Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Fuel Combustion	220.90	232.53	173.50	166.44	175.91	172.60	150.46
Other Fossil Fuel Use	1.44	2.21	1.23	1.23	1.17	0.90	0.83
Fugitive Emissions	17.49	20.88	15.33	14.85	14.36	14.57	14.25
Electricity Transmission	4.02	1.61	0.15	0.14	0.13	0.13	0.11
Out of State Energy Emissions*	101.61	133.97	114.35	103.31	107.93	101.90	91.79
Gross Total	**345.45**	**391.20**	**304.57**	**285.96**	**299.50**	**290.10**	**257.44**
% of Statewide Gross Total	*85%*	*85%*	*79%*	*77%*	*78%*	*77%*	*75%*
Net Total	**338.62**	**382.42**	**294.22**	**275.75**	**288.72**	**279.18**	**248.19**
% of Statewide Net Total	*93%*	*91%*	*85%*	*84%*	*84%*	*83%*	*81%*
Excluded Transportation Emissions	15.35	13.87	19.73	19.67	18.93	17.99	8.68

*Not an IPCC Category

The primary greenhouse gas emitted by the energy sector is carbon dioxide (CO_2) for 73% of energy emissions (Table 2). Under the IPCC approach for national governments, the CO_2 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 CO_2 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 (CH_4; 26% of energy emissions), primarily from leakage or intentional venting in the oil and gas system in New York and through the fuel system. Notably, 76% of energy sector methane is associated with out-of-state sources. Nitrous oxide (N_2O) is also a byproduct of fuel combustion, but at a lower emission rate than the gases above. Finally, the major source of sulfur hexafluoride (SF_6) globally is as an insulating gas in electricity transmission and distribution equipment, but its leakage rate in New York declined significantly since the 1990s.

[1] Per 6 NYCRR Part 496

Table 2. 2020 Energy Emissions by Gas (mmt CO2e GWP20)

Emission Category	CO_2	Biogenic CO_2	CH_4	N_2O	SF_6
Fuel Combustion	138.81	9.25	1.84	.56	na
Other Fossil Fuel Use	0.83	na	na	na	na
Fugitive Emissions	0.15	na	14.10	+	na
Electricity Transmission	Na	na	na	na	0.11
Out of State Energy Emissions*	40.10	+	51.55	0.14	na
Gross Total	**179.89**	**9.25**	**67.49**	**0.70**	**0.11**

* Not an IPCC Category

"+" less than 0.01mmt

"na" not applicable

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 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 (2022a) is a technical supplement that is citied 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 2022b). However, there are minor differences in how emission sources are organized in the IPCC approach. For example, industrial fuel combustion includes emission sources from industries that the IPCC approach split across multiple subcategories.

The most significant trend in fuel combustion emissions since 1990 was a 62% reduction from the electricity sector (Table 3). However, another major source of emissions is the transportation sector, in which emissions grew 11% from 1990 to 2019 and represented 45% of fuel combustion emissions in 2019. In 2020, transportation emissions declined 10% as compared to 1990, but are unrepresentative of current trends due to the impacts of the COVID19 global pandemic. Emissions are expected to return to previous patterns in future years. The second largest source of emissions is the use of fuels in residential buildings, such as for heating and cooking, followed by electricity generation and commercial fuel use.

Table 3. Fuel Combustion Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Electric Power	63.63	56.22	28.58	22.94	25.17	22.12	24.13
Residential	39.18	46.44	34.90	35.42	41.31	40.73	35.50
Commercial	27.24	29.93	21.53	21.86	23.01	22.70	20.05
Industrial	20.74	13.71	9.18	8.77	8.98	9.01	8.01
Transportation	70.09	86.24	79.31	77.44	77.43	78.04	62.76
Petroleum Refining	0.01	no	no	no	no	no	no
Gross Total	**220.90**	**232.53**	**173.50**	**166.44**	**175.91**	**172.60**	**150.46**

"no" not occurring

The majority of fuel combustion emissions in 2020 were from the burning of petroleum fuels, which is unsurprising as these are the main fuels used in transportation (Table 4). However, emissions from the combustion of petroleum fuels had declined 44% since 1990, while emissions from natural gas increased nearly 46%. Emissions from the combustion of coal declined 98%.

Table 4. Fuel Combustion Emissions by Fuel Category, 1990-2020 (mmt CO2e GWP20)

Fuel Category	1990	2005	2016	2017	2018	2019	2020
Petroleum Fuels	131.61	139.82	92.73	89.97	92.82	92.44	73.85
Natural Gas	47.59	59.02	71.04	67.84	74.02	71.11	69.35
Coal	33.61	23.95	2.54	1.57	1.37	1.31	0.54
Wood	8.09	9.75	7.19	7.06	7.70	7.74	6.71
Gross Total	**220.89**	**232.53**	**173.50**	**166.44**	**175.91**	**172.60**	**150.46**

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 approach, 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 1990-2020 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 2021, 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 1990-2020 timeseries. For this report, annual BTUs of fuel consumed were taken from the EIA SEDs dataset and emission factors for CO_2, CH_4, and N_2O were from the EPA (NYSERDA 2022a, EPA 2022b Table A-32).

Results

The most significant emission reduction in this report was the decrease in fuel combustion emissions in the electricity sector from 1990 to current by over 60% (Table 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 5). As described in NYSERDA (2022a), 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 5. Electricity Emissions by Fuel Type, 1990-2029 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Coal	25.04	20.60	1.51	0.61	0.68	0.46	0.16
Distillate Fuel	0.47	0.69	0.15	0.11	0.34	0.16	0.08
Natural Gas	12.59	16.52	25.82	21.09	22.72	20.73	23.19
Petroleum Coke	no	1.33	no	no	no	no	No
Residual Fuel	25.45	16.59	0.30	0.30	0.76	0.17	0.10
Wood	0.07	0.49	0.80	0.83	0.67	0.60	0.61
Gross Total	**63.63**	**56.22**	**28.58**	**22.94**	**25.17**	**22.12**	**24.13**

“+” less than 0.01mmt

“no” not applicable

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 2020 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 2021).

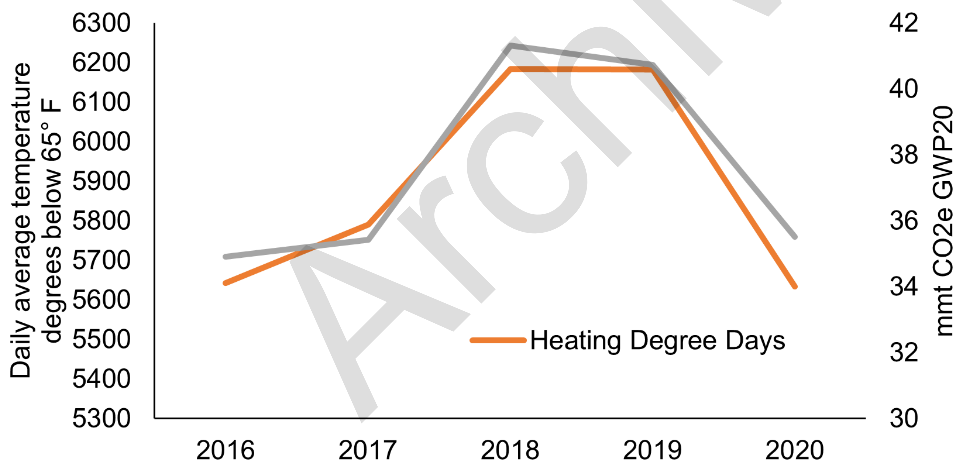
Methodology

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 CO_2, CH_4, and N_2O were from the EPA (NYSERDA 2022a). 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 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 1. Heating Degree Days and Fuel Combustion



NYSERDA Monthly Cooling and Heating Degree Day Data

When comparing 1990 emission levels to emissions in recent years (or 2016-2020), fuel combustion emissions in the Residential Commercial and Industrial (RCI) sources were 17-27% lower overall (Table 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

[2] Available at https://www.nyserda.ny.gov/about/publications/ea-reports-and-studies/weather-data/monthly-cooling-and-heating-degree-day-data

combustion levels were 26% below 1990 and industrial fuel combustion levels were 61% below 1990 levels, likely in part to the decline in manufacturing over this time period.

Table 6. RCI Fuel Combustion Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Residential	39.18	46.44	34.90	35.42	41.31	40.73	35.50
Commercial	27.24	29.93	21.53	21.86	23.01	22.70	20.05
Industrial	20.74	13.71	9.18	8.77	8.98	9.01	8.01
Gross Total	**87.17**	**90.08**	**65.61**	**66.05**	**73.30**	**72.44**	**63.57**

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 7). While combustion emissions from natural gas increased 28%, emissions of all other fuels decreased 64%.

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

Emission Category	1990	2005	2016	2017	2018	2019	2020
Coal	8.56	3.35	1.03	0.96	0.70	0.85	0.38
Distillate	21.79	24.52	10.78	10.28	12.19	12.20	9.28
Natural Gas	34.73	41.73	43.58	45.21	49.66	48.52	44.50
Wood	8.02	9.25	6.39	6.24	7.03	7.14	6.10
Other	14.07	11.23	3.84	3.37	3.73	3.73	3.30
Gross Total	**87.18**	**90.08**	**65.61**	**66.05**	**73.30**	**72.44**	**63.57**

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 approach 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 1990-2020 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 CO_2 accounted for separately. One key aspect of transportation emissions accounting relates to the treatment of fuels used for international transport, or bunker fuels (Table 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 (2022a). 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 0.78mmt 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, 2019 and 2020 were from DEC modeling of inputs. Emissions for years without modelling in this period estimated with interpolation. Emission estimates for 1990 through 2010 were conducted by the NYSDERA contractor, ERG, and are further described in NYSERDA (2022a) except that MOVES version 3 was used rather than the previous MOVES version 2014B.

Results

Transportation is the largest source of fuel combustion emissions, which on average for the 2016-2019 period has increased substantially since 1990. In 2020, road transportation emissions decreased nearly 7.2mmt CO_2e since 1990 or 12% (Table 8), and represented 84% of transportation fuel combustion emissions and 17% of statewide total emissions. Non-road source emissions declined 0.15mmt or 38% since 1990. All non-road sources increased since 1990 except for aviation, which declined 2.26mmt. However, this does not include emissions associated with international aviation (Table 10) that were excluded from this analysis.

