Appendix A: Genesee-Finger Lakes Emissions Inventory Report

Genesee - Finger Lakes Emissions Inventory

Draft

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Table of contents

Project Overview **1**

1 Emissions inventory methodology **2**

1.1 Framework 2

1.2 Inventory scope and boundaries 3

1.2.1 Scope 3
1.2.2 Emissions 6
1.2.3 Emission factors 7

1.3 Inventory structure and calculations 11

1.3.1 Historical energy-related emissions 12
1.3.2 Historical non-energy related emissions 31
1.3.3 Projected emissions (baseline scenario) 39

2 Emissions inventory results and discussion **42**

2.1 Regional emissions 42

2.1.1 Comparison to the 2013 Finger Lakes Sustainability Plan 48
2.1.2 The scale of emissions compared to other states and countries 48

2.2 Emissions by county 49

2.3 Emissions by sector 52

2.3.1 Residential emissions 52
2.3.2 Commercial emissions 57
2.3.3 Industrial emissions 60
2.3.4 Agricultural emissions 62
2.3.5 Transport emissions 64
2.3.6 Waste emissions 66
2.3.7 Transmission losses and fugitive emissions 66
2.3.8 Land Use Emissions and Removals 67

2.4 Priority areas for emission reductions 68

3 Planned future emissions inventory updates **68**

3.1 Addressing data gaps 68

3.2 Additional sectoral detail 69

3.3 Updates to the baseline projection ... 69

4 References ... 70

Appendix A. Emission Factors ... 75

2019 Emission factors for Fuel Combustion ... 75

2019 Upstream Emission factors ... 76

Appendix B. Agricultural Non-Energy Calculations and Assumptions ... 79

List of figures

Figure 1: Map of the Genesee-Finger Lakes Region (Source: www.gflrpc.org) ... 1
Figure 2: Phases of the Genesee-Finger Lakes Climate Action Strategy ... 2
Figure 3: Genesee-Finger Lakes electricity service area map ... 9
Figure 4: Aircraft landing and take-off cycle (Figure taken from: US EPA 2020) ... 27
Figure 5: Deciduous, Coniferous and Mixed Forests in New York (Source: 2019 National Land Cover Dataset) ... 38
Figure 6: Historical and baseline emissions in the Genesee-Finger Lakes region by type of emissions (using 20-yr GWP) ... 44
Figure 7: Historical and projected emissions in the Genesee-Finger Lakes region by sector (using 20-yr GWP) ... 45
Figure 8: Historical and projected emissions in the Genesee-Finger Lakes region by fuel (using 20-yr GWP) ... 46
Figure 9: Historical and project emissions in the Genesee-Finger Lakes region by greenhouse gas (using 20-yr GWP) ... 47
Figure 10: Historical and project emissions in the Genesee-Finger Lakes region by greenhouse gas (using 100-yr GWP) ... 48
Figure 11: Net emissions by county ... 51
Figure 12: Sectoral share of gross emissions in each county in 2018 ... 51
Figure 13: Historical and Projected Residential Emissions by End Use and Fuel (results in GWP20) ... 52
Figure 14: 2018 emissions (left axis) and number of households (right axis) by household type ... 54
Figure 15: 2018 emissions per household by end-use – top left is by location; top right is by building age; bottom left is by ownership; bottom right is by income group ... 55
Figure 16: Energy cost burden by county and income group in 2019. Source: U.S. Census Bureau (2020a) American Community Survey ... 56
Figure 17: Energy cost burden by county and race in 2019. Source: U.S. Census Bureau (2020a) American Community Survey. ... 56
Figure 18: Energy cost burden by county and Spanish/Hispanic/Latino origin in 2019. Source: U.S. Census Bureau (2020a) American Community Survey. ... 57

Figure 19: Energy cost burden by county and disability in 2019. Source: U.S. Census Bureau (2020a) American Community Survey. 57
Figure 20: Historical and projected emissions in the commercial sector by fuel 58
Figure 21: Electricity usage by commercial sub-sector and end-use for Upstate NY. Source: NYSERDA (2019a) 59
Figure 22: Natural gas usage by commercial sub-sector and end-use for Upstate NY. Source: NYSERDA (2019a) 60
Figure 23: Historical emissions in the industrial sub-sectors........ 60
Figure 24: Historical emissions in the industrial sector by fuel 61
Figure 25: Industrial energy breakdown by fuel and end-use for the North-eastern US. Source: US EIA (2021) 2018 Manufacturing Energy Consumption Survey........ 62
Figure 26: Historical and projected emissions in the agricultural sector 63
Figure 27: Historical emissions in the transport sector by vehicle type 64
Figure 28: Historical emissions in the transport sector by fuel 65
Figure 29: 2018 transport emissions by vehicle type and fuel 65
Figure 30: Historical solid waste and wastewater emissions by large facilities 66
Figure 31: Historical and projected transmission losses and fugitive emissions........ 67
Figure 32: Historical and projected land use emissions and removals........ 67

List of tables

Table 1: Comparison between statewide and regional emissions inventories 4
Table 2: Global Warming Potentials of greenhouse gases evaluated in the inventory........ 6
Table 3: 2019 Grid emission factors for New York (per eGRID) and the relative emission rates compared to the New York state average for major utilities in the region 10
Table 4: Comparison of the 2019 electricity mix between all of Upstate New York (per eGRID) and large utilities in the region (Source: US EPA 2021a; NYDPS 2021)........ 10
Table 5: Breakdown of sector calculations by energy and non-energy emissions 11
Table 6: Final Energy Demand Sectors and Subsectors 12
Table 7: Area Median Incomes Table 8: Income group definition........ 17
Table 9: Residential end-use technologies included in the analysis........ 18
Table 10: Residential calibration factors by county........ 19
Table 11: Commercial natural gas and electricity calibration factors by county........ 21
Table 12: Industrial natural gas and electricity calibration factors by county........ 22
Table 13: On-road transport vehicle types and fuels........ 24
Table 14: Detailed non-road transport included in LEAP model 25
Table 15: Aircraft Energy Intensity 28
Table 16: Transport gasoline calibration factors by county........ 29
Table 17: Comparison of landfill capacity between Genesee-Finger Lakes region and state-wide (large landfills only) 30
Table 18: Non-energy Sectors and Subsectors 31
Table 19: Data sources and emissions factors for the industrial non-energy emissions calculations........ 32

Table 20: Data sources and emissions factors for the agricultural non-energy emissions calculations 34
Table 21: Activity Levels in Final Energy and Non-Energy Emissions Projection 39
Table 22: Population projections by county 41
Table 23: Household projections by county (estimates) 41
Table 24: Genesee-Finger Lakes Greenhouse Gas Emissions by Economic Sector (results in GWP20) 43
Table 25: Genesee-Finger Lakes Greenhouse Gas Emissions by Fuel (results in GWP20) 45
Table 26: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP20) 46
Table 27: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP100) 47
Table 28: Comparison of Genesee-Finger Lakes emissions to other geographies 49
Table 29: Genesee-Finger Lakes Greenhouse Gas Emissions by County (results in GWP20) 49
Table 30: Residential sector emissions (results in GWP20) 53
Table 31: Commercial sector emissions (results in GWP20) 58
Table 32: Share of commercial buildings and energy usage in Upstate New York. Source: NYSERDA (2019a) 59
Table 33: 2018 livestock emission details 63
Table 34: 2018 crop emission details 63
Table 35: Top 15 sources of emissions in 2018 68
Table 36: Variables used to calculate methane emissions from manure management (2018 values from US EPA State Inventory Tool) 79
Table 37: Variables used to calculate nitrous oxide emissions from manure management (2018 values from the US EPA State Inventory Tool) 80
Table 38: Variables used to calculate nitrous oxide emissions from animal manure on soils (2018 values from US EPA's State Inventory Tool) 81
Table 39: Variables used to calculate nitrous oxide emissions from crop residues, legumes and histosols (2018 values from US EPA State Inventory Tool) 82
Table 40: Variables used to calculate nitrous oxide emissions from crop burning (2018 values from US EPA State Inventory Tool) 83
Table 41: Variables used to calculate methane emissions from crop burning (2018 values from US EPA State Inventory Tool) 84
Table 42: Variables used to calculate nitrous oxide emissions from fertilizer consumption (2018 values from US EPA State Inventory Tool) 85
Table 43: Variables used to calculate carbon dioxide emissions from liming and urea fertilizer application (2018 values from US EPA State Inventory Tool) 86

Project Overview

Figure 1: Map of the Genesee-Finger Lakes Region (Source: www.gflrpc.org)

The purpose of the climate action strategy is to help guide the development and implementation of projects across the Genesee-Finger Lakes Region that have the most significant potential to decrease greenhouse gas emissions, while also improving the vibrancy, equity, resiliency and health of the region as well. The final output of this project will be an emissions reduction target for the region and a set of corresponding measures and actions to achieve this goal, all documented in a **Climate Action Strategy for the Genesee-Finger Lakes Region**. This Plan seeks to align with the state-wide emissions targets set forth in the historic Climate Leadership and Community Protection Act (CLCPA)[1] and also takes into account the wide-ranging technological improvements since the Finger Lakes Sustainability Plan from 2013[2].

These are the project objectives:

1. To develop a database of emissions and existing climate change-related plans and policies in the Genesee-Finger Lakes Region,
2. To foster dialogue amongst regional stakeholders from different sectors, government entities and community groups to determine what kind of mitigation strategies are plausible and desirable for the Finger Lakes Region,
3. To analyze potential GHG emission reduction measures and social and economic implications of those measures, with particular emphasis on equity, inclusion and climate resiliency,
4. To develop a range of scenarios to guide a climate action strategy,
5. To set an emissions target for the region and prioritize measures that are environmentally, socially, technically, and economically feasible,
6. To identify implementation actors, requirements, timing, and constraints,
7. To develop a plan to monitor progress towards the emissions target, and

[1] Environmental Conservation Law (ECL) Article 75 and as adopted in 6 NYCRR Part 496 (https://www.dec.ny.gov/docs/administration_pdf/revrissum496.pdf)

[2] 2013 Finger Lakes Sustainability Plan: http://www.gflrpc.org/sustainabilityplan.html

8. To strengthen the capacity of local and regional stakeholders to carry out updates to the climate action strategy in the future.

The following project is led by the **Climate Solutions Accelerator (CSA)** in partnership with the **Stockholm Environment Institute's (SEI's) U.S. Center**. The proposed approach consists of four phases: scoping, baseline assessment, scenario analysis, and action plan development, with stakeholder engagement with implementation agencies, sectors, and marginalized groups playing a key role in the process. A summary of the 4-phase project approach is shown in the following figure:

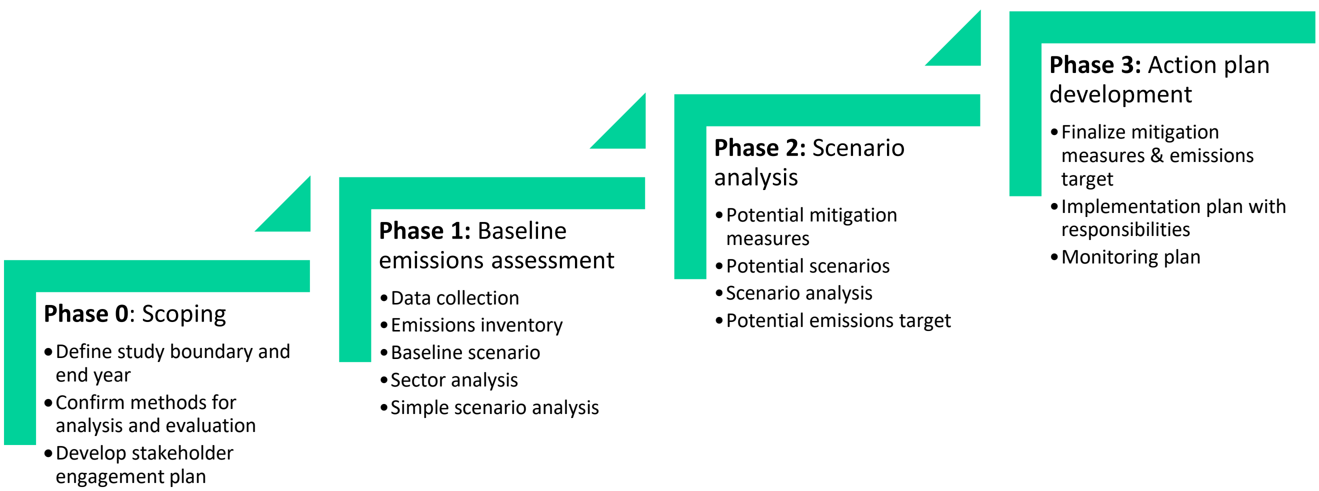

Figure 2: Phases of the Genesee-Finger Lakes Climate Action Strategy

The following report documents the results from Phase 1: Baseline Emissions Assessment.

1 Emissions inventory methodology

1.1 Framework

The baseline emissions inventory has the following objectives:

- Provide a basic understanding of the major sources of emissions in each county within the Genesee-Finger Lakes region (the "region")
- Estimate emission projections into the future (the "baseline scenario") based on historical emission rates
- Provide an idea of data gaps and areas to collect more data
- Provide a starting point for discussion on potential climate mitigation measures

This report documents the methodology and data sources used to determine county-level emissions by major economic sector for each year. The emissions inventory was developed in accordance with the 2015 New York Community and Regional GHG Inventory Guidance[3] document ("NY GHG guidance") and has been updated to align with the methodology used in the 2021 New York State Statewide Greenhouse Gas Emissions Report[4] ("NY GHG inventory") where possible. The NY GHG inventory was developed according to the guidelines set by the International Panel on Climate Change (IPCC) Taskforce on National Inventories (IPCC 2006; IPCC 2019) and presented to meet the requirements set forth in the Climate Leadership and Community Protection Act (CLCPA), including reporting emissions using 20-year Global Warming Potential (GWP), accounting for out-of-state fossil fuel production emissions associated with energy use within the state, and incorporating biogenic carbon dioxide in the calculation of gross emissions. In some cases, additional detail beyond these documents is provided in this inventory if the data allows. Other methods are used to estimate emissions if data is scarce. Assumptions are used where data is scarce, such as downscaling state-level emissions down to the county-level. All assumptions are noted in this report.

All energy and non-energy demand data and emissions factors were obtained from publicly available data sources or local organizations. This is meant to be a high-level inventory used as a starting point for discussions around large sources of emissions and large emitters, and to illuminate where data gaps lie. This inventory is not mean to be a one-time activity, but to establish a process for continually updating the emissions inventory as more data is made available by stakeholders, institutions, facilities or organizations, and to track emissions reductions over time. Suggested future updates are described in Section 3.

The emissions inventory is currently being stored in the Low Emissions Analysis Platform (LEAP)[5] with future plans to create a publicly accessible emissions inventory. LEAP provides the structure for organizing data, calculations and results for an emissions inventory. All data, equations and assumptions used in LEAP are presented in this report. LEAP is also used for the scenario analysis conducted in Phase 2 of the project.

1.2 Inventory scope and boundaries

1.2.1 Scope

The NY GHG Guidance document recommends the inclusion of all "territorial" emissions, or emissions that directly occur within a physical boundary (in this case, the boundary is the region), and if data is available, any "consumption" emissions could also be included. Consumption emissions occur from the consumption of energy or goods produced outside of the boundary or

[3] https://climatesmart.ny.gov/fileadmin/csc/documents/GHG_Inventories/ghgguide.pdf

[4] https://www.dec.ny.gov/energy/99223.html

[5] http://leap.sei.org/

indirectly through activities like commuting to work. More specifically, emissions sources are defined in the following manner:

- **Direct emissions** that occur physically within a boundary such as those emitted by burning natural gas or fuel oil in homes and businesses; also called Scope 1 emissions.
- **Indirect emissions** at electricity power plants based on the amount of electricity consumed within the boundary, regardless of where the power plants are located; also called Scope 2 emissions.
- **Other indirect, upstream, or lifecycle emissions** attributed to community activity regardless of where they occur such as commuting, the lifecycle emissions from fuels or goods like appliances, clothes, etc.; also called Scope 3 emissions

It is often the case where direct and indirect emissions are attributed to the same source. The NY GHG Guidance does not require these overlapping emissions to be reconciled, however, for the purposes of this project, we attempt to avoid double counting, such as for electricity generation.

This inventory includes emissions for the Genesee-Finger Lakes region as a whole and for each county (see Figure 1 for a map of the region). The inventory covers the emissions from the consumption of all major fuels and non-energy emission sources in the region. Emissions from fuel combustion, including emissions from fuel used for electricity generation, are provided for all economic sectors including industry, transport, households, commercial and institutional, agriculture and waste. The inventory also includes non-energy emissions from livestock and crop production, land-use, waste and industrial processes. A comparison between the NY GHG Inventory and this regional inventory is provided Table 1. There are some differences between the two inventories as a result of data availability.

Emissions from upstream fossil fuel extraction and refining processes and fugitive emissions from natural gas pipelines are included in the emissions associated with energy use in the region. All upstream fossil fuel emissions are assumed to be generated out-of-state per the NY GHG inventory. Electricity generation is not included as a separate process or sector. The inventory attributes the indirect emissions from electricity generation to the sector that consumed it. This method prevents electricity-related emissions from being double-counted.

Table 1: Comparison between statewide and regional emissions inventories

Sector	New York Statewide GHG Inventory	Genesee-Finger Lakes GHG Inventory
Electricity	Includes: • Emissions from combustion of fuel for electricity generation • Transmission and distribution losses • Emissions from imported electricity • Emissions from fossil fuel imports for electricity generation	Includes: • Transmission and distribution losses Deviation from Statewide inventory: • Emissions from combustion of fuel for electricity generation attributed to the economic sector where electricity is consumed

Sector	New York Statewide GHG Inventory	Genesee-Finger Lakes GHG Inventory
		Currently not included: • Emissions from imported electricity to region not known • Emissions from fossil fuel imports for electricity generation not known
Transport	Includes: • Emissions from fuel combustion • Emissions from product use (this includes the use of refrigerants in vehicles with HVAC or refrigeration) • Emissions from fossil fuel imports	Includes: • Emissions from fuel combustion • Emissions from fossil fuel imports Deviation from Statewide inventory: • Emissions from product use is under industrial sector. Insufficient data to separate product use by sector.
Buildings	Includes: • Emissions from fuel combustion separated by residential and commercial buildings • Emissions from product use (this includes the use of refrigerants in HVAC or refrigeration) • Emissions from fossil fuel imports	Includes: • Emissions from fuel combustion separated by residential and commercial buildings • Emissions from fossil fuel imports Deviation from Statewide inventory: • Emissions from product use is under industrial sector. Insufficient data to separate product use by sector.
Industry	Includes: • Emissions from industrial processes • Oil and gas (including fugitive emissions) • Emissions from fuel combustion • Other uses of fuels • Emissions from fossil fuel imports	Includes: • Emissions from fuel combustion • Other uses of fuels • Emissions from fossil fuel imports Deviation from Statewide inventory: • Emissions from industrial processes, including product use in the transport sector and buildings • Fugitive emissions is separate sector • Oil and gas data (incl. abandoned wells) is not readily available
Agriculture	Includes: • Livestock • Soil management	Includes: • Livestock • Soil management
Waste	Includes: • Waste (solid waste facilities, wastewater) • Exported waste	Includes: • Waste (solid waste facilities, wastewater) Currently not included: • Unclear amount of waste that is exported out of the region (if any)
Forestry & Land Use	Includes: • Forests • Urban Trees • Wetlands • Harvested wood products	Includes: • Forests • Urban Trees • Wetlands • Harvested wood products

Greenhouse gas emissions are calculated for the historical period between 2010 and 2018 and a baseline projection of emissions is provided through 2050 based on historical emission rates for a given sector, given that these rates do not exceed the historical rates of emissions growth for the region overall. The start and end year of historical data varies between sectors depending on data availability. The historical period was chosen based on data availability; there is a lack of available data before 2010 and after 2018. Baseline emission projections start after the last historical year (2019) and extend to 2050.

1.2.2 Emissions

The inventory estimates emissions from all major greenhouse gases (GHGs), namely:

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Flourinated gases, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)

GHG emissions are reported as carbon dioxide equivalent (CO_2e). Conversions from a given pollutant to CO_2e can be carried out using 20, 100, or 500-year global warming potentials (GWPs). The GWP shows how much energy 1 ton of GHG emissions will absorb over a given period (i.e., 20 years, 100 years or 500 years) relative to 1 ton of CO_2. The GWPs for the greenhouse gases analyzed in this inventory are listed in Table 2.

Table 2: Global Warming Potentials of greenhouse gases evaluated in the inventory

GHG	20-year GWP from IPCC's Fifth Assessment Report (AR5)[1]	100-Year GWP from IPCC's Fourth Assessment Report (AR4)[2]
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	84	25
Nitrous Oxide (N_2O)	254	298
Hydrofluorocarbons (HFCs) (as HFC-23)	10,800	14,800
Sulphur hexafluoride (SF_6)	17,500	22,800
Perfluorocarbons (PFCs) (as PFC-14)	4,880	7,390
Hydrofluoroethers (HFEs) (as HFE-125)	12,400	12,400
Nitrogen trifluoride (NF_3)	12,800	17,200

[1] 20-year GWP without climate carbon feedbacks used by the CLCPA; source: IPCC 2013

[2] 100-year GWP without climate carbon feedbacks used by the UNFCCC; source: IPCC 2007

All quantities of CO_2e reported in this report are calculated using the 20-year GWP. This is in accordance with the Intergovernmental Panel on Climate Change's (IPCC's) fifth assessment report (AR5) which has been adopted by the CLCPA. The 100-year GWP from IPCC's assessment report (AR4) is the conventional GHG accounting format utilized by the United Nations

Framework Convention on Climate Change (UNFCCC) for national reporting of GHG emissions. As shown in Table 2, unlike most greenhouse gases[6] which have long atmospheric lifetimes, methane's potency under the 100-yr GWP is lower compared to the 20-yr GWP. This is because methane decays relatively quickly (~9 years) and becomes less potent over time. Methane's ability to trap heat causes more warming in the short-term compared to the long-term. The CLCPA's choice of using 20-year GWP puts emphasis on methane-related warming in the upcoming 10 to 30 years. A discussion on why 20-yr GWP was chosen for the CLCPA over 100-yr GWP is provided in Howarth (2020).

There are several other air pollutants generated by the energy and non-energy sector. The following pollutants are also covered where emission factors are available:

- Carbon Monoxide (CO)
- Nitrogen Oxides (NO_x)
- Non-methane volatile organic compounds (NMVOC)
- Particulate matter (PM) (particle diameters less than 2.5 microns and 10 microns)
- Sulfur Dioxide (SO_2)

Based on the NY GHG Guidance document, the combustion of biofuels creates **biogenic** CO_2 emissions that are considered "carbon neutral". This is because carbon dioxide is taken from the atmosphere to grow the biomass source and upon combustion, the carbon dioxide is returned to the atmosphere resulting in net zero emissions. However, in the NY GHG inventory, biogenic CO_2 is shown in the reporting of gross emissions and is removed in the net emissions summary. This report follows the reporting method used in the NY GHG Inventory. Other contaminants from biofuel combustion, such as methane and nitrous oxide, are included since they are not released during natural decay processes.

1.2.3 Emission factors

Emission factors are used to calculate the emissions generated from the combustion of fuels at on-site or for electricity generation and emissions from different processes. The emissions from using natural gas for cooking will differ from using natural gas for a car depending on the combustion efficiency of the car and stove. Even combustion efficiencies between different stove brands and models will vary. This level of detail is very difficult to find, therefore, for this analysis, we use generic emission factors for a given sector and fuel or process, similar to what was used in the NY GHG Inventory. The following sub-section provides further detail on the emission factors used for this emissions inventory.

[6] Other GHG's that have lower potency under the 100-yr timeframe compared to the 20-yr timeframe include HFC-134a and CFC-11. In general, some, but not all, HFCs are short-lived.

1.2.3.1 Emission factors for fuel combustion

An emissions factor converts fuel consumption into pollutant emissions in units of mass (e.g., metric tons). A combination of bottom-up/end-use accounting and top-down/macroeconomic techniques are used to estimate fuel demands. The most widely applied bottom-up method is an activity analysis, which calculates demand as the product of an activity level (i.e., a measure of social and economic activity) and energy intensity (i.e., the average energy consumption for a device or an activity). For example, an "activity" could be the number of households that use natural gas stoves, and the "energy intensity" could be the amount of natural gas used for cooking on a natural gas stove.

The bottom-up approach has a history in the energy modeling literature (Landsberg et al. 1974) as both simple and transparent. As Bhattacharyya (2011) explains, it is an end-use oriented method commonly applied to demands separated into multiple sectors.

To ensure bottom-up estimates of fuel use are correct, the fuel demands are adjusted by a calibration factor. The formula representing this calculation is provided below:

$$Fuel\ Demand_{(sector,\ process,\ c,\ s,\ t)} = Activity_{(sector,\ process,\ c,\ s,\ t)}\ x\ FEI_{(sector,\ process,\ c,\ s,\ t)}\ x\ C_{(sector,\ c,\ t)}$$

Where:

Fuel Demand is the total fuel consumption in units of energy (e.g., GJ, MMBTU, etc.)
Total Activity is a measure of social or economic activity (i.e., number of households, GDP, etc.)
FEI is the final energy intensity, or the fuel consumption per unit of total activity
C is a calibration factor used to align bottom-up fuel estimate to actual fuel use
Sector is the economic sector
Process is the fuel combustion source
c is the county
s is the scenario
t is the year of analysis

final energy demand = activity level × energy intensity

A bottom-up analysis makes it easier to assess climate mitigation measures that tend to target specific activities. In some cases, activity data is not readily available, so a top-down analysis is made using reported fuel consumption data.

For energy-related emissions, each pollutant has an emission factor unique to each fuel, sector and combustion source (like a stove or car). Fuels also have emissions associated with upstream processes, e.g., mining, extraction, refining, and distribution. As a result, pollutant emissions are calculated using the following formulas:

$$Energy\ emissions_{(sector,\ process,\ fuel,\ GHG,\ s,\ t)} = Fuel\ Consumption_{(sector,\ process,\ s,\ t)}\ x\ Emissions\ Factor_{(sector,\ fuel,\ GHG)}$$

$$Emissions\ Factor_{(sector,\ fuel,\ GHG)} = Emissions\ Factor_{(sector,\ fuel,\ GHG)} + Emissions\ Factor_{(fuel,\ GHG)}$$

Where:

Sector is the economic sector
Process is the fuel combustion source
c is the county
s is the scenario
t is the year of analysis
fuel = type of fuel
GHG = type of greenhouse gas

The emission factors for fuel combustion and the upstream emissions associated with the fuels used in the region are provided in Appendix A.

