SEI Stockholm Environment Institute

Climate Solutions Accelerator
of the Genesee-Finger Lakes Region

Genesee - Finger Lakes Emissions Inventory

SEI report
January 2023

Emily Ghosh[1]

Susie Bresney[1]

Omar Aponte[2]

Anisha Nazareth[1]

Chris Calderon[1]

[1] Stockholm Environment Institute
[2] Climate Solutions Accelerator

Stockholm Environment Institute
Linnégatan 87D 115 23 Stockholm, Sweden
Tel: +46 8 30 80 44 www.sei.org

Author contact: Emily Ghosh
emily.ghosh@sei.org
Editor: Lynsi Burton
Cover photo: Trinity Episcopal Church and the Cayuga–Seneca Canal in Seneca Falls, Finger Lakes region, upstate New York State, USA © benedek

DOI: https://doi.org/10.51414/sei2023.005

Stockholm Environment Institute is an international non-profit research and policy organization that tackles environment and development challenges.
We connect science and decision-making to develop solutions for a sustainable future for all.
Our approach is highly collaborative: stakeholder involvement is at the heart of our efforts to build capacity, strengthen institutions, and equip partners for the long term.
Our work spans climate, water, air, and land-use issues, and integrates evidence and perspectives on governance, the economy, gender and human health.
Across our eight centres in Europe, Asia, Africa and the Americas, we engage with policy processes, development action and business practice throughout the world.

Written by:
Stockholm Environment Institute US
11 Curtis Avenue
Somerville, MA, USA 02144

Written for:
Climate Solutions Accelerator of the Genesee-Finger Lakes Region
758 South Ave Suite #4
Rochester, NY, USA 14620

Executive summary

Human-caused climate change endangers the future of our planet. Limiting climate change's worst impacts while creating a sustainable planet for all requires urgent action across all sectors and scales. These climate impacts are already posing threats to the Genesee-Finger Lakes Region (the "region") in several ways, such as heat waves, floods and fluctuating precipitation patterns. At the same time, climate action provides multiple benefits, including improving energy affordability and reliability, particularly for our lowest-income households, reducing health issues caused by air pollution such as respiratory illnesses, and boosting economic vitality through new businesses and jobs.

The Climate Solutions Accelerator of the Genesee-Finger Lakes Region (CSA), in partnership with the Stockholm Environment Institute's (SEI's) US Center, has been assessing the region's climate footprint and identifying regionally appropriate climate actions by consolidating input from a broad cross-section of communities and industries. The project's purpose is to help guide the development and implementation of climate actions across the Genesee-Finger Lakes Region that have the most significant potential to cut greenhouse gas emissions while improving the region's vibrancy, equity, resiliency and health. The final output of this project is 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 strategy was developed through a phased approach starting with a baseline emissions assessment of the region's historical sources of emissions (Phase 1), followed by a scenario analysis evaluating potential emission reduction measures and pathways (Phase 2), and finally, the development of a short-term climate action strategy outlining the way forward (Phase 3). This report is Phase 1, a summary of the baseline emissions assessment.

Report overview

The baseline emissions assessment includes an analysis of the major sources of emissions in each of the region's counties and estimates emission projections into the future (the "baseline scenario") based on historical emission rates. This report documents the methodology and data sources used to develop the emissions inventory. The emissions inventory was developed in accordance with the 2015 New York Community and Regional GHG Inventory Guidance document ("NY GHG guidance") (NYSERDA, 2015) and also aligns with the methodology used in the 2021 New York State Statewide Greenhouse Gas Emissions Report ("NY GHG inventory") (NYSDEC, 2022b) 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, 2006a, 2019) and meets the requirements set forth in New York State's Climate Leadership and Community Protection Act (CLCPA) (N.Y. Legis. Assemb., 2019), 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 (CO_2) 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 lacking, such as downscaling state-level emissions down to the county level. All assumptions are noted in this report.

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, institutional, agriculture and waste. The inventory also includes non-energy emissions from livestock and crop production, land use, waste and industrial processes.

Emissions from upstream fossil fuel extraction and refining processes, as well as fugitive emissions (leaks or losses) 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.

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. 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 in both the gross and net emissions because they are not released during natural decay processes.

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 available historical data varies between sectors. The historical period was chosen based on the years with the greatest amount of available data. Baseline emission projections start after the last historical year (2019) and extend to 2050.

Regional emission trends

In 2018, regional gross emissions were 28.6 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) (Table ES-1). This represents a slight reduction in gross emissions during the historical period, from 29.5 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) in 2010. This decrease is attributed to 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 30.4 $MMtCO_2e$ in 2050 from growth in the agricultural, industrial and commercial sectors.

Nearly 70% of historical emissions are caused by energy consumption over non-energy emissions (Table ES-2). However, non-energy emissions from waste, agricultural and industrial processes are still large and make 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, in 2050, land use and forestry-related activities will reduce emissions by -1.5 MMtCO_2e each year, or 4.9%.

Between the different sectors (Table ES-1), 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 9% of regional emissions due to the three large landfills that make up 41% of New York's existing and proposed landfill capacity. A similar composition of sectoral emissions is seen 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 and public transit, 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 (Table ES-2), gasoline consumption in vehicles represents 25% of 2018 emissions. This is followed by natural gas use in the residential, commercial and industrial sectors, resulting in 17% of 2018 emissions. Natural gas use appears to have jumped in 2018 compared to years prior in both the residential and commercial sectors. This seems to be a one-time occurrence, and not part of a larger trend.

Conversions for non-CO_2 greenhouse gases to CO_2 equivalents (CO_2e) can be carried out using 20, 100, or 500-year global warming potentials (GWPs). While the United Nations Framework Convention on Climate Change (UNFCCC) uses GWP100 for national reporting of GHG emissions in CO_2e, the CLCPA uses GWP20. The CLCPA's choice of using GWP20 puts emphasis on methane-related warming in the upcoming 10 to 30 years. When using the 100-year global warming potential (GWP100) (Table ES-4), carbon dioxide by far makes up the biggest share of greenhouse gas emitted in the region compared to other greenhouse gases, representing 72% of emissions. When viewing GWP20, (Table ES-3), carbon dioxide emissions only represent 53%, with methane making up an increased share of emissions at 39%.

Table ES-1: *Genesee-Finger Lakes Greenhouse Gas Emissions by Economic Sector (results in GWP20)*

Sector	**-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**
Transportation	9.39	32	9.57	33	8.95	31	8.69	29
On-road	8.75	30	8.95	31	8.27	29	7.93	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	19	6.34	22	6.88	24	8.16	27
Energy use	0.20	1	0.31	1	0.36	1	0.49	2
Livestock	4.90	17	5.58	20	5.97	21	6.92	23
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
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	9
Small commercial	0.36	1	0.37	1	0.38	1	0.42	1
Industrial	3.62	12	2.00	7	2.16	8	2.62	9
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	0.21	1	0.17	1	0.14	0	0.13	0
Electricity transmission & distribution	0.19	1	0.15	1	0.12	0	0.11	0
Fugitive emissions	0.02	0	0.02	0	0.02	0	0.02	0
Gross emissions total	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure ES-1: *Historical and Baseline Emissions in the Genesee-Finger Lakes Region by Type of Emissions (using GWP20)*

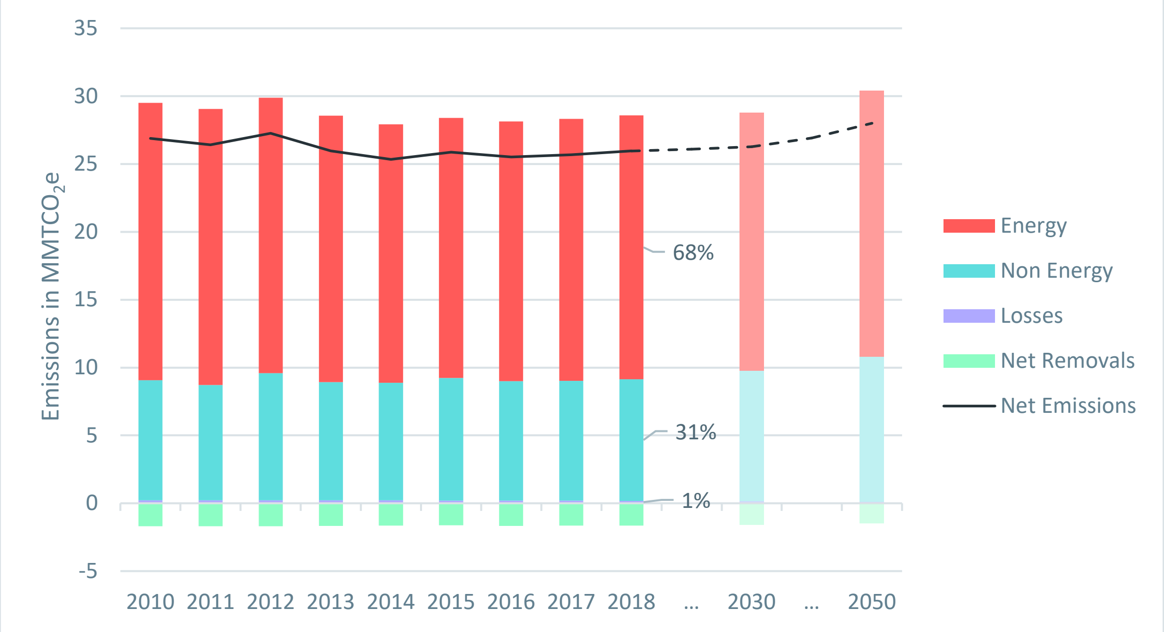


Figure ES-2: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Sector (using GWP20)*

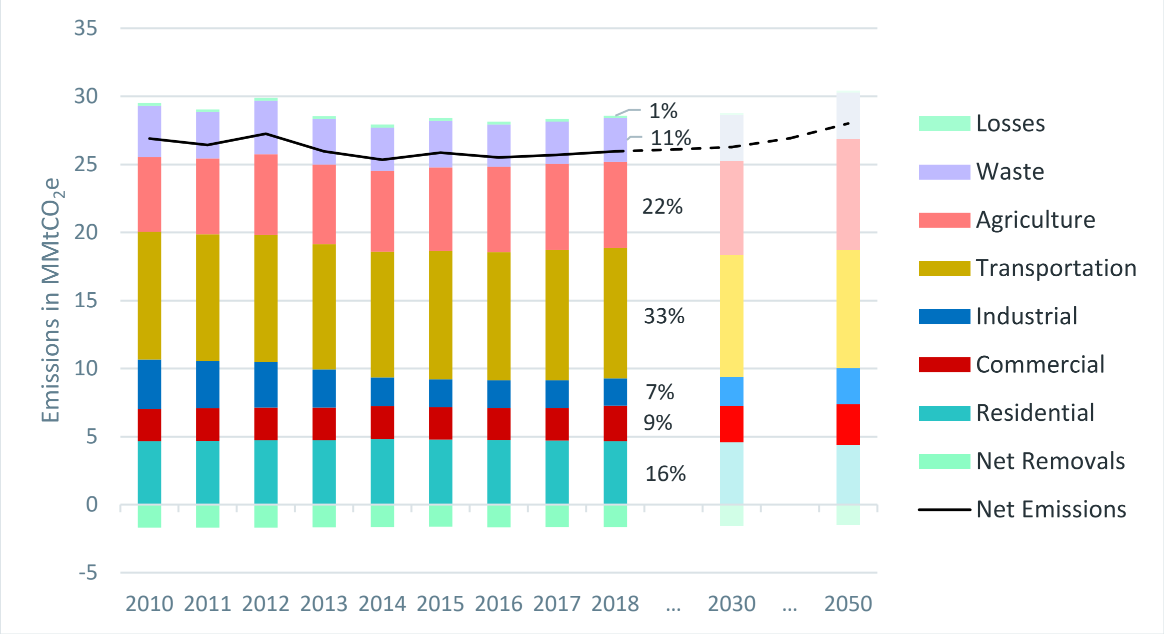


Table ES-2: *Genesee-Finger Lakes Greenhouse Gas Emissions by Fuel (results in GWP20)*

Sector	**-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**
Energy-related (Fuels)	20.64	70	19.60	69	19.17	67	19.74	65
Gasoline	6.99	24	7.01	25	6.14	21	5.25	17
Natural gas	4.62	16	4.97	17	5.19	18	5.48	18
Diesel	2.49	8	2.64	9	2.96	10	3.71	12
Electricity	2.32	8	2.18	8	2.06	7	2.27	7
Coal	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	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	8.98	31	9.60	33	10.67	35
Gross emissions total	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure ES-3: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Fuel (using GWP20)*

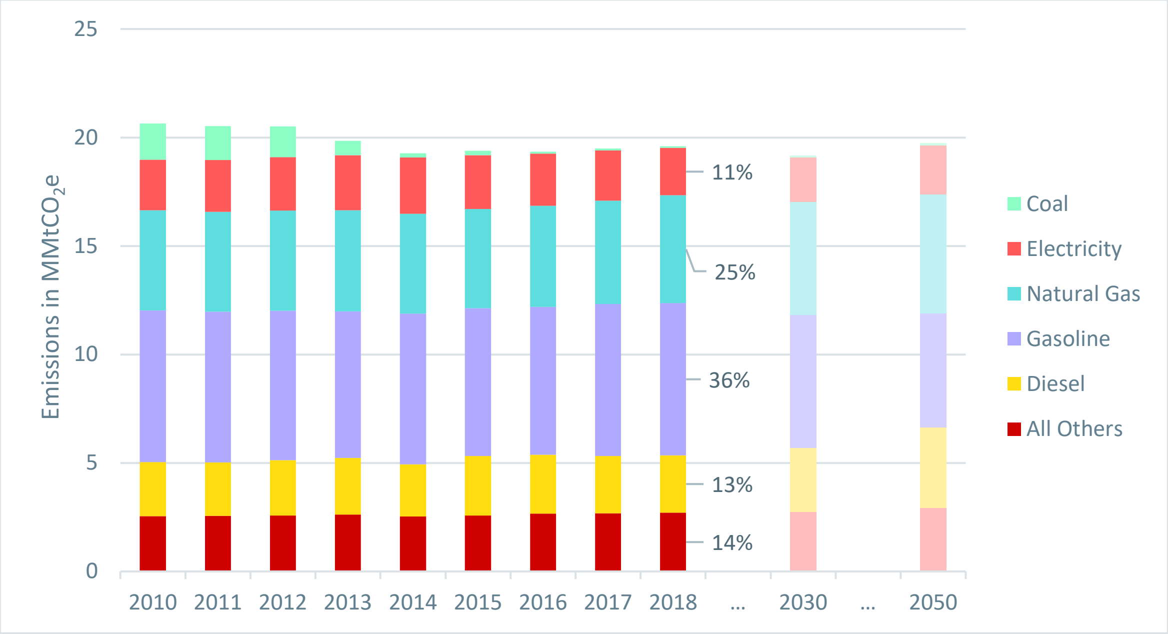


Table ES-3: *Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP20)*

Sector	**-Historical-**				**-Baseline Projection-**			
	2010		**2018**		**2030**		**2050**	
	$MMtCO_2e$	**% of total**	**$MMtCO_2e$**	**% of total**	**$MMtCO_2e$**	**% of total**	**$MMtCO_2e$**	**% of total**
GHG	29.50	100	28.57	100	28.77	100	30.42	100
CO_2 biogenic	0.92	3	0.98	3	0.93	3	0.93	3
CO_2	16.30	55	15.41	54	15.06	52	15.57	51
CH_4	11.35	38	11.15	39	11.66	41	12.56	41
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	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