Table 8. Transportation Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Road	**60.17**	**74.55**	**66.30**	**64.51**	**64.51**	**64.33**	**52.99**
Non-Road	**9.92**	**11.69**	**13.01**	**12.92**	**12.92**	**13.71**	**9.77**
Aviation	5.90	6.69	7.15	7.29	7.12	7.33	3.64
Rail	0.12	0.85	0.66	0.37	0.50	0.58	0.47
Marine	0.45	0.61	0.83	0.83	0.74	0.80	0.88
Other Transportation	3.19	2.98	3.05	3.07	3.10	3.37	3.32
Pipeline	0.26	0.57	1.31	1.37	1.45	1.64	1.47
Gross Total	**70.09**	**86.24**	**79.31**	**77.44**	**77.43**	**78.04**	**62.76**

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 55% of transportation fuel combustion emissions in 2020 (Table 9). Diesel emissions have increased 3.9mmt CO_2e since 1990 and accounted for 20% of transportation emissions in 2020. Gasoline and jet fuel experienced sharp declines in emissions as compared to 2019 as an effect of the response to the COVID19 pandemic.

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

Fuel Type	1990	2005	2016	2017	2018	2019	2020
Aviation Gasoline	0.06	0.10	0.03	0.03	0.03	0.03	0.03
CNG	+	0.20	0.32	0.17	0.18	0.23	0.20
Diesel	9.66	15.18	15.37	15.14	15.45	14.87	13.56
Gasoline	54.15	63.61	55.16	53.48	53.23	53.98	43.90
Jet Fuel	5.84	6.59	7.12	7.26	7.09	7.29	3.61
Natural Gas	0.26	0.57	1.31	1.37	1.45	1.64	1.47
Residual Fuel	0.12	na	na	na	na	na	na
Gross Total	**70.09**	**86.24**	**79.31**	**77.44**	**77.43**	**78.04**	**62.76**

"+" less than 0.01mmt

"na" not applicable

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

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

Emission Category	1990	2005	2016	2017	2018	2019	2020
Bunker (Aircraft)	11.58	8.25	13.48	14.11	13.64	13.63	6.14
Bunker (Marine Vessel)	0.60	2.63	1.97	1.32	1.33	0.72	0.78
Excluded Total	**12.18**	**10.89**	**15.45**	**15.43**	**14.97**	**14.36**	**6.92**

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 CO_2e for both1990 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 CO_2.[3] The IPCC approach 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 2022b).

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 2022a). 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 CO_2, and no CH_4 or N_2O emissions were produced.

Results

Although these non-combustion activities are not a major source of annual emissions, emissions declined 42% from 1990 to 2020, suggesting a reduction in the use of these fuels in New York State (Table 11). Emissions estimates for this category changed substantially from those presented in last year's report due to methodology changes to the apportionment of fuels by EIA in their SEDS data. Notable changes from the 2021 Statewide GHG Emissions Report include a 60% reduction in special naphtha emissions and a doubling of natural gas emissions for years 2018 and 2019 as a result of the changes in SEDS data.

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

Table 11. Emissions from Other Uses by Fuel Type, 1990-2020 (mmt CO2e GWP20)

Fuel Type	1990	2005	2016	2017	2018	2019	2020
Lubricants	0.87	0.75	0.60	0.55	0.52	0.48	0.43
Special Naphthas	0.08	0.04	0.06	0.06	0.06	0.06	0.05
Miscellaneous Petroleum Products	0.23	0.12	0.13	0.16	0.16	0.15	0.14
Natural Gas	0.09	0.06	0.08	0.10	0.13	0.12	0.12
Coal	0.02	0.76	0.29	0.29	0.22	0.02	0.01
Other Fuels	0.14	0.48	0.08	0.07	0.08	0.08	0.09
Gross Total	**1.44**	**2.21**	**1.23**	**1.23**	**1.17**	**0.90**	**0.83**

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 NYSERDA (2021b), which is an updated version of the NYS Oil and Gas Methane Inventory from 2019. The estimate of current CH_4 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 NYSERDA (2021a).

Methodology

The underlying data and methodology used in this report are described in the NYS Oil and Gas Methane Inventory (NYSERDA 2021b) as supplemented by methods described in NYSERDA (2021a). These analyses will continue to be updated as new information is made available, which is likely to result in higher estimates of fugitive CH_4 (see Planned Improvements). For these analyses, NYSERDA 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 19% since 1990 (Table 12). However, emissions from this industry remain high, and were 4.1% of total emissions in 2020 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 12. Oil and Gas Fugitive Emissions, 1990-2020 (mmt CO2e GWP20)

Gas	1990	2005	2016	2017	2018	2019	2020
Carbon dioxide	0.08	0.16	0.14	0.15	0.16	0.23	0.15
Methane	17.41	20.73	15.19	14.70	14.20	14.34	14.10
Nitrous oxide	+	+	+	+	+	+	+
Gross Total	**17.49**	**20.88**	**15.33**	**14.85**	**14.36**	**14.57**	**14.25**

"+" less than 0.01mmt

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 (SF_6) are primarily the result of leaks emitted from electric system substations and switchgear. In addition to leaks, SF_6 can also be emitted during installation, servicing, and disposal of substations and switchgear. To address the high rate of SF_6 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 SF_6 equipment continues to be installed. SF_6 is one of the strongest known greenhouse gases and has an extremely stable molecular structure. This stability also means that SF_6 degrades slowly in the atmosphere, affecting the earth's climate for thousands of years.

Methodology

Per the U.S. EPA SIT (2022a), 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, SF_6 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 SF_6 was estimated separately for ConEd. Publicly reported ConEd SF_6 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.

Results

Based on this assessment, emissions of SF_6 were greatest in the early years of the time series and declined substantially (Table 13). The emission rate has remained relatively stable with a slight downward trend in recent years, likely due to the servicing of existing equipment and the continuing installation of new SF_6 equipment across the state.

[4] https://www.epa.gov/eps-partnership/eps-partnership-accomplishments

Table 13. Electricity Transmission SF6 Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Electricity Transmission	4.02	1.61	0.15	0.14	0.13	0.13	0.11
Gross Total	**4.02**	**1.61**	**0.15**	**0.14**	**0.13**	**0.13**	**0.11**

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 14). The IPCC approach 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 NYSERDA (2022a). 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 approach and excludes emissions from bunker fuels, or fuels used for international transport ("Excluded Transportation Emissions", Table 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 14. Out of State Energy Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Imported Electricity	0.91	7.87	7.22	6.67	8.26	7.81	6.50
Imported Fossil Fuels	100.69	121.15	102.91	93.09	95.40	94.08	81.91
Gross Total	**101.61**	**133.97**	**114.35**	**103.31**	**107.93**	**101.90**	**91.79**
Excluded Transportation Emissions	**3.17**	**2.99**	**4.28**	**4.24**	**3.96**	**3.64**	**1.77**

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.

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 CO_2, CH_4, and N_2O 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 2020 compared to 1990, this is not a new trend. Instead, emissions from imported electricity have stayed between 6.5 and 10.52mmt CO_2e for almost twenty years, and below 8.3mmt CO_2e 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 (2022a). 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 currently 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 (2022a) 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 CO_2, CH_4, and N_2O from imported fossil fuels declined 15% since 1990 (Table 15). The statewide demand for fossil fuel will determine the level of emissions in this category. The COVID19 global pandemic drove a significant reduction in energy and fuel demand in 2020, which also affects imported fossil fuels emissions. 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 88% while natural gas increased 30%. NYSERDA (2022a) 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 15. Imported Fossil Fuel Emissions by Fuel Type, 1990-2020 (mmt CO2e GWP20)

Fuel Type	1990	2005	2016	2017	2018	2019	2020
CNG	+	0.17	0.22	0.05	0.05	0.05	0.04
Coal	9.24	5.97	2.17	1.68	1.76	1.41	1.08
Diesel/Distillate	11.07	14.32	9.13	8.82	9.36	8.76	7.39
Gasoline	22.74	27.77	22.69	21.89	21.18	20.89	16.98
Jet Fuel	1.51	1.77	1.95	1.98	1.86	1.84	0.91
Natural Gas	43.66	66.25	68.44	59.85	62.95	58.88	56.77
Other Fuels	12.48	9.86	2.53	2.37	2.51	2.27	2.13
Gross Total	**100.69**	**126.11**	**107.13**	**96.64**	**99.67**	**94.08**	**85.29**

"+" less than 0.01mmt

As discussed in the sections above, the IPCC approach 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 16).

Table 16. Excluded Emissions by Fuel Type, 1990-2020 (mmt CO2e GWP20)
Informational Purposes Only

Emission Category	1990	2005	2016	2017	2018	2019	2020
Diesel/Distillate	0.03	0.03	0.10	0.09	0.09	0.09	0.08
Jet Fuel	3.00	2.22	3.70	3.85	3.58	3.44	1.55
Residual Fuel	0.14	0.74	0.49	0.30	0.29	0.11	0.14
Gross Total	**3.17**	**2.99**	**4.28**	**4.24**	**3.96**	**3.64**	**1.77**

"+" less than 0.01mmt

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 (2022b), 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 (2022) 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 SF_6 emissions to New York State. DEC may seek additional data on SF_6 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 1990-2020 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_2O	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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NEW YORK STATE | Department of Environmental Conservation

Industrial Processes and Product Use

2022 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #2

Kathy Hochul, Governor | Basil Seggos, Commissioner

Table of Contents

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 the IPCC Taskforce on National Greenhouse Gas Inventories approach (or “IPCC approach”) 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 provides emission values for all years via the Open Data NY platform.

Tables

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 industrial emissions to combine energy and process emissions.

In New York, industrial process emissions are a relatively small portion of overall statewide emissions and have declined 23% since 1990 (Table 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 46.8% of national IPPU emissions in 2020 (EPA 2022b).

Table 1. Industrial Process and Product Use Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Processes	2.68	2.17	1.84	1.92	2.33	2.32	2.07
Product Use	0.04	6.79	19.23	19.86	20.42	20.89	21.32
Gross Total	**2.72**	**8.97**	**21.07**	**21.78**	**22.75**	**23.21**	**23.38**
% of statewide gross total	*1%*	*2%*	*5%*	*6%*	*6%*	*6%*	*7%*
Net Total	**2.72**	**8.97**	**21.07**	**21.78**	**22.75**	**23.21**	**23.38**
% of statewide net total	*1%*	*2%*	*6%*	*7%*	*7%*	*7%*	*8%*

Industrial Processes

Industrial processes contribute anthropogenic emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the fluorinated greenhouse gases: perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). The emissions characterized in this section occur within industries that operated in New York State from 1990 through 2020. 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 2020, industrial process emissions were 2.07mmt CO_2e GWP20, or approximately 0.6% of statewide emissions (Table 2). Overall industrial process emissions declined 23% since 1990, due to a 77% 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 2. Industrial Process Emissions 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Metals	1.63	0.78	0.58	0.57	0.53	0.39	0.37
Minerals	1.01	1.32	1.20	1.27	1.70	1.82	1.58
Electronics	0.03	0.07	0.06	0.07	0.10	0.12	0.12
Chemicals	ne	ne	ie	ie	ie	ie	ie
Gross Total	**2.68**	**2.17**	**1.84**	**1.92**	**2.33**	**2.32**	**2.07**

"ne" not estimated

"ie" included elsewhere

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 other fossil fuel use 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 other uses.