1.2.3.2 Emission factors for grid electricity

Electricity is supplied to the region through three main utilities: National Grid, Rochester Gas and Electric (RG&E) and New York State Electric and Gas (NYSEG). There are also several municipal utilities that serve the following towns: Fairport (Monroe), Churchville (Monroe), Spencerport (Monroe), Bergen (Genesee), Holley (Orleans), Arcade (Wyoming), Castile (Wyoming), Silver Springs (Wyoming) and Penn Yan (Yates). Refer to Figure 3 for the Genesee-Finger Lakes electricity service area map.

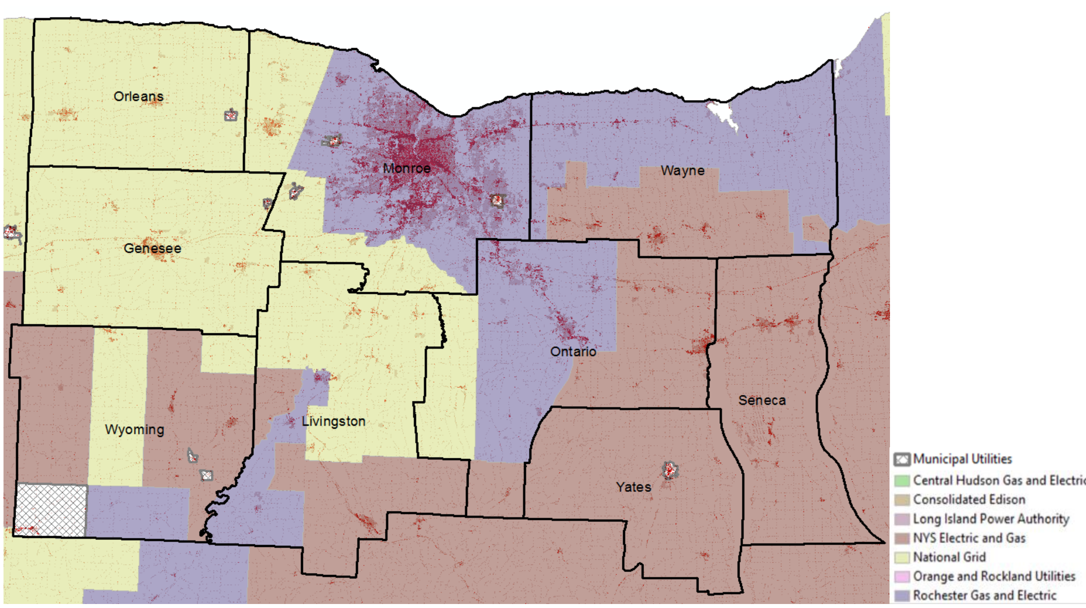

Figure 3: Genesee-Finger Lakes electricity service area map

GHG emissions from consuming grid electricity (Scope 2 emissions) are based on the carbon intensity of the grid. While the NY GHG guidance document recommends using the grid carbon intensity factor developed by NYSERDA, one was not readily available for recent years. In its place, a state-wide emissions factor was taken from the U.S. EPA Emissions & Generation Resource Integrated Database (eGRID) (US EPA 2021a). This state-wide emissions factor was adjusted based on the relative emission rates of the utilities per New York's Environmental Disclosure Labeling Program (NYDPS 2021). The 2019 grid emission factors for the state and the relative emission rates for the major electric utilities in the region are shown in Table 3. We used an average rate for the major electric utilities since they represent the majority of electricity emissions in the region.

Table 3: 2019 Grid emission factors for New York (per eGRID) and the relative emission rates compared to the New York state average for major utilities in the region

Pollutant	eGRID (lb/MWH)	National Grid[1]	RG&E	NYSEG
		(lb/MWH relative to state average)		
Carbon Dioxide (CO_2)	376.7	107%	109%	107%
Methane (CH_4)	0.028	107%[2]	109%[2]	107%[2]
Nitrous Oxide (N_2O)	0.003	107%[2]	109%[2]	107%[2]
Nitrogen Oxides (NOx) (Annual)	0.2	107%	109%	107%
Sulfur Dioxide (SO2)	0.0	105%	108%	105%

Source: (US EPA 2021a; NYDPS 2021)

[1] Listed as Niagara Mohawk Power Corporation

[2] Assumed to be same as the CO_2 value

The relative emission rates for the major utilities are higher than the state average because the share of fossil fuel-based electricity purchased by the utilities is higher and the share of hydropower is lower. Despite significant hydropower generation upstate, for which some of the utilities have bilateral contracts for, most of the utilities rely on the wholesale electricity market to meet electricity demands. The New York Independent Systems Operator (NYISO) selects the proper mix of generators to supply electricity demands at the least cost to utilities, meaning utilities end up using downstate fossil fuel capacity to meet load requirements. A comparison between the energy mix for all of New York, Upstate New York and the major utilities that serve the Genesee-Finger Lakes region - namely National Grid, RG&E and NYSEG – are in Table 4.

Table 4: Comparison of the 2019 electricity mix between all of Upstate New York (per eGRID) and large utilities in the region (Source: US EPA 2021a; NYDPS 2021)

Type of power plant	eGRID State Avg. (% share)	eGRID Upstate[1] (% share)	National Grid[2] (% share)	RG&E (% share)	NYSEG (% share)
Coal	0.3%	0.5%	3%	3%	3%
Oil	0.4%	0.1%	<1%	<1%	<1%
Gas	36%	25%	39%	42%	41%
Other Fossil	0%	0%	0%	0%	0%

Type of power plant	eGRID State Avg. (% share)	eGRID Upstate[1] (% share)	National Grid[2] (% share)	RG&E (% share)	NYSEG (% share)
Nuclear	34%	32%	35%	38%	37%
Hydro	23%	35%	18%	11%	13%
Biomass	2.2%	1.9%	<1%	<1%	<1%
Wind	3.4%	5.1%	2%	2%	2%
Solar	0.4%	0.4%	<1%	<1%	<1%
Geothermal	0%	0%	0%	0%	0%
Waste and other unknown/ purchased fuel	0%	0%	2%	2%	2%

[1] Listed as NYUP (NPCC Upstate NY)

[2] Listed as Niagara Mohawk Power Corporation

1.2.3.3 Emission factors for non-energy emissions

For non-energy related emissions, pollutant emissions are not based on fuels, but on processes, with an emissions factor associated with the process, for example, digestion processes in animals, decomposition processes in landfills, or land conversion processes. Pollutant emissions from these processes are calculated using the following formula:

$$\text{Non-energy emissions}_{(process,\ GHG)} = \text{Process x Emission Factor}_{(process,\ GHG)}$$

The emission factors to estimate non-energy emissions are provided throughout Section 1.3.2.

1.3 Inventory structure and calculations

The inventory calculates historical emissions for 2010 to 2018 and emissions projections to 2050, the target date for achieving net zero emissions according to the CLCPA. The calculations are divided into two main categories: energy emissions and non-energy emissions. As shown in Table 5, some sectors have both energy and non-energy emissions, each with its own emissions calculation methodology and data sources, as described in the remainder of this section. For reporting purposes, emissions and non-energy emissions are reported together for a given sector.

Table 5: Breakdown of sector calculations by energy and non-energy emissions

Sector	Energy Emissions	Non-Energy Emissions
Transport	X	
Buildings (Residential)	X	
Buildings (Small Commercial)	X	
Buildings (Large Commercial)	X	
Industry	X	X
Electricity (Transmission & Distribution)	X	
Fugitive Emissions	X	
Agriculture	X	X

Sector	Energy Emissions	Non-Energy Emissions
Waste (Solid Waste)	X	X
Waste (Wastewater)	X	X
Forestry & Land Use		X

A number of data sources were compiled to develop the inventory. Where possible, an end-use oriented (aka "bottom-up") approach was taken to estimate emissions, for instance, calculating transport emissions by vehicle and fuel type, rather than just by fuel. Having this level of detail lends itself well to evaluating different climate mitigation policies during the scenario analysis phase of the project (Phase 2). This includes looking at the emissions reductions from increasing the number of EVs on the road, for example, as opposed to estimating a decrease in gasoline use in the transport sector. However, the bottom-up approach was not possible for all sectors based on data availability. All bottom-up calculations for the energy sector were calibrated to actual fuel use data, where available.

The rest of this section describes the input data, assumptions and calculations used to complete the emissions inventory.

1.3.1 Historical energy-related emissions

As shown in Table 6, final energy demands are broken down by economic sector, subsector, end use, technology, and fuel. The level of detail in each sector depends on data availability.

Table 6: Final Energy Demand Sectors and Subsectors

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
Residential	Urban Centre	New Building	Renter	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
			Owner	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
		Old Building	Renter	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
			Owner	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
		New Building	Renter	Extremely Low Income

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
	Rural or Urban Periphery			Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
			Owner	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
		Old Building	Renter	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
			Owner	Extremely Low Income
				Very Low Income
				Low Income
				Moderate Income
				Middle-High Income
Small Commercial	Large Utilities	RGE		
		National Grid		
		National Fuel		
		NYSEG		
		Reserve Gas Company		
	Municipal Utilities			
Large Commercial	Large Utilities			
Industry[1]	Manufacturing	N3112 Grain and Oilseed Milling		
		N3113 Sugar and Confectionery Product Manufacturing		
		N3114 Fruit and Vegetable Preserving and Specialty Food Manufacturing		
		N3115 Dairy Product Manufacturing		
		N3116 Animal Slaughtering and Processing		
		N3119 Other Food Manufacturing		
		N3121 Beverage Manufacturing		
		N3122 Tobacco Manufacturing		
		N3132 Fabric Mills		
		N3141 Textile Furnishings Mills		
		N3149 Other Textile Product Mills		
		N3151 Apparel Knitting Mills		
		N3152 Cut and Sew Apparel Manufacturing		
		N3159 Apparel Accessories and Other Apparel Mfg		
		N3162 Footwear Manufacturing		
		N3169 Other Leather and Allied Product Manufacturing		
		N3211 Sawmills and Wood Preservation		
		N3219 Other Wood Product Manufacturing		
		N3231 Printing and Related Support Activities		
		N3241 Petroleum and Coal Products Manufacturing		
		N3251 Basic Chemical Manufacturing		
		N3254 Pharmaceutical and Medicine Manufacturing		

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
		N3259 Other Chemical Product and Preparation Mfg		
		N3261 Plastics Product Manufacturing		
		N3262 Rubber Product Manufacturing		
		N3271 Clay Product and Refractory Manufacturing		
		N3272 Glass and Glass Product Manufacturing		
		N3279 Other Nonmetallic Mineral Product Mfg		
		N3311 Iron and Steel Mills and Ferroalloy Mfg		
		N3312 Steel Product Mfg from Purchased Steel		
		N3313 Alumina and Aluminum Production & Processing		
		N3315 Foundries		
		N3321 Forging and Stamping		
		N3322 Cutlery and Handtool Manufacturing		
		N3323 Architectural and Structural Metals Mfg		
		N3325 Hardware Manufacturing		
		N3326 Spring and Wire Product Manufacturing		
		N3329 Other Fabricated Metal Product Manufacturing		
		N3332 Industrial Machinery Manufacturing		
		N3333 Commercial and Service Industry Machinery Mfg		
		N3335 Metalworking Machinery Manufacturing		
		N3339 Other General Purpose Machinery Mfg		
		N3344 Semiconductor and Other Electronic Component Manufacturing		
		N3351 Electric Lighting Equipment Manufacturing		
		N3352 Household Appliance Manufacturing		
		N3353 Electrical Equipment Manufacturing		
		N3359 Other Electrical Equipment and Component Mfg		
		N3371 Household and Institutional Furniture and Kitchen Cabinet Manufacturing		
		N3379 Other Furniture Related Product Manufacturing		
		N3391 Medical Equipment and Supplies Manufacturing		
		N3399 Other Miscellaneous Manufacturing		
		N3221 Pulp Paper and Paperboard Mills		
		N3252 Resin Synthetic Rubber and Artificial and Synthetic Fibers and Filaments Manufacturing		
		N3253 Pesticide Fertilizer and Other Agricultural Chemical Manufacturing		
		N3324 Boiler Tank and Shipping Container Mfg		
		N3328 Coating Engraving Heat Treating and Allied Activities		
		N3331 Agriculture Construction and Mining Mfg		
		N3336 Engine Turbine and Power Transmission Equipment Manufacturing		
		N3372 Office Furniture Manufacturing		
		N3327 Machine Shops Turned Product and Screw Nut and Bolt Manufacturing		
		N3133 Textile and Fabric Finishing and Coating Mills		
		N3334 HVAC & Commercial Refrigeration Equip. Mfg		
	Mining	N2111 Oil and Gas Extraction		
		N2123 Nonmetallic Mineral Mining and Quarrying		
		N2131 Support Activities for Mining		
	Construction	N2369 Building Construction		
		N2378 Heavy and Civil Engineering Construction		

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
		N2388 Specialty Trade Contractors		
Transport	On Road	Cars		
		Light passenger trucks		
		Light commercial trucks		
		Medium trucks		
		Heavy duty single unit trucks		
		Heavy duty combination trucks		
		Public Buses		
		Private Buses		
		Motorcycles		
	Non Road	Rail	Locomotive	
			Railroad Maintenance	
		Airport	Operational	
			Aircraft Landing/Takeoff	
		Marine	Pleasurecraft	
			Commerical Marine Vessels	
	Off Road	Recreational		
Agriculture[1]	N1111 Oilseed and Grain Farming			
	N1112 Vegetable and Melon Farming			
	N1113 Fruit and Tree Nut Farming			
	N1122 Hog and Pig Farming			
	N1123 Poultry and Egg Production			
	N1124 Sheep and Goat Farming			
	N1121 Cattle Ranching and Farming			
	N1119 Other Crop Farming			
	N1114 Greenhouse Nursery and Floriculture Production			
	N1129 Other Animal Production			
Solid Waste				
Wastewater				
Electricity Transmission and Distribution Losses				
Natural Gas Fugitive Emissions				

[1] The industrial and agricultural subsectors are categorized by the North American Industry Classification System (NAICS)

The following sections provides the methodology and data sources used to calculate energy-related emissions in each sector.

1.3.1.1 Residential

Emissions from residential energy demands are calculated using the formulas presented in Section 1.2.3.1 with some modification. The amount of fuel consumed in the residential sector is based on the number of households (total activity) and the energy used for various household technologies (i.e., air conditioners, furnaces, lights, etc.). The emission factors used for the residential sector are provided in Appendix A.

Per Table 6, households are divided into different groups based on geography, building age, ownership status and income classification. In total, there are 40 household types based on the various combinations of geography-building age-ownership status-income classification. Fuel demands for each household type are calculated using the following formula:

$$Energy_{c,s,t,type,fuel} = \sum\nolimits_{0...T} HH_{c,s,t,type,tech} \times FEI_{tech,fuel} \times C_{c,fuel}$$

$$HH_{c,s,t,type,tech} = HH_{c,s,t} \times f_g \times f_{g,by} \times f_{g,by,own} \times f_{g,by,own,inc} \times f_{g,by,own,inc,tech}$$

Where:

Energy is the energy use in mmbtu
HH is the number of households from the U.S. Census Bureau (2021).
FEI is the final energy intensity in mmbtu per household from US EIA (2018).
C is a calibration factor
f is the fraction of total households in a specific category. Data for f_g, $f_{g,by}$, $f_{g,by,own}$ and $f_{g,by,own,inc}$ are from Ruggles et al (2021). $f_{g,by,own,inc,ech}$ is from US EIA (2018).
tech is the end-use technology (i.e., natural gas boiler, central AC, etc.)
fuel is the type of fuel (i.e., natural gas, electricity, etc.)
c is the county
s is the scenario
t is the year of analysis
type is the household type for a given combination of *g*, *by*, *own* and *inc*
g is the geographic location of a household (urban centre / rural or urban periphery)
by is the built year of a household (new / old)
own is the ownership status of a household (owner / renter)
inc is the income group of a household (extremely low / very low / low / moderate / high)
T is the maximum number of end-use technologies

Residential Activity and Energy Intensity

The number of households in each county is available from the U.S. American Community Survey (ACS) (US Census Bureau 2021). The share of households in each household type within each county is obtained from the ACS via a web tool called IPUMS[7] (Ruggles et al. 2021). Further details on the different groups are as follows:

- **Geography:** Households were divided into two geographic groups: urban centre and urban periphery (the latter includes rural households). The data used to categorize households came from the IPUMS variable called METRO. METRO indicates whether a household is in an urban centre, urban periphery or mixed area. The number of households in the "mixed" category (per the variable called HHWT) was split into

[7] https://usa.ipums.org/usa/index.shtml

"urban centre" and "rural and urban periphery" based on the share of households located in a metropolitan area (per the variable called PCTMETRO).

- **Building vintage:** Urban and rural households were further divided into two building vintages: new or old. The built year for a household was provided by the IPUMS variable called BUILTYR. In 2002, the New York State Energy Conservation Construction Code (ECCC) had a major update to align with the International Energy Conservation Code (IECC). Given that the built year of households in ACS are provided in decadal increments, new buildings are assumed to be those built after or in the year 2000 (a few years before the updated ECCC) and old buildings are assumed to be those built before 2000.

- **Ownership status:** Old and new households were further divided into two ownership statuses: renter or owner. The ownership status for a household was provided by the variable OWNERSHPD. OWNERSHPD indicates whether a survey sample represents households that are owned (or being bought), rented or neither. Households that are "neither" are excluded from the analysis due to insufficient income and energy data for these types of households.

- **Income classification:** Rental and owned households were further divided into five income groups: extremely low income, very low income, low income, moderate income and high income. The income groups are based on area median income (AMI) as defined for each county by the U.S. Department of Housing and Urban Development (HUD) (2020). The AMI and income group definitions are shown in Table 7 and Table 8. Household were categorized based on the IPUMS variable for household income, HHINCOME.

Table 7: Area Median Incomes

County	AMI
Genesee	$73,050
Orleans	$73,050
Livingston	$73,550
Wyoming	$73,550
Ontario	$73,500
Yates	$73,500
Wayne	$73,050
Seneca	$73,050
Monroe	$76,400

Source: (U.S. HUD 2020)

Table 8: Income group definition

Income Group	Definition
Extremely Low Income	0-30% of AMI
Very Low Income	31-50% of AMI
Low Income	51-80% of AMI
Moderate Income	81-120% of AMI
Middle-High Income	120%+

Source: (NYC HPD 2021)

Energy data for each household type was taken from the U.S. Energy Information Administration's latest Residential Energy Consumption Survey (RECS) in 2015 (US EIA 2018). RECS does not have data at a county-level, therefore data for the Middle Atlantic region – which the Genesee-Finger Lakes is a part of – was used instead.

RECS microdata provides activity levels and energy intensity by various end-use categories and is available for each of the household types described above. The end-uses included in the analysis are “Air Conditioning”, “Water Heating” and “Space Heating” with fuel demands from all other end-uses combined into a single category called “Other”. The technologies and fuels under each end-use category are indicated in Table 9.

Table 9: Residential end-use technologies included in the analysis

Water Heating	Space Heating	Air Conditioning
Technologies	**Technologies**	**Technologies**
Ref. Electric Large Storage	Reference Natural Gas Boiler	Reference Central AC
Ref. Electric Small Storage or Tankless	Reference Natural Gas Furnace	Reference Room AC
Efficient Electric Large Storage	Efficient Natural Gas	Efficient Central AC
Efficient Electric Small Storage or Tankless	Other Gas	Efficient Room AC
Ref. Natural Gas Large Storage	Reference Oil Furnace	Air Source Heat Pump
Ref. Natural Gas Small Storage or Tankless	Reference Oil Boiler	Both Central and Room AC
Efficient Natural Gas Large Storage	Efficient Oil	Both Heat Pump and Room AC
Eff. Natural Gas Small Storage or Tankless	Other Oil	
Fuel Oil or Kerosene	Electric Resistance	
Propane or LPG	Electric Furnace	
Wood	Electric Heat Pump	
Solar	Portable Electric Heater	
Other Fuel	Ground Source Heat Pump	
	Solar	
	Bottled Tank or LPG	
	Wood	
	Other Fuel	
Fuels	**Fuels**	**Fuels**
Electricity	Electricity	Electricity
Natural Gas	Natural Gas	
Fuel Oil or Kerosene	Fuel Oil or Kerosene	
Propane or LPG	Propane of LPG	
Wood	Wood	
Solar	Solar	
Other	Other	

Calibration of Residential Energy Use

Residential fuel demands were calibrated using NYSERDA’s Patterns and Trends reports which provides historical fuel usage in each county. Historical natural gas and electricity data are only available for 2013 (NYSERDA 2019b). For all other fuels, 2017 data is used (NYSERDA 2021b).

A calibration factor is the ratio of actual fuel demands over estimated fuel demands and is applied to the energy intensity. The residential calibration factors used for this analysis are provided in Table 10. In almost all cases, except for Propane/LPG, estimated fuel use is higher than the actual use. Improvements to county-specific activity and end-use data could improve future estimates.

Table 10: Residential calibration factors by county

County	Electricity	Natural Gas	Diesel	Fuel Oil / Kerosene	Propane / LPG	Wood
Genesee	0.57	0.64	0.26	0.24	1.86	0.14
Livingston	0.48	0.45	0.24	0.23	2.46	0.29
Monroe	0.75	0.86	0.05	0.05	0.17	0.02
Ontario	0.45	0.92	0.17	0.16	0.85	0.09
Orleans	0.53	0.59	0.32	0.30	2.37	0.25
Seneca	0.53	0.35	0.32	0.29	3.20	0.28
Wayne	0.53	0.46	0.27	0.25	2.51	0.42
Wyoming	0.49	0.43	0.18	0.17	2.06	0.34
Yates	0.36	0.78	0.24	0.23	1.34	0.21

1.3.1.2 Small Commercial

Energy consumption for the commercial sector was only available as small and large commercial, each requiring a very different calculation methodology. A top-down approach was used to calculate energy usage in the small commercial sector due to insufficient data for a bottom-up analysis. Per Table 6, small commercial energy demands are divided into "private utilities" and "municipal utilities" that deliver electricity and natural gas. Data for other fuels used in the small commercial sector was not found.

Energy consumption from private utilities

Natural gas and electricity consumption was obtained from NYSERDA's Utility Energy Registry (UER) for small commercial buildings for the years 2016 to 2018. Large commercial energy demands were grouped with industrial usage in the UER which is why the commercial sector is divided in two. The UER defines small commercial as follows:

> *Small Commercial (SC): All non-residential rates classes eligible for opt-out Community Choice Aggregation in New York. This field differs from the Commercial data field in the National UER Data Field Library since not all commercial businesses are opt-out eligible.*

The UER provides natural gas and electricity data for each census tract. The utilities withhold data from the UER when there are insufficient customers in a given tract to ensure privacy. Therefore, the reported energy consumption in the UER is less than the actual. The total consumption of each fuel in the small commercial sector is added to the consumption in large commercial and scaled to match the total commercial demands recorded in NYSERDA's Patterns and Trends reports (NYSERDA 2019b). The calibration factors are provided later in this section.

Energy consumption from municipal utilities

Since municipal utilities are not included in the UER, energy use in small commercial areas covered by municipal utilities are extrapolated from the energy use per hectare in small commercial areas covered by private utilities using the following methodology:

1. **Using GIS software, a land use map is layered on top of a utility service area map to identify size of the residential areas in hectares serviced by each utility.** The National Land Cover Dataset (NLCD) 2016[8] is a dataset which categorizes the U.S. into 15 land cover classes. This dataset when intersected with the boundaries of each county in the Genesee-Finger Lakes region, and the service area of each utility (both large and small), provides the area of each land use class, within each county, within each utility service area. There are three land use classes in the NLCD dataset that are useful for determining commercial area. These categories are not determined by zoning but by the percentage of impervious surface in a given area, so this is not a perfect predictor of areas where small commercial exist; however, it is assumed that the high intensity category likely captures where small commercial energy use is occurring.

    - **Developed, Low intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
    - **Developed, Medium intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
    - **Developed, High intensity** - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total.

2. **Add up the total area (in hectares)** covered by high intensity (commercial) development for each county and each utility service area.

3. **Find the energy intensity of electricity and natural gas use in the commercial areas in kWH/ha or therms/ha.** This was done by dividing total energy use from each private utility (from the UER), in each county, in each year by the corresponding area.

4. **Apply the energy intensity in kWH/ha or therms/ha of the private utilities to the residential areas within the municipal utilities to determine residential energy consumption from municipal utilities.** The energy intensity within a given county are assumed to be the same, with the exception of Monroe county, where the energy intensity from Genesee is applied to the areas serviced by municipal utilities in Monroe, as these areas are less densely developed (shorter buildings) than the majority of the "developed – high intensity" areas in Monroe County, which are largely in Rochester and have significantly taller buildings and therefore a higher energy intensity.

[8] https://www.usgs.gov/centers/eros/science/national-land-cover-database

This analysis uses the following assumptions:

1. The developed – low intensity land cover class is representative of areas where commercial energy use is occurring, and is sufficient to infer energy use based on area across different parts of the counties
2. The way electricity versus gas is used in the areas where we have data (areas served by large utilities) is the same as the area where we are missing data (areas served by municipal utilities). This may be faulty if, for example, municipal electricity suppliers are much cheaper so people use more electricity in these service areas than in others.
3. No area is served by two electric utilities. This seems to be true given the shapefile of service areas.

Calibration of small commercial energy use

While the UER is the main source of data for the small commercial energy analysis, due to privacy concerns, a sizeable portion of the data is withheld for each utility. NYSERDA's Patterns and Trends reports provides the total natural gas and electricity usage for each county and is used to calibrate the private utility and municipal utility data. Only actual fuel use data for 2013 was available.

A calibration factor is the ratio of actual fuel demands over estimated fuel demands and is applied to the energy intensity. The calibration factors for the commercial sector are provided in Table 11. The total consumption of each fuel in the small commercial sector is added to the consumption in large commercial and scaled to match total commercial demands.

Table 11: Commercial natural gas and electricity calibration factors by county

County	Electricity	Natural Gas
Genesee	1.30	2.00
Livingston	0.87	0.67
Monroe	0.55	0.36
Ontario	0.68	2.09
Orleans	1.91	13.14
Seneca	0.62	1.04
Wayne	2.37	1.08
Wyoming	12.04	2.49
Yates	12.75	7.02

1.3.1.3 Industrial and Agricultural

A top-down approach was used to calculate energy usage in the small commercial sector due to insufficient data for a bottom-up analysis. Energy data for the industrial and agricultural sector was obtained from the National Renewable Energy Laboratory's (NREL's) Industrial Energy Data

Book (IEDB)[9] for the years 2010 through 2016. This dataset compiles industrial and agricultural fuel use data by county and North American Industry Classification System (NAICS) code using a number of publicly available data sources including the U.S. Environmental Protection Agency (EPA), U.S. Energy Information Agency (EIA), Census Bureau, U.S. Department of Agriculture (USDA), and U.S. Geological Survey (USGS). It reports consumption of natural gas, diesel, liquid petroleum gas, residual fuel oil, coal, coke, net electricity, and a fuel called "other". Net Electricity represents the portion of electricity taken from the grid, as opposed to Gross Electricity which would include the electricity generated on site and used internally or sold. The disadvantage of not having gross electricity demands is that if fossil fuel-based sources of energy are used to generate electricity on-site, it would not be included in the inventory. This is a major concern, for example, of bitcoin mining which requires a large amount of electricity for its operations. For instance, the Greenridge Generation facility in Yates County opened in 2018 and is already proposing to expand its operations to over 55 MW. It uses natural gas for energy generation, but the company is said to have "invested heavily in reliable, verifiable carbon offset credits to ensure it maintains net-zero carbon emissions in its bitcoin transaction processing operations".[10] Since the Greenridge Generation facility is connected to the grid, it is assumed that its emissions are already considered in the electricity emissions factor described in Section 1.2.3.2.