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

Figure ES-4: *Historical and Project Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP20)*

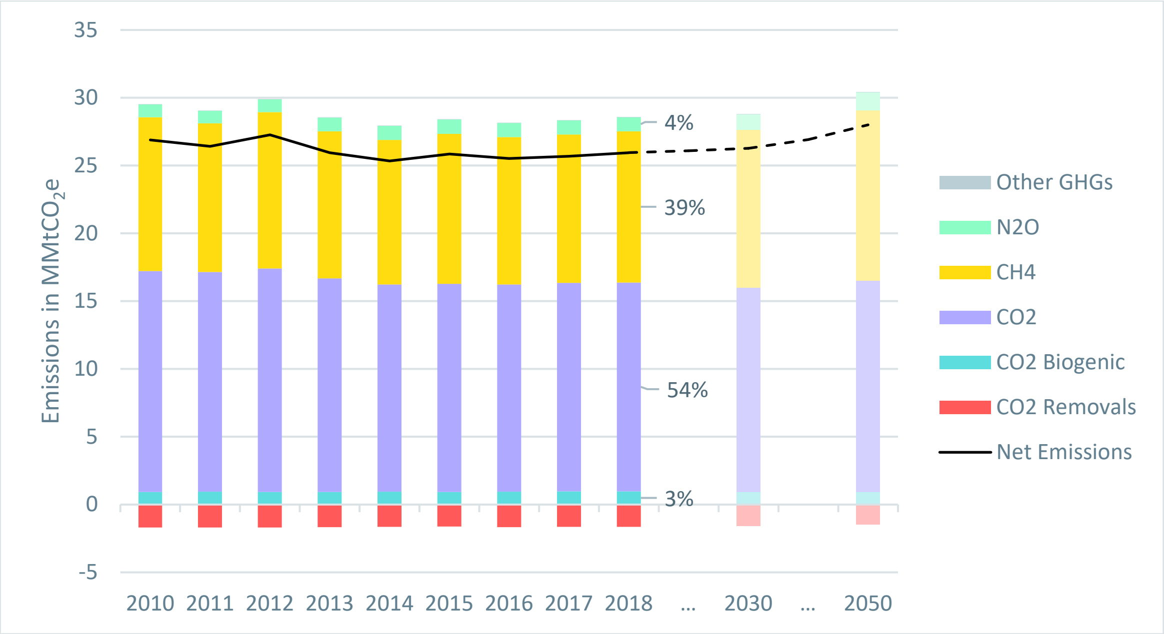
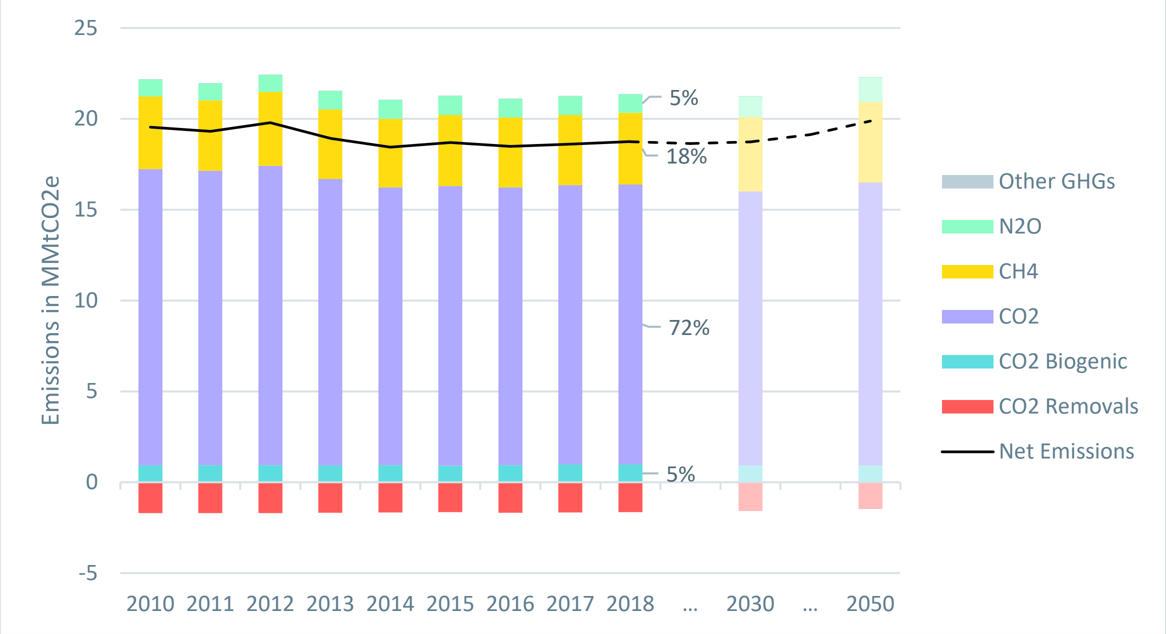


Table ES-4: *Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP100)*

Sector	**-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**
GHG	22.17	100	21.37	100	21.24	100	22.30	100
CO$_2$ biogenic	0.92	4	0.98	5	0.93	4	0.93	4
CO$_2$	16.31	74	15.41	72	15.07	71	15.57	70
CH$_4$	4.01	18	3.94	18	4.11	19	4.43	20
N$_2$O	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	**22.17**	**100**	**21.37**	**100**	**21.24**	**100**	**22.30**	**100**
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	**19.55**		**18.74**		**18.73**		**19.88**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure ES-5: *Historical and Project Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP100)*



County-level emission trends

As shown in Table ES-5 and Figure ES-6, the counties with the highest populations also have the highest emissions share, with Monroe County at 40% of the region's emissions in 2018, followed by Ontario County at 12%. The source of emissions varies from county to county, as illustrated in **Figure ES-7**. For example, Livingston, Wyoming and Yates' largest share of emissions is from agriculture–dairy farming in particular. According to the US Department of Agriculture (USDA, 2022), Wyoming contains the greatest number of cows among any county in New York State, and Yates is home to the most dairy farms, which is likely why dairy farming emissions are so high in those counties. In Seneca and Orleans, solid waste emissions represent 45% and 25% of gross emissions, respectively. This is due to the presence of two large landfills, including the Seneca Meadows landfill in Seneca County and defunct Orleans Sanitary Landfill in Orleans. Monroe and Wayne share similar emissions profiles, whereby about 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 ES-5: *Genesee-Finger Lakes Greenhouse Gas Emissions by County (results in GWP20)*

County	**-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**
Gross emissions total	29.50	100	28.57	100	28.77	100	30.42	100
Genesee	2.63	9	2.98	10	3.04	11	3.30	11
Livingston	1.96	7	2.21	8	2.38	8	2.87	9
Monroe	13.40	45	11.04	39	10.78	37	10.35	34
Ontario	3.45	12	3.45	12	3.74	13	4.41	15
Orleans	1.02	3	1.06	4	1.06	4	1.13	4
Seneca	1.61	5	2.23	8	2.23	8	2.58	8
Wayne	2.06	7	2.07	7	2.06	7	2.18	7
Wyoming	2.46	8	2.54	9	2.54	9	2.63	9
Yates	0.91	3	0.98	3	0.94	3	0.95	3
Gross emissions total	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure ES-6: *Net Emissions by County*

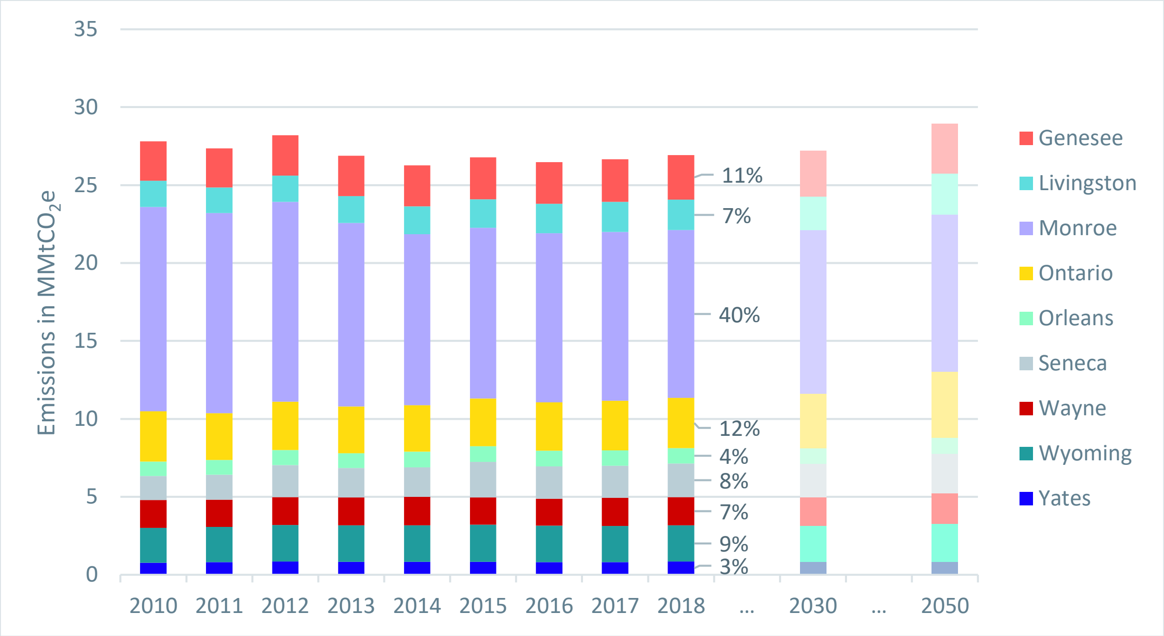
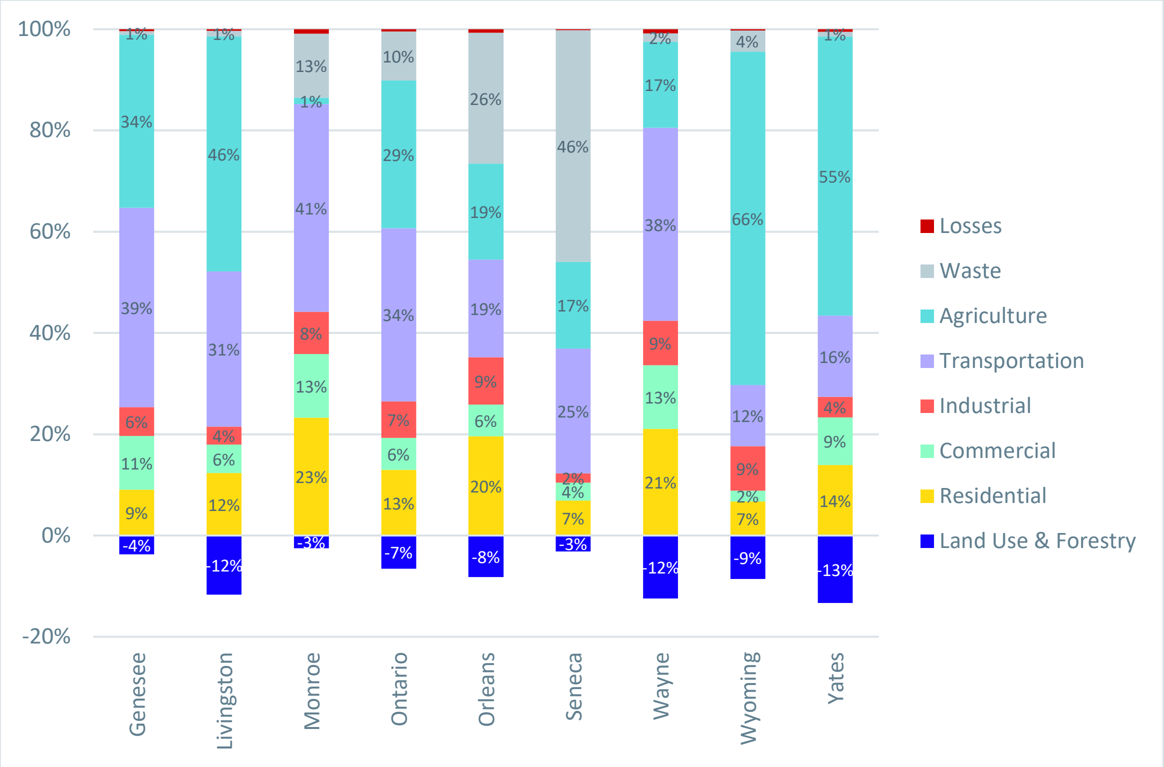


Figure ES-7: *Sectoral Share of Gross Emissions in Each County in 2018*



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

Priority areas for emission reductions

A summary of the top 15 sources of regional emissions in 2018 is given in Table ES-6, reflecting 82% of the region's emissions. Climate action around these sources of emissions should be prioritized.

Table ES-6: *Top 15 Sources of Emissions in 2018 (results in GWP20)*

Sector	Subsector	Subsector Emissions (MMtCO$_2$e)	Share of Emissions (%)
Transport	Light passenger trucks	4.3	16
Agricultural	Enteric fermentation (animal digestive processes)	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 consumption	0.5	2
Waste	Wastewater	0.5	2
Transport	Rail	0.4	2
Commercial	Propane consumption	0.4	1
Total		**22.0**	**82**

Table of contents

Executive summary ... i

Report overview ... i

Regional emission trends ... ii

County-level emission trends ... viii

Priority areas for emission reductions ... xi

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 ... 8

1.3 Inventory structure and calculations ... 12

1.3.1 Historical energy-related emissions ... 12
1.3.2 Historical non-energy-related emissions ... 31
1.3.3 Projected emissions (baseline scenario) ... 41

2 Emissions inventory results and discussion ... 44

2.1 Regional emissions ... 44

2.1.1 Comparison to the 2013 Finger Lakes Regional Sustainability Plan ... 50
2.1.2 The scale of emissions compared to other states and countries ... 50

2.2 Emissions by county ... 51

2.3 Emissions by sector ... 54

2.3.1 Residential emissions ... 54
2.3.2 Commercial emissions ... 59
2.3.3 Industrial emissions ... 62
2.3.4 Agricultural emissions ... 65
2.3.5 Transport emissions ... 67
2.3.6 Waste emissions ... 70
2.3.7 Transmission losses and fugitive emissions ... 71

2.3.8 Land use emissions and removals....72

2.4 Priority areas for emission reductions....73

3 Planned future emissions inventory updates....74

3.1 Addressing data gaps....74

3.2 Additional sectoral detail....76

4 References....76

Appendix A. Emission Factors....82

2019 Emission factors for fuel combustion....82

2019 upstream emission factors....85

Appendix B. Detailed industrial and agricultural energy results (by Orebed Analytics)....86

Appendix C. Agricultural non-energy calculations and assumptions....88

List of figures

Figure ES-1: Historical and Baseline Emissions in the Genesee-Finger Lakes Region by Type of Emissions (using GWP20)....v
Figure ES-2: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Sector (using GWP20)....v
Figure ES-3: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Fuel (using GWP20)....vi
Figure ES-4: Historical and Project Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP20)....vii
Figure ES-5: Historical and Project Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP100)....viii
Figure ES-6: Net Emissions by County....x
Figure ES-7: Sectoral Share of Gross Emissions in Each County in 2018....x
Figure 0-1: Map of the Genesee-Finger Lakes Region Source: www.gflrpc.org....1
Figure 0-2: Phases of the Genesee-Finger Lakes Climate Action Strategy....2
Figure 1-1: Genesee-Finger Lakes Electricity Service Area Map....10
Figure 1-2: *Aircraft landing and take-off cycle*....28
Figure 1-3: *Deciduous, Coniferous and Mixed Forests in New York*....40
Figure 2-1: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Type of Emissions (using GWP20)....46
Figure 2-2: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Sector (using GWP20)....47