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 3).

[1] The U.S. GHGRP lists one chemical facility with process emissions (i.e., emissions not related to stationary combustion). The facility reported 0.022-0.034mmt of CO2 per year for "hydrogen production", 2016-2020.

Table 3. Metal Industry Process Emissions 1990-2020 (mmt CO2e GWP20)

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CO_2	**0.75**	**0.62**	**0.56**	**0.55**	**0.51**	**0.37**	**0.35**
Aluminum	0.41	0.28	0.22	0.22	0.21	0.22	0.22
Ferroalloys	0.20	0.20	0.21	0.18	0.18	na	na
Iron and Steel	0.09	0.09	0.09	0.10	0.07	0.07	0.05
Lead	0.05	0.05	0.05	0.06	0.05	0.08	0.07
CH_4	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Ferroalloys	+	+	+	+	+	na	na
Iron and Steel	+	+	+	+	+	+	+
PFCs	**0.88**	**0.16**	**0.01**	**0.02**	**0.02**	**0.02**	**0.02**
Aluminum	0.88	0.16	0.01	0.02	0.02	0.02	0.02
Gross Total	**1.63**	**0.78**	**0.58**	**0.57**	**0.53**	**0.39**	**0.37**

"+" less than 0.01mmt

"na" not applicable

Aluminum

Aluminum production results in process emissions of CO_2 and PFCs. CO_2 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 CO_2. Emissions of the PFCs perfluoromethane (CF_4) and perfluoroethane (C_2F_6), 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 2022b).

Methodology

For 1990 through 2010, emissions were estimated by applying the IPCC production method-specific (e.g., prebake or Soderberg) CO_2 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 (C_2F_6, CF_4) 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 2022c).

Results

Emissions have declined 81% since 1990 to 0.24mmt CO_2e (Table 3). 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 CO_2 and CH_4 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 since 2019 (Table 3). 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 CO_2 and CH_4. Multiple steps in the steel making process produce emissions. The majority of CO_2 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 2022c). 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 2022c).

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 (Table 3). Emissions declined 34% in 2018 compared to 2017 and remained stable in 2019. Iron and Steel is possibly the only IPPU category that was affected by the 2020 COVID19 global pandemic. Emissions declined 44% 1990-2020 and 29% 2019-2020. The decrease in emissions in 2020 is reflective of national decreases due to the impacts from the COVID19 global pandemic (EPA 2022a).

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. CO_2 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 2022c). 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 2022c).

Results

After relatively stable emissions from 2010-2018, emissions have since risen. Emissions from lead production increased 40% in 2020 as compared to 1990 (Table 3).

Minerals

The minerals category refers to the production of cement, and the uses of carbonates and soda ash. In each of these categories, CO_2 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 4).

Table 4. Mineral Industry Process CO2 Emissions, 1990-2020 (mmt CO2)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Cement	0.67	0.80	0.62	0.83	1.28	1.26	1.02
Other Process Use of Carbonates	0.15	0.36	0.45	0.32	0.30	0.45	0.45
Soda Ash	0.20	0.17	0.13	0.12	0.12	0.12	0.11
Gross Total	**1.01**	**1.32**	**1.20**	**1.27**	**1.70**	**1.82**	**1.58**

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 CO_2 when calcium carbonate is heated in a cement kiln to form lime (calcium oxide) and CO_2.

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 2022a). 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 2022c).

Results

Although this analysis suggest that emissions increased in recent years (Table 4), 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 CO_2 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 2022a). 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 have since declined 15% (Table 4). Emissions in 2020 for this category are slightly more than three times 1990 emissions. 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 2022b).

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. CO_2 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 2022b).

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 32% since to 1990, while estimated emissions in New York have increased 57% (Table 4).

Electronics

The electronics manufacturing industry employs numerous greenhouse gases in production processes (Table 5). 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.

Table 5. Semiconductor Industry Emissions by Gas, 1990-2020 (mmt CO2e GWP20)

Gas	1990	2005	2016	2017	2018	2019	2020
N_2O	+	+	0.02	0.02	0.02	0.02	0.02
HFCs	+	+	+	+	+	+	+
PFCs	0.03	0.05	0.04	0.05	0.07	0.08	0.09
SF_6	0.01	0.01	+	+	+	+	+
NF_3	+	+	+	+	+	+	0.01
Gross Total	**0.03**	**0.07**	**0.06**	**0.07**	**0.10**	**0.12**	**0.12**

"+" less than 0.01mmt

Semiconductor manufacturing uses and emits a variety of greenhouse gases in its production process. Greenhouse gasses emitted include nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). 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., CF_4 generated from C_2F_6). 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 2022c).

Results

Based on this analysis, greenhouse gases associated with semiconductor manufacturing may have increased since 1990 (Table 5) 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 SF_6 are incredibly powerful and long-lived greenhouse gases. In some cases, emissions will persist in the atmosphere for hundreds of thousands of years.

Industrial Products

The IPCC's IPPU sector includes various emission sources associated with the use of manufactured or packaged goods (Table 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 6. Industrial Product Emissions, 1990-2019 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Ozone-Depleting Substance Substitutes	0.04	6.79	19.23	19.86	20.42	20.89	21.31
N_2O 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**	**19.23**	**19.86**	**20.42**	**20.89**	**21.31**

"+" less than 0.01mmt

"ie" included elsewhere

N_2O Product Use

Nitrous oxide (N_2O) 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 N_2O 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

[2] EPA (2021) page 4-7

greenhouse gas inventory (EPA 2022b). As EPA describes it, the N_2O 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 N_2O are either covered in other sections of the national inventory or are non-emissive.

Methods

To estimate emissions at the state-level, annual U.S. emissions for 1990-2020 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 N_2O 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 approach (IPCC 2006). For 1990-2003, the EPA used a combination of industry data and expert interviews. From 2004-2020, the EPA used the 2003 estimated value. EPA (2022a) also describes planned improvement for their analysis.

Results

The EPA (2022a) analysis found that N_2O product use emissions remained flat at less than 1000 metric tons CO_2e per year from 1990-2003 because substitutes have been introduced to meet increasing demand. There are no new data for this emission source.

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 SF_6 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 approach 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 7). 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 7. ODS Substitute Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Refrigerants	+	3.50	11.70	12.59	13.47	14.24	14.97
Foam Blowing Agents	no	0.72	2.38	2.44	2.43	2.43	2.42
Aerosols	0.04	2.15	4.59	4.27	3.93	3.63	3.34
Solvents and Fire Suppression	no	0.42	0.56	0.56	0.59	0.59	0.59
Gross Total	**0.04**	**6.79**	**19.23**	**19.86**	**20.42**	**20.89**	**21.31**

"+" less than 0.01mmt

Refrigerant emissions can be divided into multiple end-uses (Table 8) based on the type of equipment and user. The largest source of emissions in 2020 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 8. Refrigerant Emissions by End Use, 1990-2020 (mmt CO2e GWP20)
*Other includes dehumidifiers and clothes dryers

Category/End-Use	**1990**	**2005**	**2016**	**2017**	**2018**	**2019**	**2020**
Refrigeration	**0.01**	**1.21**	**4.93**	**5.30**	**5.65**	**5.98**	**6.33**
Commercial	0.01	1.03	4.34	4.69	5.04	5.37	5.71
Residential	no	0.05	0.41	0.42	0.42	0.42	0.42
Transportation	no	0.13	0.18	0.19	0.19	0.19	0.19
HVAC	**no**	**2.28**	**6.71**	**7.24**	**7.75**	**8.17**	**8.55**
Commercial	no	0.02	1.68	1.97	2.25	2.55	2.84
Residential	no	0.03	1.40	1.64	1.88	2.10	2.32
Transportation	no	2.23	3.63	3.63	3.62	3.52	3.39
Other*	**no**	**no**	**0.03**	**0.03**	**0.04**	**0.05**	**0.06**
Residential	no	no	0.03	0.03	0.04	0.05	0.06
Commercial	no	no	+	+	+	+	+
Industrial Processes	**no**	**0.01**	**0.03**	**0.03**	**0.03**	**0.04**	**0.04**
Gross Total	**0.01**	**3.50**	**11.70**	**12.59**	**13.47**	**14.24**	**14.97**

“no” not occurring

“+” less than 0.01mmt

The substances used in this IPCC category represent individual HFC gases, blends of HFCs, and blends that include other non-HFC substances (Table 9). 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 9. Emissions by ODS Substitute (mmt CO2e GWP20)
Note: Pure HFCs do not include emissions from blends.

ASHRAE #	GWP20	2020 Emission
R-125	6090	
R-134a	3710	4.42
R-143a	6940	
R-152a	506	
R-227ea	5360	
R-236fa	6940	+
R-245fa	2920	
R-32	2430	0.02
R-365mfc	2660	
R-404A	6437	3.49
R-407A	4406	0.22
R-407C	4011	0.12
R-410A	4260	4.99
R-4310mee	4310	
R-466A	1891	
R-507	6515	1.69
R-507A	6515	

"+" less than 0.01mmt.

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 2022a), facility reporting to the EPA (EPA 2022c), or a combination of both. These methods follow IPCC approach 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. DEC plans to further investigate ODS emissions as an informational item, when appropriate state-level data are available.

Abbreviations

AC	Air conditioner
CFC	Chlorofluorocarbon
CF_4	Perfluoromethane
C_2F_6	Perfluoroethane
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
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
N2O	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

2022 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #3

Kathy Hochul, Governor | Basil Seggos, Commissioner

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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 the IPCC Taskforce on National Greenhouse Gas Inventories approach (or “IPCC approach”) as applied in the U.S. national greenhouse gas emissions report (IPCC 2006 and 2019, EPA 2022a). The accompanying Summary Report provides a comparison with other accounting methods, including by economic sector or using conventional accounting formats. DEC also provides emission values for all years via the Open Data NY platform.