A summary of the industrial and agricultural sub-sectors included in the inventory is in Table 6. The emission factors used to translate fuel usage to emissions is provided in **Appendix A**. A detailed report from Orebed Analytics in **Appendix C** provides additional results on industrial and agricultural energy demands in the Genesee-Finger Lakes region.

Calibration of industrial and agricultural energy use

NYSERDA's Patterns and Trends reports provides the total natural gas and electricity usage for each county and is used to calibrate the industrial electricity and natural gas demands using the calibration factors provided in Table 12. Fuel use data for 2013 was the only year available. The actual energy used by the agricultural sector is not known and was not calibrated.

Table 12: Industrial natural gas and electricity calibration factors by county

County	Electricity	Natural Gas
Genesee	1.77	0.69
Livingston	2.10	1.02
Monroe	0.92	0.61
Ontario	0.89	0.30
Orleans	1.16	0.15

[9] https://data.nrel.gov/submissions/122

[10] https://greenidge.com/our-operations/

Seneca	0.62	0.47
Wayne	1.61	1.44
Wyoming	1.19	0.70
Yates	0.56	0.82

1.3.1.4 Large Commercial

Energy consumption for the commercial sector was only available as small and large commercial, each requiring a very different calculation methodology. A top-down approach was used to calculate energy usage in the large commercial sector due to insufficient data to use a bottom-up approach.

Large commercial demands were calculated by subtracting the energy data from NYSERDA's Utility Energy Registry (UER) – which includes both large commercial and industrial in a single category – from the industrial demands provided by NREL's IEDB (see previous section for details). The UER presents the large commercial and industrial demands in a category named "Other", which is defined as follows:

> *Other (O): This is all non-residential rates classes not opt-out eligible for opt-out Community Choice Aggregation in New York. These are typically large commercial and industrial rate classes on demand meters.*

The UER dataset only includes natural gas and electricity. There is only one year where the UER and IEDB datasets overlap, the year 2016. Since the UER withholds some data due to privacy concerns, and, as a result, reports a lower amount of energy usage than actually consumed, the calibration factor was applied to the UER data prior the calculation.

Calibration of large commercial energy use

The calibration of large commercial was combined with small commercial since actual commercial demands were not disaggregated. Refer to Section 1.3.1.2 for calibration factors.

1.3.1.5 Transport

As shown in Table 6, the transport sector is divided into On-Road, Non-Road and Off-Road transport, with the energy and emissions calculations described below.

On-road transport

A bottom-up estimate of fuel demands was made for on-road transport. The inventory includes on-road transport energy data for the years 2010 to 2017. The on-road vehicle classes shown in Table 6 are further disaggregated by vehicle type and fuel (see Table 13).

Table 13: On-road transport vehicle types and fuels

Vehicle Class	Vehicle Type*	Fuel*
- Cars - Light passenger trucks - Light commercial trucks - Medium trucks - Heavy duty single unit trucks - Heavy duty combination trucks - Private Buses - Public Buses - Motorcycles	Gasoline	Gasoline
		Ethanol
	Flex	Gasoline
		Ethanol
	Electric Battery	Electricity
	Electric Plug In	Electricity
		Gasoline
	Propane	Propane
	Diesel	Diesel
	Compressed Natural Gas	Compressed Natural Gas

*Note: the same vehicle types and fuels are repeated for each vehicle class

The following equation is used to determine the energy consumed by each vehicle class:

$$\mathit{Fuel\ Consumption}_{\text{Class, Type, Fuel}} = \\ \#\ \text{of}\ \mathit{Vehicles}_{\text{class}} \times \mathit{VehicleMiles}_{\text{class}} \times \%\text{type}_{\text{class, type}} \times (1/FE_{\text{class, type}}) \times \%\text{fuel}_{\text{class,type, fuel}}$$

Where:

- **Fuel Consumption**$_{\text{class, type, fuel}}$ = Total amount of fuel used in gallons
- **#Vehicles**$_{\text{class}}$ = Number of registered vehicles for each vehicle class is from the New York Department of Transportation (NY DOT), except for public buses which is from the Federal Transit Administration's (FTA's) National Transit Database (NTD) (2022).
- **VehicleMiles**$_{\text{class}}$ = Total community-wide miles travelled summed across a vehicle class using traffic data from the U.S. Department of Transportation (US DOT) and NY DOT, except the data for public buses is from the FTA's NTD (2022).
- **%type**$_{\text{class,type}}$ = Fraction of vehicle class made up by the specific vehicle type (%) from the NY DOT.
- **FE**$_{\text{class, type}}$ = Fuel economy for the specific vehicle type expressed in miles/gallon from the U.S. Environmental Protection Agency (EPA) and the US DOT.
- **%fuel**$_{\text{class,type,fuel}}$ = Fraction of fuel share by vehicle type (%). Electric plug-in vehicles are separated into electric and gasoline portion. It is assumed that PHEV's run on electricity 55% of the time. Also, according to the NY GHG Guidance document, all conventional gasoline is assumed to be a 10% blend of ethanol, and carbon emissions associated with ethanol are considered biogenic.

A detailed report from Orebed Analytics in **Appendix C** includes the data sources and calculations used for determining the number of vehicles, vehicle miles travelled, fuel economy and percent share of vehicle types and fuels used. This report provided data for all bus types together, therefore adjustments were made to separate out private and public buses. The total number of buses from Orebed Analytics' report was subtracted by the number of public buses reported by the FTA's National Transit Database to determine the number of private buses. The same was done for vehicle miles.

Non-road transport

As shown in Table 6, the non-road sector includes rail, airport, and marine transport. In the model, non-road transport is further disaggregated, as shown in the following table.

Table 14: Detailed non-road transport included in LEAP model

Subsector	Type	Subtype (fuel)
Rail	Locomotive	Class I line haul (diesel)
		Class II and III line haul (diesel)
		Amtrak passenger (diesel)
	Railroad maintenance	Railway maintenance (four-stroke gasoline)
		Railway maintenance (diesel)
		Railway maintenance (LPG)
Airport	Operational	Support equipment (four-stroke gasoline)
		Support equipment (diesel)
		Support equipment (LPG)
	Aircraft Landing/Takeoff	Commercial (jet kerosene)
		Air Taxi Piston (aviation gasoline)
		Air Taxi Turbine (jet kerosene)
		General Aviation Piston (aviation gasoline)
		General Aviation Turbine (jet kerosene)
		Military (jet kerosene)
Marine	Pleasurecraft	Outboard (diesel)
		Inboard Sterndrive (diesel)
		Inboard Sterndrive (four stroke gasoline)
		Personal Water Craft (two stroke gasoline)
		Outboard (two stroke)
	Commercial Marine Vessels	C1C2 Port Emissions Main Engine (diesel)
		C1C2 Port Emissions Auxiliary Engine (diesel)
		C1C2 Underway Emissions Main Engine (diesel)
		C1C2 Underway Emissions Auxiliary Engine (diesel)
		C3 Underway Main Engine (diesel)
		C3 Underway Auxiliary Engine (diesel)

Rail

Rail is disaggregated into two sectors: locomotives and railroad maintenance. Locomotives are further divided into three categories: Class I line haul, Class II/III line haul and Amtrak, all which use diesel to run. Data was obtained for the years 2002 and 2017. The 2002 data was taken from NYSERDA's 2002 Locomotive Survey for New York State (NYSERDA 2007) which reports fuel consumption by county for Class I locomotives and Amtrak trains, and emissions data and emissions factors for Class II and III locomotives. The quantity of energy consumed by Class I and III locomotives was estimated by dividing their total emissions by the emissions factor for nitrogen oxides[11].

The 2017 fuel consumption data for locomotives was back calculated from the emissions and emission factors reported for non-point sources in the US EPA's 2017 National Emissions Inventory (US EPA 2019b; US EPA 2020b)[12].

Airport

Airport emissions are associated with operating the airport and aircraft landing and takeoff (Scope 1 emissions). Emissions related to airplane travel (cruise emissions) has not been incorporated at the time of writing the report. The U.S. Bureau of Transportation Statistics appears to have annual air carrier statistics with mileage on flights originating in the Genesee-Finger Lakes region. However, additional carrier information would be needed to know the type of aircraft, fuel and fust combustion intensity.

Fuel consumption and emission factors for airport operations were obtained from the US EPA's MOVES3 model for non-road sources (US EPA 2021) for the years 1990 through 2050. Data was extracted across 5-year intervals. MOVES3 reports three different fuels consumed for airport support equipment including gasoline, diesel and LPG. The emissions factor changes slightly year to year.

The aircraft landing and take-off (LTO) cycle is the basis for calculating aircraft emissions around airports. Shown in Figure 4, the LTO cycle consists of all activities near the airport that occur below the altitude of 3,000 ft (1,000 m) including taxi-in and out, take-off, and landing. Cruise consists of the activities that occur above 3,000 ft (1,000 m) including the climb to cruise altitude, cruise, and descent from cruise altitudes. Cruise emissions are currently not included in the emissions inventory.

[11] Fuel consumption was estimated by dividing the total emissions by the emissions factor for nitrogen oxides. An emissions factor for another pollutant could also have been used and would have given the same result.
[12] See footnote 6

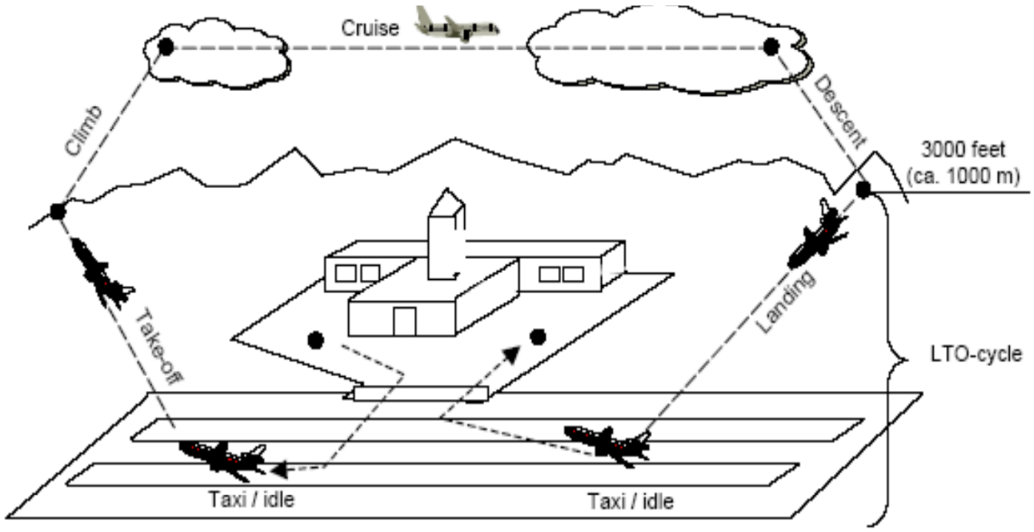

Figure 4: Aircraft landing and take-off cycle (Figure taken from: US EPA 2020)

Fuel consumption related to aircraft operations is calculated by multiplying the number of LTO cycles by the kilograms of fuel use per LTO (Total fuel use = LTO cycles x fuel use kg/LTO). The number of LTOs per aircraft type comes from the LTO database in US EPA's 2017 National Emissions Inventory (US EPA 2019a). Since this database only has data for 2017, the Federal Aviation Authority's Terminal Area Forecast was used to fill in the data between 2000 to 2045 by calculating the itinerant operations relative to 2017, and then multiplying this relative value to the 2017 LTO data to get the LTO data for all other years.

The energy intensity of 850 kg/LTO is based on the fuel use for an average domestic fleet per Table 2 in the IPCC Greenhouse Gas Inventory Reference Manual for Aircraft Emissions (IPCC 2001).[13] For this analysis, the energy intensity was assumed to only apply to commercial aviation. All other aircraft types were assumed to be a fraction of the commercial aviation fuel burn per hour data.[14] First, the weighted average fuel burn per hour for commercial aircraft was calculated to be 958 gal/hr based on fuel burn and block hour data in Tables 3-5, 3-6, 3-7, 3-8 of FAA's 2021 report on Economic Values for Evaluation of FAA Investment and Regulatory Decisions (FAA 2021). In comparison, Table 3-8 of the FAA report lists the average fuel burn of a piston engine at 45 gal/hr and a turbine engine at 71 gal/hr based on a turbopprop engine under 20 seats (FAA 2021). In the absence of better data, the average fuel burn of military

[13] This is a very conservative estimate of energy intensity as it assumes that fuel consumption per LTO has remained the same since 2001 (i.e., the date of the IPCC report).

[14] This assumes that the ratio of LTO fuel consumption to cruise fuel consumption is constant across all aircraft engine classes.

aircraft is assumed to be the same as commercial aircraft. The resulting energy intensity for each aircraft type is shown in the following table:

Table 15: Aircraft Energy Intensity

Aircraft type	Energy Intensity in kg/LTO
Commercial	850
Air Taxi Piston	850 x (45/958)
Air Taxi Turbine	850 x (71/958)
General Aviation Piston	850 x (45/958)
General Aviation Turbine	850 x (71/958)
Military	850

Marine

Marine includes pleasurecraft and commercial marine vessels.

Similar to railroad maintenance, fuel consumption for pleasurecraft were obtained from the US EPA's MOVES3 model for non-road sources (US EPA 2021) for the years 1990 through 2050. MOVES3 reports the following types of pleasurecraft:

- Outboard (two-stroke gasoline and diesel)
- Inboard sterndrive (four-stroke gasoline and diesel)
- Personal watercraft (two-stroke gasoline)

Data was extracted from MOVES3 across 5-year intervals. The 2017 fuel consumption data for commercial marine vessels was back calculated from the total emissions and emissions factors reported for non-point sources in the US EPA's 2017 National Emissions Inventory (US EPA 2020c; US EPA 2020b)[15]. The NEI reports the following commercial marine vessels:

- Category 1 (< 7 L/cyl) and Cateory 2 (7 to 30 L/cyl) Port Emissions Main Engine
- Category 1 (< 7 L/cyl) and Cateory 2 (7 to 30 L/cyl) Port Emissions Auxiliary Engine
- Category 1 (< 7 L/cyl) and Cateory 2 (7 to 30 L/cyl) Underway Emissions Main Engine
- Category 1 (< 7 L/cyl) and Cateory 2 (7 to 30 L/cyl) Underway Emissions Auxiliary Engine
- Category 3 (≥ 30 L/cyl) Underway Emissions Main Engine
- Category 3 (≥ 30 L/cyl) Underway Emissions Auxiliary Engine

All C1/C2/C3 vessels are assumed to be Tier 0 (made before 2004).

Off-road transport

[15] See footnote 6

According to the NY GHG Guidance document, off-road transport includes “agricultural machinery, construction and maintenance vehicles, lawn and garden equipment, and other equipment that uses transportation fuels but do not operate on roads”. Any fuels purchased within the agricultural and industrial (construction, mining and manufacturing) sectors have already been included in the agricultural and industrial sector emissions. The off-road transport sector in the model includes recreational vehicles such as:

- All terrain vehicles (two-stroke and four-stroke gasoline)
- Off-road motorcycles (two-stroke and four-stroke gasoline)
- Specialty vehicle carts (two-stroke and four-stroke gasoline, diesel, LPG)
- Snowmobiles (two-stroke gasoline)
- Golf carts (four-stroke golf carts)

Energy consumption was estimated by dividing the total emissions by the emissions factor obtained from the US EPA’s MOVES3 model (US EPA 2021c) for the years 1990 through 2050. Data was extracted across 5-year intervals. The emissions factor changes slightly year to year.

Calibration of transport energy demands

NYSERDA’s Patterns and Trends report (NYSERDA 2021b) provides data on gasoline sales for the years 1995 to 2017 for each county and is used to calibrate transport demands using the calibration factors given in Table 16. Usage data for other transport fuels was not readily available.

Table 16: Transport gasoline calibration factors by county

County	2010	2011	2012	2013	2014	2015	2016	2017
Monroe	1.15	1.14	1.12	1.13	1.14	1.13	1.14	1.16
Genesee	1.36	1.30	1.29	1.33	1.46	1.46	1.42	1.49
Seneca	1.08	1.57	1.54	1.38	1.44	1.53	1.77	1.80
Yates	0.93	0.92	0.90	0.90	0.96	0.94	0.91	0.97
Wyoming	1.18	1.14	1.16	1.18	1.24	1.23	1.20	1.22
Wayne	1.11	1.12	1.13	1.16	1.27	1.26	1.25	1.29
Orleans	0.95	0.95	0.96	0.96	1.05	1.04	0.98	1.04
Livingston	1.26	1.30	1.32	1.32	1.41	1.35	1.30	1.32
Ontario	1.10	1.11	1.11	1.08	1.12	1.09	1.08	1.20

1.3.1.6 Solid Waste (Landfills) and Wastewater

All energy-related solid waste and wastewater treatment plant emissions and fuel consumption data for 2010 to 2019 was obtained from the US EPA’s Facility Level Information on

GreenHouse Gases Tool (FLIGHT)[16]. All large landfills in the region have landfill gas recovery systems. The recovered landfill gas is either flared or used to generate electricity through international combustion engines. The Seneca Meadows Landfill Gas to Energy (LFGTE) facility also converts landfill gas to renewable natural gas (RNG). The RNG is purchased by the Sacramento Municipal District.

For the High Acres Landfill and Recycling Center, landfill gas emissions in the inventory do not match up exactly with what was reported due to changes in higher heating values between equipment and across years. Also, landfill gas appears to be called biogas in the years before 2012.

Table 17: Comparison of landfill capacity between Genesee-Finger Lakes region and state-wide (large landfills only)

Facility Name	County	2018 Waste Quantity (tons)	Existing Annual Permit Limits (tons/year)	Existing & Planned Capacity Under Permit (tons)	Proposed Capacity Not Under Permit (tons)
High Acres West. Exp. LF	Monroe	938,719	1,074,500	41,777,500	
Mill Seat SLF	Monroe	572,948	598,650	29,124,000	
Ontario County SLF	Ontario	914,393	920,693	6,679,796	
Seneca Meadows LF	Seneca	2,163,293	2,190,000	10,589,393	
Total in Genesee-Finger Lakes		4,589,353	4,783,843	88,170,689	
Total across New York State		**9,579,688**	**11,196,833**	**213,371,486**	**4,794,000**

Source: (NY DEC 2019)

1.3.1.7 Transmission and Distribution Losses

An electricity loss rate for New York was determined using data from the US EIA State Electricity Profiles[17]. Table 10. Supply and disposition of electricity, 1990 through 2019. It was calculated by dividing estimated losses by total electric industry retail sales for the years 1990 through 2019. The electricity loss rate was found to decline over time, from 9.7% in 1990 to 8.2% in 2010 and 6.8% in 2019.

1.3.1.8 Fugitive Emissions

A natural gas loss rate of 3.6% is taken from a recent study by Howarth (2020) on methane emissions in New York. The loss rate represents methane losses from the production, gathering, processing, transmission, and storage of natural gas.

[16] US EPA Flight tool available at https://ghgdata.epa.gov/ghgp/main.do

[17] US EIA State Electricity Profiles: New York (https://www.eia.gov/electricity/state/NewYork/)

1.3.2 Historical non-energy related emissions

Non-energy emissions are broken down in the model by economic sector, subsector and emissions. The level of detail in each sector depends on the data available to the project team. Table 18 lists the sectors and subsectors represented in the non-energy inventory.

Table 18: Non-energy Sectors and Subsectors

Sector	Subsector Level 1	Subsector Level 2
Industrial Processes	Cement Production	
	Limestone and Dolomite Consumption	
	Soda Ash Consumption	
	Ozone Depleting Substances (ODS) Substitutes	
	Iron and Steel Production	Blast Oven Furnace with coke oven
		Blast Oven Furnace w/o coke oven
		Electric Arc Furnace
	Semiconductor	
	Electricity Generation	
	Urea Consumption	
Agricultural	Enteric Fermentation	Dairy Cows
		Beef Cows
		Calves
		Goat
		Sheep
		Swine
		Llama
	Manure Management	Dairy Cows
		Beef Cows
		Calves
		Goat
		Sheep
		Swine
		Llama
		Layers
		Pullets
		Broilers
		Roosters
	Soil Animals	*Same as Manure Management*
	Soil Animal Runoff and Leaching	*Same as Manure Management*
	Soil Plant Residues	Alfalfa
		Corn for Grain
		All Wheat
		Barley
		Sorghum for Grain
		Oats
		Rye
		Soybeans
		Dry Edible Beans
		Dry Edible Peas
		Red Clover

Sector	Subsector Level 1	Subsector Level 2
		Crimson Clover
	Soils Plant Residue Burning	Corn for Grain
		All Wheat
		Barley
		Soybeans
	Soils Liming and Urea Fertilization	Limestone Use
		Dolomite Use
		Urea Fertilizer
	Soil Plant Fertilizers	Synthetic
		Dried Blood
		Compost
		Dried Manure
		Activated Sewage Sludge
		Other Sewage Sludge
		Tankage
		Other
	Soils Plant Fertilizers Runoff and Leaching	*Same as Soil Plant Fertilizers*
Solid Waste		
Wastewater		
Land Use Sequestration	Harvested Wood Products	
	Forest Remaining Forest	
	Land Converted to Forest	
	Wetland	
	Urban Trees	
Land Use Emissions	Forest Converted to Land	
	Forest Fires	

The following sections provides the data sources used to calculate non energy-related emissions in each sector.

1.3.2.1 Industrial

Industrial non-energy emissions were calculated using the methodology set forth in the US EPA's State Inventory and Projection Tool (SIT) Industrial Processes Module (US EPA 2017). Full details are provided in Table 19.

Table 19: Data sources and emissions factors for the industrial non-energy emissions calculations

SIT Industrial Processes Module	Occurs in region?	Emissions calculation methodology	Emissions Factor from SIT
Cement production	Yes	State cement clinker production data from SIT (REF) allocated to each county based on the number of employees employed in the sector according to the Census (NAICS 3273)[1]. Clinker production multiplied by emissions factor. Cement kiln dust emissions	Clinker = 0.507 MtCO2 Emitted / Mt of Clinker Produced Cement Kiln Dust = 0.020 MT CKD CO2 Emitted / MT of Clinker CO2 Emitted

SIT Industrial Processes Module	Occurs in region?	Emissions calculation methodology	Emissions Factor from SIT
		calculated based on clinker emissions.	
Lime manufacture	No	-	
Limestone and dolomite consumption	Yes	State limestone and dolomite combined usage and production data from SIT (REF) separated using US-level usage to production ratio (US EPA 2017). The resulting state-wide usage data was allocated to each county based on number of employees employed in the sectors that use limestone, including iron and steel mills (NAICS 331110) and glass manufacturing (NAICS 32721)[1,2]. The usage data is multiplied by the emissions factor.	Limestone = 0.440 MT CO2 Emitted / MT Limestone used (Calcite) Dolomite = 0.484 MT CO2 Emitted / MT Limestone used (Dolomite)
Soda ash manufacture and consumption	Yes	Soda ash consumption for the U.S. taken from the SIT (US EPA 2017) and allocated to each county based on population (US EPA 2017; NYSERDA 2021b; Vespa et al. 2020). The usage data is multiplied by the emissions factor.	Soda ash consumption = 0.415 MT CO2 Emitted / MT Soda Ash consumed
Iron and steel production	Yes	State-wide raw steel production (US EPA 2017) allocated to each county based on total energy use in the sector (NAICS 331110) (McMillan 2019). Data was disaggregated into production method using the ratios provided in the SIT. The production data by method is multiplied by the emissions factor.	BOF with Coke Oven = 1.72 MT CO2 Emitted / MT Crude Steel Produced BOF without Coke Oven = 1.46 MT CO2 Emitted / MT Crude Steel Produced EAF = 0.08 MT CO2 Emitted / MT Crude Steel Produced
Ammonia manufacture	No	-	-
Nitric acid production	No	-	-
Adipic acid production	No	-	-
Aluminum production	No	-	-

SIT Industrial Processes Module	Occurs in region?	Emissions calculation methodology	Emissions Factor from SIT
HCFC-22 production	Unsure	-	-
Consumption of Substitutes for Ozone Depleting Substances (ODS)	Yes	Emissions from ODS substitutes for the U.S. taken from the SIT (US EPA 2017) and allocated to each county based on population (US EPA 2017; NYSERDA 2021b; Vespa et al. 2020).	n/a – downscaled emissions
Semiconductor manufacture	Yes	State-wide emissions for semiconductor manufacturing (US EPA 2017) allocated to each county based on total energy use in the sector (NAICS 334413) (McMillan 2019).	n/a – downscaled emissions
Electric Power Transmission and Distribution	Yes	SF6 consumption from electricity for the U.S. taken from the SIT (US EPA 2017) and allocated to each county based on county electricity sales/use (NYSERDA 2017; US EPA 2017). The usage data is multiplied by the emissions factor.	Electric Power = 1.0 MT SF6 Emitted / MT SF6 Consumed (Sold)
Magnesium Production and Processing	No	-	-

[1] Employment data obtained from U.S. Census County Business Patterns dataset (US Census Bureau n.d.)
[2] Other industries that use limestone / dolomite that do not exist in the region include coal mining (NAICS 2121), soda ash manufacturing (NAICS 325181) and sugar refining (31131)

1.3.2.2 Agricultural

Agricultural non-energy emissions were calculated using the methodology set forth in the US EPA's State Inventory and Projection Tool (SIT) Agricultural Module (US EPA 2017). Full details are provided in Table 20. The equations and variables used to calculate emissions are provided in **Appendix B**.