Figure 2-3: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Fuel (using GWP20) 48
Figure 2-4: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP20) 49
Figure 2-5: Historical and Projected Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP100) 50
Figure 2-6: Net Emissions by County 53
Figure 2-7: Sectoral Share of Gross Emissions in Each County in 2018 53
Figure 2-8: Historical and Projected Residential Emissions by End Use and Fuel (results in GWP20) 54
Figure 2-9: 2018 Emissions (left axis) and Number of Households (right axis) by Household Type and Income (in GWP20) 55
Figure 2-10: 2018 emissions per household by end-use (results in GWP20) 56
Figure 2-11: *Energy Cost Burden by County and Income Group in 2019* 58
Figure 2-12: Energy Cost Burden by County and Race in 2019 58
Figure 2-13: *Energy Cost Burden by County and Spanish/Hispanic/Latino Origin in 2019* 59
Figure 2-14: Energy Cost Burden by County and Disability in 2019 59
Figure 2-15: Historical and Projected Emissions in the Commercial Sector by Fuel (results in GWP20) 60
Figure 2-16: *Electricity Usage by Commercial Sub-sector and End Use for Upstate NY* 61
Figure 2-17: *Natural Gas Usage by Commercial Sub-sector and End Use for Upstate NY* 62
Figure 2-18: Historical and projected emissions in the industrial sub-sectors (results in GWP20)... 63
Figure 2-19: Historical and Projected Emissions in the Industrial Sector by Fuel (results in GWP20) 63
Figure 2-20: *Industrial Energy Breakdown by Fuel and End-use for the Northeastern US* 64
Figure 2-21: Historical and Projected Emissions in the Agricultural Sector (results in GWP20) 65
Figure 2-22: Historical and Projected Emissions in the Transport Sector by Vehicle Type (results in GWP20) 67
Figure 2-23: Historical and Projected Emissions in the Transport Sector by Fuel (results in GWP20) 69
Figure 2-24: 2018 Transport Emissions by Vehicle Type and Fuel (results in GWP20) 69
Figure 2-25: Historical and Projected Solid Waste and Wastewater Emissions by Large Facilities (results in GWP20) 70
Figure 2-26: Historical and Projected Transmission Losses and Fugitive Emissions (results in GWP20) 71
Figure 2-27: Historical and Projected Land Use Emissions and Removals (results in GWP20) 72

List of tables

Table ES-1: Genesee-Finger Lakes Greenhouse Gas Emissions by Economic Sector (results in GWP20) iv
Table ES-2: Genesee-Finger Lakes Greenhouse Gas Emissions by Fuel (results in GWP20) vi
Table ES-3: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP20) vii

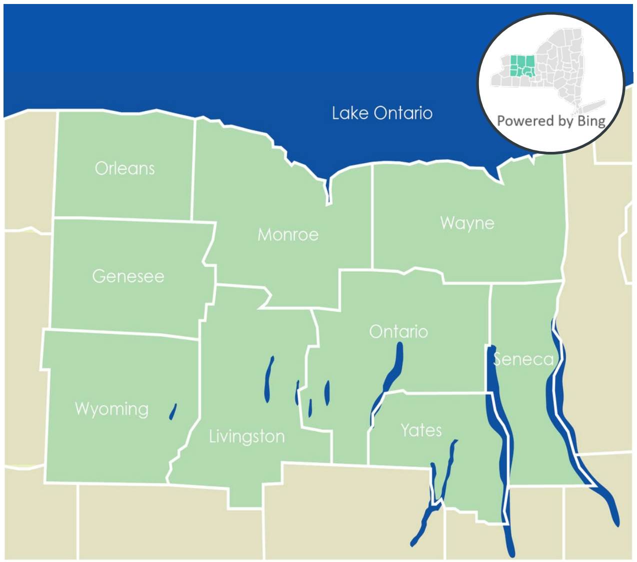
Table ES-4: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP100) viii
Table ES-5: Genesee-Finger Lakes Greenhouse Gas Emissions by County (results in GWP20) ix
Table ES-6: Top 15 Sources of Emissions in 2018 (results in GWP20) xi
Table 1-1: Comparison Between Statewide and Regional Emissions Inventories 5
Table 1-1-2: Global Warming Potentials (GWP) of Greenhouse Gases Evaluated in the Inventory ... 6
Table 1-3: 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 1-4: Comparison of the 2019 Electricity Mix Between all of Upstate New York (per eGRID) and Large Utilities in the Region 11
Table 1-5: Breakdown of Sector Calculations by Energy and Non-energy Emissions 12
Table 1-6: Final Energy Demand Sectors and Subsectors for Each County 13
Table 1-7: Area Median Incomes (AMI) 18
Table 1-8: Income Group Definition 18
Table 1-9: Residential End-use Technologies Included in the Residential Analysis 18
Table 1-10: Residential Calibration Factors by County 19
Table 1-11: Industrial Natural Gas and Electricity Calibration Factors by County 21
Table 1-12: Commercial Natural Gas and Electricity Calibration Factors by County 24
Table 1-13: On-road Transport Vehicle Types and Fuels 25
Table 1-14: Detailed Non-road Rransport Included in LEAP Model 26
Table 1-15: Aircraft Energy Intensity 29
Table 1-16: Transport Gasoline Calibration Factors by County 30
Table 1-17: Comparison of Landfill Capacity between Genesee-Finger Lakes Region and Statewide 31
Table 1-18: Non-energy Sectors and Subsectors 32
Table 1-19: Data Sources and Emissions Factors for the Industrial Non-energy emissions Calculations 33
Table 1-20: Data Sources and Emissions Factors for the Agricultural Non-energy Emissions Calculations 36
Table 1-21: Activity Levels in Final Energy and Non-Energy Emissions Projection 41
Table 1-22: Population Projections by County 43
Table 1-23: Household Projections by County 43
Table 2-1: Genesee-Finger Lakes Greenhouse Gas Emissions by Economic Sector (results in GWP20) 45
Table 2-2: Genesee-Finger Lakes Greenhouse Gas Emissions by Fuel (results in GWP20) 47
Table 2-3: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP20) 48
Table 2-4: Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP100) 49
Table 2-5: Comparison of Genesee-Finger Lakes Emissions to other Geographies 51
Table 2-6: Genesee-Finger Lakes Greenhouse Gas Emissions by County (results in GWP20) 51
Table 2-7: Residential sector emissions (results in GWP20) 54
Table 2-8: Commercial Sector Emissions by Fuel (results in GWP20) 60
Table 2-9: Share of Commercial Buildings and Energy Usage in Upstate New York 61
Table 2-10: Industrial Sector Emissions by Fuel (results in GWP20) 64

Table 2-11: Agricultural Sector Emissions (results in GWP20) 66
Table 2-12: 2018 Livestock Emissions (results in GWP20) 66
Table 2-13: *2018 Crop Emission (results in GWP20)* 67
Table 2-14: Transport Sector Emissions (results in GWP20) 68
Table 2-15: Waste Sector Emissions (results in GWP20) 70
Table 2-16: Land use sector emissions and removals (results in GWP20) 72
Table 2-17: Top 15 Sources of Emissions in 2018 (results in GWP20) 73
Table A-1: 2019 Emission factors for fuel combustion 82
Table A-2: 2019 upstream emission factors 85
Table C-3: Variables Used to Calculate Methane Emissions from Manure Management (2018 values from US EPA State Inventory Tool) 88
Table C-3: Variables Used to Calculate Nitrous Oxide Emissions from Manure Management (2018 values from the US EPA State Inventory Tool) 89
Table C-4: Variables used to calculate nitrous oxide emissions from animal manure on soils (2018 values from US EPA's State Inventory Tool) 90
Table C-5: Variables Used to Calculate Nitrous Oxide Emissions from Crop Residues, Legumes and Histosols (2018 values from US EPA State Inventory Tool) 92
Table C-6: Variables Used to Calculate Nitrous Oxide Emissions from Crop Burning (2018 values from US EPA State Inventory Tool) 93
Table C-7: Variables Used to Calculate Methane Emissions from Crop Burning (2018 values from US EPA State Inventory Tool) 93
Table C-8: Variables Used to Calculate Nitrous Oxide Emissions from Fertilizer Consumption (2018 values from US EPA State Inventory Tool) 94
Table C-9: Variables Used to Calculate Carbon Dioxide Emissions from Liming and Urea Fertilizer Application (2018 values from US EPA State Inventory Tool) 95

Project overview

Climate change caused by human activities is endangering the future of our planet. Limiting the worst impacts of climate change while creating a sustainable planet for all requires urgent action across all sectors and scales. These climate impacts already pose threats to the Genesee-Finger Lakes Region (the "region") in multiple ways, such as heat waves, floods and fluctuating precipitation patterns. At the same time, there climate action yields multiple benefits, including improving energy affordability and reliability (particularly for our lowest-income households), reducing health issues like respiratory illnesses caused by air pollution, and increasing economic vitality through new businesses and jobs.

Figure 0-1: *Map of the Genesee-Finger Lakes Region*
Source: www.gflrpc.org



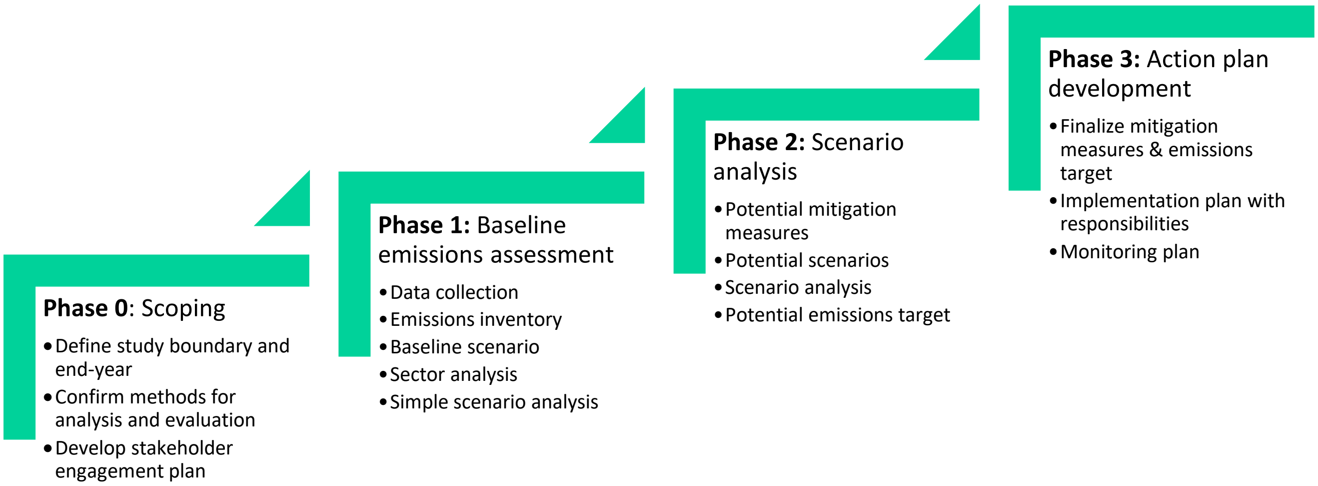
The Climate Solutions Accelerator of the Genesee-Finger Lakes Region (CSA), in partnership with the Stockholm Environment Institute's (SEI's) US Center, has been assessing the region's climate footprint and identifying regionally appropriate climate actions by consolidating input from a broad cross-section of communities and industries. The project's purpose is to help guide the development and implementation of climate actions across the Genesee-Finger Lakes Region with the most significant potential to cut greenhouse gas emissions while improving the region's vibrancy, equity, resiliency, and health. The final output of this project is 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**. The Strategy seeks to align with the state-wide emissions targets outlined in New York’s historic Climate Leadership and Community Protection Act (CLCPA) (N.Y. Legis. Assemb., 2019), also taking into account the wideranging technological improvements since the Finger Lakes Sustainability Plan in 2013 (GFLRPC, 2013). The objectives of the Climate Action Strategy are:

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

The project approach includes four phases: scoping, baseline assessment, scenario analysis, and action plan development, with stakeholder engagement with implementation agencies, industry, and civil society organizations playing a key role in the process. A summary of the four-phase project approach is shown in **Figure 0-2**:

Figure 0-2: *Phases of the Genesee-Finger Lakes Climate Action Strategy*



Phase 0: Scoping
- Define study boundary and end-year
- Confirm methods for analysis and evaluation
- Develop stakeholder engagement plan

Phase 1: Baseline emissions assessment
- Data collection
- Emissions inventory
- Baseline scenario
- Sector analysis
- Simple scenario analysis

Phase 2: Scenario analysis
- Potential mitigation measures
- Potential scenarios
- Scenario analysis
- Potential emissions target

Phase 3: Action plan development
- Finalize mitigation measures & emissions target
- Implementation plan with responsibilities
- Monitoring plan

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 for future data collection.

- Provide a starting point for discussion of potential climate mitigation measures.

This report documents the methodology and data sources used to determine county-level emissions in the Genesee-Finger Lakes region by major economic sector. The emissions inventory was developed in accordance with the *2015 New York Community and Regional GHG Inventory Guidance* ("NY GHG guidance") (NYSERDA, 2015) and updated to align with the methodology used in the *2021 New York State Statewide Greenhouse Gas Emissions Report* ("NY GHG inventory") (NYSDEC, 2022b) 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, 2006a, 2019) and meets the requirements set forth in New York State's Climate Leadership and Community Protection Act (CLCPA) (N.Y. Legis. Assemb., 2019), including reporting emissions using 20-year Global Warming Potential (GWP) for converting non-CO_2 pollutant quantities to CO_2 equivalents, accounting for out-of-state fossil fuel production emissions associated with energy use within the state, and incorporating biogenic carbon dioxide (CO_2 from the combustion of biofuels, or other organic material) 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 on large sources of emissions and large emitters, and to illuminate where data gaps lie. This inventory is not meant 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 and planned future updates are described in Section 3.

The emissions inventory data are maintained by SEI in the Low Emissions Analysis Platform (LEAP) with 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 recommends the inclusion of all "territorial" emissions, or emissions that directly occur within a physical boundary (in this case, the region), and if data is available, the inclusion of "consumption" emissions. Consumption emissions occur from the consumption of energy or goods produced outside of the boundary. More specifically, emissions sources are defined as follows:

- **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** produced 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 and clothes (also called Scope 3 emissions)

It is common that direct and indirect emissions come from 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 0-1 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/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 in Table 1-1. There are some differences between the two inventories because of variations in 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 the region’s energy. 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, but grouped with the sector that consumed it. This method prevents electricity-related emissions from being double-counted.

The inventory does not capture emissions from consuming goods imported from outside of the region. While there is data on imported emissions on a country-level, this data is not readily available on a state or regional basis.