Tables

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 2020, total agricultural emissions were 22.08mmt CO_2e or 44.5% higher than in 1990 (Table 1). Most agricultural emissions are from livestock (93%). In 2020, agriculture represented approximately 6% of statewide emissions, when measured using CLCPA accounting. However, statewide emission levels in 2020 are not representative of long-term trends due to the effects of the COVID19 global pandemic on the energy sector (see *Summary Report*). While the AFOLU sector does not appear to be greatly affected by the pandemic, 2016-2019 emissions are more representative of current, statewide emissions. Further information on the relative contribution of agricultural emissions is described below. Agricultural practices also contribute to the removal of carbon dioxide from the atmosphere or as part of Land Use "net emission removals" per the IPCC approach (Table 2).

Table 1. AFOLU Agriculture Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Livestock	13.56	15.07	19.59	19.57	20.13	19.65	20.48
Soil Management	1.72	1.63	1.62	1.62	1.61	1.60	1.60
Gross Total	**15.28**	**16.70**	**20.21**	**21.20**	**21.75**	**21.25**	**22.08**
% of statewide gross total	*3.7%*	*3.6%*	*5.4%*	*5.6%*	*5.6%*	*5.6%*	*6.3%*
Net Total	**15.28**	**16.70**	**20.21**	**21.20**	**21.75**	**21.25**	**22.08**
% of statewide net total	*4.1%*	*3.9%*	*5.9%*	*6.2%*	*6.1%*	*6.1%*	*7.0%*

Table 2. AFOLU Net Emission Removals, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Harvested Wood Products	-1.54	-1.86	-1.64	-1.56	-1.51	-1.31	-1.33
Land Use	-31.57	-29.77	-27.87	-27.48	-27.15	-26.81	-26.71
Net Emission Removals	**-33.11**	**-31.63**	**-29.50**	**-29.05**	**-29.65**	**-28.12**	**-28.04**
Excluded Wetland Emissions	12.68	12.58	12.62	12.62	12.62	12.62	12.62

"+" less than 0.01mmt

"na" not applicable

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 net carbon uptake and storage by various land-use categories, particularly forest land (Table 2). Land use and land-use change drove 95% of net emission removals in 2020, but these removals have declined 12% since 1990 primarily because of forest land conversions to other land-use categories.

This inventory reports methane (CH_4) emissions from freshwater wetlands, water bodies, flooded land that has remained flooded, and land that has been converted to flooded land. Only the CH_4 emissions from the latter two flooded land categories are included in the net 'Land Use' totals in Table 2 and contribute to the AFOLU sector's total emissions. This is because these emissions result from human activities and land management decisions (EPA 2022a). In contrast, CH_4 emissions from freshwater wetlands and water bodies that are not considered flooded land are reported separately as 'Excluded Wetland Emissions' in Table 2. This is in keeping with the IPCC approach, which capture anthropogenic emissions and sequestration by 'managed lands,' but do not count non-anthropogenic emissions from unmanaged, naturally functioning ecosystems toward inventory totals.

In the U.S., the EPA interprets flooded lands and coastal wetlands as managed lands, and therefore includes the CH_4 emissions and CO_2 sequestration fluxes attributed to these ecosystems in the national greenhouse gas inventory (EPA 2022a). However, the contributions of freshwater wetlands are only counted in the EPA's national inventory if the wetlands are harvested for peat (EPA 2022a). DEC continues to seek feedback on whether all freshwater wetlands in New York should be considered managed lands that contribute toward the sectoral total in a similar manner to coastal wetlands. In the interim, annual CH_4 emissions from wetlands and water bodies are provided for informational purposes only, whereas the CO_2 sequestered by freshwater wetland biomass and soil carbon is counted toward the sectoral total.

These decisions affect accounting for the CLCPA net zero emission reduction goal, but they do not affect accounting for achievement of the statewide GHG emission limits established in ECL § 75-0107 and promulgated as 6 NYCRR Part 496. Finally, it should be noted that the net impact of the CH_4 emitted relative to the CO_2 sequestered by freshwater wetlands depends on the time horizon over which these are estimated. The CLCPA requires DEC to report all non-CO_2 emissions as CO_2 equivalents by using the Global Warming Potentials (GWPs) estimated over a 20-year time horizon to make the conversions. Using a 20-year rather than a 100-year GWP weights CH_4 emissions more heavily relative to an amount of CO_2 sequestered. However, protected wetland ecosystems can function over longer timescales than 20 or even 100 years, and their ability to both sequester CO_2 while also emitting CH4 may have a net-cooling effect on climate when considered over these longer timescales (Neubauer 2014).

Agricultural Emissions

Agriculture contributes to anthropogenic emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Livestock and soil nutrient management practices produce these emissions (Table 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. These emission estimates were developed by Peter Woodbury and Jenifer Wightman (Cornell University) using IPCC methodology (IPCC 2019). Estimates of CO_2

sequestration by soils in cropland that remains cropland, and emissions that occur when other land-use categories (for example, forest land) are converted to cropland were developed by the EPA (EPA, 2022a and 2022b) and are included under Land Use (Table 10) in the Net Emission Removals section of this report. 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)*.

Livestock

Livestock management practices are the largest source of emissions in the agricultural sector, and they have increased 51% since 1990 (Table 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 3. Livestock Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Animal Feeding	11.67	11.34	13.38	13.63	13.52	13.42	13.71
Manure Management	1.89	3.73	6.21	5.95	6.61	6.24	6.77
Gross Total	**13.56**	**15.07**	**19.59**	**19.57**	**20.13**	**19.65**	**20.48**

"+" less than 0.01mmt

"na" not applicable

Animal Feeding

Ruminant animals produce CH_4 as they digest the organic carbon in their feed. Specifically, anaerobic microbes present in the animals' digestive systems convert some of the feed into CH_4 that is then exhaled or belched by the animals.

Methodology

This analysis includes the historic and current CH_4 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) (USDA 2020a) and CH_4 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). The NASS provided historical data on percent milkfat, animal number, and milk production (USDA 2020a). The DMI values were used to calculate an emission factor (kg CH_4 per head per year; equation 10.21A, IPCC 2019).

Results

From 1990 to 2020, CH_4 emissions from animal feeding (enteric fermentation) increased 18% (Table 4). The largest annual contributions to emissions were made by dairy cattle. Emission trends primarily reflect herd size, except among 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 in which herd sizes increased 1990 through 2017.

Table 4. Animal Feeding Methane Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Source	1990	2005	2016	2017	2018	2019	2020
Dairy Cattle	9.41	8.94	10.48	10.54	10.55	10.54	10.67
Beef Cattle	1.90	1.99	2.61	2.82	2.72	2.63	2.69
Horses	0.27	0.29	0.23	0.23	0.23	0.23	0.23
Sheep	0.07	0.06	0.06	0.06	0.06	0.06	0.07
Swine	0.01	+	+	+	+	+	+
Goats	+	0.03	0.02	0.02	0.02	0.02	0.03
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**	**13.44**	**13.71**	**13.61**	**13.52**	**13.71**

"+" less than 0.01mmt

"ne" not estimated

Manure Management

Manure management systems (MMS) that are used to treat and store livestock and poultry waste also emit CH_4 and N_2O. Manure stored in conditions that promote anaerobiosis will produce CH_4 (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 CH_4 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 CH_4. Microorganisms also produce N_2O as they act on the N compounds present in livestock and poultry waste. The series of microbial reactions that yield N_2O 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 N_2O emissions. In the first, volatile manure N (mainly NH_3 and NOx) moves through the air and is deposited on soils and the surfaces of lakes and other water bodies where it stimulates N_2O production. 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 N_2O 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 NASS (USDA 2020a). 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 animals may number in the tens of thousands. State permits for livestock farms in New York are based on livestock numbers alone, regardless of discharge status. Since 1999, all CAFOs operate under the no-discharge CAFO General Permit issued under the state Environmental Conservation Law (ECL) 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.

CH_4 emissions from dairy cattle and non-dairy animals were estimated separately. IPCC emission factors were applied to each type of animal: CH_4 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 N_2O emissions factors were applied to the fraction of manure in each type of MMS (Table 10.21, IPCC 2019).

Results

Total N_2O emissions from manure management nearly doubled between 1990 and 2020 and CH_4 emissions more than tripled (Table 3, 5). In 2020, total N_2O emissions from manure management were estimated to be 0.36mmt CO_2e; in 1990 while emissions were 0.19mmt CO_2e. These values include both direct and indirect N_2O emissions from manure management. Dairy accounted for 84% and 86% of N_2O emissions from the entire 1990 and 2020 livestock herds, respectively. To avoid double counting, these tables do not include emissions of N_2O from field applied manure at any time (see the Soil Nitrogen Management section). CH_4 emissions from manure management increased from 1.70mmt CO_2e in 1990 to 6.40mmt CO_2e in 2020 as a result of increased liquid storage of dairy manure.

Table 5. Manure Management Emissions, 1990-2020 (mmt CO2e GWP20)

Gas/Source	1990	2005	2016	2017	2018	2019	2020
CH_4	**1.70**	**3.48**	**5.88**	**5.60**	**6.25**	**5.88**	**6.40**
Dairy Herd	1.51	3.27	5.54	5.24	5.93	5.54	6.05
Other Cattle	0.01	0.03	0.06	0.05	0.05	0.05	0.06
Swine	0.05	0.04	0.02	0.02	0.02	0.03	0.03
Chickens	0.10	0.12	0.23	0.26	0.22	0.24	0.24
Other Poultry	+	+	+	+	+	+	+
Horses	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Sheep	+	+	+	+	+	+	+
Goats	+	+	+	+	+	+	+
Mules/Asses	+	+	+	+	+	+	+
N_2O	**0.19**	**0.25**	**0.34**	**0.35**	**0.36**	**0.36**	**0.36**
Dairy Herd	0.16	0.21	0.29	0.30	0.31	0.31	0.32
Other Cattle	+	+	+	+	+	+	+
Swine	+	+	+	+	+	+	+
Poultry	0.02	0.02	0.03	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**	**3.73**	**6.21**	**5.95**	**6.61**	**6.24**	**6.77**

"+" less than 0.01mmt

"ne" not estimated

Soil Management

The IPCC approach include multiple emission sources under the AFOLU subcategory, "aggregated sources and non-CO_2 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 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 approach 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 2020 were 120,000 tons CO2e lower than in 1990, or 7% lower (Table 6). Most of these emissions are associated with soil nitrogen management (90% in 2020) that encompasses fertilizer application practices that result in N_2O emissions.