Table 20: Data sources and emissions factors for the agricultural non-energy emissions calculations

SIT Agricultural Non-Energy Module	Occurs in region?	Emissions calculation methodology	Emissions Factors
Enteric Fermentation	Yes	These are the emissions from the digestive processes of animals. The number of livestock heads for each county was obtained from USDA's National Agricultural Statistics	Emision factors in kg CH_4/head Dairy Cows = 160.2 Beef Cows = 94.3

SIT Agricultural Non-Energy Module	Occurs in region?	Emissions calculation methodology	Emissions Factors
		Service (USDA 2021). This was multiplied with an emissions factor to obtain methane emissions.	Calves[1] = 54.1 Goat = 5 Sheep = 8 Swine = 1.5 Llama[2] = 8
Manure Management (methane emissions)	Yes	These are the methane emissions from managing manure. It is calculated by multiplying the amount of volatile solids produced from each animal by an emissions factor.	See Table 36: Variables used to calculate methane emissions from manure management (2018 values from US EPA State Inventory Tool)
Manure Management	Yes	These are the nitrous oxide emissions from managing manure. It is calculated by multiplying the amount of nitrogen excreted from each animal by an emissions factor.	E1, Emissions factor for anaerobic lagoons and liquid systems = 0.001 kg N2O-N/kg N E2, Emissions factor for solid storage, drylot, and other systems = 0.02 kg N2O-N/kg N
Soil Animals	Yes	These are the nitrous oxide emissions from manure on agricultural soils. It is calculated by multiplying the amount of nitrogen excreted from each animal by an emissions factor.	E3, Emissions factor for indirect volatilization to NH3 and NOx = 0.01 kg N2O N/kg N E4, Emissions factor for Ag Soils Animal Pasture = 0.02 kg N2O / kg N E5, Emissions factor for Ag Soils Animal Ground = 0.0125 kg N2O / kg N
Soil Animal Runoff and Leaching	Yes	These are the nitrous oxide emissions from runoff and leaching from livestock onto agricultural soils. It is calculated by multiplying the amount of nitrogen excreted from each animal by an emissions factor.	E6, Emission factor for Ag Soils Leaching = 0.0075 kg N2O N/kg N
Soil Plant Residues, Legumes and Histosols	Yes	These are the nitrous oxide emissions from from crop residues, and the cultivation of nitrogen-fixing crops and histosols (highly organic soils). It is calculated by	E7, emission factor for crop residues = 0.01 kg N2O N/kg N

SIT Agricultural Non-Energy Module	Occurs in region?	Emissions calculation methodology	Emissions Factors
		multiplying the amount of nitrogen in residue by an emissions factor.	
Soil Plant Residue Burning	Yes	These are the nitrous oxide and methane emissions from burning crop residues. It is calculated by multiplying the nitrogen or methane content in the burnt residue by an emissions factor.	E9, Ag Soils Burning N2O to N Emissions Ratio = 0.007 N_2O/N E10, Ag Soils Burning CH4 to C Emissions ratio = 16/12 CH_4/C
Soil Plant Fertilizers	Yes	These are the nitrous oxide emissions from the application of fertilizers. It is calculated by multiplying the volatilization rate of fertilizer by an emissions factor.	E11, Emission factor for Ag Soils Plant Direct = 0.01 kg N2O N/kg N E12, Emission factor for Ag Soils Plant Indirect = 0.01 kg N2O N/kg N
Soils Plant Fertilizers Runoff and Leaching	Yes	These are the nitrous oxide emissions from the from runoff and leaching of fertilizer in agricultural soils. It is calculated by multiplying the volatilization of fertilizer in consumed fertilizer by an emissions factor.	E6, Emission factor for Ag Soils Leaching = 0.0075 kg N2O N/kg N
Soils Liming and Urea Fertilization	Yes	These are the carbon dioxide emissions from the application of limestone and dolomite for the liming of soils and for the use of urea as fertilizer. The emissions are calculated by multiplying the application of limestone/ dolomite/urea fertilizer by an emissions factor.	EF, limestone = 0.059 tons C/tons limestone applied EF, dolomite = 0.064 tons C/tons dolomite applied EF, urea fertilizer = 0.2 tons C/tons urea fertilizer applied
Rice cultivation	No	-	
Liming	No	-	

[1] Value is average of Beef and cattle replacements 0-12 mos

[2] Assumed to be the same as sheep

1.3.2.3 Solid Waste (Landfills)

The level of methane emissions generated from landfills less the methane recovered by recovery systems between 2010 to 2019 was obtained from the US EPA's Facility Level Information on GreenHouse Gases Tool (FLIGHT)[18].

1.3.2.4 Wastewater treatment

Non-energy emissions from wastewater treatment are divided into municipal wastewater treatment plants and septic systems. The fraction of the population using septic systems was obtained from the American Housing Survey (US Census Bureau 2019). Rochester was the only city in the Genesee-Finger Lakes region with data on the share of housing units using septic systems of 18.6%.

For the population connected to municipal wastewater treatment systems, wastewater non-energy emissions were calculated using the methodology set forth in the US EPA's State Inventory and Projection Tool (SIT) Wastewater Module (US EPA 2017).

Methane emissions from septic systems were calculated using the approach taken in the NY GHG Inventory (NYDEC 2022a) whereby a default emission factor of 10.7 g CH_4 per person per day from Leverenz et al. (2010) was applied.

1.3.2.5 Land Use

The main categories of land use emissions are harvested wood products and forest ecosystems. Per Table 18, in our model, the land use sector is divided into Land Use Emissions (positive emissions) and Land Use Sequestration (negative emissions) but are reported together in the results section. To estimate land use emissions (both positive and negative) for the counties in the Genesee-Finger Lakes region, emissions were downscaled from the state level results as reported in the NY GHG Inventory's Waste Sector Report (NYDEC 2022a). The various land use categories and approach used for downscaling are described as follows:

Land use that sequesters carbon:

- **Harvested wood products (HWPs)** are wood-based materials harvested from forests and continue to sequester carbon through products like plywood, paper or wood for fuel and can be used to build houses or furniture. HWP emissions were downscaled based on the sawmill capacity in each county compared to the state's sawmill capacity using data reported by the NY Department of Conservation (NYDEC 2017).
- **Forest Remaining Forest (FRF)** emissions considers the changes in carbon stock and emissions of non-CO_2 gases from five carbon pools including aboveground biomass,

[18] US EPA GHG FLIGHT tool available at https://ghgdata.epa.gov/ghgp/main.do

belowground biomass, dead wood, litter, and soil organic matter (IPCC 2003) . The total FRF emissions across all pools were downscaled based on the amount of forest area in each county compared to the state using GIS data from the 2019 National Land Cover Dataset (MRLC 2022b). This includes deciduous, evergreen and mixed forests.

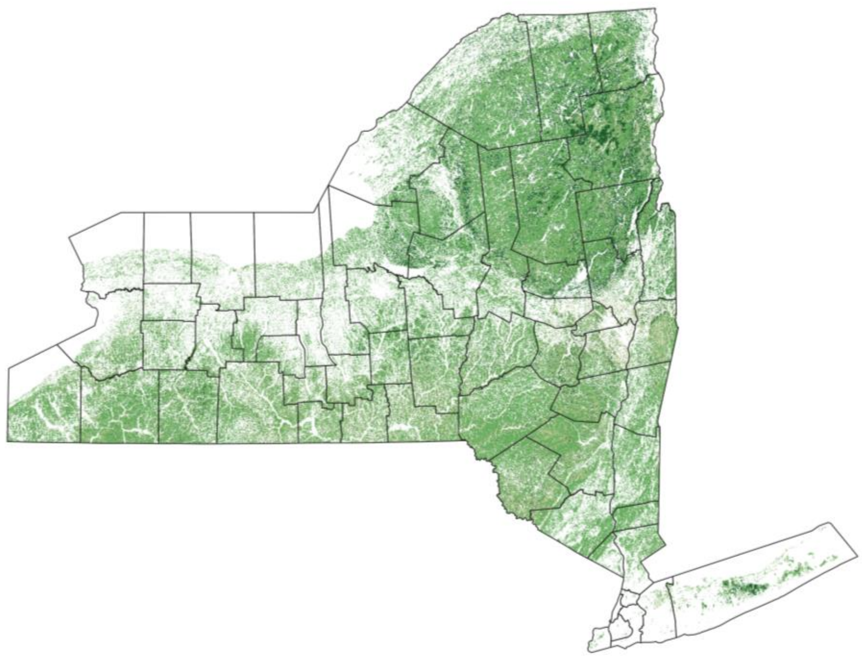

Figure 5: Deciduous, Coniferous and Mixed Forests in New York (Source: 2019 National Land Cover Dataset)

- **Land Converted to Forest (LCF)** emissions considers the sequestration of carbon through the conversion of managed lands (i.e., cropland, settlements, wetlands, other lands) to forests by afforestation and reforestation. The LCF emissions across all pools were downscaled based on the amount of land use change in each county compared to the state using GIS data from the 2019 National Land Cover Change Index Dataset (MRLC 2022a). This includes changes to/from any type of forest.

- **Urban trees** are located in settlements (developed areas) and are an important source of carbon sequestration. Emissions from urban trees were downscaled based on the amount of developed areas in each county compared to the state using GIS data from the 2019 National Land Cover Dataset (MRLC 2022b). This includes low-, medium- and high-intensity developed areas.

- **Wetlands**, particularly vegetated wetlands, are effective at sequestering carbon and storing it in plants and soils. Net emissions from wetlands were downscaled based on the wetland area in each county compared to the state using GIS data from the

2019 National Land Cover Dataset (MRLC 2022b). This includes woody wetlands and emergent herbaceous wetlands.

Land use that emits carbon:

- **Forest Converted to Land (FCL)** emissions considers the release of carbon through the conversion of forests to managed lands (i.e., cropland, settlements, wetlands, other lands) by deforestation. The FCL emissions across all pools were downscaled based on the amount of land use change in each county compared to the state using GIS data from the 2019 National Land Cover Change Index Dataset (MRLC 2022a). This includes changes to/from any type of forest.

- **Forest fires** result in the release of greenhouse gas emissions. Forest fire emissions were downscaled based on the amount of forest area in each county compared to the state using GIS data from the 2019 National Land Cover Dataset (MRLC 2022b). This includes deciduous, evergreen and mixed forests.

1.3.3 Projected emissions (baseline scenario)

Projections in the LEAP model are arranged into *scenarios*. A scenario is an internally consistent, physically plausible storyline that describes how the economy, energy system, pollutant emissions, and costs might evolve over time—in other words, a possible future. In LEAP, scenarios are developed in a hierarchy allowing each scenario to inherit assumptions from another scenario. In this way, a scenario can mirror a pre-existing scenario except for a few key parameters, isolating the effects of these changes.

The core scenario is the baseline scenario. The baseline scenario in this model extends to 2050, which is consistent with the end date specified for the state-wide emissions reduction targets per the CLCPA. It envisions a future in which no significant new mitigation policies are enacted and historical trends in key drivers of energy use and emissions continue. The other scenarios to be completed in Phase 2 of the project are mitigation scenarios, which inherit data from the baseline scenario and are measured in comparison to it. Two types of mitigation scenarios are considered: scenarios that add one discrete mitigation option to the baseline ("mitigation mini-scenarios") and scenarios that combine multiple mini-scenarios into a portfolio of mitigation options ("combined mitigation scenarios"). This arrangement facilitates the analysis of particular mitigation options in isolation, as well as their potential interactions with other options. The mitigation scenarios will be assessed in Phase 2.

In the model, projections of future energy and non-energy demands depend on forecasted activity levels of population, vehicle use, crop area, and other sector-dependent activities. Table 21 identifies the activity for sectors and subsectors where projected demands are calculated by activity analysis.

Table 21: Activity Levels in Final Energy and Non-Energy Emissions Projection

Sector/Subsector	Activity
Energy	
Residential	Population
Small/Large Commercial	n/a – projects historical energy use
Industrial	n/a – projects historical energy use
Agricultural	n/a – projects historical energy use
Transport – on-road	Number of vehicles & vehicle miles travelled
Transport – non-road	n/a – projects historical energy use
Transport – off-road	n/a – projects historical energy use
Solid Waste	n/a – projects historical energy use
Wastewater	n/a – projects historical energy use
Transmission Losses	Electricity Demands
Fugitive Emissions	Natural Gas Demands
Non-Energy	
Non-energy industrial processes	
Cement Production	Cement Production
Limestone/Dolomite	Limestone Consumption Dolomite Consumption
Soda Ash	Soda Ash Consumption
ODS Substitutes	n/a – projects historical emissions
Iron and Steel	Iron and Steel Production
Semiconductors	n/a – projects historical emissions
Electricity Generation	Electricity Generation
Urea Consumption	Urea Consumption
Non-energy agricultural processes	
Enteric Fermentation **Manure Management** **Soil Animals** **Soil Animal Runoff and Leaching**	Number of Livestock
Soils Plant Residues **Soils Plant Residue Burning**	Crop production
Soils Plant Fertilizer **Soil Plant Fertilizers Runoff and Leaching**	Fertilizer Consumption
Soils Liming and Urea Fertilization	Limestone use Dolomite use Urea fertilizer use
Non-energy waste processes	
Solid waste	n/a – projects historical emissions
Wastewater	Population
Land use processes	
Harvested wood products	n/a – projects historical emissions
Forest Remaining Forest	n/a – projects historical emissions
Land Converted to Forest	n/a – projects historical emissions
Forest Converted to Land	n/a – projects historical emissions
Forest fires	n/a – projects historical emissions
Urban Trees	n/a – projects historical emissions
Wetlands	n/a – projects historical emissions

Population projections are from the Cornell Program on Applied Demographics (2017). This projection does not include increased migration into the region from climate refugees. All other projections are estimated from historical growth rates. Growth rates were constrained to +1.75/-1.25% to avoid excessive positive or negative changes in emissions over time. These growth rate constraints are in-line with the average annual change in emissions across sectors.

Table 22: Population projections by county

County	2010	2020	2030	2040	2050[1]
Genesee	60,079	57,756	56,077	54,128	52,179
Livingston	65,393	64,054	63,726	63,954	64,182
Monroe	744,344	754,529	758,536	751,581	744,636
Ontario	107,931	111,349	114,374	114,770	115,166
Orleans	42,883	40,529	38,967	37,431	35,895
Seneca	35,251	34,724	34,487	33,850	33,213
Wayne	93,772	89,564	86,754	83,088	79,422
Wyoming	42,155	40,057	38,647	37,766	36,885
Yates	25,348	24,787	24,706	24,857	25,008
Total	**1,217,156**	**1,217,349**	**1,216,274**	**1,201,425**	**1,186,586**

Source: Cornell Program on Applied Demographics (2017)
[1] Estimated

Table 23: Household projections by county (estimates)

County	2010	2020	2030	2040	2050
Genesee	25,409	26,068	27,011	27,825	28,626
Livingston	26,774	28,084	29,919	32,154	34,555
Monroe	318,793	334,395	347,863	356,662	365,657
Ontario	47,290	51,879	56,665	60,464	64,517
Orleans	18,300	18,754	19,552	20,366	21,177
Seneca	15,810	16,821	18,045	19,131	20,274
Wayne	40,825	41,820	43,445	44,626	45,750
Wyoming	17,876	18,332	19,088	20,130	21,218
Yates	13,303	13,849	14,695	15,739	16,857
Total	**524,380**	**550,002**	**576,284**	**597,097**	**618,632**

The effects of climate change upon space heating and cooling demands in the residential and commercial sectors are incorporated into the baseline projection. Cooling and heating degree day data for Rochester, NY between 2010 and 2020 were taken from Oikolab[19]. The average annual change in cooling and heating degree days was calculated relative to 2015, the year of the U.S. EIA Residential Energy Consumption Survey and applied to the energy intensity of space heating and air conditioning technologies in the residential sector. For the commercial sector, since a top-down analysis of energy demands was used, we needed to first estimate space heating and air conditioning demands prior to adjusting the demands based on climate change. Space heating demands were estimated to be 2.2% of natural gas consumption and air conditioning demands 9.0% of electricity consumption based on NYSERDA's Commercial Baseline Study (NYSERDA 2019a).

2 Emissions inventory results and discussion

This section presents selected results from the emissions inventory and baseline scenario at the regional and county scales, and across different sectors, fuels and greenhouse gases. Additional results can be generated upon request.

The results are reported in gross and net emissions. In accordance with the CLCPA guidelines, gross emissions include biogenic CO_2. Net emissions consider net emissions removals from the land use sector and omits biogenic CO_2.

2.1 Regional emissions

Table 24 provides a detailed summary of regional emissions both historically and under baseline projections. Figure 6 to Figure 10 illustrates the region-wide emissions in different ways – type of emissions, sector, fuel, greenhouse gas and global warming potential.

The results show a slight reduction in gross emissions during the historical period from 29.9 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) in 2010 to 29.0 $MMtCO_2e$ in 2018. This decrease is from the decline in industry in the early 2010s as well as a shift to cleaner forms of electricity production. The baseline projection shows that emissions will increase to 30.9 $MMtCO_2e$ in 2050 from growth in the agricultural, industrial and commercial sectors.

Overall, historical emissions are largely from consuming energy rather than non-energy emissions. However, non-energy emissions from agricultural and industrial processes are still high making up 31% of the total emissions in 2018. Average net emissions removals from harvested wood products, land use change and forestry during the historical period are around -1.7 $MMtCO_2e$, or 5.7% of gross emissions. In the baseline projection, land use and forestry-

[19] https://climate-explorer.oikolab.com/climate-explorer

related activities will reduce emissions by -1.6 $MMtCO_2e$ on average, or by 5.2% of gross emissions.

Between the different sectors, transport-related emissions are the highest in the region at 33% of 2018 emissions, followed by agricultural emissions (22%) and residential emissions (16%). Solid waste emissions represent 11% of regional emissions due to the three large landfills that make up 41% of New York's existing and proposed landfill capacity (see Table 17 for details). Generally, a similar composition of sectoral emissions are shown in the baseline projection, with slight increases in agricultural, commercial and industrial emissions, and decreases in transport and residential emissions.

The availability, accessibility and use of alternative modes of transport, including electric vehicles, is low across the region keeping transport emissions high overall. Residential energy consumption continues to be driven by space heating, in particular natural gas-based heating systems. Agricultural emissions from energy consumption are low, but non-energy emissions, particularly from dairy farming, make up most of the emissions from this sector.

Among fuels, gasoline consumption in vehicles represents 35% of 2018 emissions. This is followed by natural gas use in the residential, commercial and industrial sectors resulting in 27% of 2018 emissions. Natural gas use appears to have jumped in 2018 compared to years prior in both the residential and commercial sectors. As discussed in Section 2.3.1, this appears to be one-time occurrence, and not part of a larger trend.

According to the 100-year global warming potentials, carbon dioxide is by far the biggest greenhouse gas emitted in the region compared to other greenhouse gases representing 72% of the share of emissions. When viewing the 20-year global warming potential, carbon dioxide emissions are reduced to 53% with methane making up a larger share of emissions (40%).

Table 24: Genesee-Finger Lakes Greenhouse Gas Emissions by Economic Sector (results in GWP20)

Sector	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total
Transportation	9.39	31%	9.57	33%	8.93	31%	8.67	28%
On-road	8.75	29%	8.95	31%	8.26	28%	7.91	26%
Non-road	0.62	2%	0.60	2%	0.65	2%	0.73	2%
Off-road	0.02	0%	0.02	0%	0.03	0%	0.03	0%
Agricultural	5.49	18%	6.34	22%	6.88	24%	8.16	26%
Energy Use	0.20	1%	0.31	1%	0.36	1%	0.49	2%
Livestock	4.90	16%	5.58	19%	5.97	20%	6.92	22%
Soil Management	0.39	1%	0.46	2%	0.54	2%	0.75	2%
Residential	4.67	16%	4.66	16%	4.58	16%	4.38	14%
Space Heating	3.21	11%	3.24	11%	3.12	11%	2.81	9%
Water Heating	0.70	2%	0.70	2%	0.73	3%	0.79	3%
Air Conditioning	0.07	0%	0.06	0%	0.07	0%	0.09	0%

Sector	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
Other Uses	0.68	2%	0.66	2%	0.65	2%	0.70	2%
Commercial	2.37	8%	2.60	9%	2.67	9%	3.01	10%
Large Commercial	2.00	7%	2.23	8%	2.29	8%	2.59	8%
Small Commercial	0.36	1%	0.37	1%	0.38	1%	0.42	1%
Industrial	3.62	12%	2.00	7%	2.16	7%	2.62	8%
Construction	0.27	1%	0.29	1%	0.32	1%	0.38	1%
Manufacturing	3.06	10%	1.45	5%	1.58	5%	1.97	6%
Mining	0.07	0%	0.07	0%	0.06	0%	0.05	0%
Processes	0.22	1%	0.20	1%	0.21	1%	0.22	1%
Waste	3.75	13%	3.22	11%	3.40	12%	3.42	11%
Solid Waste	3.16	11%	2.63	9%	2.80	10%	2.84	9%
Wastewater	0.59	2%	0.59	2%	0.60	2%	0.59	2%
Losses	0.62	2%	0.62	2%	0.61	2%	0.62	2%
Electricity T&D	0.19	1%	0.15	1%	0.12	0%	0.11	0%
Fugitive Emissions	0.43	1%	0.46	2%	0.48	2%	0.51	2%
Gross Emissions Total	**29.92**		**29.02**		**29.22**		**30.88**	
Net Emission Removal	-1.69		-1.64		-1.57		-1.48	
Biogenic CO_2	0.92		0.98		0.93		0.93	
Net Emissions Total	**27.31**		**26.40**		**26.72**		**28.47**	

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross Emissions includes biogenic CO_2.

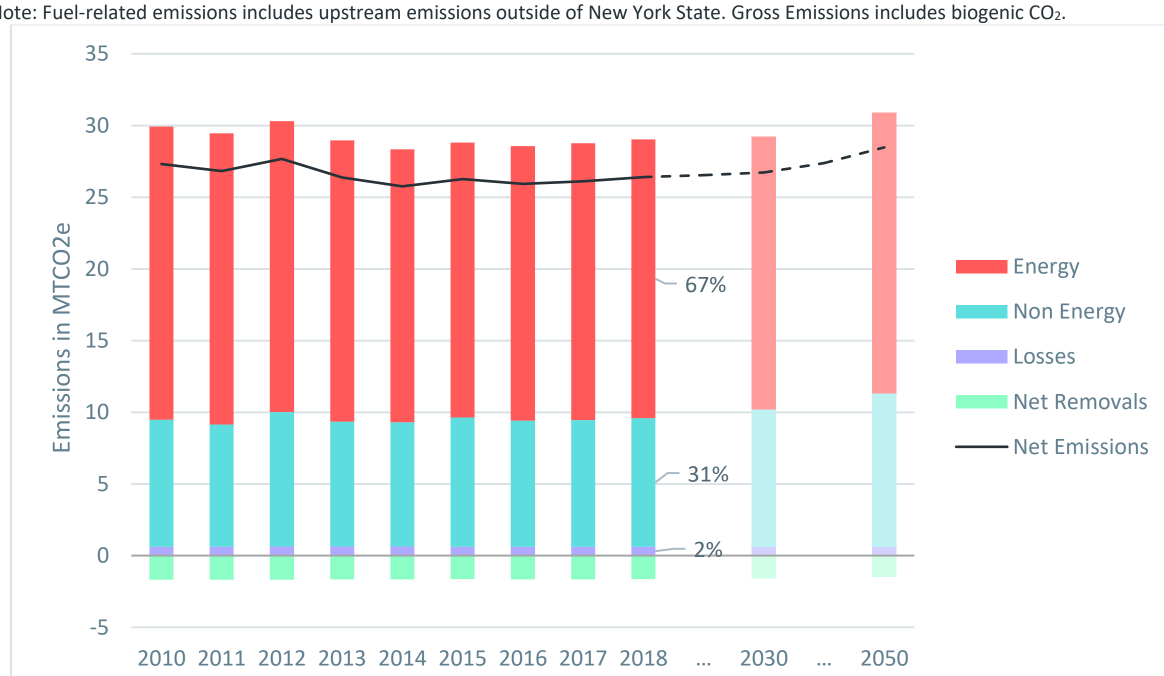

Figure 6: Historical and baseline emissions in the Genesee-Finger Lakes region by type of emissions (using 20-yr GWP)

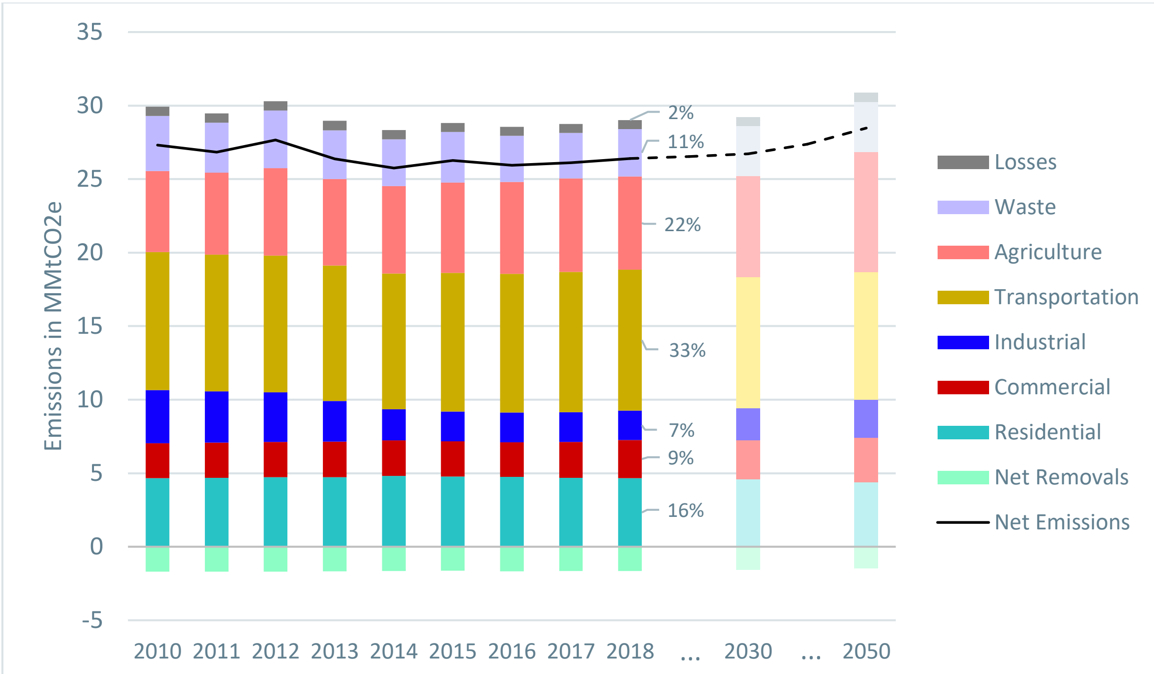

Figure 7: Historical and projected emissions in the Genesee-Finger Lakes region by sector (using 20-yr GWP)

Table 25: Genesee-Finger Lakes Greenhouse Gas Emissions by Fuel (results in GWP20)

Sector	**-Historical-**				**-Baseline Projection-**			
	2010		**2018**		**2030**		**2050**	
	MMtCO₂e	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**
Energy-related (Fuels)	21.06	70%	20.05	69%	19.62	67%	20.21	65%
Gasoline	6.99	23%	7.01	24%	6.14	21%	5.24	17%
Natural Gas	5.03	17%	5.42	19%	5.66	19%	5.98	19%
Diesel	2.49	8%	2.64	9%	2.95	10%	3.70	12%
Electricity	2.32	8%	2.18	8%	2.06	7%	2.27	7%
Coal Unspecified	1.67	6%	0.08	0%	0.09	0%	0.10	0%
Propane and LPG	0.80	3%	0.88	3%	0.90	3%	0.96	3%
Wood	0.47	2%	0.48	2%	0.45	2%	0.41	1%
Ethanol	0.35	1%	0.35	1%	0.30	1%	0.26	1%
Residual Fuel Oil and Kerosene	0.35	1%	0.33	1%	0.34	1%	0.36	1%
Other Fuel	0.58	2%	0.67	2%	0.75	3%	0.93	3%
Non Energy-related	8.86	30%	8.90	31%	9.60	33%	10.67	35%
Gross Emissions Total	**29.92**		**29.02**		**29.22**		**30.88**	
Net Emission Removal	-1.69		-1.64		-1.57		-1.48	
Biogenic CO_2	0.92		0.98		0.93		0.93	
Net Emissions Total	**27.31**		**26.40**		**26.72**		**28.47**	

Sector	-Historical-		-Baseline Projection-	
	2010	2018	2030	2050

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross Emissions includes biogenic CO_2.