Table 1-1: *Comparison Between Statewide and Regional Emissions Inventories*

Sector	New York Statewide GHG Inventory	Genesee-Finger Lakes GHG Inventory
Electricity	Includes: • Emissions from fuel combustion 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 fuel combustion for electricity generation attributed to the economic sector where electricity is consumed 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 (including use of refrigerants in vehicles with HVAC or refrigeration systems) • Emissions from fossil fuel imports	Includes: • Emissions from fuel combustion • Emissions from fossil fuel imports Deviation from statewide inventory: • Emissions from product use (e.g. refrigerants) 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 (including use of refrigerants in HVAC or refrigeration systems) • 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 (i.e., refrigerants) 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 (such as the manufacturing or use of plastics, asphalt or lubricants) • Emissions from fossil fuel imports	Includes: • Emissions from fuel combustion • Other uses of fuels (such as the manufacturing or use of plastics, asphalt or lubricants) • Emissions from fossil fuel imports Deviation from Statewide inventory: • Emissions from industrial processes, including product use (e.g. refrigerants) in the transport sector and buildings • Fugitive emissions is separate sector • Oil and gas production data (incl. abandoned wells) is not available

Sector	New York Statewide GHG Inventory	Genesee-Finger Lakes GHG Inventory
Agriculture	Includes: • Livestock • Soil management	Includes: • Livestock • Soil management
Waste	Includes: • Waste (solid waste facilities, wastewater) • Exported waste	Includes: • Waste (solid waste facilities, wastewater) Not included: • Waste 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 the years with the greatest amount of available data. 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 estimates the amount of energy absorbed by 1 ton of GHG emissions over a given period (e.g. 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 1-2.

Table 1-1-2: *Global Warming Potentials (GWP) 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 (i.e. a feedback loop where warming may weaken the atmosphere's capacity to absorb GHGs, leading to higher atmospheric concentrations of GHGs and more warming) 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 values from the Intergovernmental Panel on Climate Change's (IPCC's) fifth assessment report (AR5), which was adopted by the CLCPA. The 100-year GWP from IPCC's fourth assessment report (AR4) is the conventional GHG accounting format used by the United Nations Framework Convention on Climate Change (UNFCCC) for national reporting of GHG emissions. As shown in Table 1-2, unlike most greenhouse gases which have long atmospheric lifetimes, methane's potency under the 100-year GWP is lower compared to the 20-year GWP. This is because methane decays relatively quickly (about nine 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 a 20-year GWP was chosen for the CLCPA over 100-year GWP is given in Howarth (2020). (Other GHGs that are less potent under the 100-year timeframe compared to the 20-year timeframe include 1,1,1,2-Tetrafluoroethane (also known as hydrofluorocarbon HFC-134a) and Trichlorofluoromethane (also known as chlorofluorocarbon CFC-11). In general, some, but not all, HFCs are short-lived.)

Several other air pollutants are produced by the energy and non-energy sectors. Where the data allows, here are some other pollutants that are also considered in our analysis, though not reported on due to our focus on pollutants that cause climate change (i.e. greenhouse gases):

- 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 in both the gross and net emissions since they are not released during natural decay processes.

1.2.3 Emission factors

Emission factors are used to calculate the emissions generated from on-site fuel combustion, from electricity generation and emissions from various industrial, agricultural, waste and land use change processes. The emissions from cooking with natural gas 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 those used in the NY GHG Inventory. The following sub-section provides further detail on the emission factors used for this emissions inventory.

1.2.3.1 Emission factors for fuel combustion

For energy-related emissions, an emission factor is a measure of how much pollutant is emitted per unit of fuel consumed, and it varies depending on what sector and activity the fuel is used in. To calculate pollutant emissions from a given source of energy, the amount of fuel consumed is multiplied by an emissions factor specific to that type of fuel. In this study, a bottom-up/end-use accounting technique is used to estimate fuel demands where the data allowed. Top-down/macroeconomic methods are then used to fill in data gaps. 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. A bottom-up analysis makes it easier to assess climate mitigation measures that target specific activities. In some cases, activity data is not readily available, so a top-down analysis is made using reported fuel consumption data.

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 the accuracy of bottom-up estimates of fuel, 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. gigajoules, million British thermal units)
Total Activity is a measure of social or economic activity (e.g. number of households, GDP)
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 estimates 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

For energy-related emissions (fuel combustion and grid electricity), 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, such as mining, extraction, refining and distribution. As a result, pollutant emissions are calculated using the following formulas:

$$\text{Energy emissions}_{(sector,\ process,\ fuel,\ GHG,\ c,\ s,\ t)} = \text{Fuel Demand}_{(sector,\ process,\ c,\ s,\ t)} \times \text{Emissions Factor}_{(sector,\ fuel,\ GHG)}$$

$$\text{Emissions Factor}_{(sector,\ fuel,\ GHG)} = \text{Combustion Emissions Factor}_{(sector,\ fuel,\ GHG)} + \text{Upstream Emissions Factor}_{(fuel,\ GHG)}$$

Where:

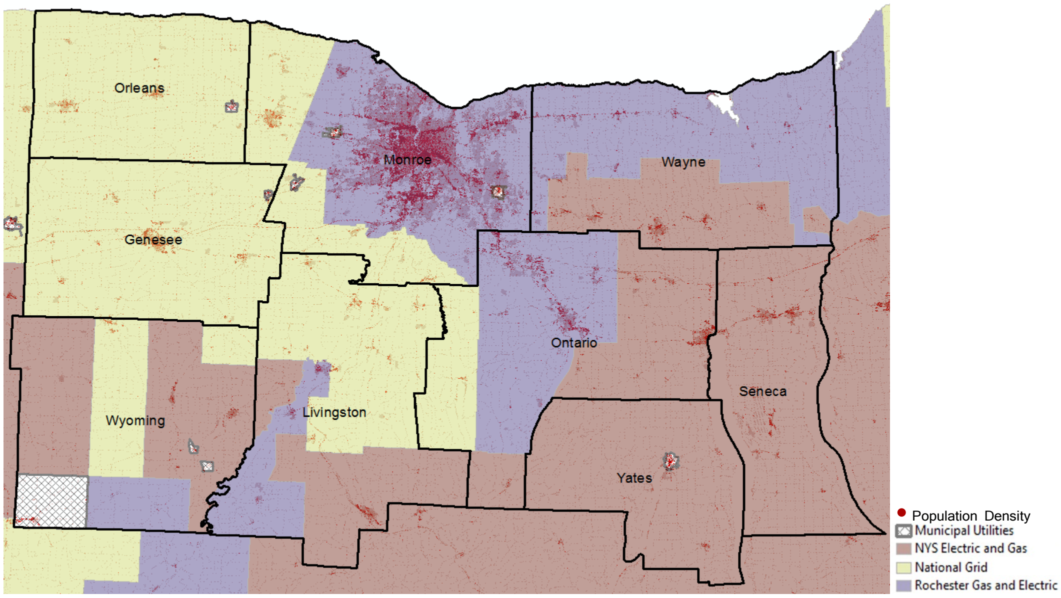
Sector is the economic sector
Process is the fuel combustion source
c is the county
s is the scenario
t is the year of analysis
fuel = type of fuel
GHG = type of greenhouse gas

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 1-1 for the Genesee-Finger Lakes electricity service area map.

Figure 1-1: *Genesee-Finger Lakes Electricity Service Area Map*



GHG emissions from consuming grid electricity (Scope 2 emissions) are based on the grid's carbon intensity, the quantity of emissions per unit of energy consumed. While the NY GHG guidance document recommends using the grid carbon intensity factor developed by New York State Energy Research and Development Authority (NYSERDA), one was not publicly reported in recent years. In its place, a statewide emissions factor was taken from the US EPA Emissions & Generation Resource Integrated Database (eGRID) (US EPA, 2021a). This statewide emission factor was adjusted based on the relative emission rates of the utilities as documented in New York's Environmental Disclosure Label 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 1-3. We used an average rate for the major electric utilities since they represent the majority of electricity emissions in the region.

Table 1-3: *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	National Grid[1]	RG&E	NYSEG
	(lb/MWH)	(% 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 (SO_2)	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 the utilities purchase is higher and the share of hydropower is lower. Despite significant hydropower generation upstate, for which some of the utilities have bilateral contracts, most of the utilities rely on the wholesale electricity market to meet electricity demands. The New York Independent System Operator (NYISO) selects the 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 of 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 1-4.

Table 1-4: *Comparison of the 2019 Electricity Mix Between all of Upstate New York (per eGRID) and Large Utilities in the Region*

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
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

Sources: US EPA (2021a), NYDPS (2021)

[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:

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

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 CLCPA's target date for achieving net zero emissions. The calculations are divided into two main categories: energy emissions and non-energy emissions. As shown in Table 1-5, some sectors have both energy and non-energy emissions, each with their own emissions calculation methodology and data sources, as described in the remainder of this section. For reporting purposes, energy emissions and non-energy emissions are reported together for a given sector.

Table 1-5: *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
Waste (Solid waste)	X	X
Waste (wastewater)	X	X
Land use & forestry		X

Several data sources were compiled to develop the inventory. Where possible, an end-use-oriented (bottom-up) approach was taken to estimate emissions, for instance, calculating transport emissions by vehicle and fuel type, rather than just by fuel. This level of detail lends itself 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 electric vehicles 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, depending 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 1-6, 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 1-6: *Final Energy Demand Sectors and Subsectors for Each County*

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
Residential	Urban center	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
	Rural or urban periphery	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
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		

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
		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 Manufacturing		
		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		
		N3259 Other chemical product and preparation Manufacturing		
		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 manufacturing		
		N3311 Iron and steel mills and ferroalloy manufacturing		
		N3312 Steel product manufacturing from purchased steel		
		N3313 Alumina and aluminum production and processing		
		N3315 Foundries		
		N3321 Forging and stamping		
		N3322 Cutlery and handtool manufacturing		
		N3323 Architectural and structural metals manufacturing		
		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 manufacturing		
		N3335 Metalworking machinery manufacturing		
		N3339 Other general purpose machinery manufacturing		
		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 manufacturing		
		N3371 Household and institutional furniture and kitchen cabinet manufacturing		

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
		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 manufacturing		
		N3328 Coating engraving heat treating and allied activities		
		N3331 Agriculture construction and mining manufacturing		
		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 and commercial refrigeration equipment manufacturing		
	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		
		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			

Sector	Subsector Level 1	Subsector Level 2	Subsector Level 3	Subsector Level 4
	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 (e.g. air conditioners, furnaces, lights). The emission factors used for the residential sector are provided in **Appendix A**.

Per Table 1-6, 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:

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

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

Where:

Energy is the energy use in MMBtu
HH is the number of households from the US 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 $f_{g,by,own,inc}$ comes from Ruggles et al (2021)
–$f_{g,by,own,inc,ech}$ is from US EIA (2018)
c is the county
s is the scenario
t is the year of analysis
type is the household type based on a combination of *g*, *by*, *own* and *inc*
fuel is the type of fuel (e.g. natural gas, electricity, etc.)
tech is the end-use technology (e.g. natural gas boiler, central AC)
g is the geographic location of a household (urban center/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/middle-high)
T is the total number of end-use technologies

Residential activity and energy intensity

The number of households in each county is available from the US American Community Survey (ACS) (US Census Bureau, 2021). The share of households and household type within each county is calculated from the ACS via a web tool called IPUMS (Ruggles et al., 2021). Data from IPUMS was available for the years 2012 to 2019 at the time of this analysis. Further details on the different household groupings are as follows:

- **Geography:** Households were divided into two geographic groups: "urban center" and "rural or urban periphery". The data used to categorize households is from the IPUMS variable called METRO. METRO indicates whether a household is in an urban center, urban periphery (what we call "rural or urban periphery" since it includes rural households) or mixed area. The households in the "mixed" category were divided between "urban center" and "rural or urban periphery" based on the share of households located in a metropolitan area (per the variable called PCTMETRO). Energy data is not provided for mixed areas, so it was necessary to divide up the mixed category in this way.

- **Building vintage:** Urban and rural households were further divided into two building vintages based on their level of energy efficiency: "new" or "old". The built year for a household was provided by the IPUMS variable called BUILTYR. New buildings are assumed to be those built after or in the year 2000, around the time of a major building code update, and old buildings are assumed to be those built before 2000. In 2002, the New York State Energy Conservation Construction Code (ECCC) was significantly revised to align its minimum efficiency standards for new construction with those of the model International Energy Conservation Code (IECC). Because the year of construction for homes in ACS are given in decadal increments, homes that were built from 2000–02 will not have been built under the updated codes; thus, there will be some "new" homes under the old codes.

- **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 IPUMS 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 middle-high income. The income groups are based on the area median income (AMI) defined for each county by the US Department of Housing and Urban Development (HUD) (2020). The AMI and income group definitions are shown in Table 1-7 and Table 1-8. Households were categorized based on the data in the IPUMS variable for household income, HHINCOME.

Table 1-7: *Area Median Incomes (AMI)*

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: US HUD (2020)

Table 1-8: *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 Department of Housing Preservation and Development (2021)

Energy data for each household type was taken from the US 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 includes the Genesee-Finger Lakes region – was used instead.

RECS microdata provides activity levels and energy intensity for various end-use categories and is available for each of the household types described above. The end uses specified in our analysis are air conditioning, water heating and space heating, with fuel demands from all other end uses (e.g. refrigeration, cooking, clothes washing and drying, dishwashing) combined into a single category called “Other.” The technologies and fuels under each end-use category are indicated in Table 1-9.

Table 1-9: *Residential End-use Technologies Included in the Residential Analysis*

Water Heating	Space Heating	Air Conditioning (AC)
Technologies	**Technologies**	**Technologies**
Reference 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	

Water Heating	Space Heating	Air Conditioning (AC)
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	

Note: “Efficient” technologies have higher rates of efficiency compared to the average model used today (e.g. “Reference” technology)

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 the estimated fuel demands we generated through the bottom-up analysis, which is then applied to the energy intensity. The residential calibration factors used for this analysis are provided in Table 1-10. 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 yield more accurate future estimates.

Table 1-10: *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 Industrial and agricultural

Energy data for the industrial and agricultural sector was obtained from the National Renewable Energy Laboratory's (NREL's) Industrial Energy Data Book (IEDB) 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 several publicly available data sources, including the US Environmental Protection Agency (EPA), US Energy Information Agency (EIA), US Census Bureau, US Department of Agriculture (USDA), and US Geological Survey (USGS).

NREL's IEDB reports consumption of natural gas, diesel, liquid petroleum gas, residual fuel oil, coal, petroleum coke, net electricity, and "other" fuel for the industrial and agricultural sectors. 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 demand data from IEDB or elsewhere 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 Greenidge Generation facility in Yates County opened in 2018 and is already proposing to expand its operations to over 55 megawatts (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". Since the Greenidge Generation facility is connected to the grid, it is assumed that its emissions are already captured in the electricity emissions factor described in Section 1.2.3.2, though this would need to be verified.

A summary of the industrial and agricultural sub-sectors included in the inventory is in Table 1-6. The emission factors used to translate fuel usage to emissions is provided in **Appendix A**. A detailed report from Orebed Analytics in **Appendix B** provides additional results on industrial and agricultural energy demands in the Genesee-Finger Lakes region.

Calibration of industrial and agricultural energy use

A calibration factor is the ratio of actual fuel demands over our estimated fuel demands from the bottom-up analysis, which is then applied to the energy intensity.

NYSERDA's Patterns and Trends reports provides the total natural gas and electricity use for each county and is used to calibrate the industrial electricity and natural gas demands using the calibration factors provided in Table 1-11. Fuel use data for 2013 was the only year available (NYSERDA, 2019b). The actual energy used by the agricultural sector is not publicly reported by NYSERDA and was not calibrated.