Table 6. Soil Management Emissions, 1990-2020 (mmt CO2e GWP20)

Gas/Source	**1990**	**2005**	**2016**	**2017**	**2018**	**2019**	**2020**
CO_2	**0.14**	**0.15**	**0.15**	**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	0.03	0.03	0.03	0.03	0.03
N_2O	**1.58**	**1.49**	**1.46**	**1.47**	**1.46**	**1.45**	**1.45**
Soil Nitrogen Management	1.58	1.49	1.46	1.47	1.46	1.45	1.45
Gross Total	**1.72**	**1.63**	**1.62**	**1.62**	**1.61**	**1.60**	**1.60**

Liming

Crushed limestone and dolomite are added to soils by land managers to increase soil pH. CO_2 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 (EPA 2022d) as well as older data from the Census of Agriculture (Bureau of the Census 1989). The CO_2 emissions for each census year were calculated using the emission factors from West & McBride (2005) for limestone and dolomite and summed to estimate total CO_2 emissions due to agricultural liming.

Results

Emissions from liming of soils have fluctuated very little over the past 25 years in New York and contribute 0.12 or 0.13mmt CO_2e for each year since 1990 (Table 6). Since the area of cropland changes slowly, if at all, from one year to the next, the use of lime also does not vary much.

Urea Application

Adding urea fertilizer to soils causes emission of CO_2 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 CO_2 and NH_3 into urea molecules. This fixation and emission cycle is rapid, and accurately accounting for its net impact on CO_2 emissions is difficult. However, the CO_2 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 CO_2 was assumed.

Results

CO_2 emissions from field application of synthetic urea increased from 0.02mmt CO_2e in 1990 to 0.03mmt CO_2e in 2020 (Table 6), following increased use of urea fertilizers.

Soil Nitrogen Management

Emission sources from soil nitrogen management practices include direct and indirect N_2O emissions from managed soils, and indirect N_2O emissions from field application and management of manure. Agricultural activities that lead to direct N_2O 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 N_2O through nitrification and denitrification and add N to soil through N fixation.

Methodology

Nitrogen from a variety of sources can be added to soil. The IPCC provides default N_2O 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, N_2O emissions from organic soils that have been drained for agricultural activity were 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 N_2O 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 N_2O 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 N_2O 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 (USDA 2019). The estimated N content of specific crop residues and the emission factor of 0.006 kg N_2O 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 (USDA 2008). Linear interpolation was used to extend these area estimates to other years. The IPCC's default emission factor of 13 kg N_2O-N per hectare per year was used to estimate the annual N_2O flux (IPCC 2014).

Results

Annual N_2O emissions from agricultural soils are estimated to be 8% lower in 2020 compared to 1990, based on available data on synthetic fertilizer sales (16% lower in recent years). Changes also reflect a decrease in N_2O emissions from daily spread of manure as dairy manure management practices have changed over time. Although data are not available for 2020, total N_2O 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 2020, 67% of total N_2O emissions were direct, and 33% were indirect (Table 7).

Table 7. Soil Nitrogen Management N2O Emissions, 1990-2020 (mmt CO2e GWP20)

Emission Type	1990	2005	2016	2017	2018	2019	2020
Direct	1.06	1.00	0.98	0.99	0.98	0.97	0.98
Indirect	0.52	0.49	0.48	0.48	0.48	0.47	0.48
Gross Total	**1.58**	**1.49**	**1.46**	**1.47**	**1.46**	**1.45**	**1.45**

"ne" not estimated

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 8 illustrates the trend in net removals from 1990 through 2020 as described in more detail below. Overall net removals have decreased by 12% since 1990, but net removals associated with harvested wood products and most land-use categories have remained relatively stable. For reasons discussed below, annual carbon sequestration by NY forest land has steadily declined since 1990. The excluded net emissions are CH_4 emissions from wetlands and water bodies.

Table 8. Net CO2 Removals, 1990-2020 (mmt CO2e GWP20)

Emission Category	1990	2005	2016	2017	2018	2019	2020
Harvested Wood Products	-1.54	-1.86	-1.64	-1.56	-1.51	-1.31	-1.33
Land Use	-31.57	-29.77	-27.87	-27.48	-27.15	-26.81	-26.71
Net Emission Removals	**-33.11**	**-31.63**	**-29.50**	**-29.05**	**-28.65**	**-28.12**	**-28.04**
Excluded Net Emissions	12.68	12.58	12.62	12.62	12.62	12.62	12.62

Harvested Wood Products

Most timber harvested from forest land in New York is used to produce harvested wood products (HWPs), which include, for example, sawn wood used in housing construction and paper. HWPs sequester CO_2 for a duration that depends on the lifespan of the product and the rate at which it is converted back to CO_2 through decay in landfills or waste combustion.

Emission estimates for this section of the report were developed in conjunction with Robert Malmsheimer, 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 (TPO) data, were used to estimate annual board feet of sawtimber-based HWPs used between 1999 and 2020, 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 analysis in *Sectoral Report #4: Waste* Report of this inventory includes 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

Annual trends in CO_2 removal by HWP roughly correspond with those in new housing construction in the Northeast, peaking in 2001 at -1.97mmt CO_2, declining to a minimum of -1.17mmt CO_2 per year in 2009, recovering to an average of -1.57 from 2015 to 2018 (Table 9). The drop in 2019 and 2020 to –1.31 and –1.33mmt CO_2, respectively, may reflect changes in mill survey response rates during the COVID19 global pandemic.

Table 9. Harvested Wood Products CO2 Removals, 1990-2020 (mmt CO2)

Origin/Destination	1990	2005	2016	2017	2018	2019	2020
NY/NY	-1.09	-1.21	-1.07	-1.07	-1.05	-0.94	-0.92
NY/Out	-0.42	-0.56	-0.37	-0.32	-0.29	-0.26	-0.25
Out/NY	-0.03	-0.09	-0.20	-0.17	-0.17	-0.11	-0.16
Net Emission Removals	**-1.54**	**-1.86**	**-1.64**	**-1.56**	**-1.51**	**-1.31**	**-1.33**

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 2020 (Table 10). 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 CO_2 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 approach (IPCC, 2019). Quantifying the net emission removals through land use and land-use change requires accounting for the differences in carbon sequestration and greenhouse gas emissions per unit area among land-use categories and surveying changes in the areal extent of land-use categories over time. Land parcels that have remained under the same category of land use for 20 years or more are classified as forest remaining forest, grassland remaining grassland, cropland remaining cropland, etc. Lands that have been converted from one land-use category to another within 20 years are classified based on their land-use categories before and after conversion (e.g., cropland converted to forest, forest converted to grassland, etc.).

Since the previous inventory, the EPA has made available net emissions and emission removals estimates for cropland, grassland, and settlements in New York from 1990 through 2020 (EPA 2022b and Table 10). These estimates are now included along with emission removals by forest land and wetlands. Conversions of other land-use categories to cropland, grassland, and settlement have subsumed the previous inventory's estimates of forest land conversions and wetland conversions to cropland, grassland, settlement, and other land. This shift aligns this inventory with the IPCC's guidance that emissions or emission removals associated with land that remains under a particular land-use category (e.g., forest land) should be added to emissions or emission removals associated with any conversions to that land-use category (e.g., cropland to forest land, grassland to forest land, settlement to forest land, etc.). Note that unlike the other land-use categories, the EPA's cropland estimates reflect soil carbon stock changes and not carbon storage in biomass, litter, or dead organic matter on that cropland (EPA 2022a and 2022b).

Table 10. Land Use Net Emissions and Emission Removals, 1990-2020 (mmt CO2e GWP20)

Land Type	1990	2005	2016	2017	2018	2019	2020
Forest land	-30.08	-28.21	-26.78	-26.54	-26.29	-26.01	-25.75
Forest converted to other land	0.33	0.33	0.34	0.34	0.34	0.34	0.34
Wetlands	-0.87	-0.75	-0.93	-0.88	-0.88	-0.88	-0.88
Flooded land	1.06	1.05	1.04	1.04	1.04	1.04	1.04
Cropland	-0.10	0.07	0.45	0.46	0.54	0.58	0.48
Grassland	-0.38	-0.99	-0.27	-0.19	-0.18	-0.16	-0.22
Settlement	1.99	2.63	2.38	2.38	2.37	2.37	2.37
Settlement trees	-3.52	-3.91	-4.09	-4.09	-4.09	-4.09	-4.09
Net Emission Removals	**-31.57**	**-29.38**	**-27.87**	**-27.48**	**-27.15**	**-26.81**	**-26.71**

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 CO_2e than they emit on an annual basis. Specifically, forest land that has remained forest land removes additional CO_2 as organic carbon every year, equivalent to -23.66mmt CO_2 in 2020 (Table 11). The conversion of other land-use categories to forest land removed an additional -2.09mmt CO_2 in 2020 because forest land removes more CO_2 per unit area than any other land-use category.

Methodology

This report uses state data from the EPA and U.S. Forest Service on annual forest CO_2e emissions and sequestration (Domke et al. 2022; EPA 2022b; Walters et al. 2022). 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 (see the Planned Improvements section). The annual Forest Service analysis assesses the sequestration of CO_2 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 CO_2 emissions from 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 categories. Observed conversions of field plots from one land-use category to another are used to quantify the impact of the conversions on organic carbon stocks in the absence of other data. Conversions of forest to cropland or grassland include changes in soil organic carbon stocks, aboveground and belowground biomass, dead wood, and litter carbon stocks. 'Forest land converted to other land' is currently an orphan land use conversion type that is estimated by the U.S. Forest Service and will be combined into an 'other land' use category when a complete estimate becomes available. Trees located in settlements that remain settlements are reported as "settlement trees."

Achieving a wall-to-wall assessment of carbon sequestration and emissions by the different land-use categories 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 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 2022a).

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 CO_2 sequestered per year from 1990 to 2020). However, forested wetlands also have the potential to produce CH_4 and N_2O emissions as well as sequester CO_2. 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-use category includes emissions and emission removals associated with forest land remaining forest land and conversions of other land-use categories to forest land. In the previous inventory, forest land conversions to other land-use categories were also included in the forest land-use category. Although these emissions are still reported in Table 11, they are counted implicitly among the other land-use categories as conversions. For inventory purposes, forest land conversions are now split up among the other land-use categories so that, for example, emissions associated with forest land converted to cropland is now considered a part of the cropland category's emissions. Most net emission removals were by forest land that remained forest land, but an additional -2mmt CO_2 per year was also removed through the conversion of cropland, grassland, settlements, wetlands, and other lands to forest land. However, the emission removals by conversions of the other land-use categories to forest land were more than offset by over 3mmt CO_2 of emitted annually as forest land is converted to other land-use categories. Finally, emissions of CH_4 and N_2O from forest fires were estimated and reported by the Forest Service and are accounted for in the net emission removals attributed to forest land (Walters et al. 2022).