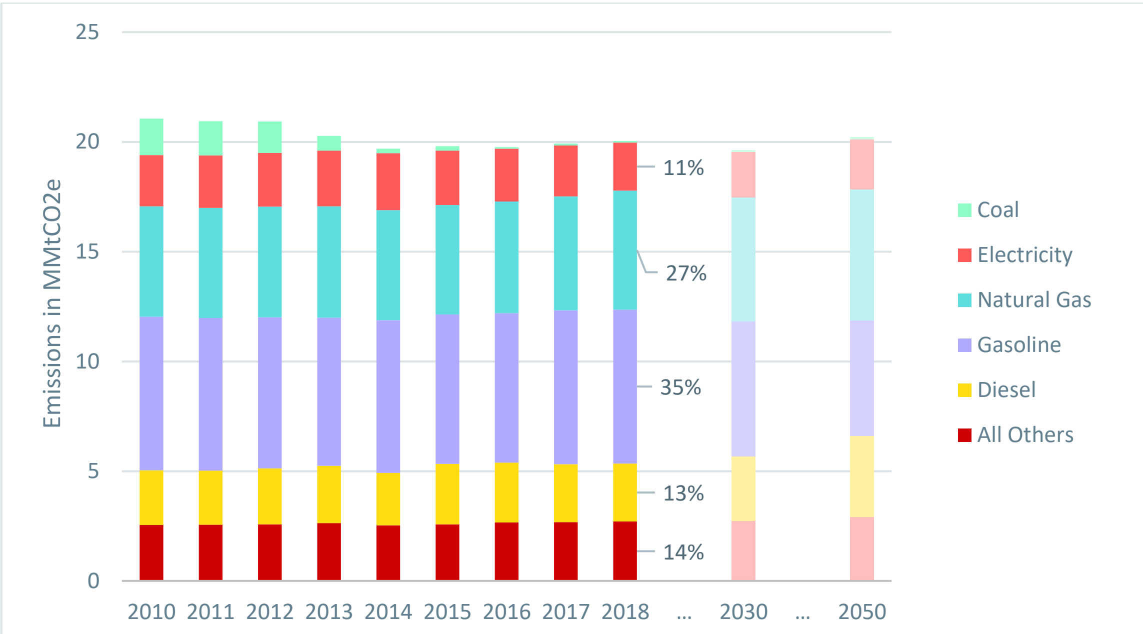

Figure 8: Historical and projected emissions in the Genesee-Finger Lakes region by fuel (using 20-yr GWP)

Table 26: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP20)

Sector	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	MMtCO₂e	% of total	MMtCO₂e	% of total	MMtCO₂e	% of total	MMtCO₂e	% of total
GHG	29.92	100%	29.02	100%	29.22	100%	30.88	100%
CO_2 biogenic	0.92	3%	0.98	3%	0.93	3%	0.93	3%
CO_2	16.30	54%	15.41	53%	15.05	52%	15.55	50%
CH_4	11.76	39%	11.59	40%	12.12	41%	13.05	42%
N_2O	0.93	3%	1.03	4%	1.12	4%	1.35	4%
Other	<0.01	0%	<0.01	0%	<0.01	0%	<0.01	0%
Gross Emissions Total	**29.92**		**29.02**		**29.22**		**30.88**	
Net CO_2 Removal	-1.69		-1.64		-1.57		-1.48	
CO_2 biogenic	0.92		0.98		0.93		0.93	
Net Emissions Total	**27.31**		**26.40**		**26.72**		**28.47**	

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross Emissions includes biogenic CO_2.

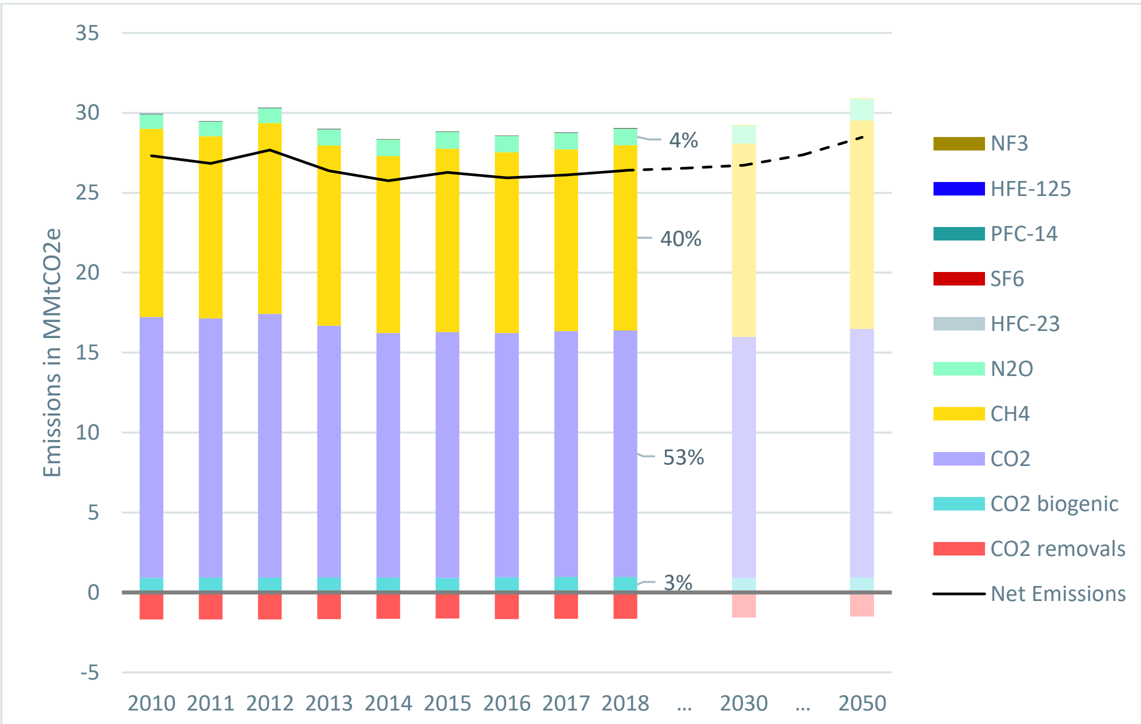

Figure 9: Historical and project emissions in the Genesee-Finger Lakes region by greenhouse gas (using 20-yr GWP)

Table 27: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP100)

Sector	**-Historical-**				**-Baseline Projection-**			
	2010		**2018**		**2030**		**2050**	
	MMtCO₂e	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**
GHG	22.32	100%	21.53	100%	21.39	100%	22.45	100%
CO_2 biogenic	0.92	4%	0.98	5%	0.93	4%	0.93	4%
CO_2	16.31	73%	15.42	72%	15.06	70%	15.56	69%
CH_4	4.15	19%	4.09	19%	4.28	20%	4.60	21%
N_2O	0.93	4%	1.04	5%	1.12	5%	1.35	6%
Other	<0.01	0%	<0.01	0%	<0.01	0%	<0.01	0%
Gross Emissions Total	**22.32**		**21.53**		**21.39**		**22.45**	
Net CO_2 Removal	-1.70		-1.65		-1.58		-1.48	
CO_2 biogenic	0.92		0.98		0.93		0.93	
Net Emissions Total	**19.70**		**18.90**		**18.89**		**20.04**	

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross Emissions includes biogenic CO_2.

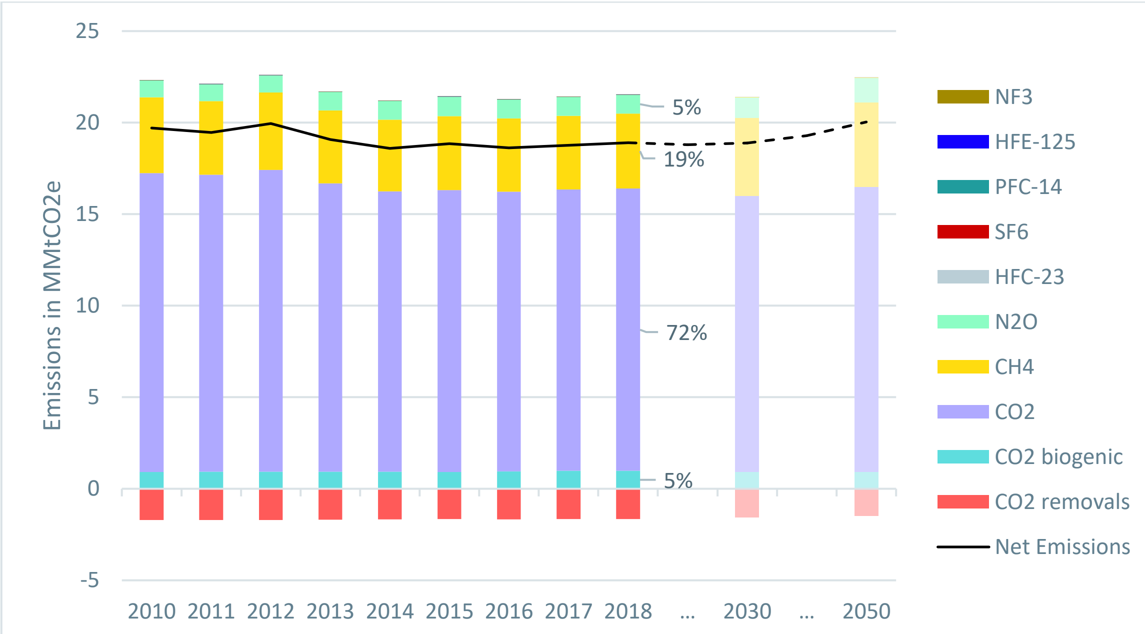

Figure 10: Historical and project emissions in the Genesee-Finger Lakes region by greenhouse gas (using 100-yr GWP)

2.1.1 Comparison to the 2013 Finger Lakes Sustainability Plan

It is important to highlight that there is slight difference in the results of the emissions inventory presented in the 2013 Finger Lakes Sustainability Plan. The 2010 emissions in the previous plan was 16.1 $MMtCO_2e$ which is slightly lower than the 17.7 $MMtCO_2e$ calculated in the current inventory when using 100-yr GWP, omitting land-use, import emissions and biogenic CO_2. There are also differences between counties and sectors. The differences between the two inventories are attributed to variations in the approach and emission factors.

2.1.2 The scale of emissions compared to other states and countries

Table 28 compares the emissions in the Genesee-Finger Lakes region to other states and countries. For comparison purposes, we use 100-yr GWP which is typically used by other countries and states for reporting emissions estimates. The comparison finds that the region's emissions are similar to states with similar population sizes, such as Rhode Island and Delaware. However, it is producing the same level of emissions as countries like Costa Rica and Benin which have significantly larger populations. Given that the remaining carbon budget is quickly diminishing, it is necessary for the region, and high-income countries in general, to take their fair share of climate action in order to avoid catastrophic climate change (Kartha et al. 2020). There are significant equity implications to this as those individuals and countries who have contributed the least to climate change will experience the most devastating climate impacts (IPCC et al. 2018). The targets set out in New York's Climate Leadership and Community

Protection Act (CLCPA) provides an indication to the level of climate action necessary in the region.

Table 28: Comparison of Genesee-Finger Lakes emissions to other geographies

Region, state or country	2018 Emissions ($MMtCO_2$ GWP100)*	Population (Millions)
Rhode Island	11.5[2]	1.1[4]
Nepal	12.0[1]	28.1[3]
Zimbabwe	12.3[1]	14.4[3]
Genesee-Finger Lakes Region	**12.8**	**1.2**
Delaware	13.3[2]	1.0[4]
Slovenia	14.1[1]	2.1[3]
Ghana	16.1[1]	29.8[3]

* CO_2 emissions in 2018 under GWP100. Excludes land use emissions, biogenic CO_2 and upstream emissions.
[1] Country CO_2 excluding Land Use, Land Use Change and Forestry (LULUCF) from CAIT (Climate Watch 2022)
[2] State CO_2 excluding LULUCF from US State Inventory (Climate Watch 2022)
[3] Country population estimates from UN DESA (2019)
[4] State population estimates from US Census Bureau (2020b)

2.2 Emissions by county

As shown in Figure 11 and Table 29, the counties with the highest populations also have the highest emissions share with Monroe County at 40% of the region's emissions, followed by Ontario County at 12%. The source of emissions varies from county to county, as illustrated in Figure 12. For example, Livingston, Wyoming and Yate's largest share of emissions is from agriculture, in particular, dairy farming. According to the US Department of Agriculture (USDA 2022), Wyoming has the highest number of cows among any county in New York State, and Yate has the highest number of dairy farms, which is likely why dairy farming emissions are so high. In the county's of Seneca and Orleans, solid waste emissions represent 45% and 25% of gross emissions. This is due to the presence of two large landfills, including the Seneca Meadows landfill in Seneca County and Orleans Sanitary Landfill in Orleans. Monroe and Wayne share similar emissions profiles whereby around 38-40% of emissions are attributed to vehicles (transport) and 21-23% of emissions to households (residential). Genesee also has a high share of transport emissions (39%) as well agricultural emissions (34%) mainly from dairy farming.

Table 29: Genesee-Finger Lakes Greenhouse Gas Emissions by County (results in GWP20)

Sector	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total
Gross Emissions Total	**29.92**	**100%**	**29.02**	**100%**	**29.22**	**100%**	**30.88**	**100%**
Genesee	2.66	9%	3.02	10%	3.09	11%	3.34	11%
Livingston	1.98	7%	2.23	8%	2.40	8%	2.89	9%
Monroe	13.64	46%	11.29	39%	11.02	38%	10.61	34%
Ontario	3.49	12%	3.49	12%	3.78	13%	4.45	14%
Orleans	1.05	3%	1.09	4%	1.08	4%	1.16	4%

Sector	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
Seneca	1.62	5%	2.24	8%	2.24	8%	2.59	8%
Wayne	2.10	7%	2.11	7%	2.10	7%	2.22	7%
Wyoming	2.47	8%	2.56	9%	2.56	9%	2.66	9%
Yates	0.92	3%	0.99	3%	0.96	3%	0.96	3%
Gross Emissions Total	**29.92**		**29.02**		**29.22**		**30.88**	
Net Emission Removal	-1.69		-1.64		-1.57		-1.48	
Genesee	-0.11	7%	-0.11	7%	-0.11	7%	-0.11	8%
Livingston	-0.27	16%	-0.26	16%	-0.24	15%	-0.21	14%
Monroe	-0.28	17%	-0.28	17%	-0.28	18%	-0.28	19%
Ontario	-0.23	14%	-0.23	14%	-0.21	14%	-0.20	13%
Orleans	-0.09	5%	-0.09	5%	-0.09	5%	-0.09	6%
Seneca	-0.07	4%	-0.07	4%	-0.07	4%	-0.07	5%
Wayne	-0.27	16%	-0.26	16%	-0.24	15%	-0.22	15%
Wyoming	-0.23	13%	-0.22	13%	-0.21	13%	-0.19	13%
Yates	-0.13	8%	-0.13	8%	-0.12	8%	-0.11	8%
Biogenic CO_2	0.92		0.98		0.93		0.93	
Genesee	0.07	7%	0.06	6%	0.06	6%	0.05	5%
Livingston	0.06	6%	0.06	6%	0.05	6%	0.05	5%
Monroe	0.38	42%	0.35	36%	0.31	34%	0.25	27%
Ontario	0.09	10%	0.09	10%	0.09	10%	0.08	9%
Orleans	0.04	4%	0.04	4%	0.03	4%	0.03	3%
Seneca	0.14	15%	0.23	23%	0.25	27%	0.34	37%
Wayne	0.08	9%	0.08	8%	0.07	8%	0.07	7%
Wyoming	0.03	4%	0.04	4%	0.03	4%	0.03	3%
Yates	0.03	3%	0.03	3%	0.03	3%	0.03	3%
Net Emissions Total	**27.31**		**26.40**		**26.72**		**28.47**	

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross Emissions includes biogenic CO_2.

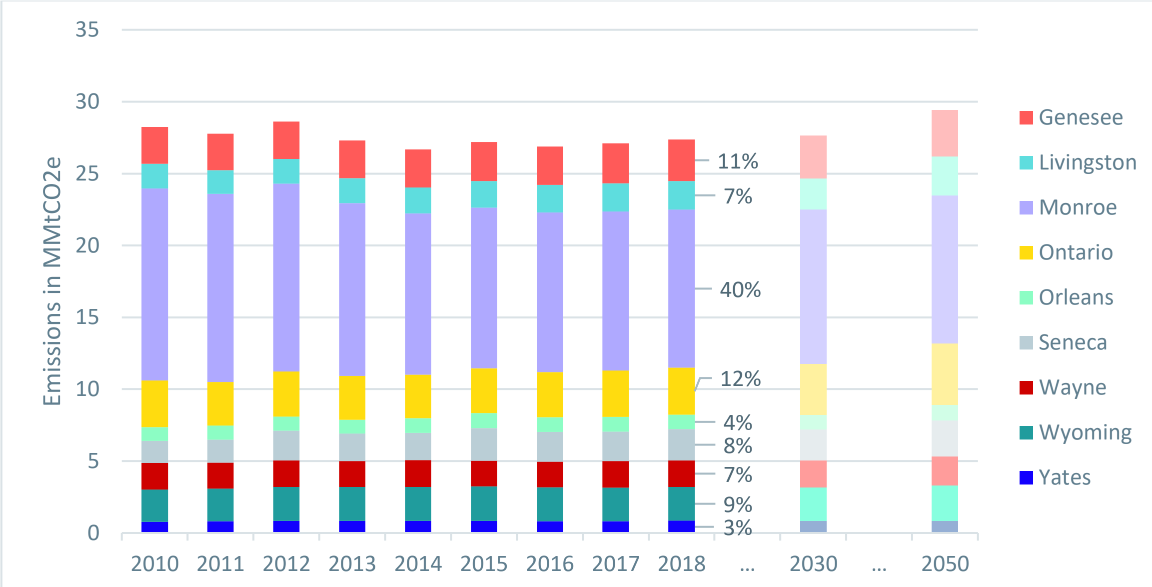

Figure 11: Net emissions by county

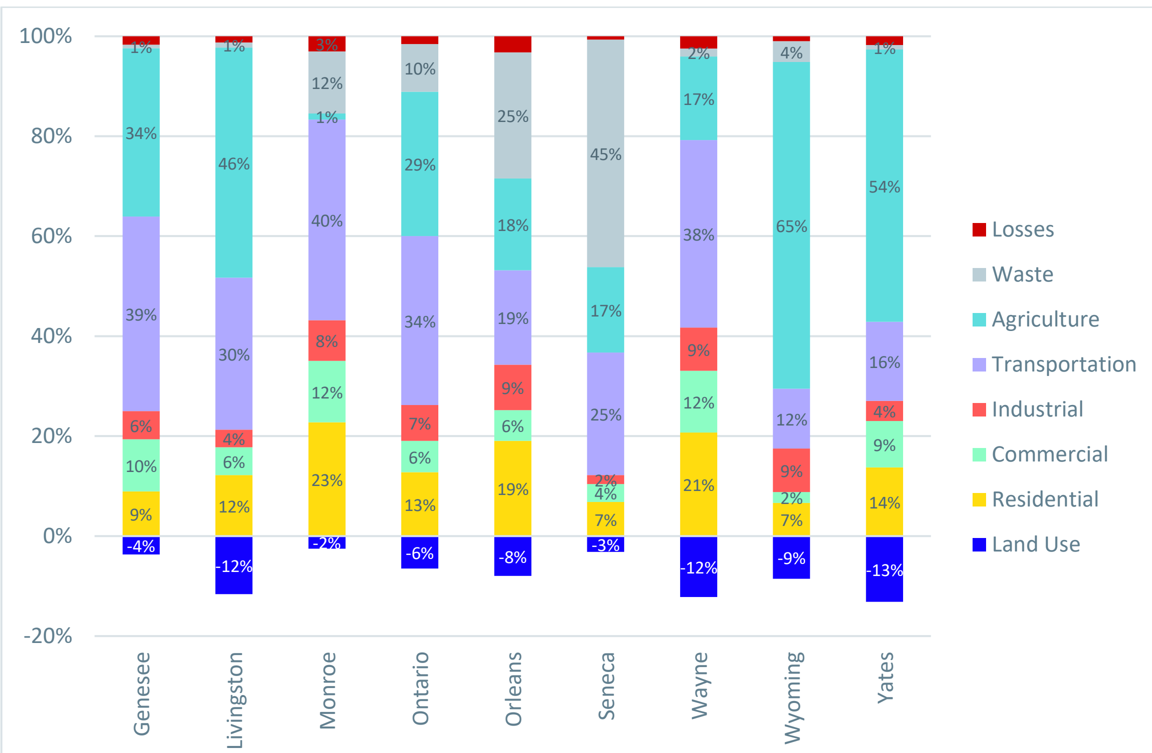

Figure 12: Sectoral share of gross emissions in each county in 2018

Note: Share of emissions is relative to the county's 2018 gross emissions.

2.3 Emissions by sector

This section takes a closer look at the emissions from each sector on a region-wide level.

2.3.1 Residential emissions

Space heating using natural gas is the dominant source of emissions in the residential sector, followed by water heating and other uses such as from appliances, lighting, electronics and more (Figure 13). Consumption of diesel, fuel oil, propane and wood such as for heating or cooking, make up around 19% of residential emissions.

Natural gas use jumps in 2018 compared to previous years. This coincides with a substantial increase in heating degree-days in the months of March, April and October in 2018 (NYSERDA 2021a)[20], suggesting that households may have kept their heating on later in the year (April) and turned it on earlier in the year (October). However, the increase in heating degree-days in 2018 does not appear to be part of a larger trend. In fact, space heating demands are expected to decrease in the baseline projection because of climate change. On the other hand, air conditioning demands are expected to increase from an increase in hotter days due to climate change. Since the emissions from electricity consumption are less than other fuels, air conditioning has a lower footprint compared to other end-uses.

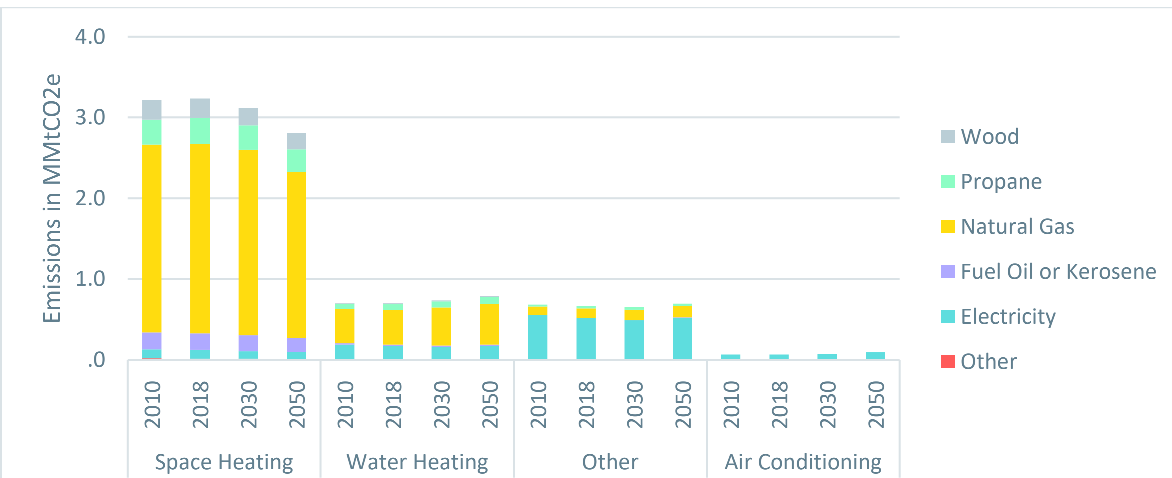

Figure 13: Historical and Projected Residential Emissions by End Use and Fuel (results in GWP20)

[20] This value for Rochester. Note that heating and cooling degree-days are indicators of heating and cooling energy needs. According to NYSERDA, heating degree days are the number of degrees the daily average temperature falls below 65° F.

Table 30: Residential sector emissions (results in GWP20)

Sector – Residential	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total
Space Heating	3.21	68.9%	3.24	69.4%	3.12	68.2%	2.81	64.0%
Electricity	0.11	2.4%	0.11	2.3%	0.09	2.1%	0.08	1.9%
Fuel Oil or Kerosene	0.21	4.5%	0.20	4.4%	0.19	4.3%	0.18	4.1%
Natural Gas	2.33	49.8%	2.35	50.3%	2.30	50.3%	2.06	46.9%
Propane	0.31	6.7%	0.32	7.0%	0.30	6.5%	0.27	6.3%
Wood	0.24	5.1%	0.24	5.1%	0.22	4.8%	0.20	4.6%
Other	0.02	0.4%	0.01	0.3%	0.01	0.3%	0.01	0.3%
Water Heating	0.70	15.0%	0.70	15.0%	0.73	16.0%	0.79	18.0%
Electricity	0.19	4.0%	0.17	3.7%	0.16	3.5%	0.17	3.9%
Fuel Oil or Kerosene	0.01	0.3%	0.02	0.3%	0.02	0.4%	0.02	0.4%
Natural Gas	0.42	9.1%	0.43	9.2%	0.47	10.3%	0.50	11.5%
Propane	0.07	1.5%	0.07	1.5%	0.07	1.6%	0.08	1.9%
Wood	0.01	0.1%	0.01	0.3%	0.01	0.3%	0.01	0.3%
Other	0.68	14.7%	0.66	14.2%	0.65	14.2%	0.70	15.9%
Electricity	0.55	11.9%	0.52	11.1%	0.49	10.7%	0.52	11.9%
Fuel Oil or Kerosene	0.00	0.0%	0.00	0.0%	0.00	0.0%	0.00	0.0%
Natural Gas	0.10	2.2%	0.12	2.5%	0.13	2.8%	0.14	3.1%
Propane	0.03	0.6%	0.03	0.6%	0.03	0.7%	0.03	0.8%
Air Conditioning	0.07	1.4%	0.06	1.4%	0.07	1.6%	0.09	2.1%
Electricity	0.07	1.4%	0.06	1.4%	0.07	1.6%	0.09	2.1%
Gross Emissions Total (Residential)	**4.67**		**4.66**		**4.58**		**4.38**	
Net Emission Removal	n/a		n/a		n/a		n/a	
Biogenic CO_2	0.37		0.38		0.35		0.32	
Net Emissions Total (Residential)	**4.29**		**4.28**		**4.22**		**4.06**	

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross Emissions includes biogenic CO_2.