Table 1-11: *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
Seneca	0.62	0.47
Wayne	1.61	1.44
Wyoming	1.19	0.70
Yates	0.56	0.82

1.3.1.3 Large commercial

We calculated commercial energy use by treating small and large commercial categories separately, as NYSERDA groups large commercial data together with industrial demands. Once we could isolate the industrial demands, we could then quantify the large commercial results and combine them with the small commercial data so we could get a picture of the commercial sector's demand as a whole.

Both the large and small commercial categories required top-down calculations because of insufficient data available to use the bottom-up approach.

We determined large commercial demands by subtracting the industrial demands provided by NREL's IEDB (see previous section for details) from the energy data in NYSERDA's Utility Energy Registry (UER) – the database that groups industrial with large commercial demands. The UER presents the large commercial and industrial demands in a category named "Other", which is defined as follows:

> *Other (O): A unique formulation adopted by the New York PSC as the aggregated load of non-residential accounts NOT eligible for Community Choice Aggregation by virtue of the rate class. These are typically larger demand-class customers.*

The UER dataset only includes natural gas and electricity, which covers a limited range of fuels compared to the IEDB dataset. The UER and IEDB datasets overlap in one year only, 2016, and so this year of data was used for the large commercial analysis. Since the UER withholds some data due to privacy concerns, and, as a result, reports a lower amount of energy usage than actually consumed, we first applied a calibration factor to the UER data to estimate the total amount of natural gas and electricity consumed by the "Other" sector and then calculated the proportion used for large commercial.

Calibration of large commercial energy use

The calibration of large commercial was combined with small commercial, since actual commercial demands from NYSERDA's Patterns and Trends reports are not disaggregated into small and large commercial. Refer to Section 1.3.1.4 for the calibration factors used for the commercial sector as a whole.

1.3.1.4 Small commercial

We used a top-down approach to calculate energy use in the small commercial sector due to insufficient data for a bottom-up analysis. Per Table 1-6, 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 available.

Energy consumption from private utilities

Natural gas and electricity consumption was obtained from NYSERDA's UER for small commercial buildings using private utilities for the years 2016 to 2018. The UER defines small commercial as follows:

> *Small Commercial (SC): A unique formulation adopted by the New York PSC as the aggregated load of non-residential accounts eligible for Community Choice Aggregation by virtue of the rate class. These are typically smaller, non-demand class customers.*

The UER provides natural gas and electricity data for each census tract. To ensure privacy, the utilities withhold data from the UER when there are not enough customers in a given tract to obscure each customer's identity. 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 which provides total quantities of different fuels used at a county and sector level (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 commercial areas in hectares serviced by each utility.** The National Land Cover Dataset (NLCD) 2016 is a dataset which categorizes the US 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 cover class, within each county, within each utility service area. There are

three land cover 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 (i.e. paved) surface in a given area:

- **Developed, Low intensity –** Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49% 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% 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 80–100% of the total.

  While these categories are not perfect predictors of areas where small commercial entities exist, for these purposes, we assumed that the high-intensity land cover category likely captures where small commercial energy use occurs.

2. **Add up the total area (in hectares)** covered by high intensity 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 kilowatt hours per hectare (kWH/ha) or therms per hectare (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. Due to insufficient data, we are unable to determine what share of the total area in each of the categories described in Step 1 is commercial or residential, but assume that small commercial has similar intensity to residential.

4. **Apply the energy intensity in kWH/ha or therms/ha of the private utilities to the commercial areas within the municipal utilities to determine commercial energy consumption from municipal utilities.** The energy intensity within a given county and utility are assumed to be the same, with the exception of Monroe County. In Monroe County, the energy intensity of municipal utilities is assumed to be similar to the level in “developed – high intensity” areas in Genesee County. This assumption is used because the areas serviced by municipal utilities in Monroe are closer in resemblance to the “developed – high intensity” Genesee County. The “developed – high intensity” areas in Monroe County are largely in the city of Rochester, which has significantly taller buildings and higher-density neighborhoods than those found in the areas currently serviced by municipal utilities.

This analysis uses the following assumptions:

1. The developed, high-intensity land cover class represents areas where commercial energy use occurs, 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, private 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, enabling people to use more electricity in these service areas than in others.
3. No area is served by two electric utilities. This appears true given the map of service areas in Figure 1-1.

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's commercial sector and is used to calibrate the private utility and municipal utility data. Only actual fuel use data for 2013 was available.

The calibration factors for the commercial sector as a whole are provided In Table 1-12. 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. That scaling factor is the calibration factor listed in the table below.

Table 1-122: *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

1.3.1.5 Transport

As shown in Table 1-6, 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

We calculated a bottom-up estimate of fuel demands 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 1-6 are further disaggregated by vehicle type and fuel (see Table 1-13).

Table 1-13: *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:

$$
\begin{aligned}
&Fuel\ Consumption_{\text{Class, Type, Fuel}} = \\
&\qquad \#ofVehicles_{\text{class}} \times VehicleMiles_{\text{class}} \times \%type_{\text{class, type}} \times (1/FE_{\text{class, type}}) \times \%fuel_{\text{class,type, fuel}}
\end{aligned}
$$

Where:
Fuel Consumption$_{class,\ type,\ fuel}$ is the total amount of fuel used in gallons for a given vehicle class, vehicle type and fuel

#ofVehicles$_{class}$ is the number of registered vehicles for each vehicle class 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$_{class}$ is the total community-wide miles travelled added up across a vehicle class using traffic data from the US Department of Transportation (US DOT) and NY DOT, except for public buses where the data is from the FTA’s NTD (2022).

%type$_{class,type}$ is the fraction of each vehicle class made up by a specific vehicle type (%) from the NY DOT.

FE$_{class,\ type}$ is the fuel economy for a specific vehicle type expressed in miles per gallon from the US Environmental Protection Agency (EPA) and the US DOT.

%fuel$_{class,type,fuel}$ is the fraction of fuel share by vehicle type (%). Electric plug-in vehicles are separated into electric and gasoline sub-categories. Here we assume that plug-in hybrid electric vehicles (PHEVs) 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.

Data was compiled and calculated by Orebed Analytics. Details are available upon request, including information on data sources and calculations used for determining the number of vehicles, vehicle miles traveled, fuel economy and percent share of vehicle types and fuels used. The data provided by Oredbed Analytics was 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 1-6, the non-road sector includes rail, airport and marine transport. In the model, non-road transport is further disaggregated, as provided in Table 1-14.

Table 1-14: *Detailed Non-road Rransport 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*	C1/C2 Port emissions main engine (diesel)
		C1/C2 Port emissions auxiliary engine (diesel)
		C1/C2 Underway emissions main engine (diesel)
		C1/C2 Underway emissions auxiliary engine (diesel)
		C3 Underway main engine (diesel)
		C3 Underway auxiliary engine (diesel)

*Note: The U.S. Maritime Commission designates ships as "C1," "C2" or "C3" to distinguish different capacities and lengths.

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 of which use diesel to run. (The Surface Transportation Board designates railroad carriers as Class I, II, or III according to annual revenue criteria.) We gathered data for locomotives from the years 2002 and 2017. The 2002 data was taken from NYSERDA’s 2002 Locomotive Survey for New York State (Southern Research Institute, 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 II and III locomotives was estimated by dividing their total emissions by the emissions factor for nitrogen oxides. Any other pollutant's emissions factor would have given the same result in these calculations.

A similar method was used to calculate the 2017 locomotive fuel consumption data, which was back-calculated using emissions and emission factors reported for non-point sources in the US EPA’s 2017 National Emissions Inventory (US EPA, 2019b, 2020a).

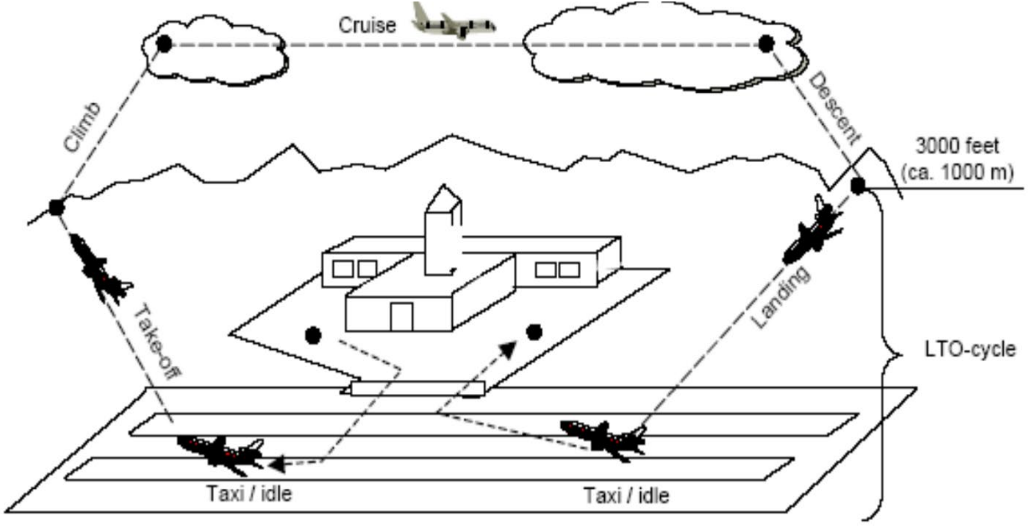
Airport

Airport emissions are associated with operating the airport, as well as aircraft landing and takeoff (Scope 1 emissions). Emissions that occur mid-airplane travel (known as cruise emissions) have not been incorporated in this report. While the US Bureau of Transportation Statistics appears to have annual air carrier statistics with mileage on flights originating in the Genesee-Finger Lakes region, additional carrier information is required – the type of aircraft, fuel and fuel combustion intensity of those flights – to estimate cruise emissions.

The aircraft landing and take-off (LTO) cycle provides our basis for calculating aircraft emissions around airports. Shown in Figure 1-2, the LTO cycle consists of all activities near the airport that occur below the altitude of 3000 ft (1000 m), including taxi-in and out, take-off and landing. Cruise consists of the activities that occur above that altitude, including the climb to cruise altitude, cruise and descent from cruise altitudes.

Fuel consumption and emission factors for airport operations were obtained from the US EPA’s MOVES3 model for non-road sources (US EPA, 2021c) for the years 1990 through 2050. The data was extracted from the MOVES3 model for every five years instead of every year to reduce processing time. MOVES3 reports three different fuels consumed for airport support equipment, including gasoline, diesel and LPG. The emissions factor changes slightly year to year.

Figure 1-2: *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 contains data for 2017, we used the Federal Aviation Authority's Terminal Area Forecast 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 generate 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 2001 IPCC Greenhouse Gas Inventory Reference Manual for Aircraft Emissions (IPCC, 2001). (This is a very conservative estimate of energy intensity, as it assumes that fuel consumption per LTO has remained the same since 2001.) 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. This assumes that the ratio of LTO fuel consumption to cruise fuel consumption is constant across all aircraft engine classes. To calculate this ratio, 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). (A block hour is the time to taxi to the runway, fly in the air, and taxi to the gate.) Then, the fuel consumption of the non-commercial airplane types were taken from Table 3-8 of the FAA report. Table 3-8 lists the average fuel burn of a piston engine at 45 gal/hr and a turbine engine at 71 gal/hr based on a turboprop engine under 20 seats (FAA, 2021). In the absence of better data, the average fuel burn of military aircraft is assumed to be the same as commercial aircraft. The resulting energy intensity for each aircraft type is shown in Table 1-15:

Table 1-15: *Aircraft Energy Intensity*

Aircraft type	Energy Intensity in kg/LTO
Commercial	850
Air taxi piston	850 x (45/958) = 40
Air taxi turbine	850 x (71/958) = 63
General aviation piston	850 x (45/958) = 40
General aviation turbine	850 x (71/958) = 63
Military	850

Marine

Marine includes pleasurecraft and commercial marine vessels. As with railroad maintenance, fuel consumption for pleasurecraft was obtained from the US EPA's MOVES3 model for non-road sources (US EPA, 2021c) 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 for every five years instead of every year to reduce processing time. The 2017 fuel consumption for commercial marine vessels was estimated by back-calculating from the total emissions and emissions factors reported for non-point sources in the US EPA's 2017 National Emissions Inventory (US EPA, 2020b, 2020a). The Inventory reports the following commercial marine vessels categories based on the vessel's water displacement volume in liters per cylinder (L/cyl), its status (at port or underway) and its engine type:

- Category 1 (< 7 L/cyl) and Category 2 (7 to 30 L/cyl) Port Emissions Main Engine
- Category 1 (< 7 L/cyl) and Category 2 (7 to 30 L/cyl) Port Emissions Auxiliary Engine
- Category 1 (< 7 L/cyl) and Category 2 (7 to 30 L/cyl) Underway Emissions Main Engine
- Category 1 (< 7 L/cyl) and Category 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) based on the US EPA.

Off-road transport

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 the following recreational vehicles:

- 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 gasoline)

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 for every five years. 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 1-16. Usage data of other transport fuels were not readily available.

Table 1-16: *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

We obtained all energy-related solid waste and wastewater treatment plant emissions and fuel consumption data for 2010 to 2019 from the US EPA's Facility Level Information on GreenHouse gases Tool (FLIGHT). FLIGHT includes emissions from large facilities that emit greater than 25,000 $MTCO_2e$ per year, so smaller wastewater and solid waste facilities are not included in the analysis. According to FLIGHT, there are no municipal solid waste combustion facilities in the region. All large landfills in the region have landfill gas recovery systems. The recovered landfill gas is either flared or used to generate electricity through internal combustion engines. The largest operating landfill in New York state, the Seneca Meadows Landfill, has a Landfill Gas to Energy (LFGTE) facility that also removes the impurities from landfill gas to create renewable natural gas (RNG). The RNG is purchased by the Sacramento Municipal District in California.

For the High Acres Landfill and Recycling Center, landfill gas emissions in this emissions inventory are slightly different (<5%) from what was reported in FLIGHT due to differences in fuel characteristics. Our report assumes the same fuel characteristics across years, whereas

FLIGHT accounts for changes in higher heating values between equipment and across years. Also, landfill gas appears to be called biogas in the years before 2012 in FLIGHT.

Table 1-17: *Comparison of Landfill Capacity between Genesee-Finger Lakes Region and Statewide*

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: NYSDEC (2019)

1.3.1.7 Transmission and distribution losses

We determined an electricity loss rate for New York using data from the US EIA State Electricity Profiles, Table 10, titled, “Supply and disposition of electricity, 1990 through 2019.” The loss rate was calculated by dividing estimated losses by the 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.

1.3.2 Historical non-energy-related emissions

Non-energy emissions are broken down in the model by economic sector, subsector and source of emissions. The level of detail in each sector depends on the data available to the project team. Table 1-18 lists the sectors and subsectors represented in the non-energy inventory.

Table 1-18: *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
		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

Sector	Subsector Level 1	Subsector Level 2
		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 1-19.