Table 11. Forest Net Emissions and Emission Removals, 1990-2020 (mmt CO2e GWP20)

Land Use Change	1990	2005	2016	2017	2018	2019	2020
Forest Remaining Forest	-27.92	-26.08	-24.71	-24.45	-24.20	-23.92	-23.66
Land Converted to Forest	-2.16	-2.13	-2.09	-2.09	-2.09	-2.09	-2.09
Forest Converted to Land	3.31	3.41	3.48	3.48	3.48	3.47	3.48
Forest Fire	nd	nd	0.02	nd	nd	nd	+
Net Emission Removals	**-26.77**	**-24.80**	**-23.30**	**-23.06**	**-22.81**	**-22.54**	**-22.27**

"nd" no data

"+" less than 0.01mmt

Forest Land Remaining Forest Land

Forest land remaining forest land sequestered far more CO_2 than any other land-use category (-26.08mmt CO_2 sequestered in 2005 and -23.66mmt CO_2 sequestered in 2020). The declining trend in annual CO_2 sequestration is due in part to the conversion of forest land to other land-use categories (3.48mmt CO_2 emitted in 2020 and an average of 3.45mmt CO_2 emitted per year between 2005 and 2020), which was not matched by the rate at which CO_2 was sequestered as other land-use categories were converted to forest land (-2.09mmt CO_2 sequestered in 2020 and an average of -2.10mmt CO_2 per year sequestered between 2005 and 2020). Future inventories will include an assessment of the impact of interannual changes in the rate at which forest land that remains forest land sequesters CO_2 and stores it as organic carbon.

Land Converted to Forest Land

Cropland conversion to forest land sequestered an average of -0.61mmt CO_2 per year from 2005 to 2020. Settlement conversions to forest land sequestered an average of -1.02mmt CO_2 per year from 2005 to 2020. Wetlands converted to forest land sequestered an average of -0.28mmt CO_2 per year from 2005 to 2020. Other lands converted to forest land sequestered -0.20mmt CO_2 per year from 2005 to 2020. Grassland converted to forest sequestered an average of -0.02mmt CO_2 per year from 2005 to 2020.

Forest Land Converted to Land

Conversion of forest land to cropland resulted in an average of 1.33mmt CO_2 emitted per year between 2005 and 2020. Conversion to settlements resulted in an average of 1.37mmt CO_2 emitted per year between 2005 and 2020. Smaller emissions were caused by conversion to wetlands (an average of 0.41mmt CO_2 emitted per year between 2005 and 2020) and other lands (an average of 0.34mmt CO_2 emitted per year between 2005 and 2020). There were no emissions attributed to grassland conversions between 2005 and 2020.

Wetlands, Water Bodies, and Flooded Land

Emissions and emission removals attributed to wetlands and CH_4 emissions from other water bodies are reported here along with EPA's estimates of CO_2 and CH_4 emissions from land flooded as a direct result of human interventions such as dam and pond construction (EPA 2022a). Wetlands contribute most of the emissions and emission removals estimates in this section. Wetlands, like forest land, sequester CO_2 and store it as organic carbon in plant biomass and soils. Unlike forest land, whose area is estimated by the Forest Service according to a land-use definition, the areal extent of wetlands is estimated here using land cover observations. All New York wetlands are inventoried here, even those that do not directly undergo management 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 CO_2 as organic carbon and storing it in their soils. This is because water-saturated soils tend to be low-oxygen soils, and oxygen scarcity slows the rate of decay that would normally convert organic carbon back into CO_2 (IPCC 2014). Wetland soils can also be important sources of CH_4 and N_2O. Freshwater wetlands are an important source of CH_4 whereas CH_4 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). CH_4 emissions from freshwater wetlands are provided for informational purposes and are not included in net totals. N_2O 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 volatilized 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 CH_4, whereas the emission factor for CH_4 from palustrine wetlands is assumed to be 157 kg CH_4 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. After 2016, wetland areas have been held constant and will be updated with appropriate interpolations once the next CCAP land-cover classification map is made available.

Wetland carbon sequestration by the following organic carbon reservoirs is assessed: soil carbon and aboveground and belowground biomass. Annual CO_2 fluxes into soil carbon are geometric means of soil and sediment core 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 2022a). Aboveground wetland biomass is assumed to sequester -3.05 to -3.17mt of carbon per hectare per year. Belowground biomass sequesters -6.44 to -6.54mt carbon per hectare per year in estuarine wetlands, and -3.57 to -3.65mt 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 but changes in CO_2 sequestration in soil carbon or soil carbon stock changes 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. 2022, Walter et al. 2022). Therefore, they have not been included in the CO_2 sequestration calculations for palustrine wetlands, but their CH_4 emissions are included here. No land areas 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 CO_2 sequestration by estuarine wetlands. The CCAP maps also resolve 19 other land-cover classes 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 CO_2 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 2020 and multiplied by the seagrass soil carbon sequestration fluxes reported by Salinas et al. (2020).

The USGS National Hydrography Dataset (NHD) maps (USGS 2016) were used to estimate CH_4 emissions from lakes, ponds, and other water bodies in New York. The water bodies were grouped into 7 size classes (<0.001 km^2 to >100 km^2) and their areas multiplied by the size-specific CO_2 and CH_4 emission fluxes according to Holgerson and Raymond (2016). Emissions from water bodies that cross state boundaries (Lake Erie, Lake Ontario, Lake Champlain, and the Allegheny Reservoir) are scaled to the proportions of the water bodies' total areas that fall within the state's political boundaries. Mapped stream and river features are not included in this estimate pending further method development. There is a small amount of overlap between

[1] https://github.com/Smithsonian/Coastal-Wetland-NGGI-Data-Public
[2] https://www.dec.ny.gov/docs/fish_marine_pdf/finalseagrassreport.pdf

water bodies mapped in the NHD and the emergent wetland 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 data sets. Emission factors for CH_4 ranged from 3.5 to 133.5kg CH4 per hectare per year for water bodies with areas greater than 100 km^2 to water bodies with areas smaller than 0.001 km^2, respectively (Holgerson and Raymond 2016). CO_2 emissions were not estimated to avoid double counting CO_2 derived from organic carbon sourced from other land-use categories.

The EPA's state estimates of CH_4 and CO_2 emissions from land flooded as a result of direct human interventions includes reservoirs, canals and ditches, constructed freshwater ponds, and inundation areas (EPA 2022a and 2022b; IPCC 2019). The emissions calculations distinguish between land that has been flooded for more than 20 years (flooded land remaining flooded land) and land that has been flooded for less than 20 years (land converted to flooded land) because emission factors are higher for recently flooded land. Emission factors were also split between the state's two climate zones, warm temperate moist and cool temperate. Flooded land was identified and areas estimated using NHD maps, the National Lakes Assessment (EPA 2022c), the National Inventory of Dams (USACE 2021), and the Navigable Waterways dataset (DHS 2022). Note that there may be overlap in the emissions estimated for water bodies, which include reservoirs and ponds, and the subset of reservoirs and ponds that are considered flooded land by the EPA. The total area of water bodies included in that emissions calculation is 15,566 km^2 in 2020 whereas the total area of reservoirs and freshwater ponds included in the flooded land emissions estimate was 1,780 km^2 in 2020, so this overlap is probably on the order of 10% but also depends on the emission factors applied in the areas of overlap. For flooded land remaining flooded land, surface emission factors of 54 or 80kg CH_4 per hectare per year were applied to reservoirs in cool temperate or warm temperate moist zones, respectively, along with a 9% downstream emission factor (IPCC 2019). CO_2 emissions were not estimated for flooded land remaining flooded land to avoid double counting CO_2 derived from organic carbon sourced from other land-use categories. For land converted to flooded land, surface emission factors of 128 or 85kg CH_4 per hectare per year were applied to reservoirs in warm temperate moist or cool temperate climate zones, respectively, along with a 9% downstream emission factor. CO_2 surface emission factors applied to freshwater ponds and reservoirs were 5.4 or 3.7mt CO_2 per hectare per year in the warm temperate moist or cool temperate climate zones, respectively. The same surface emission factor of 183kg CH_4 per hectare per year was applied to all constructed freshwater ponds, regardless of their age or climate zone. The highest CH_4 emission factor (416kg CH_4 per hectare per year) was applied to canals and ditches in both climate zones (IPCC 2019).

Results

The wetland category is broken into four types of land use and land use change, as described above (Table 12). Palustrine wetlands were responsible for 94% of annual removals by wetlands in 2020. However, this accounting does not include CH_4 emissions from palustrine wetlands (Table 13).

Table 12. Wetland Net CO2 Removals, 1990-2020 (mmt CO2)

Land Use Change	1990	2005	2016	2017	2018	2019	2020
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	-1.13	-1.27	-1.22	-1.22	-1.22	-1.22
Land Converted to Wetlands	0.40	0.41	0.42	0.42	0.42	0.42	0.42
Wetlands Converted to Water	+	0.06	+	+	+	+	+
Net Emission Removals	**-0.87**	**-0.75**	**-0.93**	**-0.88**	**-0.88**	**-0.88**	**-0.88**

"+" less than 0.01mmt

Wetlands Remaining Wetlands

Palustrine wetlands sequester more CO_2 (-1.22mmt CO_2 in 2020) than estuarine wetlands (-0.08mmt CO_2 in 2020), mainly because palustrine wetlands occupy more land in NY. Forested palustrine wetlands sequester more CO_2 than any other type of wetlands (-3.91mmt CO_2 in 2020) due to their larger area and capacity to form biomass. However, to avoid double counting, these removals are not included in the net emission removals by wetlands in Table 12 because they are included in the forest land areas contributing net emission removals in Table 11. Estuarine wetlands include -0.02mmt CO_2 sequestered per year as soil carbon accumulated by seagrass meadows in NY waters and -0.06mmt CO_2 sequestered per year by estuarine wetlands as biomass and soil carbon (Table 12). Estimated CH_4 emissions from palustrine wetlands and water bodies are 0.14mmt CH_4 per year (11.99mmt CO_2e) and 0.007mmt CH_4 (0.63mmt CO_2e) per year, respectively (Table 12). Forested palustrine wetlands contribute 0.11mmt CH_4 (9.14mmt CO_2e) per year to the palustrine wetlands total, and this is reported here because the Forest Service does not currently include this CH_4 source in its forest inventory (Grant Domke, personal communication). The CH_4 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 CO_2. 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 CO_2 per year between 2002 and 2010 but were less than 0.01mmt CO_2 per year from 1990 to 2001 and from 2011 to 2020.