The majority of the Genesee-Finger Lakes' population live in older households (i.e., pre-2000) that they own. In 2018, high income households (i.e., household income of greater than or equal to 120K per year) made up roughly 35% of the region's emissions and 31% of the region's population. Generally, the emissions align with the number of households for a given household type as illustrated in Figure 14**Error! Reference source not found.**. A similar pattern of emissions is seen in the baseline projection through 2050.

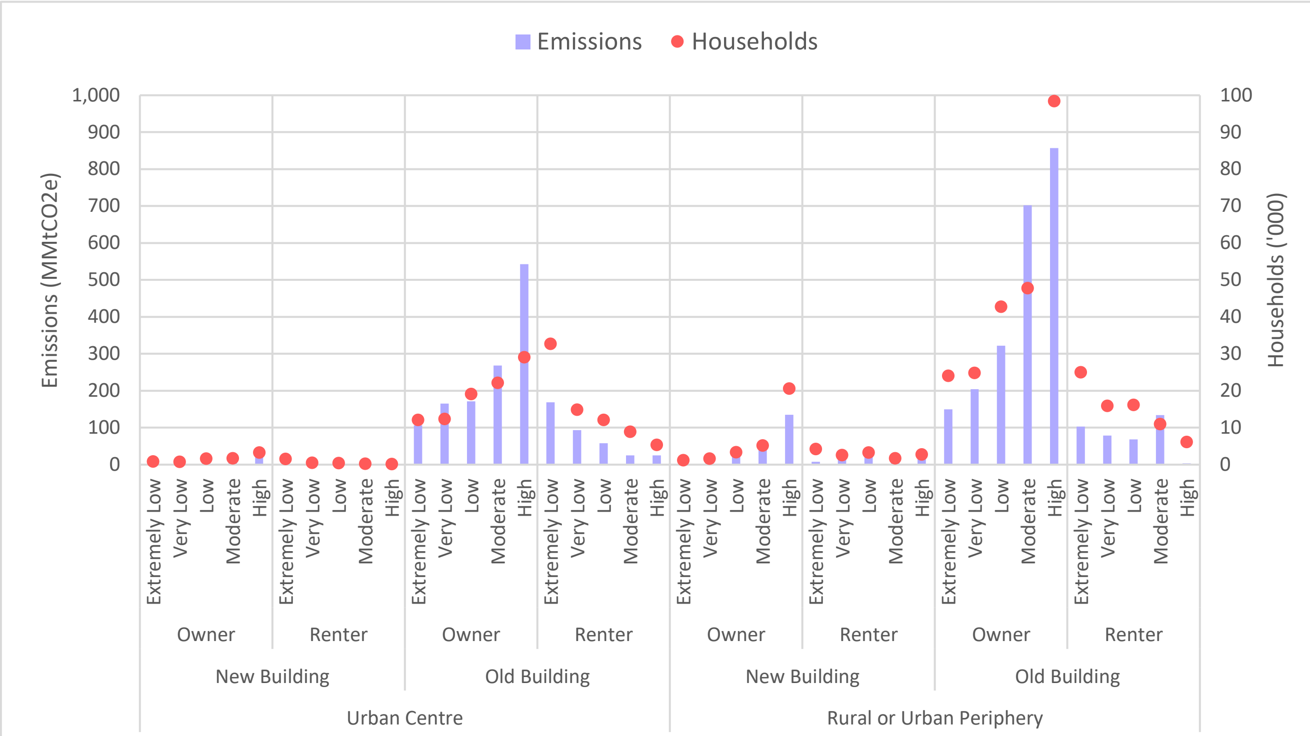

Figure 14: 2018 emissions (left axis) and number of households (right axis) by household type

The emissions under each household category are further reviewed on a per household basis in Figure 15. The results show that urban households have higher emissions compared to rural households or households in the urban periphery (i.e., suburbs). The higher footprint of urban households is attributed to high-income households using significantly more fossil-based energy for space heating compared to the average low- or moderate-income household in urban areas (12.9 $MMtCO_2e$ per high-income urban household versus an average 5.85 $MMtCO_2e$ per low- or moderate-income urban household).

Older buildings, as in buildings built before 2000, have slightly higher emissions per household compared to new buildings. This is unsurprising given that newer buildings are built under the NY State Energy Conservation Construction Code which underwent significant updates in 2002.

Owners have almost double the emissions compared to renters. This tends to correlate with the fact that lower income households are primarily renters. Lower income households have lower emissions compared to moderate- and high-income households due to differences in energy consumption. Very low-income households appear to use more natural gas for space heating compared to low-income households, although the reason behind this is unclear. Moderate-income households appear to have higher space heating demands compared to high-income households. This is because approximately 37% of moderate-income households use propane or wood for space heating which is less energy-efficient, meaning that more energy is needed to generate the same amount of heat compared to a natural gas furnace or heat pump.

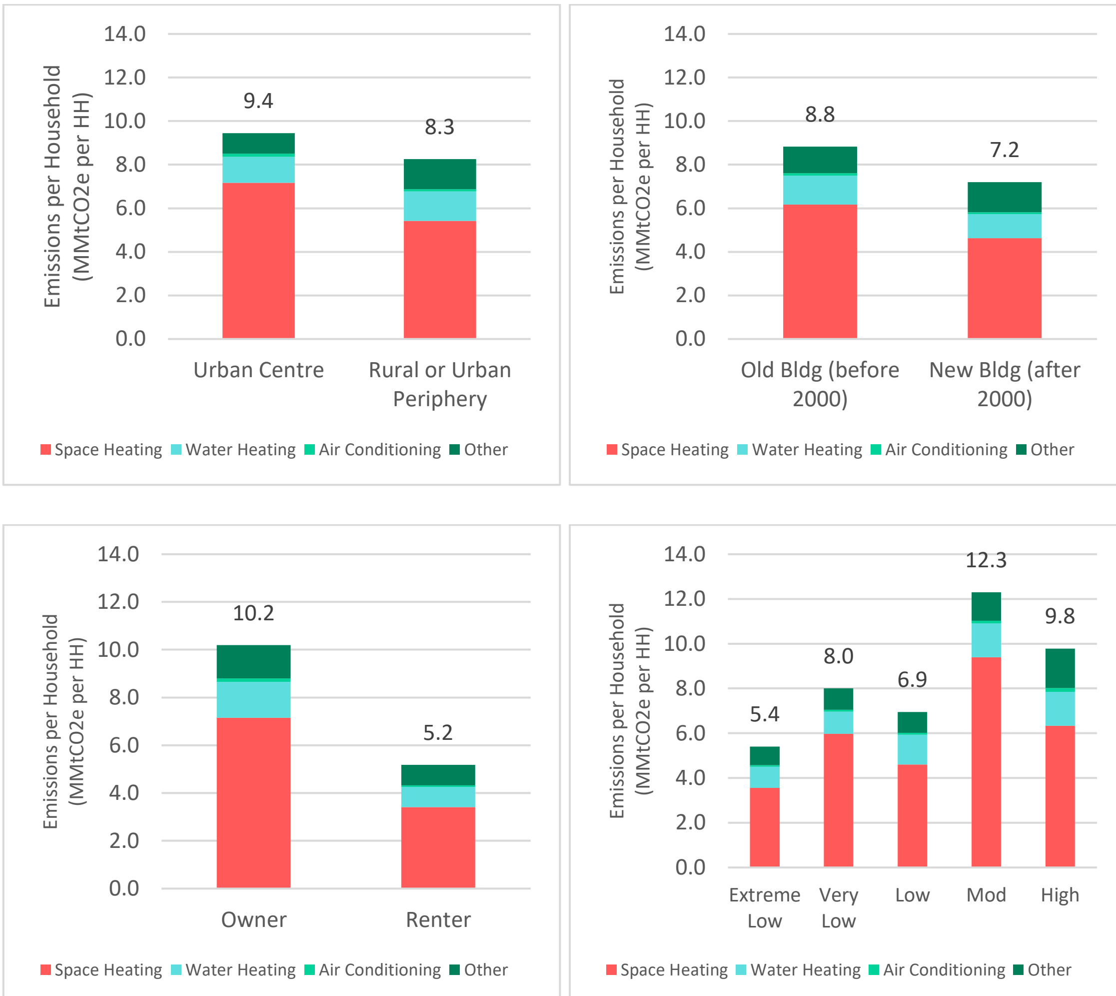

Figure 15: 2018 emissions per household by end-use – top left is by location; top right is by building age; bottom left is by ownership; bottom right is by income group

Despite using less energy, the energy burden on lower income households tends be high. The energy burden is the percentage of household income spent on energy bills. Figure 16 through Figure 19 shows the energy burden across different groups – income, race, disability and Spanish/Hispanic/Latino ethnicity - using data from the American Community Survey. According to the American Council for an Energy-Efficient Economy (2020), a high energy burden is above 6% and severe energy burden is above 10%. The figures show that in every county, extremely low-income households experience a high energy burden and very low-income households have severe energy burdens. Also, several marginalized groups have higher energy burdens than the average household, such as Black, Native American, Spanish/Hispanic/Latino households, and those with disabilities.

The energy cost burden can be high, especially in older, poorly insulated homes using inefficient heating systems. While there are financial incentives from utilities and state agencies to switch to electric heat pumps and to weatherize the home, it can be challenging for those living in rental units to access those incentives, and the time and paperwork involved can be tedious.

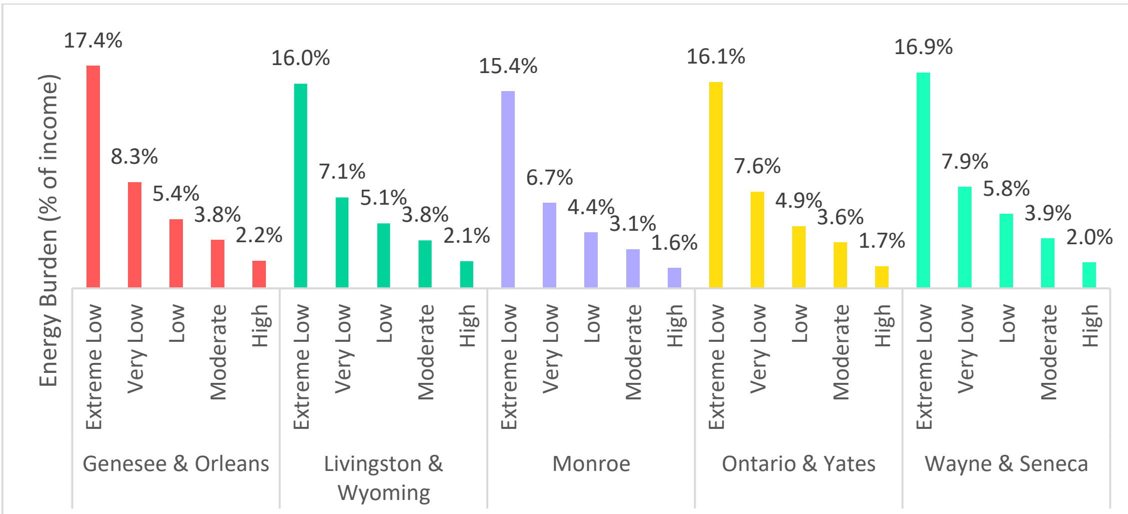

Figure 16: Energy cost burden by county and income group in 2019. Source: U.S. Census Bureau (2020a) American Community Survey

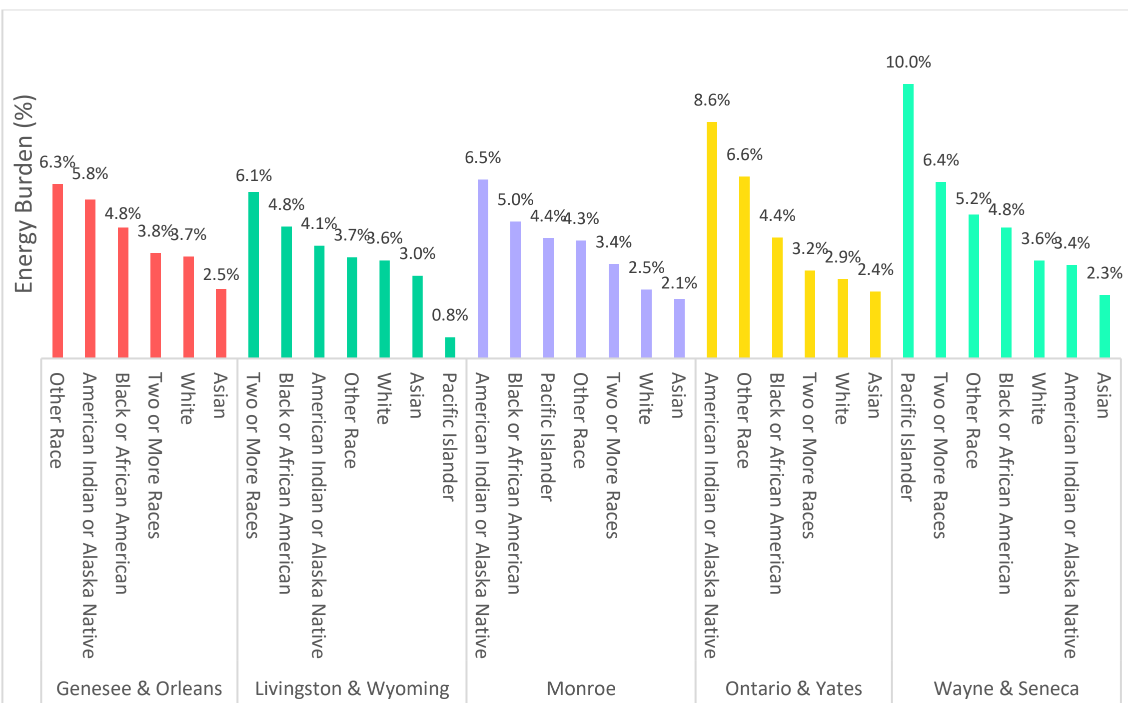

Figure 17: Energy cost burden by county and race in 2019. Source: U.S. Census Bureau (2020a) American Community Survey.

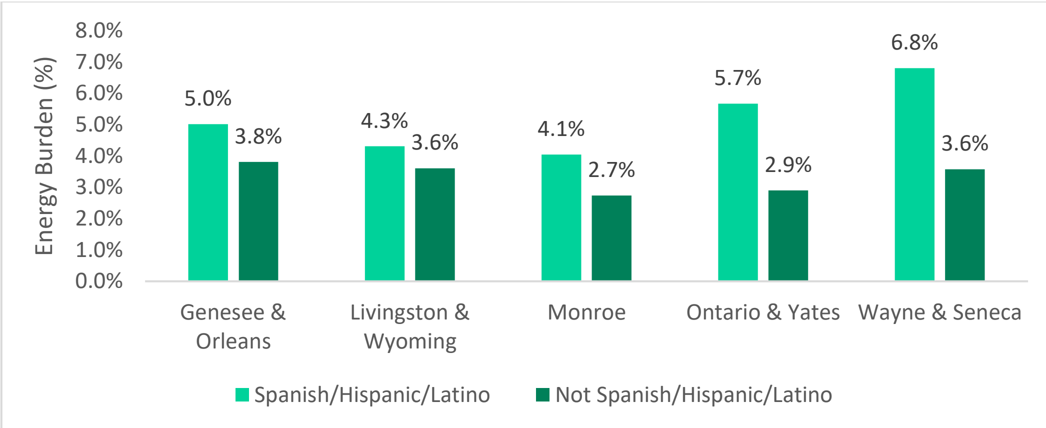

Figure 18: Energy cost burden by county and Spanish/Hispanic/Latino origin in 2019. Source: U.S. Census Bureau (2020a) American Community Survey.

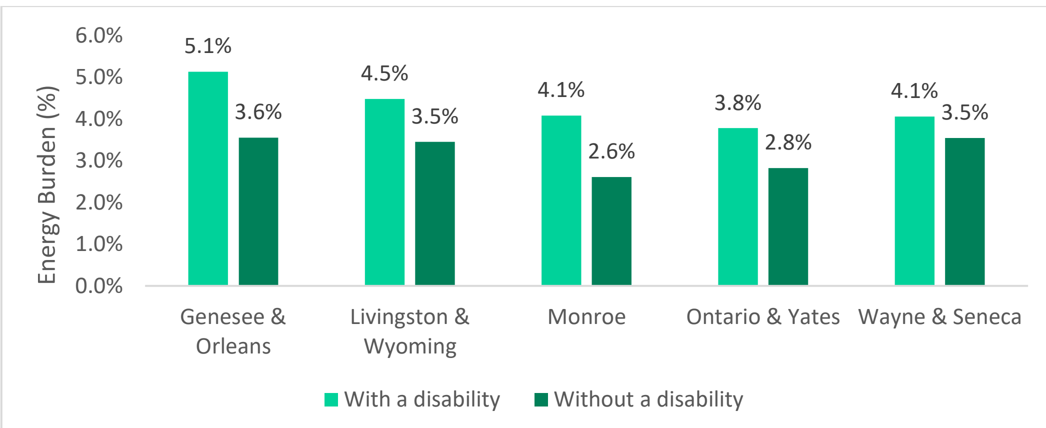

Figure 19: Energy cost burden by county and disability in 2019. Source: U.S. Census Bureau (2020a) American Community Survey.

2.3.2 Commercial emissions

Energy data for the commercial sector was limited to natural gas and electricity. As shown in Figure 20, the emissions are largely from natural gas, which jumps to 53% of total commercial emissions compared to previous years. As discussed in the section on the residential sector (Section 2.3.1), this jump coincides with increased heating degree-days in the months of March, April and October in 2018 (NYSERDA 2021a)[21], suggesting that commercial buildings may have kept their heating on later in the year (April) and turned it on earlier in the year (October).

[21] This is for Rochester. Note that heating and cooling degree-days are indicators of heating and cooling energy needs. According to NYSERDA, heating degree days are the number of degrees the daily average temperature falls below 65° F.

However, the increase in heating degree-days in 2018 does not appear to be part of a larger trend.

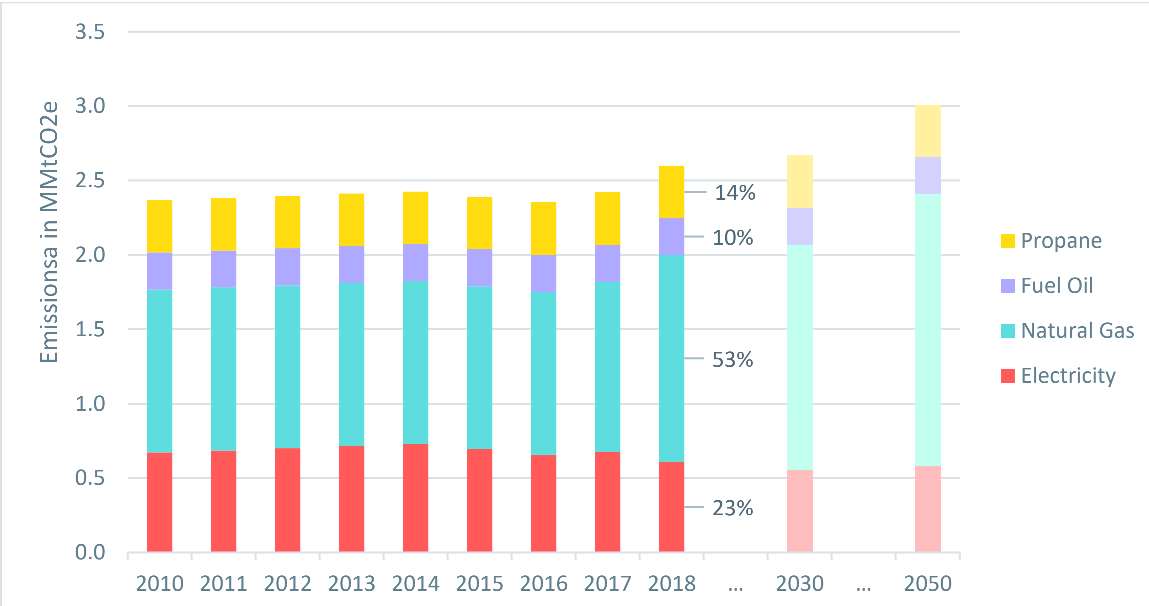

Figure 20: Historical and projected emissions in the commercial sector by fuel

Table 31: Commercial sector emissions (results in GWP20)

Sector – Commercial	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	MMtCO$_2$e	% of total	MMtCO$_2$e	% of total	MMtCO$_2$e	% of total	MMtCO$_2$e	% of total
Fuel	2.37	100%	2.60	100%	2.67	100%	3.01	100%
Electricity	0.67	28%	0.61	23%	0.55	21%	0.58	19%
Natural Gas	0.25	10%	0.25	10%	0.25	9%	0.25	8%
Propane	0.35	15%	0.35	14%	0.35	13%	0.35	12%
Fuel Oil	1.10	46%	1.39	53%	1.52	57%	1.82	61%
Gross Emissions Total (Commercial)	**2.37**		**2.60**		**2.67**		**3.01**	
Net Emission Removal	n/a		n/a		n/a		n/a	
Biogenic CO_2	0		0		0		0	
Net Emissions Total (Commercial)	**2.37**		**2.60**		**2.67**		**3.01**	

The commercial sector includes offices (including government), retail, restaurants, schools, healthcare, warehouses, grocery stores and lodging. In 2018, NYSERDA commissioned the *Commercial Statewide Baseline Study of New York State* to understand the energy usage across the various commercial sub-sectors. The study divides the results into three regions: Upstate

New York, Downstate New York, and Long Island/Hudson Valley. Summaries from the study from Upstate New York (which the Genesee-Finger Lakes is a part of) are provided in Table 32, Figure 21 and Figure 22. While the results may differ by county and sub-sector, generally HVAC, plug loads and lighting are major sources of electricity and natural gas use.

Table 32: Share of commercial buildings and energy usage in Upstate New York. Source: NYSERDA (2019a)

Commercial Sub-sector	Medium / Large Bldgs[1]	Small Bldgs[1]	Electric Sales	Natural Gas Sales	Fuel Oil Sales	Propane Sales
Total Quantities	**91,324 Buildings**	**21,153 Buildings**	**15,410,624 MWH**	**75,244,648 MMBTU**	**14,108,541 MMBTU**	**21,228,338 MMBTU**
Office / Government	27%	4%	36%	13%	5%	4%
Retail	23%	3%	11%	18%	17%	10%
Food Service	7%	4%	7%	11%	1%	6%
Grocery	5%	2%	7%	2%	1%	1%
Healthcare	1%	2%	8%	13%	21%	9%
Education	6%	1%	12%	24%	30%	21%
Lodging	5%	2%	4%	14%	21%	46%
Warehouse	7%	1%	16%	5%	4%	2%
Total Shares	**100%**		**100%**	**100%**	**100%**	**100%**

[1] Medium and Large buildings use greater than 75 MWH/year. Small buildings use less than 75 MWH/year.

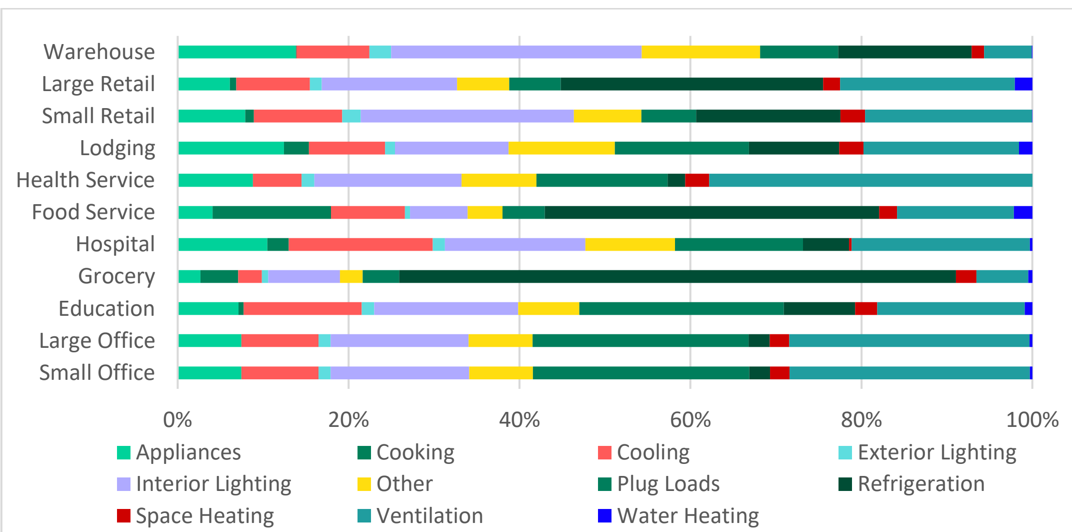

Figure 21: Electricity usage by commercial sub-sector and end-use for Upstate NY. Source: NYSERDA (2019a)

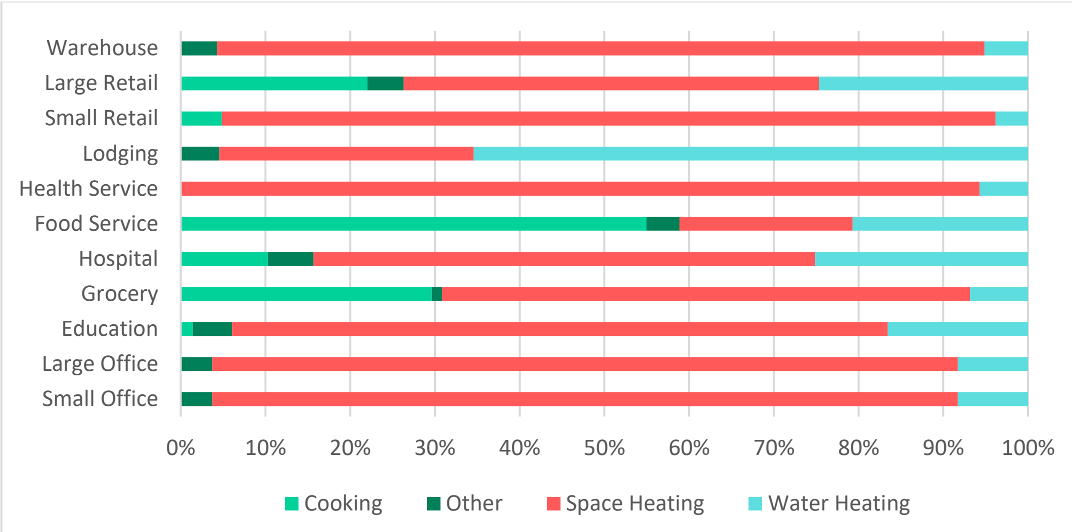

Figure 22: Natural gas usage by commercial sub-sector and end-use for Upstate NY. Source: NYSERDA (2019a)

2.3.3 Industrial emissions

The emissions inventory includes over 68 industries by North American Industrial Classification Standard (NAICS) code. Figure 23 shows the industries and industrial processes that are the most emissions intensive (including both energy and non energy emissions). In 2010, other chemical manufacturing had the highest share of emissions in the region at 49%. However, the sector experienced a steep decline as many major manufacturers in Rochester, including Kodak, Xerox, and Bausch + Lomb, significantly downscaled their operations between 2010 and 2014. Emissions in this sector reduced to 0.5% in 2014 and is now at around 10%. The highest share of emissions in 2018 came from construction-related industry called specialty trade contractors. This sub-sector includes site preparation activities, concrete work and heavy construction equipment rental and leasing, to name a few.