Table 1-19: *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 (USGS, 2019) 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 calculated based on clinker emissions.	Clinker = 0.507 $MtCO_2$ emitted / Mt of clinker produced Cement kiln dust (CKD) = 0.02 Mt CKD CO_2 emitted / Mt of clinker CO_2 emitted
Lime manufacture	No	-	

SIT Industrial Processes Module	Occurs in Region?	Emissions Calculation Methodology	Emissions Factor from SIT
Limestone and dolomite consumption	Yes	State limestone and dolomite combined usage and production data from SIT (USGS, 2020) 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 = 0.44 Mt CO_2 emitted / Mt limestone used (calcite) Dolomite = 0.484 Mt CO_2 Emitted / Mt limestone used (Dolomite)
Soda ash manufacture and consumption	Yes	Soda ash consumption for the US 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 CO_2 emitted / Mt soda ash consumed
Iron and steel production	Yes	Statewide 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.	Blast Oven Furnace (BOF) with coke oven = 1.72 Mt CO_2 emitted / Mt crude steel produced BOF without coke oven = 1.46 Mt CO_2 Emitted / Mt crude steel produced Electric Arc Furnace (EAF) = 0.08 Mt CO_2 emitted / Mt crude steel produced
Ammonia manufacture	No	-	-
Nitric acid production	No	-	-
Adipic acid production	No	-	-
Aluminum production	No	-	-
HCFC-22 production	Unsure	-	-

SIT Industrial Processes Module	Occurs in Region?	Emissions Calculation Methodology	Emissions Factor from SIT
Consumption of substitutes for ozone-depleting substances (ODS)	Yes	Emissions from ODS substitutes for the US taken from the SIT (US EPA, 2017) and allocated to each county based on population (US EPA, 2017; NYSERDA, 2021b; Vespa et al., 2020).	Emission factor not used. Estimated emissions by downscaling state-wide emissions to each county
Semiconductor manufacture	Yes	Statewide emissions for semiconductor manufacturing (US EPA, 2017) allocated to each county based on total energy use in the sector (NAICS 334413) (McMillan, 2019).	Emission factor not used. Estimated emissions by downscaling state-wide emissions to each county.
Electric power transmission and distribution	Yes	Sulfur hexafluoride (SF6) consumption from electricity for the US 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 Mt SF6 Emitted / MT SF6 Consumed (Sold)
Magnesium production and processing	No	-	-

[1] Employment data obtained from US 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) 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). An overview of the non-energy emissions that were calculated and their respective methodology are provided in Table 1-20. The equations and variables used to calculate emissions are provided in **Appendix C**.

Table 1-20: *Data Sources and Emissions Factors for the Agricultural Non-energy Emissions Calculations*

SIT Agricultural Non-Energy Module	Occurs in Region?	Emissions Calculation Methodology	Emission 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 Service (USDA, 2022). This was multiplied with an emissions factor to obtain methane (CH_4) emissions.	Emission factors in kg CH_4/head: Dairy cows = 160.2 Beef cows = 94.3 Calves[1] = 54.1 Goat = 5 Sheep = 8 Swine = 1.5 Llama[2] = 8
Manure management (methane emissions)	Yes	These are the methane (CH_4) emissions from managing manure. It is calculated by multiplying the amount of volatile solids produced from each animal by an emissions factor.	See Table C-1: Variables used to calculate methane emissions from manure management (2018 values from US EPA State Inventory Tool)
Manure management (nitrous oxide emissions)	Yes	These are the nitrous oxide (N_2O) emissions from managing manure. It is calculated by multiplying the amount of nitrogen (N) excreted from each animal by an emissions factor.	Emissions factor for anaerobic lagoons and liquid systems = 0.001 kg nitrous oxide as nitrogen per kg nitrogen (kg N_2O-N/kg N) Emissions factor for solid storage, drylot and other systems = 0.02 kg N_2O-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.	Emissions factor for indirect volatilization to NH_3 and NOx = 0.01 kg N_2O / kg N Emissions factor for ag soils animal pasture = 0.02 kg N_2O / kg N Emissions factor for ag soils animal ground = 0.0125 kg N_2O / kg N

SIT Agricultural Non-Energy Module	Occurs in Region?	Emissions Calculation Methodology	Emission Factors
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.	Emission factor for ag soils leaching = 0.0075 kg N_2O-N/kg N
Soil plant residues, legumes and histosols	Yes	These are the nitrous oxide emissions from crop residues, and the cultivation of nitrogen-fixing crops and histosols (highly organic soils). It is calculated by multiplying the amount of nitrogen in residue by an emissions factor.	Emission factor for crop residues = 0.01 kg N_2O-N/kg N
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.	Emission factor for agricultural soils burning N_2O to N emissions ratio = 0.007 N_2O/N Emission factor for agricultural soils burning CH_4 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.	Emission factor for ag soils plant direct = 0.01 kg N_2O-N/kg N Emission factor for ag soils plant indirect = 0.01 kg N_2O-N/kg N
Soils plant fertilizers runoff and leaching	Yes	These are the nitrous oxide emissions from the runoff and leaching of fertilizer from soils. It is calculated by multiplying the volatilization of fertilizer from consumed fertilizer by an emissions factor.	Emission factor for ag soils leaching = 0.0075 kg N_2O-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 the application of urea as fertilizer. The emissions are calculated by multiplying the application of limestone/	Emission factor, limestone = 0.059 tons carbon (C)/tons limestone applied

SIT Agricultural Non-Energy Module	Occurs in Region?	Emissions Calculation Methodology	Emission Factors
		dolomite/urea fertilizer by an emissions factor.	Emission factor, dolomite = 0.064 tons C/tons dolomite applied Emission factor, urea fertilizer = 0.2 tons C/tons urea fertilizer applied
Rice cultivation	No	-	
Liming	No	-	

[1] The emissions factor for cattle is the average value of beef and cattle replacements between 0–12 months as listed in the US EPA's SIT Agricultural Module (US EPA, 2017)

[2] Emissions factor for llama is assumed to be the same as sheep

1.3.2.3 *Solid waste (landfills)*

The level of methane emissions generated from landfills, subtracting 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).

1.3.2.4 *Wastewater treatment*

Non-energy emissions from wastewater treatment are divided into municipal wastewater treatment plants and septic systems. Based on the U.S. American Housing Survey, 18.6% of households in Rochester use septic systems (US Census Bureau, 2019). Rochester was the only city in the Genesee-Finger Lakes region to have data on the share of housing units using septic systems, so this share was used as an estimate for other towns.

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 (NYSDEC, 2022a) of a default emission factor of 10.7 g CH_4 per person per day from Leverenz et al. (2010).

1.3.2.5 *Land use*

The main categories of land use emissions are harvested wood products and forest ecosystems. Per Table 1-18, 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 as the net emissions resulting from emissions minus sequestration. 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 reported in the NY GHG Inventory's Waste Sector Report (NYSDEC, 2022a). The various land use categories and the approach used for downscaling are described as follows:

Land use that sequesters carbon:

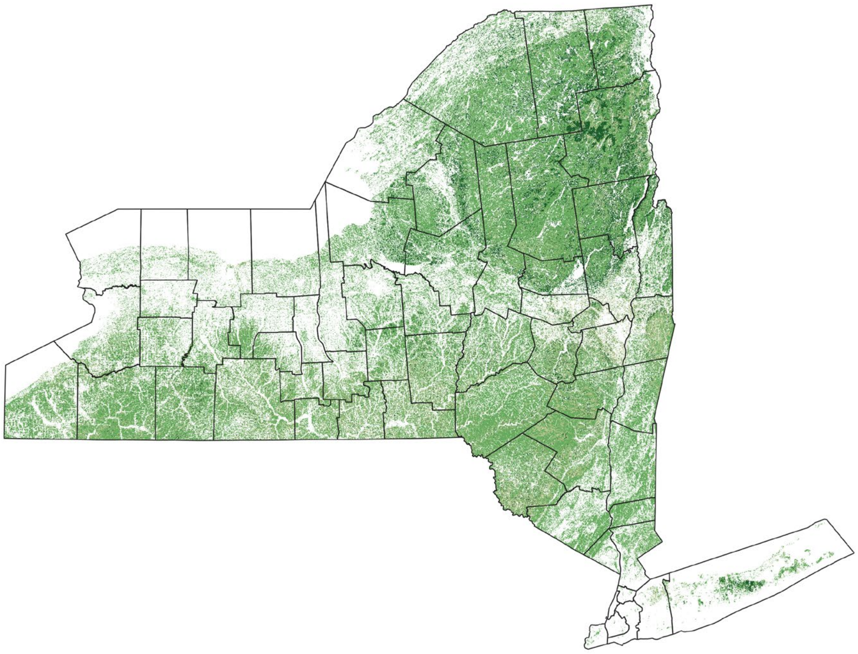
- **Harvested wood products (HWPs)** are wood-based materials harvested from forests that sequester (store) carbon through products like plywood, paper or wood for fuel. HWPs, once they are cut down and removed from their living systems, cannot absorb or sequester additional carbon from the air. They can continue to sequester the carbon unless they are burned. Plywood, for example, can be used to build houses or furniture. County-level HWP emissions are downscaled from the sawmill capacity in the state using sawmill capacity data from the NY Department of Conservation **(NYSDEC, 2017)**.

- **Forest remaining forest (FRF)** emissions considers the changes in carbon stock and emissions of non-CO_2 gases from five carbon pools: aboveground biomass, 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 Database **(MRLC, 2022)**. This includes deciduous, evergreen and mixed forests (Figure 1-3).

- **Land converted to forest (LCF)** emissions consider the sequestration of carbon through the conversion of managed lands (e.g. cropland, settlements, wetlands) 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 Database (MRLC, 2022). This includes changes to or from any type of forest.

- **Urban trees** are located in 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, 2022). This includes low-, medium- and high-intensity developed areas.

Figure 1-3: *Deciduous, Coniferous and Mixed Forests in New York*



Source: MRLC (2022)

- **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, 2022). 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 (e.g. cropland, settlements, wetlands) 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 Database (MRLC, 2022). This includes changes to/from any type of forest.

- **Forest fires** 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 Database (MRLC, 2022). 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 constructed 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 statewide emissions reduction targets in the CLCPA. The baseline envisions a future in which no significant new mitigation policies are enacted and historical trends in energy use and emissions continue. The other scenarios to be created in Phase 2 of the project are mitigation scenarios, which inherit data from the baseline scenario and are assessed 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 1-21 identifies the activity for sectors and subsectors where projected demands are calculated by activity analysis.

Table 1-21: *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

Sector/Subsector	Activity
	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 **Soils 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 as the extent of future migration has not yet been determined. However, as noted in the City of Rochester's *Climate Change Resilience Plan* "Rochester has and will continue to see increased immigration to the area due to extreme events" (City of Rochester, 2019, p. 40). 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 1-22: *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] SEI estimate extrapolated from Cornell projections

Table 1-23: *Household Projections by County*

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 on 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. The average annual change in cooling and heating degree days, which is an indication of how warm or cold a place is, was calculated relative to 2015, the year of the US 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 first estimated space heating and air conditioning demands prior to adjusting these demands based on climate change. Space heating demands in the commercial sector are 2.2% of natural gas consumption and air conditioning demands 9% 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 2-1 provides a detailed summary of regional emissions both historically and under baseline projections. Figure 2-1 to Figure 2-5 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 29.5 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) in 2010 to 28.6 $MMtCO_2e$ 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 30.4 $MMtCO_2e$ in 2050 from growth in the agricultural, industrial and commercial sectors.

Overall, historical emissions have come more from consuming energy rather than non-energy sources. However, non-energy emissions from agricultural and industrial processes are still high, making up 31% of the total emissions in 2018. In comparison, non-energy emissions make up 23% of the state emissions (NYSDEC, 2022b). 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, in 2050, land use and forestry-related activities will reduce emissions by -1.5 $MMtCO_2e$ each year, or by 4.9%.

Among the 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 9% of regional emissions due to the three large landfills that make up 41% of New York's existing and proposed landfill capacity (see Table 1-17 for details). Generally, the baseline projection yields a similar composition of sectoral emissions, 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 and public transit, is low across the region, keeping transport emissions high overall. Residential energy consumption continues to be driven by space heating, and natural gas-based heating systems in particular. 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 25% of 2018 emissions. This is followed by natural gas use in the residential, commercial and industrial sectors, resulting in 17% 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 a one-time occurrence, and not part of a larger trend.

According to the 100-year global warming potentials, carbon dioxide comprises the greatest proportion of greenhouse gases 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 (39%).

Table 2-1: *Genesee-Finger Lakes Greenhouse Gas Emissions by Economic Sector (results in GWP20)*

Sector	**-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**
Transportation	9.39	32	9.57	33	8.95	31	8.69	29
On-road	8.75	30	8.95	31	8.27	29	7.93	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	19	6.34	22	6.88	24	8.16	27
Energy use	0.20	1	0.31	1	0.36	1	0.49	2
Livestock	4.90	17	5.58	20	5.97	21	6.92	23
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
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	9
Small commercial	0.36	1	0.37	1	0.38	1	0.42	1
Industrial	3.62	12	2.00	7	2.16	8	2.62	9
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	0.21	1	0.17	1	0.14	0	0.13	0
Electricity transmission & distribution	0.19	1	0.15	1	0.12	0	0.11	0
Fugitive emissions	0.02	0	0.02	0	0.02	0	0.02	0
Gross emissions total	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**

Sector	**-Historical-**		**-Baseline Projection-**	
	2010	**2018**	**2030**	**2050**
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	**26.89**	**25.95**	**26.27**	**28.00**

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

Figure 2-1: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Type of Emissions (using GWP20)*

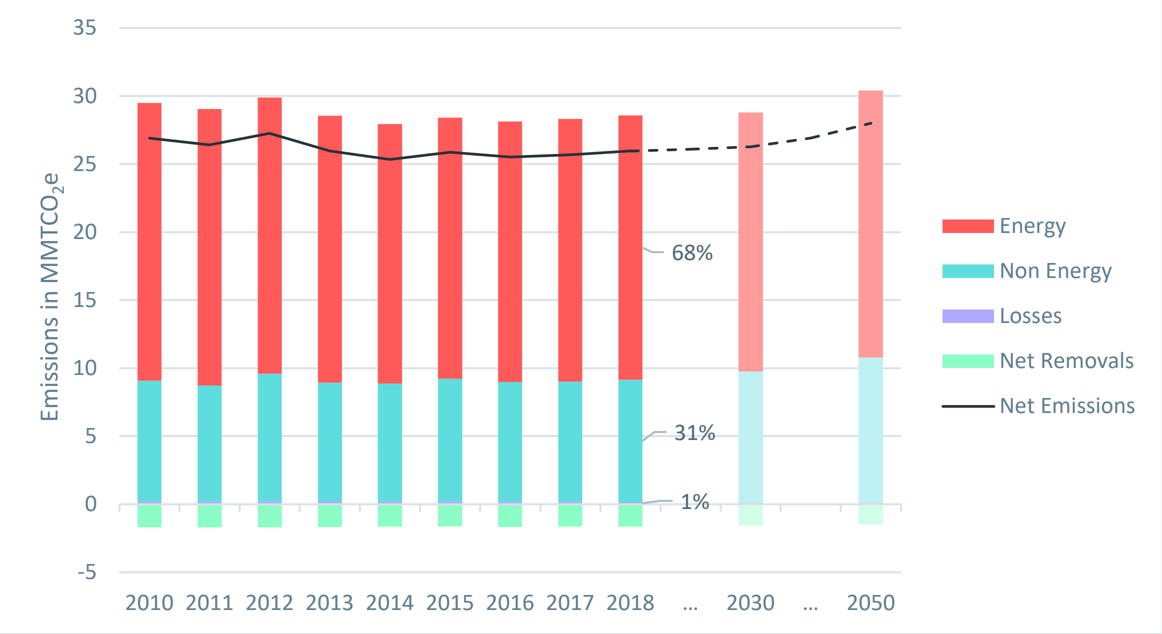


Figure 2-2: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Sector (using GWP20)*