Lands Converted to Wetlands

Conversion of forest land to wetlands emitted 0.42mmt CO_2 in 2020 (Walters et al. 2022). Conversion of other lands to wetlands contributed an average of 200 metric tons of CO_2 per year from 1990 to 2020.

Excluded Wetland Emissions

As indicated in the introduction to this report, this assessment omits CH_4 emissions by freshwater wetlands and water bodies (Table 13) from total net removals by wetlands. If these emissions were included, they would be subtracted from net emission removals attributed to the land use categories above (Table 12). These estimates are also preliminary, and these emissions are not included in the U.S. national greenhouse gas inventory (EPA 2022a).

Table 13. Excluded Wetland CH4 Emissions, 1990-2020 (mmt CO2e GWP20)
Informational Purposes Only

Emission Source	1990	2005	2016	2017	2018	2019	2020
Palustrine Wetlands	12.05	11.95	11.99	11.99	11.99	11.99	11.99
Water Bodies	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Excluded Net Emissions	**12.68**	**12.58**	**12.62**	**12.62**	**12.62**	**12.62**	**12.62**

Flooded Land

Emissions of CO_2 and CH_4 from land flooded through direct human intervention are included in total net removals (Table 14). These estimates are included in the U.S. national greenhouse gas inventory (EPA 2022a) and the net emissions of this inventory. Nearly all emissions were CH_4 (0.012mmt CH_4 in 2020) and reservoirs were responsible for most of the emissions (92% from 1990 to 2020).

Table 14. Flooded Land Emissions, 1990-2020 (mmt CO2e)

Type	1990	2005	2016	2017	2018	2019	2020
CH_4	**1.05**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**
Reservoirs	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Constructed Ponds	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Canals and Ditches	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Inundation Areas	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO_2	**0.01**	**+**	**+**	**+**	**+**	**+**	**+**
Reservoirs	0.01	+	+	+	+	+	+
Constructed Ponds	+	+	+	+	+	+	+
Net Emissions	**1.06**	**1.05**	**1.04**	**1.04**	**1.04**	**1.04**	**1.04**

"+" less than 0.01mmt

Cropland and Grassland

Cropland, grassland, and settlement areas are defined using the USDA's National Resources Inventory (NRI) (USDA 2020b) and the National Land Cover Dataset (USGS 2000). Land converted to cropland includes all cropland that was in another land use category within the previous 20 years. The same timeframe applies to land converted to grassland. Estimates of annual CO_2 sequestration in soil organic carbon on cropland remaining cropland and land converted to cropland were made based on soil organic carbon stock changes modeled with the Daycent biogeochemical model (EPA 2022a). Stock changes in biomass, litter and dead organic matter on cropland are not counted but are included for other land use categories (e.g., forest land) that are converted to cropland. Emissions resulting from land converted to cropland more than offset the annual CO_2 sequestration by the soil of cropland remaining cropland (Table 15). Conversions of forest land to cropland dominated these emissions, averaging 1.3mmt CO_2 per year from 2005 to 2020 (Walters et al. 2022). Grassland remaining grassland transitioned from net sequestration between 1990 and 2011 (an average of -0.21 mmt CO_2 per year) to net emission from 2012 to 2020 (an average of 0.004 mmt CO_2 per year) (EPA 2022b) because of time variations in weather and land management regime that were incorporated into Daycent.

Table 15. Cropland, Grassland, and Settlement Net Removals, 1990-2020 (mmt CO2)

Land Use Change	1990	2005	2016	2017	2018	2019	2020
Cropland Remaining Cropland	-1.20	-0.76	-0.85	-0.83	-0.75	-0.71	-0.80
Land Converted to Cropland	1.10	0.83	1.30	1.29	1.29	1.29	1.28
Grassland Remaining Grassland	-0.14	-0.32	-0.05	0.03	0.03	0.05	-
Land Converted to Grassland	-0.24	-0.66	-0.21	-0.22	-0.22	-0.21	-0.22
Settlement Remaining Settlement	0.42	0.42	0.47	0.47	0.47	0.47	0.47
Land Converted to Settlement	1.57	2.21	1.90	1.90	1.90	1.90	1.90
Settlement Trees	-3.52	-3.91	-4.09	-4.09	-4.09	-4.09	-4.09
Net Emission Removals	**-2.01**	**-2.19**	**-1.54**	**-1.44**	**-1.36**	**-1.30**	**-1.46**

"-" negative values > 0.01mmt

Settlements

Settlement trees are located in settlements that remain settlements and other land use categories that are converted to settlements. They contributed a significant amount to annual carbon sequestration (-4.09mmt CO_2 in 2020). However, conversion of forest land to settlements is also a large source of CO_2 as stored forest carbon is released to the atmosphere (1.37mmt CO_2 in 2020 and an average of 1.37mmt CO_2 per year since 2005 (Walters et al. 2022)). Emissions associated with settlements remaining settlements are produced by organic soils in these areas, which are assumed to emit CO_2 at a similar rate to cropland on drained organic soil (EPA 2022a).

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

Future work will specify how soil carbon stock changes are affected by tillage, crop types, and crop residue management practices, either in Daycent model results or by using literature-based or IPCC-recommended factors (IPCC 2019).

Wetlands and Other Water Bodies

Improvements to the wetland CH_4 emission factors and CO_2 removal estimates are planned for future inventories. Field research undertaken this year and over the next three years by Meredith Holgerson (Cornell University, College of Agriculture and Life Sciences) will directly measure CH_4 emission factors that are specific to the state’s freshwater wetland ecosystem types. These will be paired with field measurements of CO_2 sequestration in wetland soils and sediment organic carbon to replace estimates made using IPCC default emission factors. Other planned improvements include revising the spatial boundaries that separate wetlands that emit CH_4 from those that do not using regional salt water interface maps. 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 CH_4 emissions from wetlands inundated by water with a salinity higher than 0.5 ppt. Holmquist et al. (2018) provide probability distributions of wetland CH_4 emission across salinity gradients that can then be paired with salinity maps to improve emissions estimates. Finally, constructed ponds, such as farm ponds, are like wetlands in that they potentially sequester CO_2 as organic carbon in sediment, and also emit CH_4. Additional work undertaken through the Cornell University project will measure CO_2 and CH_4 emissions and CO_2 sequestration at a range of different constructed ponds. The goal is to identify the net contribution of their GHG emissions and removals and the impacts of different land use and soil management regimes on this contribution.

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
DHS	U.S. Department of Homeland Security
DMI	Dry matter intake
ECL	Environmental Conservation Law
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
mt	Metric tons
N	Nitrogen
N_2O	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
NOx	Nitrogen oxides
NRI	National Resources Inventory
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

2022 NYS GREENHOUSE GAS EMISSIONS REPORT

SECTORAL REPORT #4

Kathy Hochul, Governor | Basil Seggos, Commissioner

Table of Contents

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 the IPCC Taskforce on National Greenhouse Gas Inventories approach (or “IPCC approach”) 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.

Tables

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 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 approach 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 approach and U.S. national greenhouse gas inventory in three ways. First, the IPCC approach 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 approach only consider emissions that occur within the given jurisdiction. However, the exporting of waste represents a potentially large source of emission leakage[1] 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 approach for national net emission accounting, the carbon dioxide (CO_2) produced from waste is considered biogenic and reported separately from other anthropogenic emissions. The same practice is applied in this report in that biogenic CO_2 is also excluded from net emission totals. However, CO_2 emissions associated with the combustion of waste and landfill gas are included as part of gross emission totals (Table 1, Table 2), while emissions associated with natural decomposition are omitted entirely.

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 (CH_4) that could be generated from waste deposited in a landfill each year. The methodology employed in this report uses an emission factor for "CH_4 generation potential" of 100 m^3 per ton municipal solid waste (MSW) (EPA 2022a). This is equivalent to 5.71 metric tons CO2e per ton MSW using a 20-year Global Warming Potential. CH_4 generation potential does not account for oxidation of CH_4 in the cover layer, or CH_4 destruction via capture systems.

[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.

In 2020, total statewide emissions for the waste sector were 41.95mmt CO_2e GWP20 on a gross basis, which was 12% of all statewide gross emissions (Table 1). Waste sector emissions decreased 3 percent from 1990 to 2020. The largest source of emissions in all years was what the IPCC approach refer to as “solid waste management” (or landfills). As discussed below, non-CO_2 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 CO_2 is omitted in net totals and this includes CO_2 from the combustion of waste and waste gas.

Importantly, total emissions include those associated with the exporting of waste, which has increased from 1.18mmt CO_2e in 1990 to 16.26mmt CO_2e in 2020 (“Exported Waste”, Table 1). DEC seeks comment on whether exported wastes should be excluded from emission totals in the future given limitations on the State’s ability to directly control such emissions leakage.

Table 1. Waste Emissions, 1990-2020 (mmt CO2e GWP20)

* Includes in-state and out-of-state emission sources

Emission Category	1990	2005	2016	2017	2018	2019	2020
Solid Waste Management*	34.03	37.97	35.23	35.82	35.18	35.42	35.64
Biological Treatment of Solid Waste	no	ne	ne	ne	ne	ne	ne
Waste Combustion*	4.00	3.46	2.87	3.22	3.20	3.20	3.20
Wastewater	2.78	2.95	3.03	3.02	3.02	3.00	3.11
Gross Total	**40.81**	**44.39**	**41.13**	**42.06**	**41.39**	**41.62**	**41.95**
% of statewide gross total	*10%*	*10%*	*11%*	*11%*	*11%*	*11%*	*12%*
Net Total	**39.16**	**42.78**	**39.66**	**40.49**	**39.79**	**40.02**	**40.38**
% of statewide net total	*11%*	*10%*	*11%*	*12%*	*12%*	*12%*	*13%*
Exported Waste	1.18	10.70	15.50	15.67	15.84	16.05	16.26

“no” not occurring

“ne” not estimated

The waste sector is responsible for emissions of CO_2, CH_4, and nitrous oxide (N_2O). CH_4 is the primary greenhouse gas and represented 90% of all waste emissions in 2020 (Table 2). The relative amount of each gas reflects the types of waste management used in New York. CH_4 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 CH_4 is shorter lived in the atmosphere than CO_2 and N_2O.