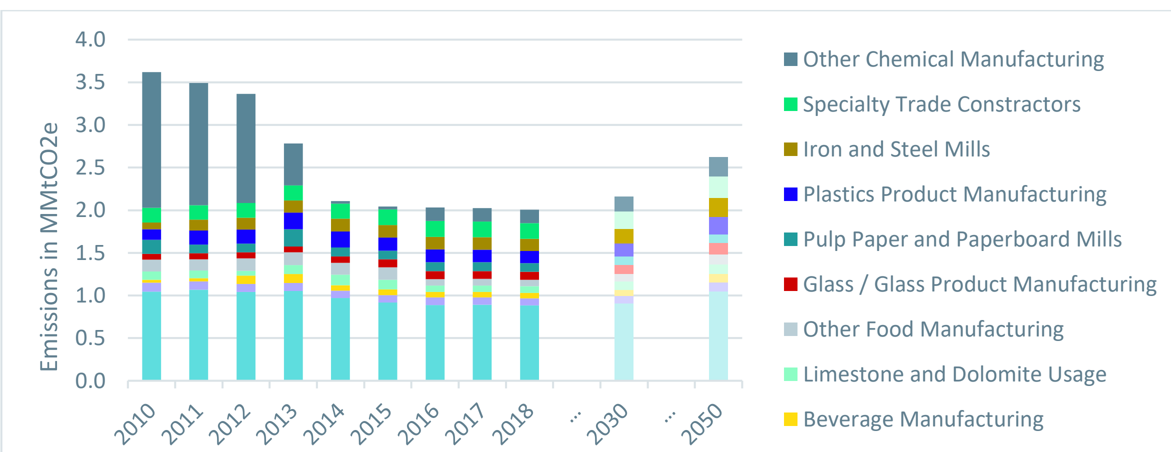

Figure 23: Historical and projected emissions in the industrial sub-sectors

Figure 24 shows that the facility closures from other chemical manufacturing led to the decline in industrial coal use in the region. Other prominent sources of emissions comes from electricity, natural gas and diesel. Using data from the US EIA's *Manufacturing Energy Consumption Survey,* Figure 25 breaks down which end uses the fuels are used for. There are four types of end-uses identified in the survey, including:

- **Indirect Uses-Boiler Fuel:** Conventional boiler use, CHP and/or cogeneration
- **Direct Uses-Total Process:** Process heating, process cooling and refrigeration, machine drives, electro-chemical processes, other process use
- **Direct Uses-Total Nonprocess:** Facility HVAC and lighting, other facility support, onsite transportation, conventional electricity generation, other nonprocess use
- **End Use Not Reported**

The survey data is reported by census region. Figure 25 shows data for the Northeast, which the Genesee-Finger Lakes region is a part of. The majority of fuel is used directly for industrial processes, with the exception of coal which is used for generating heat indirectly.

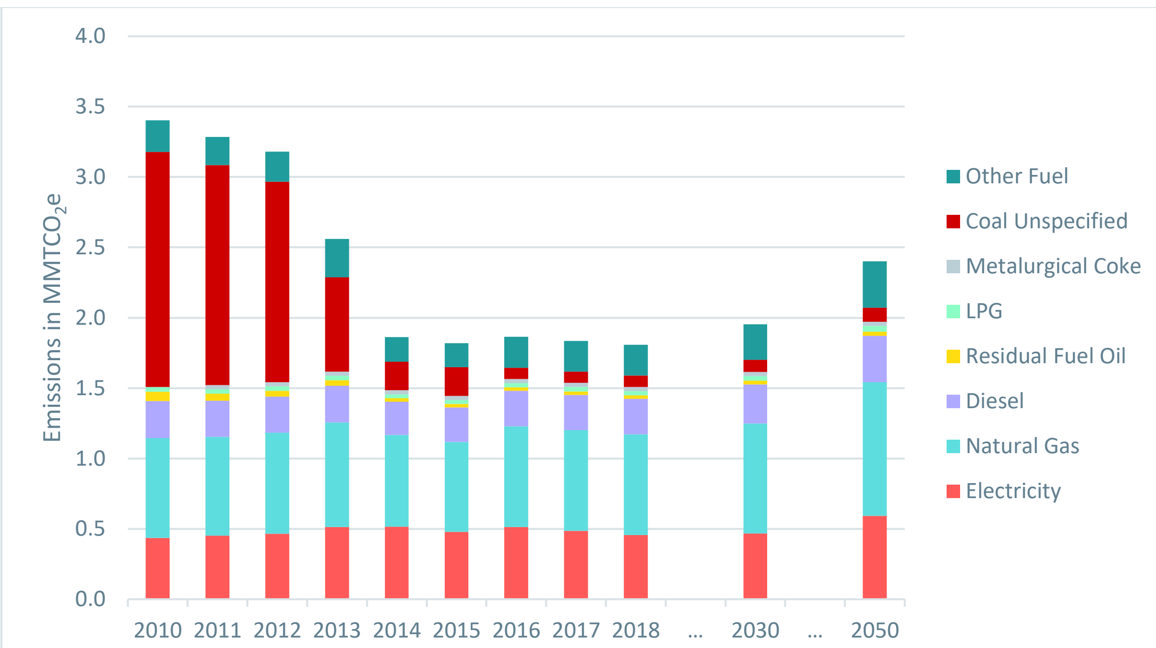

Figure 24: Historical emissions in the industrial sector by fuel

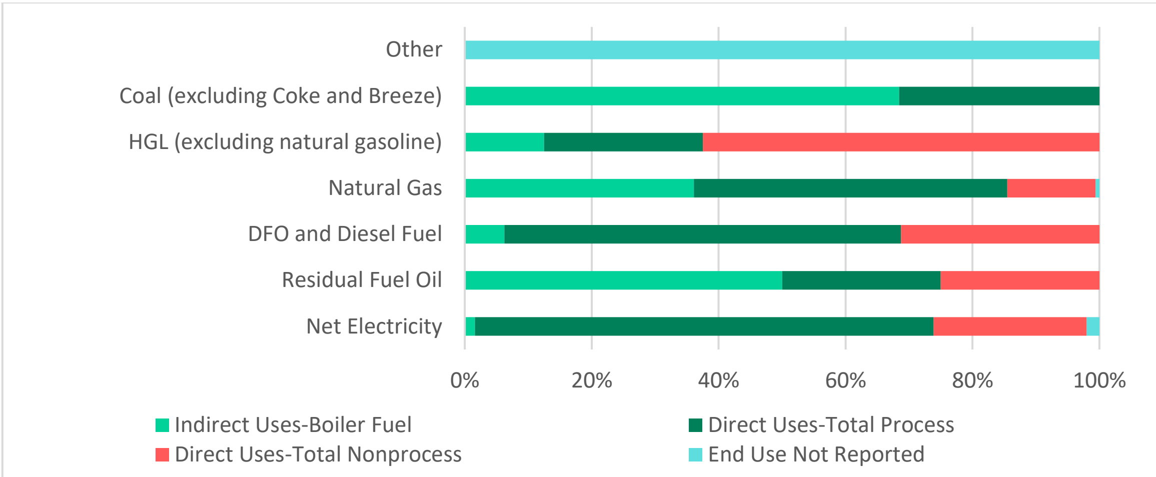

Figure 25: Industrial energy breakdown by fuel and end-use for the North-eastern US. Source: US EIA (2021) 2018 Manufacturing Energy Consumption Survey

2.3.4 Agricultural emissions

Figure 26 presents the historical emissions in the agricultural sector. Energy use in agriculture is small relative to non-energy emissions. The largest source of emissions is from livestock, including enteric fermentation (51%) and manure management (34%). During the process of enteric fermentation, carbohydrates are broken down in the digestive system by microorganisms and produce hydrogen (H_2), carbon dioxide (CO_2) and methane (CH_4). As shown in Table 33, the majority of enteric fermentation emissions in the region originates from dairy cows. In general, dairy cows produce the highest emissions per head compared to the other animals included in the analysis.

In addition to enteric fermentation, manure produces methane upon decomposition. Manure handling and climatic conditions impacts the level of methane that is emitted. Some farmers capture the methane and either flare it or convert it into bioenergy. Currently, the model uses a methane conversion factor taken from the US EPA's State Inventory Tool that is weighted based on the share of typical manure management systems in New York state. It is unclear how much of the conversion factor includes systems that capture methane gas from manure decomposition.

Crop residues and fertilizer use accounts for 8% of agricultural emissions. Residue emissions are generated when the residue left behind after a harvest decomposes. According to Table 34, alfalfa has the highest level of residue emissions, followed by soybeans. Despite a lower amount of production, soybeans are much more emissions intensive compared to alfalfa.

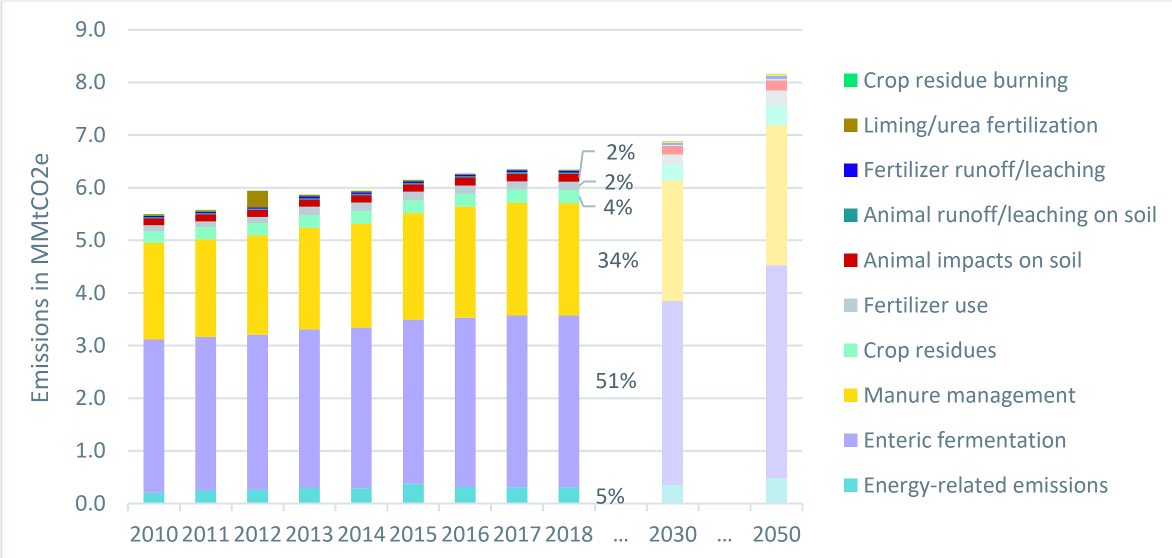

Figure 26: Historical and projected emissions in the agricultural sector

Table 33: 2018 livestock emission details

Animal	Livestock (heads)	Enteric Fermen-tation ($MMtCO_2e$)	Manure Manage-ment ($MMtCO_2e$)	Soil Animals ($MMtCO_2e$)	Soil Animal Runoff / Leaching ($MMtCO_2e$)	Total Emissions ($MMtCO_2e$)	MtCO2e per head
Dairy Cows	161,834	2.234	2.110	0.146	0.025	4.515	27.901
Beef Cows	14,184	0.119	0.002	n/a	n/a	0.122	8.576
Calves	192,040	0.890	0.006	n/a	n/a	0.896	4.665
Goat	3,852	0.001	0.000	n/a	n/a	0.002	0.407
Sheep	22,852	0.016	0.001	0.001	0.000	0.019	0.814
Swine	22,963	0.003	0.015	0.002	0.000	0.020	0.892
Llama	2,080	0.001	0.000	0.000	0.000	0.002	0.730
Layers	178,749	n/a	0.002	0.001	0.000	0.002	0.013
Pullets	1,896	n/a	0.000	0.000	0.000	0.000	0.011
Broilers	9,665	n/a	0.000	0.000	0.000	0.000	0.003
Roosters	194	n/a	0.000	0.000	0.000	0.000	0.332
Total	**610,309**	**3.265**	**2.137**	**0.150**	**0.025**	**5.578**	**9.139**

Table 34: 2018 crop emission details

Crop	Crop production (metric tons)	Crop Residues ($MMtCO_2e$)	Crop Residue Burning ($MMtCO_2e$)	Total emissions ($MMtCO_2e$)	$MtCO_2e$ per metric ton
Alfalfa	1,249	0.13660	n/a	1.37E-01	109.3
Corn for Grain	925	0.01808	2.83E-05	1.81E-02	19.6

All Wheat	125	0.00369	4.20E-06	3.69E-03	29.6
Barley	3	0.00010	1.00E-07	1.02E-04	33.3
Sorghum for Grain	0	0.00003	n/a	2.65E-05	64.3
Oats	7	0.00017	n/a	1.65E-04	23.9
Rye	2	0.00007	n/a	6.95E-05	29.9
Soybeans	186	0.09061	8.65E-05	9.07E-02	487.2
Dry Edible Beans	-	n/a	n/a	0.00E+00	0.0
Dry Edible Peas	1	0.00058	n/a	5.84E-04	440.9
Red Clover	0	0.00000	n/a	3.80E-06	152.0
Crimson Clover	0	0.00000	n/a	7.00E-07	140.0
Total	**2,499**	**0.24993**	**1.19E-04**	**2.50E-01**	**100.0**

2.3.5 Transport emissions

Among the various sectors, transport has the highest share of emissions in the region. As shown in Figure 27, light passenger trucks and cars dominate transport emissions, alongside a fair share of emissions from heavy duty combination trucks. Based on Figure 28 and Figure 29, between the various fuels, gasoline accounts 73% of emissions in 2018, with diesel at 22%. Electric vehicle use is low.

Off-road and non-road transport produce a low level of emissions compared to on-road transport, but when combined, it is comparable to the amount of emissions produced from enteric fermentation or transmission losses.

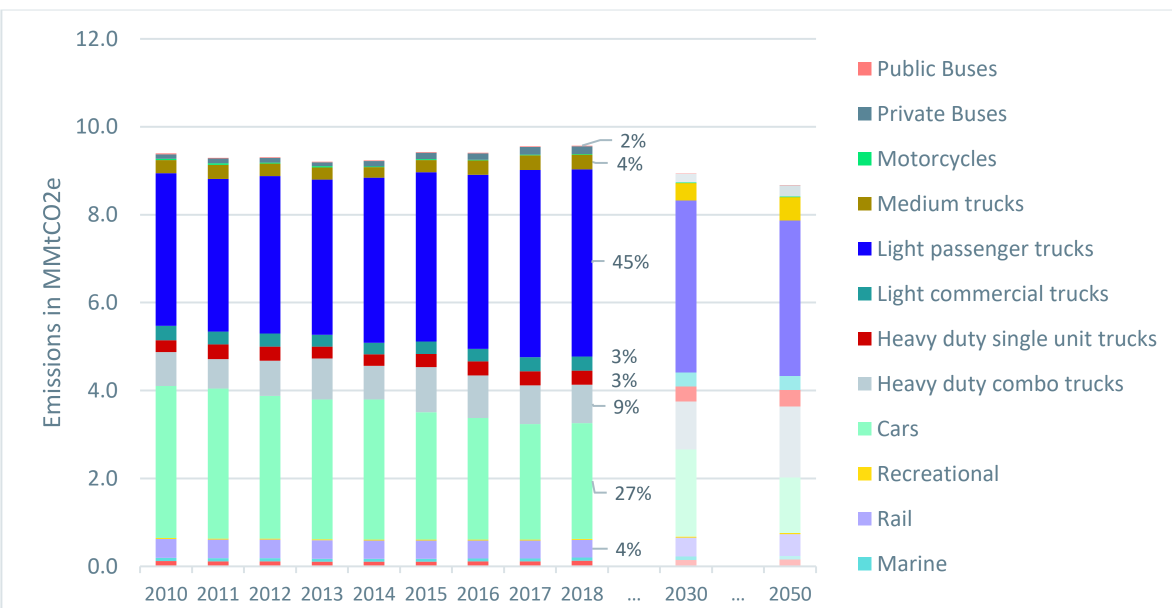

Figure 27: Historical emissions in the transport sector by vehicle type

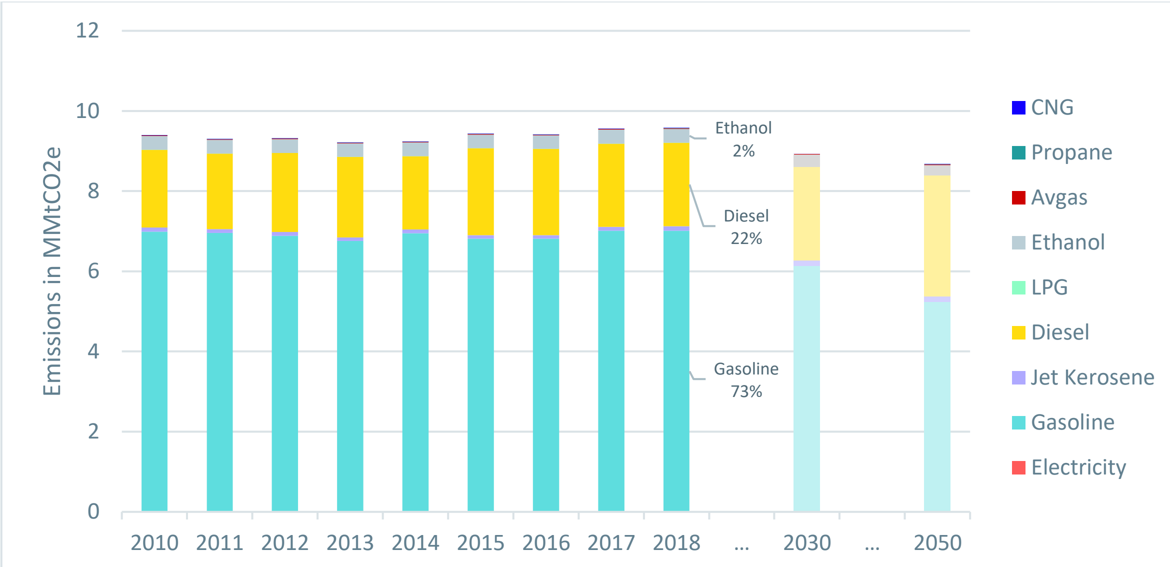

Figure 28: Historical emissions in the transport sector by fuel

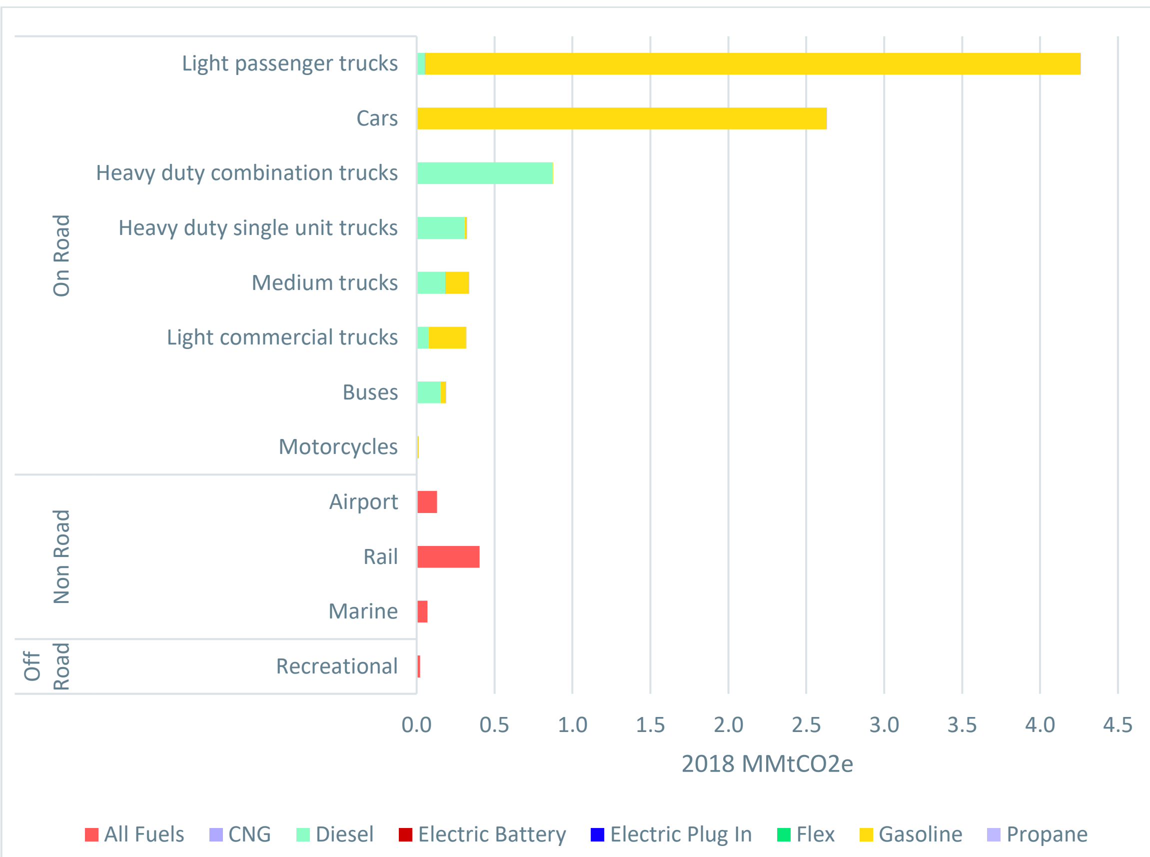

Figure 29: 2018 transport emissions by vehicle type and fuel

2.3.6 Waste emissions

Combined energy and non-energy emissions from the solid waste and wastewater sectors are presented in Figure 30. As discussed in the methodology, these emissions are from large emitters in the sector. It currently does not capture emissions from consuming goods imported from outside of the region, state or country.

The emissions appear to be decreasing over time. This could possible be due to more waste being diverted to recycling, reduced waste generation, the capture of gases and other greenhouse gases, or improved plant efficiencies.

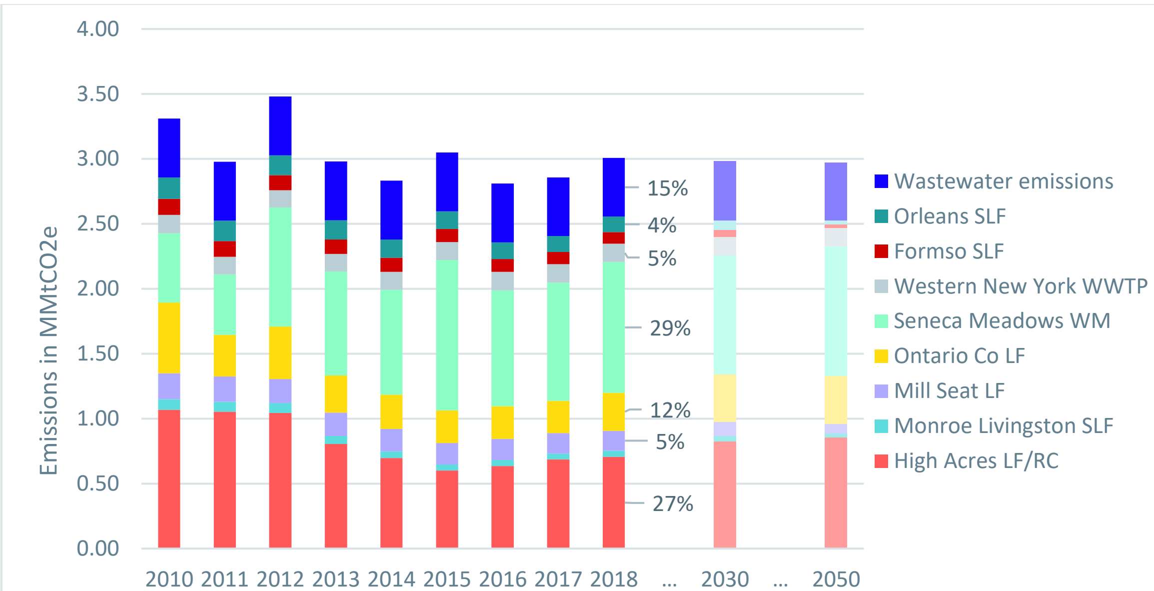

Figure 30: Historical solid waste and wastewater emissions by large facilities

2.3.7 Transmission losses and fugitive emissions

Fugitive emissions from natural gas pipelines contributed to 0.46 $MMtCO_2e$ in 2018 compared to electricity at only 0.15 $MMtCO_2e$. The decline in transmission losses during the historical period is projected into the future from 7.0% in 2018 to 4.6% in 2050. Since natural gas fugitive emissions are assumed to be the same in the future, fugitive emissions increase alongside natural gas demands.

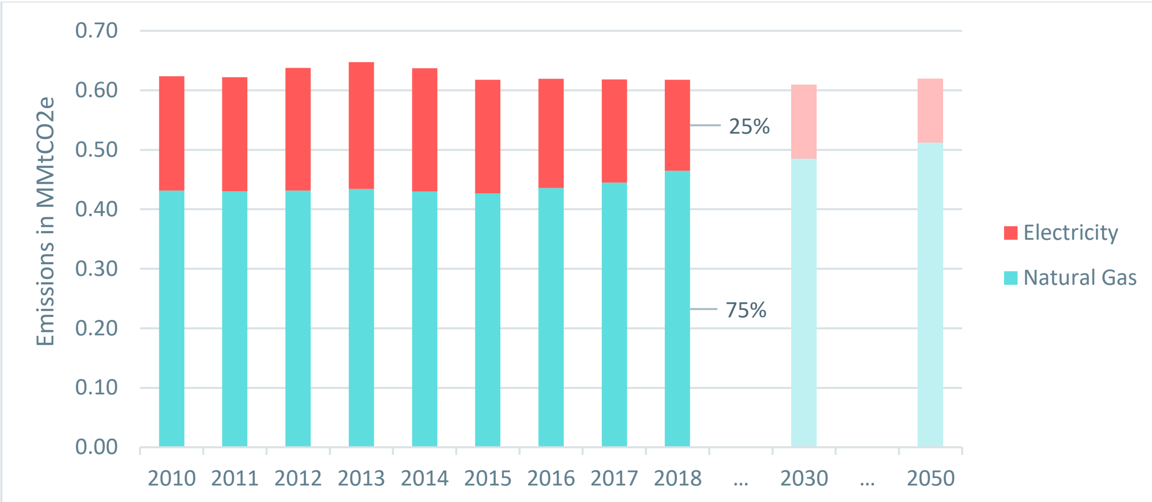

Figure 31: Historical and projected transmission losses and fugitive emissions

2.3.8 Land Use Emissions and Removals

The land use sector is the main source of removals in the region. In 2018, approximately 1.1 $MMtCO_2e$ is removed by forests remaining as forests, followed by 0.4 from urban trees. Emissions removals from forests are projected to decline to 0.9 $MMtCO_2e$ by 2050.