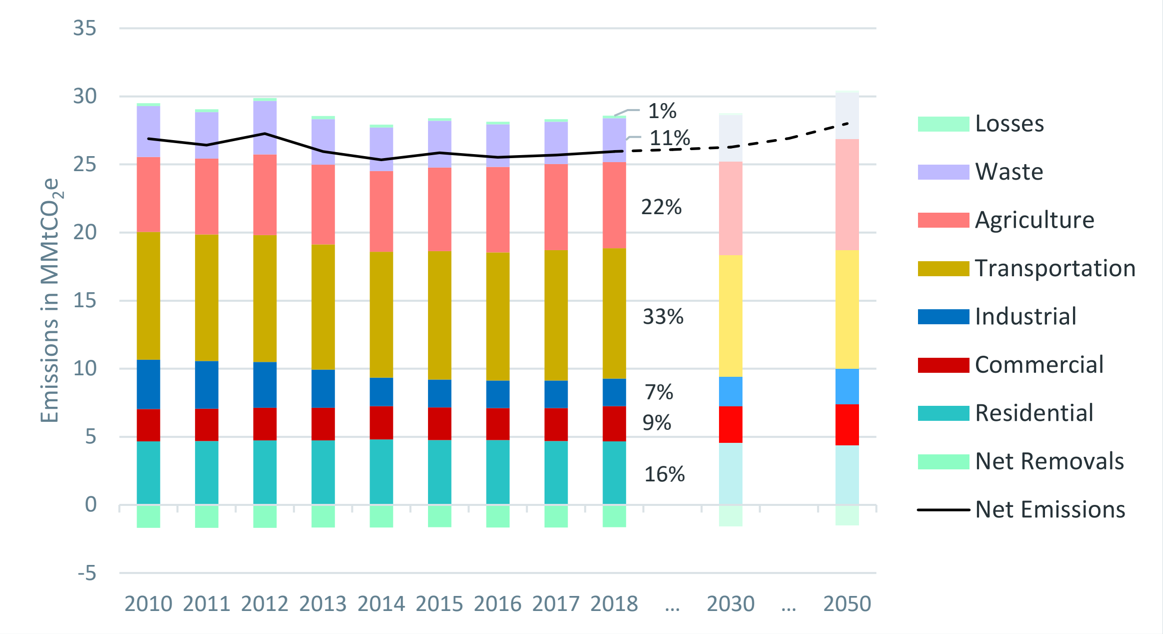


Table 2-2: *Genesee-Finger Lakes Greenhouse Gas Emissions by Fuel (results in GWP20)*

Sector	**-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**
Energy-related (fuels)	20.64	70	19.60	69	19.17	67	19.74	65
Gasoline	6.99	24	7.01	25	6.14	21	5.25	17
Natural Gas	4.62	16	4.97	17	5.19	18	5.48	18
Diesel	2.49	8	2.64	9	2.96	10	3.71	12
Electricity	2.32	8	2.18	8	2.06	7	2.27	7
Coal	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	8.98	31	9.60	33	10.67	35
Gross emissions total	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure 2-3: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Fuel (using GWP20)*

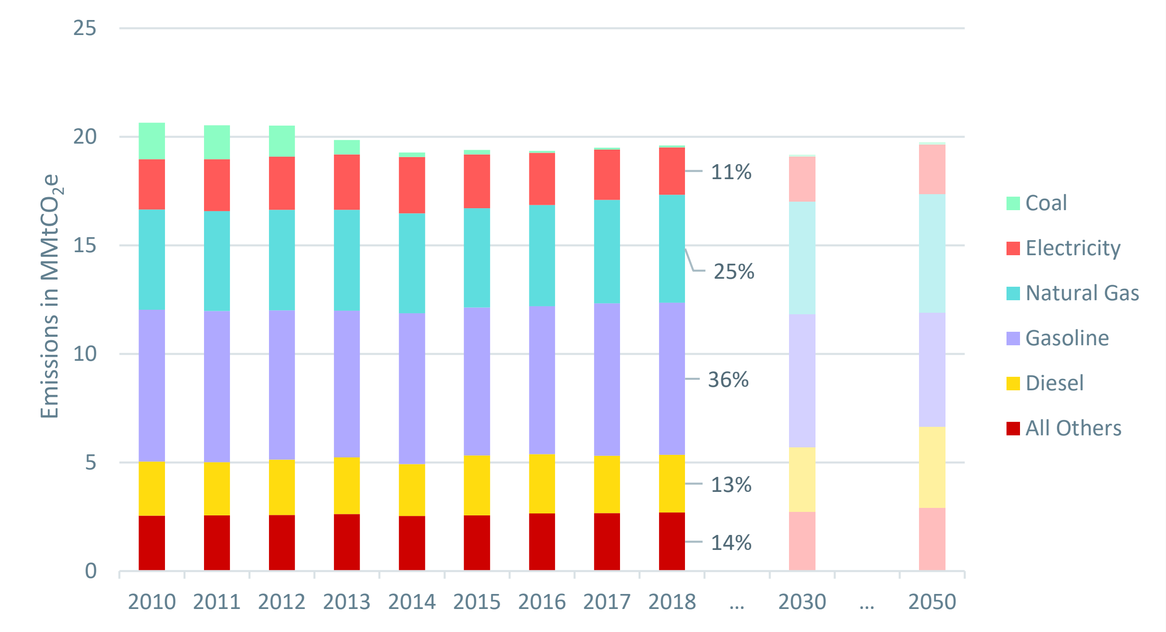


Table 2-3: *Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP20)*

Sector	**-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**
GHG	29.50	100	28.57	100	28.77	100	30.42	100
CO$_2$ biogenic	0.92	3	0.98	3	0.93	3	0.93	3
CO$_2$	16.30	55	15.41	54	15.06	52	15.57	51
CH$_4$	11.35	38	11.15	39	11.66	41	12.56	41
N$_2$O	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	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure 2-4: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP20)*

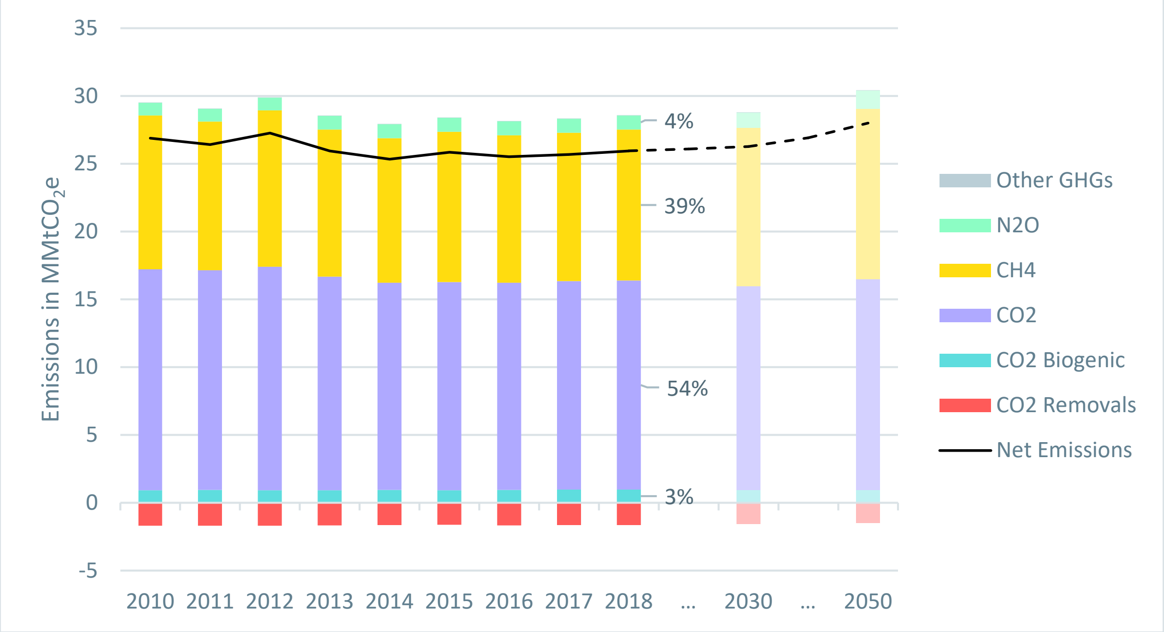
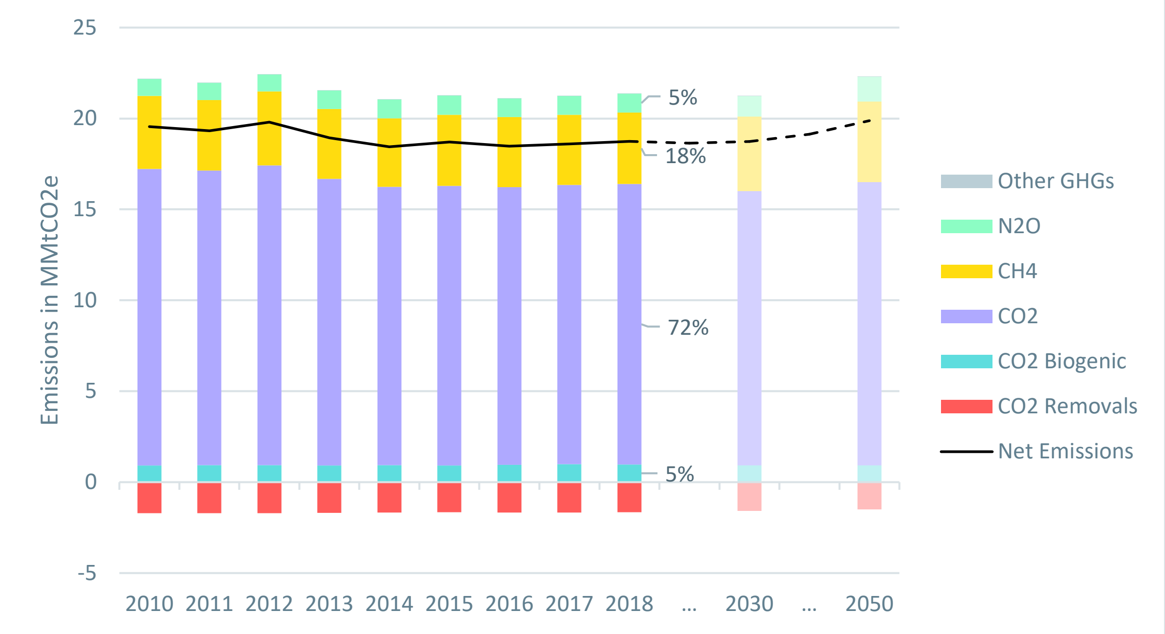


Table 2-4: *Genesee-Finger Lakes Greenhouse Gas Emissions by Greenhouse Gas (results in GWP100)*

Sector	**-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**
GHG	22.17	100	21.37	100	21.24	100	22.30	100
CO$_2$ biogenic	0.92	4	0.98	5	0.93	4	0.93	4
CO$_2$	16.31	74	15.41	72	15.07	71	15.57	70
CH$_4$	4.01	18	3.94	18	4.11	19	4.43	20
N$_2$O	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	**22.17**	**100**	**21.37**	**100**	**21.24**	**100**	**22.30**	**100**
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	**19.55**		**18.74**		**18.73**		**19.88**	

Note: Fuel-related emissions includes upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure 2-5: *Historical and Projected Emissions in the Genesee-Finger Lakes Region by Greenhouse Gas (using GWP100)*



2.1.1 Comparison to the 2013 Finger Lakes Regional Sustainability Plan

It is important to highlight the difference between this inventory and the results of the 2010 emissions inventory presented in the 2013 Finger Lakes Sustainability Plan. The previous inventory calculated emissions using GWP100 and did not include land-use emissions, imported fossil fuel emissions and biogenic CO_2 as these were not required at the time. The 2010 emissions in the previous plan were reported as 16.1 $MMtCO_2e$, which is slightly lower than the 17.5 $MMtCO_2e$ calculated in the current inventory when using GWP100, 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 data sources and emissions factors. These variations result from taking a bottom-up approach for this analysis.

2.1.2 The scale of emissions compared to other states and countries

Table 2-5 compares the emissions in the Genesee-Finger Lakes region to other states and countries. For comparison purposes, we use GWP100, which is typically used by other countries and states for reporting emission estimates. The comparison finds that the region's emissions are comparable to states with similar population sizes, such as Rhode Island and Delaware. However, it produces the same level of emissions as countries like Costa Rica and Benin, which have significantly larger populations. Given that the remaining global 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, 2018). The targets set out in New York's Climate Leadership and Community Protection Act (CLCPA) provides an indication of the level of climate action necessary in the region.

Table 2-5: *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 2-6 and Table 2-6, the counties with the highest populations also have the highest emissions share, with Monroe County at 40% of the region's emissions in 2018, followed by Ontario County at 12%. The source of emissions varies from county to county, as illustrated in Figure 2-7. For example, Livingston, Wyoming and Yates Counties' largest share of emissions is from agriculture, particularly dairy farming. According to the US Department of Agriculture (USDA, 2022), Wyoming County has the highest number of cows among any county in New York State, and Yates has the highest number of dairy farms. In the counties of Seneca and Orleans, solid waste emissions represent 45% and 25% of gross emissions, respectively. 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, with about 38–40% of emissions 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 2-6: *Genesee-Finger Lakes Greenhouse Gas Emissions by County (results in GWP20)*

Sector	**-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**
Gross emissions	29.50	100	28.57	100	28.77	100	30.42	100
Genesee	2.63	9	2.98	10	3.04	11	3.30	11
Livingston	1.96	7	2.21	8	2.38	8	2.87	9
Monroe	13.40	45	11.04	39	10.78	37	10.35	34
Ontario	3.45	12	3.45	12	3.74	13	4.41	15
Orleans	1.02	3	1.06	4	1.06	4	1.13	4
Seneca	1.61	5	2.23	8	2.23	8	2.58	8
Wayne	2.06	7	2.07	7	2.06	7	2.18	7
Wyoming	2.46	8	2.54	9	2.54	9	2.63	9
Yates	0.91	3	0.98	3	0.94	3	0.95	3
Gross emissions total	**29.50**	**100**	**28.57**	**100**	**28.77**	**100**	**30.42**	**100**
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	**26.89**		**25.95**		**26.27**		**28.00**	

Note: Fuel-related emissions include upstream emissions outside of New York State. Gross emissions include biogenic CO$_2$.