Table 2. 2020 Waste Emissions by Gas (mmt CO2e GWP20)

Emission Category	CO_2	Biogenic CO_2	CH_4	N_2O
Solid Waste Management	na	0.52	35.12	na
Biological Treatment of Solid Waste	na	ne	ne	ne
Waste Combustion	2.02	1.05	0.09	0.04
Wastewater	na	na	2.59	0.52
Gross Total	**2.02**	**1.57**	**37.80**	**0.56**

"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.[2] 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 CH_4 to CO_2 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 CH_4 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 2022a) 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 approach, 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 CH_4 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

[2] As described in the New York State Solid Waste Management Plan

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 CO_2 emission factor were applied to the CH_4 capture data and these emissions are included in the New York landfills totals. Data covering the 2019 and 2020 period are currently under review. For the purposes of this report, 2018 data were used to fill in for 2019 and 2020. 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 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 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 CO_2e). This reflects both the diversion of MSW to out of state landfills, and the enhanced adoption of CH_4 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.

CO_2 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 CH_4 capture and destruction systems employed at out of state facilities.

Table 3. Solid Waste Management Emissions by Gas, 1990-2020 (mmt CO2e GWP20)

Gas/Location	**1990**	**2005**	**2016**	**2017**	**2018**	**2019**	**2020**
Biogenic CO_2	**0.05**	**0.33**	**0.51**	**0.49**	**0.52**	**0.52**	**0.52**
New York landfills	0.05	0.33	0.51	0.49	0.52	0.52	0.52
Out of State landfills	na	na	na	na	na	na	na
CH_4	**33.98**	**37.64**	**34.72**	**35.32**	**34.65**	**34.89**	**35.12**
New York landfills	33.20	27.55	19.82	20.26	19.41	19.44	19.46
Out of State landfills	0.78	10.10	14.90	15.07	15.24	15.45	15.66
Gross Total	**34.03**	**37.97**	**35.23**	**35.82**	**35.18**	**35.42**	**35.64**
Exported Waste	0.78	10.10	14.90	15.07	15.24	15.45	15.66

"na" not applicable

Biological Treatment of Solid Waste

In addition to landfilling, organic solid waste can be treated through composting or anaerobic digestion.[3] 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 CO_2 generated from composting organic waste would not be included in greenhouse gas accounting. The emissions of CH_4 and N_2O are minimal and will depend on the management of the compost. Current State regulations require large compositing facilities to manage organic waste in a way that minimizes these emissions.[4]

Anaerobic digestion is used to accelerate the decomposition of organic waste without oxygen (i.e., in an anaerobic environment), which promotes CH_4 production. The CH_4 may be captured and used for energy production but there is the potential for CH_4 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 CH_4 emissions from these digesters 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.

[3] The IPCC approach also includes mechanical-biological treatment, but this is not used in New York.

[4] 6 NYCRR Part 361

Waste Combustion

This category of emissions includes the CO_2, CH_4, and N_2O 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 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 CO_2. 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 CO_2 and biogenic-CO_2, the latter of which is deducted when calculating net emission totals. Unlike landfilling, municipal waste combustion was not associated with a large volume of CH_4 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 2022c). The SIT was not used because it does not estimate biogenic CO_2, or emissions from the combustion of organic material. The remaining CO_2 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 2020 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 CO_2 includes fossil and biogenic CO_2, which are both anthropogenic. However, biogenic CO_2 is conventionally excluded. As a planned improvement, DEC is evaluating methods for apportioning CO_2 emissions as biogenic or fossil, 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 CO_2 was estimated for the period 2010-2020 by applying the percent of total CO_2 emitted from in-state waste combustion facilities reporting to the U.S. EPA Greenhouse Gas Reporting Program (GHGRP) to be biogenic (EPA 2022d). For the period 1990-2009 the average percent biogenic CO_2 of the 2010-2020 period was applied. The annual ratio of in-state biogenic to non-biogenic CO_2 emissions was applied to out-of-state waste combustion CO_2 emissions. In 2018, in-state waste combustion resulted in 1.5mmt of fossil CO_2, which was 60% of total in-state waste combustion CO_2. The remaining 0.99mmt CO_2 were of biogenic origin.

Results

Waste combustion emissions in 2018, and reported here for 2019 and 2020 until data becomes available, were 3.2mmt, a reduction of 20% since 1990 (Table 4). The majority of emissions are CO_2 (96%), with some CH_4 and N_2O from incomplete combustion. Exported wastes are a small portion of total waste combustion emissions and this has not changed appreciably over the timeseries.

Table 4. Waste Combustion Emissions by Gas, 1990-2020 (mmt CO2e GWP20)

Gas/Location	1990	2005	2016	2017	2018	2019	2020
CO_2	**2.24**	**2.05**	**1.79**	**2.01**	**1.99**	**1.99**	**2.02**
New York facilities	2.08	1.65	1.30	1.52	1.50	1.50	1.53
Out of State facilities	0.16	0.40	0.49	0.49	0.49	0.49	0.49
Biogenic CO_2	**1.60**	**1.27**	**0.97**	**1.08**	**1.08**	**1.07**	**1.05**
New York facilities	1.38	1.09	0.88	1.00	0.99	0.99	0.96
Out of State facilities	0.22	0.18	0.09	0.09	0.09	0.09	0.09
CH_4	**0.11**	**0.10**	**0.08**	**0.09**	**0.09**	**0.09**	**0.09**
New York facilities	0.10	0.08	0.06	0.07	0.07	0.07	0.07
Out of State facilities	0.01	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	**0.05**	**0.04**	**0.03**	**0.04**	**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**	**2.87**	**3.22**	**3.20**	**3.20**	**3.20**
Exported Waste	0.40	0.60	0.60	0.60	0.60	0.60	0.60

"+" less than 0.01mmt

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 CO_2 associated with natural decomposition is not estimated here.

Wastewater treatment practices involve both aerobic and anaerobic decomposition. CH_4 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 CH_4. This is less common in centralized systems as the majority of wastewater treatment facilities in New York use aerobic treatment methods, and the remainder using anaerobic methods utilize methane capture to mitigate emissions. However, anaerobic pockets can develop in facilities utilizing aerobic treatment methods, depending on operational factors. On a per capita basis, centralized systems (108.9 kg CO_2e per year) are much less emissive than septic systems (353.3 kg CO_2e per year). N_2O 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 method was used with revised emission factors to estimate CH_4 and N_2O production from wastewater (EPA 2022a). 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 CH_4 emissions were calculated by applying a default emission factor of 10.7 g CH_4 per person per day (Leverenz et al. 2010) to the fraction of the state population using septic system wastewater treatment.

For centralized wastewater systems, CH_4 and N_2O emissions were calculated using the methodology and emission factors from the IPCC approach (IPCC 2019, Volume 5, chapters 2 and 6). CH_4 was estimated based on the maximum amount of CH_4 that can be produced from a given quantity of organic matter in wastewater (0.6 kg CH_4 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 0.05 was applied to estimate the fraction of wastewater organic matter that was converted anaerobically (Scheehle and Doorn 2003). Direct N_2O emissions from wastewater treatment facilities were estimated assuming production of 4 g N_2O per person per year. Another emission factor of 0.005 g N_2O-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 2022b). 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 12% since 1990 in New York State (Table 5). Of note is that while only an estimated 18.6% of New York's State population utilizes septic systems, they account for 43% of total wastewater emissions. 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 5. Wastewater Emissions, 1990-2020 (mmt CO2e GWP20)

Gas/Treatment	1990	2005	2016	2017	2018	2019	2020
CH_4	**2.32**	**2.46**	**2.52**	**2.52**	**2.51**	**2.50**	**2.59**
Centralized Wastewater	1.22	1.29	1.32	1.32	1.32	1.31	1.36
Septic Systems	1.10	1.17	1.20	1.20	1.19	1.19	1.23
N_2O	**0.47**	**0.50**	**0.51**	**0.51**	**0.51**	**0.50**	**0.52**
Centralized Wastewater	0.38	0.41	0.42	0.42	0.41	0.41	0.43
Septic Systems	0.08	0.09	0.09	0.09	0.09	0.09	0.09
Gross Total	**2.78**	**2.95**	**3.03**	**3.02**	**3.02**	**3.00**	**3.11**

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 approach. 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 N_2O emissions estimates. Finally, the contribution of industrial and commercial wastewater to CH_4 and N_2O 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
CO2e	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_2O	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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Appendix: 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: 2020 Emission Rates for Upstream Out-of-State Sources (g/mmbtu)

Fuel Type	CO_2	CH_4	N_2O	Total CO_2e
Natural Gas	12,206	350	0.14	41,671
Diesel/ Distillate Fuel	14,599	119	0.25	24,638
Coal	3,297	401	0.10	37,029
Kerosene/Jet Fuel	9,449	106	0.16	18,413
Gasoline (E85)	4,915	33	0.08	7,671
Gasoline	18,902	125	0.32	29,504
LPG	16,582	119	0.26	26,648
Petroleum Coke	11,030	110	0.20	20,342
Residual Fuel	11,183	109	0.19	20,423

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_2O	Total CO_2e
Asphalt and Road Oil	7,961	103	0.12	16,663
Lubricants	19,402	114	0.37	29,063
Waxes	18,743	113	0.36	28,336
Miscellaneous Petroleum Products	10,142	107	0.17	19,208
Special Naphthas	13,795	115	0.25	23,521

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_2O	Total CO_2e
Natural Gas and Renewable Natural Gas (RNG/biogas)	2.17	73	n/a	6,145

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	0.001034	Standard cubic foot
Diesel/Distillate Fuel	0.137	U.S. gallon
Coal	25.53	Short Ton
Kerosene/Jet Fuel	0.135	U.S. gallon
Gasoline E85	0.094	U.S. gallon
Gasoline	0.125	U.S. gallon
LPG	0.120	U.S. gallon
Petroleum Coke	0.083	U.S. gallon
Residual Fuel	0.091	U.S. gallon
Asphalt and Road Oil	0.136	U.S. gallon
Lubricants	0.150	U.S. gallon
Waxes	0.158	U.S. gallon
Misc. Petroleum Products	0.144	U.S. gallon
Special Naphthas	0.131	U.S. gallon
Biodiesel	0.138	U.S. gallon