Forest converted to land for settlement or agriculture is the main source of emissions in the land use sector at 0.2 $MMtCO_2e$, remaining at this level through 2050.

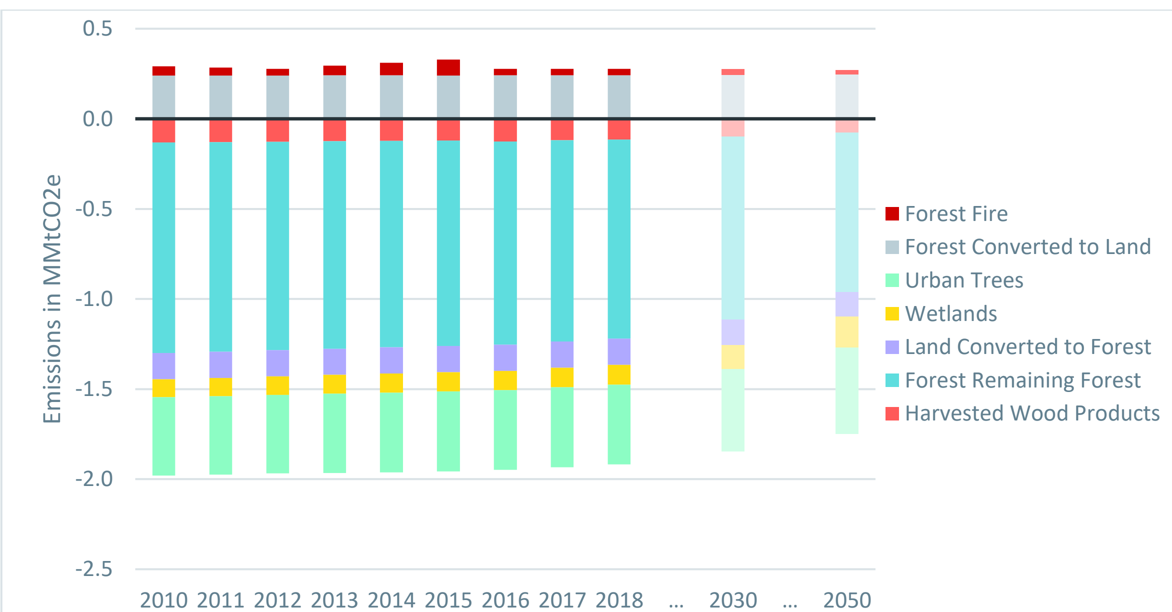

Figure 32: Historical and projected land use emissions and removals

2.4 Priority areas for emission reductions

A summary of the top 15 sources of regional emissions in 2018 is given in Table 35, reflecting 81% of the region's emissions. Climate action around these sources of emissions should be prioritized.

Table 35: Top 15 sources of emissions in 2018

Sector	Subsector	Emissions ($MMtCO_2e$)	Share of Emissions (%)
Transport	Light passenger trucks	4.3	16%
Agricultural	Enteric fermentation	3.3	12%
Residential	Space Heating	3.2	12%
Transport	Cars	2.6	10%
Agricultural	Manure management	2.1	8%
Commercial	Natural gas consumption	1.1	4%
Transport	Heavy duty combination trucks	0.9	3%
Waste	Seneca Meadows Landfill	0.8	3%
Residential	Water Heating	0.7	3%
Residential	Other End Uses	0.7	2%
Waste	High Acres Landfill and Recycling Center	0.6	2%
Commercial	Electricity	0.5	2%
Losses	Fugitive Emissions	0.5	2%
Waste	Wastewater	0.5	2%
Transport	Rail	0.4	1%
Total		**22.1**	**81%**

3 Planned future emissions inventory updates

The development of this emissions inventory is not a one-time exercise, and will need to be continually updated as new and better data is provided and

3.1 Addressing data gaps

While the current version of the model includes all major sectors and fuel types, there are a few data gaps that have been identified so far that need to be addressed in a future iteration of the inventory. It is not expected that these gaps will significantly change the findings presented in the emissions inventory but will ensure completeness.

- **Calibrate energy demands from other sectors**. Currently, county-level electricity and natural gas consumption in residential, commercial and industrial sector are calibrated using 2013 data, and gasoline sales for the years 1995 to 2017. Data on the historical energy consumption for other sectors and fuels are needed to ensure the modelled usage matches actual consumption.

- **Street lighting.** It is unclear if the commercial usage (i.e., the energy usage reported by utilities in the UER) includes street lighting.
- **Bottom-up calculation of wastewater and solid waste emissions.** Currently, the model only includes large wastewater and solid waste facilities that are located within the region. A bottom-up calculation of wastewater and solid waste generated by households, commercial and institutional entities and industry would ensure a complete inventory of those emissions.
- **HCFC-22 production.** As of January 1, 2020, the US EPA mandated phasing out hydrochlorofluorocarbons (HCFCs) production and imports. HCFC-22, also known as R-22, is a potent greenhouse gas commonly used in residential air conditioners. It is unclear if HCFC-22 was produced in the region prior to the phase-out date, and including it in inventory can help ensure a more complete historical record of emissions.
- **Digital currency (e.g., Bitcoin mining).** The scale of bitcoin mining in the region is unclear, but there are significant concerns related to its energy consumption.

3.2 Additional sectoral detail

This first iteration of the emissions inventory was to understand the scale of emissions from each sector, in each county and the region overall. More sectoral detail will enable a better understanding of the source of those emissions to help identify targeted emissions reduction policies. Sectors to update and add further detail include:

- Disaggregating the residential sector by ownership (renter, owner) and end-use
- Disaggregating commercial sector by subsector and end-use
- Disaggregating industrial sector by end-use
- Include multiple years of data for rail, marine and airport sub-sectors

3.3 Updates to the baseline projection

The baseline projection could be updated to reflect key dynamics that a simple population-driven baseline does not readily capture, such as expected energy efficiency improvements, saturation effects, response to expected price changes, and so on. This could be done by parameterizing the results of the recent and respected regional and national analyses, such as USDOE/EIA's Annual Energy Outlook (AEO). The use of AEO captures the impact of recently enacted federal legislation and regulations on projected vehicle fuel economy, on biofuel availability and use, and other key factors. The baseline could also include other adopted policies, including national (e.g. appliance efficiency standards), state (e.g. residential building codes), regional and local plans and policies (e.g. existing climate action plans).

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APPENDIX A

Emission factors

Appendix A. Emission Factors

2019 Emission factors for Fuel Combustion

Sector	Fuel	CO_2 (kg/MMBTU)[1]	CH_4 (g/GJ)	N_2O (g/GJ)
Electricity	Coal	95.63	0.7	3.6
Electricity	Distillate fuel	74.14	0.9	0.4
Electricity	Natural gas	52.91	1	0.3
Electricity	Petroleum coke	102.12	0.7	3.6
Electricity	Residual fuel	75.09	0.8	0.3
Electricity	Wood	103.14	11	7
Residential	Coal	95.74	300	1.5
Residential	Distillate fuel	74.14	10	0.6
Residential	Kerosene	73.19	10	0.6
Residential	LPG	62.88	5	0.1
Residential	Natural gas	52.91	5	0.1
Residential	Wood	103.14	300	4
Residential	Electricity	50.03[4]	3.53[4]	0.38[4]
Commercial	Coal	95.74	10	1.5
Commercial	Distillate fuel	74.14	10	0.6
Commercial	Kerosene	73.19	10	0.6
Commercial	LPG	62.88	5	0.1
Commercial	Natural gas	52.91	5	0.1
Commercial	Residual fuel	75.09	10	0.6
Commercial	Wood	103.14	300	4
Commercial	Electricity	50.03[4]	3.53[4]	0.38[4]
Industrial	Asphalt and road oil	75.35	3	0.6
Industrial	Coal: coking	93.83	10	1.5
Industrial	Coal: other	95.59	10	1.5
Industrial	Distillate fuel	74.14	3	0.6
Industrial	Kerosene	73.19	3	0.6
Industrial	LPG	62.88	1	0.1
Industrial	Lubricants	74.07	3	0.6
Industrial	Miscellaneous petroleum products	74.47	3	0.6
Industrial	Natural gas	52.91	1	0.1
Industrial	Petroleum coke	102.12	3	0.6
Industrial	Residual fuel	75.09	3	0.6
Industrial	Special naphthas	72.38	3	0.6
Industrial	Waxes	72.60	3	0.6

Sector	Fuel	CO_2 (kg/MMBTU)[1]	CH_4 (g/GJ)	N_2O (g/GJ)
Industrial	Wood	93.87	30	4
Industrial	Electricity	50.03[4]	3.53[4]	0.38[4]
Transportation—On road	Motor gasoline	71.35	25	8
Transportation—On road	Distillate	74.14	3.9	3.9
Transportation—On road	Natural gas	52.91	5[2]	0.1[2]
Transportation—On road	Electricity	50.03[4]	3.53[4]	0.38[4]
Transportation—Aviation	Aviation gasoline	69.15	60	0.9
Transportation—Aviation	Jet fuel	72.23	0	2.5
Transportation—Railroad	Distillate fuel	74.14	0.25[3]	0.08[3]
Transportation—Military	Distillate fuel	74.14	2.01[3]	0.054[3]
Transportation—Military	Residual fuel oil	75.09	0.31[3]	0.088[3]
Transportation—Bunker Vessel	Distillate fuel	74.14	2.01[3]	0.054[3]
Transportation—Bunker Vessel	Residual fuel oil	75.09	0.31[3]	0.088[3]
Transportation—Other Nonroad	Distillate fuel	74.14	0.295[3]	0.274[3]
Transportation—Other Nonroad	Industrial/commercial equipment: gasoline—4 stroke	71.35	1.09[3]	0.6[3]
Transportation—Other Nonroad	Construction/mining equipment: equipment gasoline—4 stroke	71.35	1.085[3]	0.597[3]
Transportation—Other Nonroad	Airport equipment gasoline—4 stroke	71.35	1.39[3]	0.764[3]
Transportation—Other Nonroad	Construction/mining equipment: equipment gasoline—4 stroke	71.35	1.085[3]	0.597[3]
Transportation—Other Nonroad	Construction/mining equipment: equipment gasoline—4 stroke	71.35	1.085[3]	0.597[3]
Transportation—Other Nonroad	Lawn and garden equipment: residential gasoline—4 stroke	71.35	0.98[3]	0.537[3]
Transportation—Other Nonroad	Ships and boats: gasoline—4 stroke	71.35	0.802[3]	0.003[3]
Transportation—Other Nonroad	Recreational equipment: gasoline—4 stroke	71.35	1.54[3]	0.795[3]

Source: U.S. EPA (2021b) and IPCC (2006) as cited in ERG (2021)

[1] Converted carbon content in fuel to carbon dioxide by multiplying by 44/12

[2] Estimate based on Commercial Natural Gas

[3] Units in g/kg fuel

[4] Multiplied by utility factor per Table 3 in Section 1.2.3.2

2019 Upstream Emission factors

Sector	CO_2 (g/MMBTU)[1]	CH_4 (g/MMBTU)	N_2O (g/MMBTU)
Natural Gas	12,131	357	0.14
Diesel/Distillate Fuel	15,164	121	0.26
Coal	3,300	364	0.10

Sector	CO_2 (g/MMBTU)[1]	CH_4 (g/MMBTU)	N_2O (g/MMBTU)
Kerosene/Jet Fuel	10.071	109	0.17
Gasoline (E85)	5,097	33	0.08
Gasoline	19,604	128	0.33
LPG	17,295	121	0.27
Petroleum Coke	11,612	112	0.20
Residual Fuel	11,799	111	0.19

Source: New York Department of Environmental Conservation (2022b)

APPENDIX B

Agricultural Non-Energy Calculations and Assumptions

Appendix B. Agricultural Non-Energy Calculations and Assumptions

Enteric Fermentation

The calculation of methane emissions from enteric fermentation are described in Table 20.

Manure Management (methane emissions)

Based on the methodology from the US EPA State Inventory Tool (2017), the calculation of methane emissions from manure management are as follows:

$$CH_4 = [H]*[TAM]*[VS]*[MPE]*[WMCF]*[ConCH4]$$

Where:
[H] = Livestock heads from USDA (2021) (heads)
[TAM] = typical animal mass (kg)
[VS] = volatile solids (kg VS/head/yr)
[MPE] = Maximum Potential Emissions (m^3 CH_4/kg VS)
[WMCF] = Weighted Methane conversion factors (fraction)
[ConCH4] = Convert m^3 CH_4 to kg CH_4

The Methane Conversion Factor (MCF) reflects the potential for emitting methane based on manure management practices and climate. The Weighted MCF is the weighted factor, based on the distribution of manure managment and feeding practices.

Table 36: Variables used to calculate methane emissions from manure management (2018 values from US EPA State Inventory Tool)

Animal	Typical Animal Mass [kg]	Volatile Solids [kg VS/head/yr]	Max. Potential Emissions [m^3 CH_4/kg VS]	Weighted methane conversion factors [fraction]
Dairy	na	2887	0.24	0.309
Beef	na	1674	0.17	0.009
Calves[1]	123	7.7	0.17	0.009
Goat[1]	64	9.5	0.17	0.009
Sheep[1,2]	53	8.3	0.28	0.006
Swine[1,3]	83	5.5	0.48	0.165
Llama[1,4]	53	8.3	0.28	0.006
Layers[1]	2	11	0.39[5]	0.049
Pullets[1]	2	10	0.39	0.049
Broilers[1]	1	17	0.39	0.015
Roosters[1,5]	2	11	0.39	0.049

[1]The units of volatile solids for these animals are in kg VS/head/per day, not per year.
[2] Values are based on the average of all categories of sheep
[3] Values are based on the average of all categories of swine
[4] Values assumed to be same as sheep
[5] Values assumed to be same as chickens

Manure management (nitrous oxide emissions)

Based on the methodology from the US EPA State Inventory Tool (2017), the calculation of nitrous oxide emissions from manure management are as follows:

$$N_2O = (([K\text{-}Nitrogen]*[\%AN])*E1 + ([K\text{-}Nitrogen]*[\%OT])*E2) * [ConN2O]$$

Where:
[K-Nitrogen] = [H]*[TAM]*[NEx] = Kjeldahl-Nitrogen excreted (kg)
[H] = Livestock heads from USDA (2021)
[TAM] = typical animal mass (kg)
[NEx] = Nitrogen Excreted (kg NEx/head/year)
[%AN] = Share of manure managed in anaerobic lagoons and liquid systems
[%OT] = Share of manure managed in solid storage, drylot & other systems
[E1] = 0.001 = Emissions factor for anaerobic lagoons and liquid systems (kg N2O-N/kg N)
[E2] = 0.02 = Emissions factor for solid storage, drylot, and other systems (kg N2O-N/kg N)
[ConN2O] = Conversion from N2O to N2

Table 37: Variables used to calculate nitrous oxide emissions from manure management (2018 values from the US EPA State Inventory Tool)

Animal	Typical Animal Mass [kg]	Nitrogen Excreted [kg NEx/head/yr]	Manure in anaerobic system or lagoon [%]	Manure in solid storage, drylot or other [%]
Dairy	na	160.59	43	40
Beef	na	0	43	40
Calves[1]	123	0	43	40
Goat[1]	64	0	0	0
Sheep[1,2]	53	0.45	0	50
Swine[1,3]	83	0.55	53	0
Llama[1,4]	53	0.45	0	50
Layers[1]	2	0.79	5	0.5
Pullets[1]	2	0.79	5	0.5
Broilers[1]	1	0.96	0	100
Roosters[1,5]	2	1.1	5	95

[1]The units of nitrogen excreted for these animals are in kg NEx/head/per day, not per year.
[2] Values are based on the average of all categories of sheep
[3] Values are based on the average of all categories of swine
[4] Values assumed to be same as sheep

[5] Values assumed to be same as chickens

Soil Animals

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate direct and indirect emissions from animal manure on agricultural soils:

$$N_2O = (([K\text{-}Nitrogen]*0.2*E3 + ([K\text{-}Nitrogen]*[\%P])*E4 + ([K\text{-}Nitrogen]*[\%M] + [K\text{-}Nitrogen]*[\%S])*(1-0.2)*E5) * [ConN2O]$$

Where:
[K-Nitrogen] = [H]*[TAM]*[NEx] = Kjeldahl-Nitrogen excreted (kg)
[H] = Livestock heads from USDA (2021)
[TAM] = typical animal mass (kg)
[NEx] = Nitrogen Excreted (kg NEx/head/year)
[%P] = Share of manure deposited directly into pastures
[%S] = Share of manure applied as daily spread
[%M] = Share of manure handled in managed systems
E3 = 0.01 = Emissions factor for indirect volatilization to NH3 and NOx [kg N2O N/kg N]
E4 = 0.02 = Emissions factor for Ag Soils Animal Pasture [kg]
E5 = 0.0125 = Emissions factor for Ag Soils Animal Ground [kg]
[ConN2O] = Conversion from N_2O to N2

Table 38: Variables used to calculate nitrous oxide emissions from animal manure on soils (2018 values from US EPA's State Inventory Tool)

Animal	Typical Animal Mass [kg]	Nitrogen Excreted [kg NEx/head/yr]	Manure on Pastures [%]	Manure managed [%]	Manure spread on ground [%]
Dairy	na	160.59	14	83	3
Beef	na	0	100	0	0
Calves[1]	123	0	100	0	0
Goat[1]	64	0	100	0	0
Sheep[1,2]	53	0.45	50	50	0
Swine[1,3]	83	0.55	41	54	0
Llama[1,4]	53	0.45	50	50	0
Layers[1]	2	0.79	0	100	0
Pullets[1]	2	0.79	0	100	0
Broilers[1]	1	0.96	0	100	0
Roosters[1,5]	2	1.1	0	100	0

[1]The units of nitrogen excreted for these animals are in kg NEx/head/per day, not per year.
[2] Values are based on the average of all categories of sheep
[3] Values are based on the average of all categories of swine
[4] Values assumed to be same as sheep
[5] Values assumed to be same as chickens

Soil Animal Runoff and Leaching

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate the nitrous oxide emissions from runoff and leaching from livestock onto agricultural soils:

N_2O = [K-Nitrogen] * 0.3 * E6 * [ConN2O]

Where:
[K-Nitrogen] = [H]*[TAM]*[NEx] = Kjeldahl-Nitrogen excreted (kg)
[H] = Livestock heads from USDA (2021)
[TAM] = typical animal mass (kg)
[NEx] = Nitrogen Excreted (kg NEx/head/year)
E6 = 0.0075 = Emission factor for Ag Soils Leaching [kg N2O N/kg N]
[ConN2O] = Conversion from N_2O to N2

See Table 38 for data used for each variable.

Soil Plant Residues, Legumes and Histosols (Nitrous oxide emissions)

Using the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate emissions from crop residues, and the cultivation of nitrogen-fixing crops and histosols (highly organic soils):

$$N_2O = (([P]*[RR]*[FD]*[FA]*[NR])*E7 + ([P]*(1+[RR])*[FD]*[NB])*E7) * [ConN2O]$$

[P] = Crop Production [kg] from USDA (2021)
[RR] = Residue Crop Mass Ratio
[FD] = Residue Dry Matter Fraction
[FA] = Fraction Residue Applied
[NR] = N Content of Residue
[NB] = 0.0 = N content of aboveground biomass for N-fixing crop production
E7 = 0.01 = Emission Factor (kg N2O N/kg N)
[ConN2O] = Conversion from N_2O to N_2

Table 39: Variables used to calculate nitrous oxide emissions from crop residues, legumes and histosols (2018 values from US EPA State Inventory Tool)

Crop	Residue Crop Mass Ratio	Residue Dry Matter Fraction	Fraction Residue Applied	N Content of Residue
Alfalfa	0	0.85	0	0
Corn for Grain	1	0.91	0.9	0.0058
All Wheat	1.3	0.93	0.9	0.0062

Barley	1.2	0.93	0.9	0.0077
Sorghum for Grain	1.4	0.91	0.9	0.0108
Oats	1.3	0.92	0.9	0.007
Rye	1.6	0.9	0.9	0.0048
Soybeans	2.1	0.87	0.9	0.023
Dry Edible Beans	2.1	0.87	1.6	0.0168
Dry Edible Peas	1.5	0.87	0.9	0.0168
Red Clover	0	0	0	0
Crimson Clover	0	0	0	0

Soils Plant Residue Burning (nitrous oxide emissions)

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate emissions from burning residues to clear and prepare the field for the next cropping cycle:

$$N_2O = [P]*[RR]*[FB]*[FD]*[BE]*[CE]*[NC]*E9*[ConN2O]$$

[P] = Crop Production [kg] from USDA (2021)
[RR] = Residue Crop Mass Ratio
[FB] = Fraction Residue Burned
[FD] = Residue Dry Matter Fraction
[BE] = Burning Efficiency
[CE] = Combustion Efficiency
[NC] = N Content
E8 = 0.007 = Ag Soils Burning N2O to N Emissions Ratio [N2O/N]
[ConN2O] = Conversion from N_2O to N_2

Table 40: Variables used to calculate nitrous oxide emissions from crop burning (2018 values from US EPA State Inventory Tool)

Crop	Residue Crop Mass Ratio	Fraction Residue Burned	Residue Dry Matter Fraction	Burning Efficiency	Combust-ion Efficiency	Nitrogen Content
Corn for Grain	1	0.002	0.91	0.93	0.88	0.0006
All Wheat	1.3	0.002	0.93	0.93	0.88	0.006
Barley	1.2	0.002	0.93	0.93	0.88	0.008
Soybeans	2.1	0.005	0.87	0.93	0.88	0.023

Soils Plant Residue Burning (methane emissions)

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate emissions from burning residues to clear and prepare the field for the next cropping cycle:

$$CH_4 = [P]*[RR]*[FB]*[FD]*[BE]*[CE]* [CC]*E10*[ConCH4]$$

[P] = Crop Production [kg] from USDA (2021)
[RR] = Residue Crop Mass Ratio
[FB] = Fraction Residue Burned
[FD] = Residue Dry Matter Fraction
[BE] = Burning Efficiency
[CE] = Combustion Efficiency
[CC] = C Content
E10 = 16/12 = Ag Soils Burning CH4 to C Emissions Ratio [CH4/C]
[ConCH4] = Conversion from CH_4 to C

Table 41: Variables used to calculate methane emissions from crop burning (2018 values from US EPA State Inventory Tool)

Crop	Residue Crop Mass Ratio	Fraction Residue Burned	Residue Dry Matter Fraction	Burning Efficiency	Combust-ion Efficiency	Carbon Content
Corn for Grain	1	0.002	0.91	0.93	0.88	0.4478
All Wheat	1.3	0.002	0.93	0.93	0.88	0.4428
Barley	1.2	0.002	0.93	0.93	0.88	0.4485
Soybeans	2.1	0.005	0.87	0.93	0.88	0.45

Soil Plant Fertilizers

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate direct and indirect emissions from soils from fertilizer application:

$$N_2O = ([NF]*[NN]*(1-[V]))*E11 + ([NF]*[NN]*[V])*E12$$

Where:
[NF] = [F]*[FS] = N in Fertilizers [kg Total Nitrogen]
[F] = Fertilizer consumption [kg]
[FS] = Fraction of fertilizer consumption by type of fertilizer
[NN] = Nitrogen Content of Non-Manure Organics
[V] = Volatilization of Fertilizers
E11 = 0.01 = Emission factor for Ag Soils Plant Direct[kg N2O N/kg N]
E12 = 0.01 = Emission factor for Ag Soils Plant Indirect [kg N2O N/kg N]

County-level fertilizer consumption is estimated by taking the state-wide fertilizer consumption (US EPA 2017) and allocating it to each county based on fertilizer expenditures from USDA (2021)[22].

Table 42: Variables used to calculate nitrous oxide emissions from fertilizer consumption (2018 values from US EPA State Inventory Tool)

Fertilizer Type	Fraction of fertilizer use	Nitrogen content of non-manure organics	Volatilization of fertilizers
Synthetic	0.998	n/a	0.10
Dried blood	0	0.041	0.20
Compost	0	0.041	0.20
Dried manure	0.00007	0.01	0.20
Activated sewage sludge	0.0004	0.041	0.20
Other sewage sludge	0	0.041	0.20
Tankage	0	0.041	0.20
Other	0.001	0.041	0.20

Soil Plant Fertilizers Runoff and Leaching

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate nitrous oxide emissions from runoff and leaching of fertilizer in agricultural soils:

$$N_2O = ([NF]*[NN]*[V]*[L])*E6$$

Where:
[NF] = [F]*[FS] = N in Fertilizers [kg Total Nitrogen]
[F] = Fertilizer consumption [kg]
[FS] = Fraction of fertilizer consumption by type of fertilizer
[NN] = Nitrogen Content of Non-Manure Organics
[V] = Volatilization of Fertilizers
[L] = 0.3 = Leaching factor
E6 = 0.0075 = Emission factor for Ag Soils Leaching [kg N2O N/kg N]

County-level fertilizer consumption is estimated by taking the state-wide fertilizer consumption (US EPA 2017) and allocating it to each county based on fertilizer expenditures from USDA (2021)[23]. See Table 42 for the data used for the remaining variables.

[22] See FERTILIZER TOTALS, INCL LIME & SOIL CONDITIONERS - EXPENSE, MEASURED IN $
[23] See FERTILIZER TOTALS, INCL LIME & SOIL CONDITIONERS - EXPENSE, MEASURED IN $

Soils Liming and Urea Fertilizer

Based on the methodology from the US EPA State Inventory Tool (2017), this is the equation to calculate carbon dioxide emissions from the application of limestone and dolomite for the liming of soils and for the use of urea as fertilizer:

$$CO_2 = [A]*EF*[ConCO2]$$

Where:
[A] = Amount applied to soil [metric tons]
EF = Emission Factors [tons C/tons applied]
[ConCO2] = 12/44 = Weight conversion from C to CO2

Table 43: Variables used to calculate carbon dioxide emissions from liming and urea fertilizer application (2018 values from US EPA State Inventory Tool)

Chemical/ Mineral	Amount applied to soil [metric tons]	Emission factor [tons C/tons applied]
Limestone	County-level limestone/dolomite/urea fertilization consumption for agriculture is estimated by taking the state-wide consumption values from US EPA (2017) and allocating it to each county based on fertilizer expenditures from USDA (2021)	0.059
Dolomite		0.064
Urea		0.200

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