Figure 2-6: *Net Emissions by County*

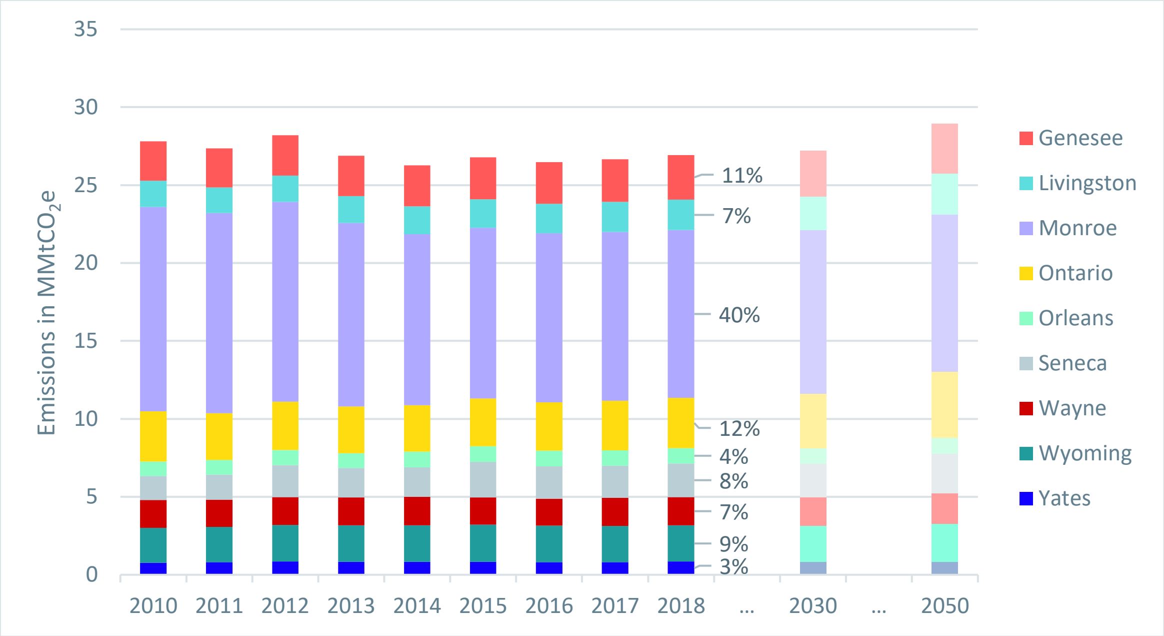
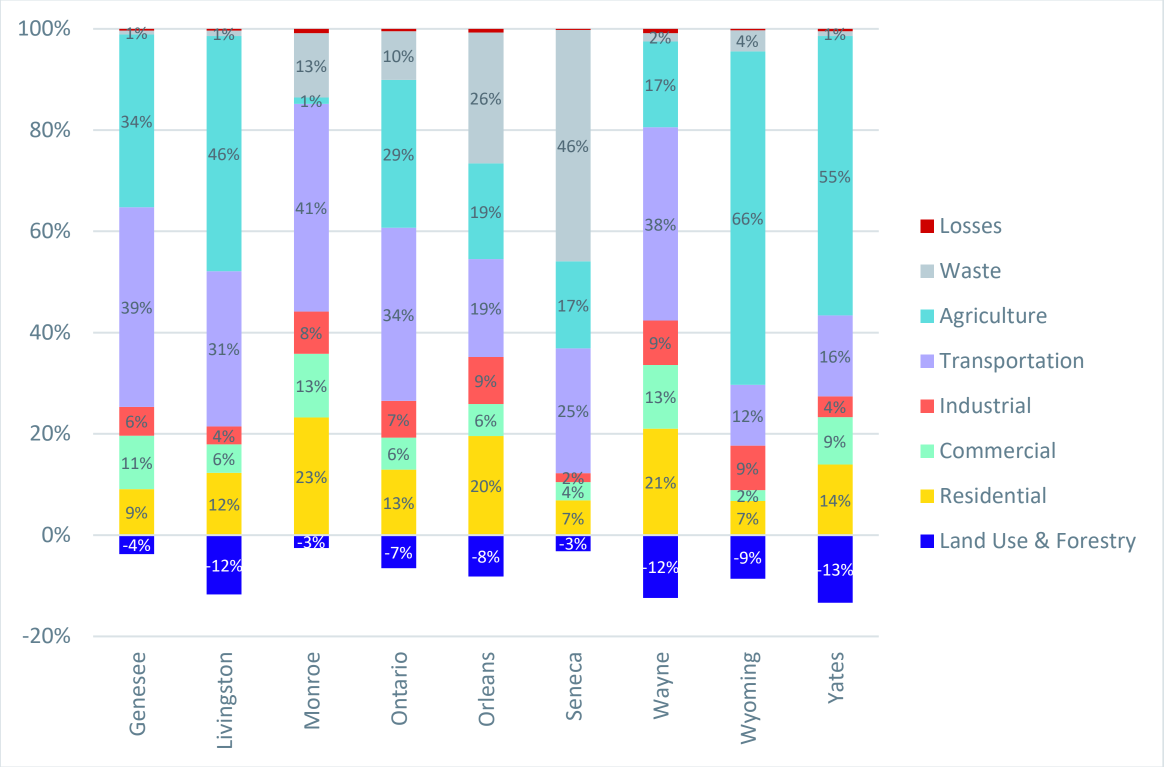


Figure 2-7: *Sectoral Share of Gross Emissions in Each County in 2018*



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 and electronics (Figure 2-8). 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 Rochester's heating degree days in the months of March, April and October in 2018 (NYSERDA, 2021a), 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 climb with an increase in hotter days. Because electricity consumption – which powers air conditioning – emits less than other fuels, air conditioning has a lower footprint compared to other end uses.

Figure 2-8: *Historical and Projected Residential Emissions by End Use and Fuel (results in GWP20)*

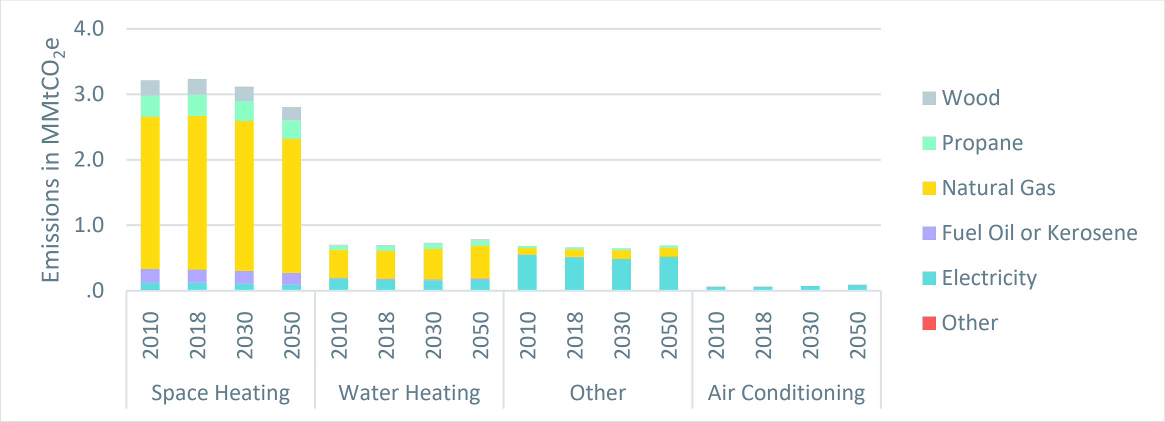


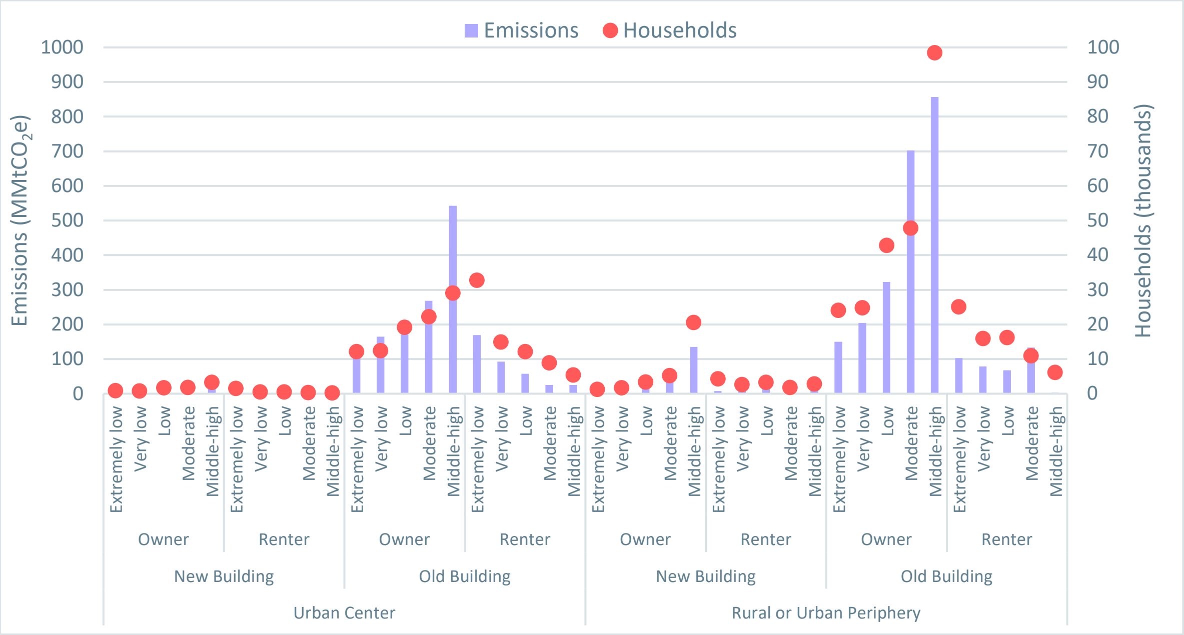
Table 2-7: *Residential sector emissions (results in GWP20)*

Sector – Residential	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	MMtCO₂e	% of total	MMtCO₂e	% of total	MMtCO₂e	% of total	MMtCO₂e	% of total
Space heating	3.21	69	3.24	69	3.12	68	2.81	64
Electricity	0.11	2	0.11	2	0.09	2	0.08	2
Fuel oil or kerosene	0.21	5	0.20	4	0.19	4	0.18	4
Natural gas	2.33	50	2.35	50	2.30	50	2.06	47
Propane	0.31	7	0.32	7	0.30	7	0.27	6

Sector – Residential	**-Historical-**				**-Baseline Projection-**			
	2010		**2018**		**2030**		**2050**	
Wood	0.24	5	0.24	5	0.22	5	0.20	5
Other	0.02	0	0.01	0	0.01	0	0.01	0
Water heating	0.70	15	0.70	15	0.73	16	0.79	18
Electricity	0.19	4	0.17	4	0.16	4	0.17	4
Fuel oil or kerosene	0.01	0	0.02	0	0.02	0	0.02	0
Natural gas	0.42	9	0.43	9	0.47	10	0.50	11
Propane	0.07	1	0.07	2	0.07	2	0.08	2
Wood	0.01	0	0.01	0	0.01	0	0.01	0
Other	0.68	15	0.66	14	0.65	14	0.70	16
Electricity	0.55	12	0.52	11	0.49	11	0.52	12
Fuel oil or kerosene	0.00	0	0.00	0	0.00	0	0.00	0
Natural gas	0.10	2	0.12	3	0.13	3	0.14	3
Propane	0.03	1	0.03	1	0.03	1	0.03	1
Air Conditioning	0.07	1	0.06	1	0.07	2	0.09	2
Electricity	0.07	1	0.06	1	0.07	2	0.09	2
Gross Emissions Total (residential)	**4.67**	**100**	**4.66**	**100**	**4.58**	**100**	**4.38**	**100**
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 include upstream emissions outside of New York State. Gross emission includes biogenic CO_2.

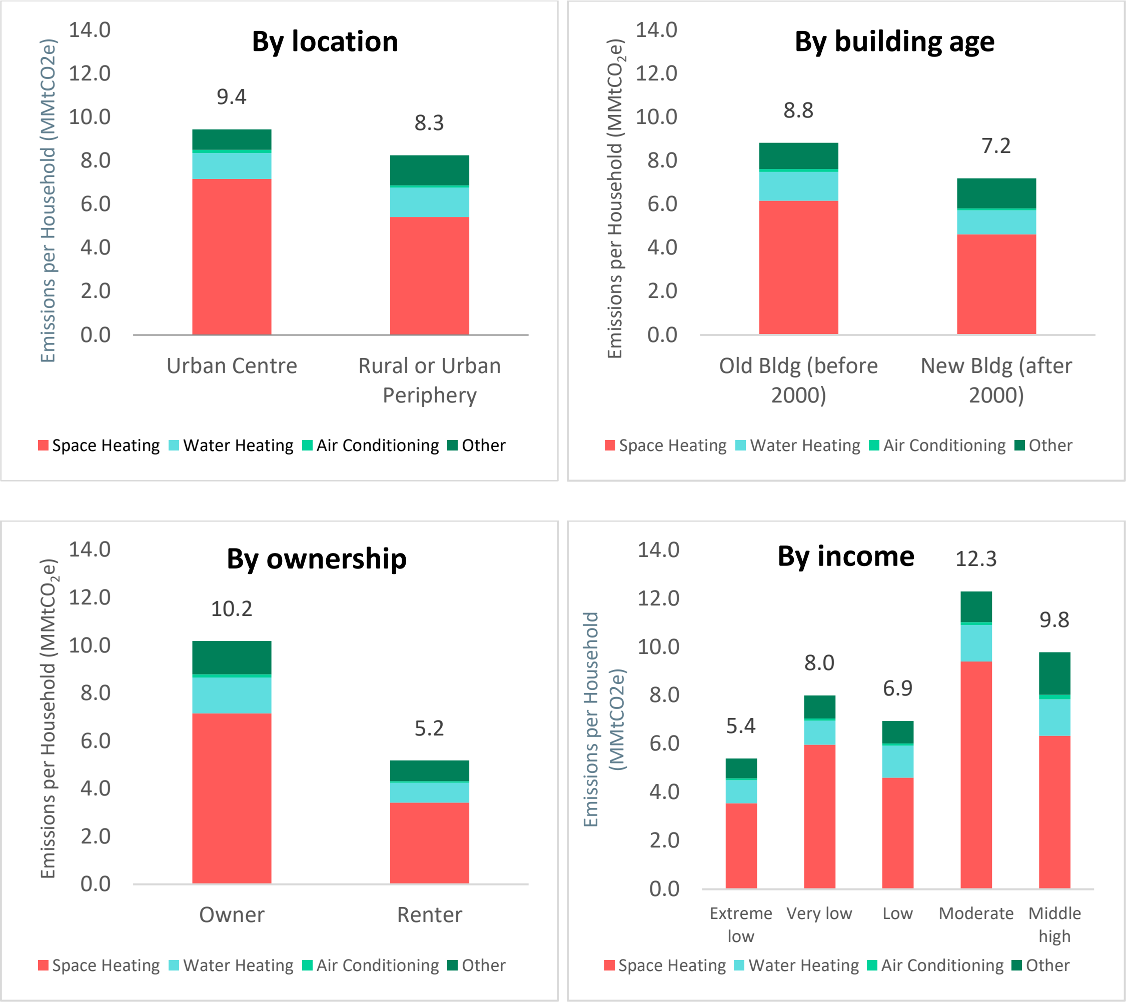
Figure 2-9: *2018 Emissions (left axis) and Number of Households (right axis) by Household Type and Income (in GWP20)*



Most of the Genesee-Finger Lakes' population live in older households (i.e. pre-2000) that they own. In 2018, middle-high income households (i.e. annual household income greater than or equal to $120 000) made up roughly 35% of the region's emissions and 31% of the region's population. Generally, emission levels are proportional to the number of households for a given household type as illustrated in Figure 2-9. A similar pattern of emissions is seen in the baseline projection through 2050.

The emissions under each household category are further reviewed on a per-household basis in Figure 2-10. The results show that urban households emit more 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$_2$e per high-income urban household versus an average 5.85 MMtCO$_2$e per low- or moderate-income urban household).

Figure 2-10: *2018 emissions per household by end-use (results in GWP20)*



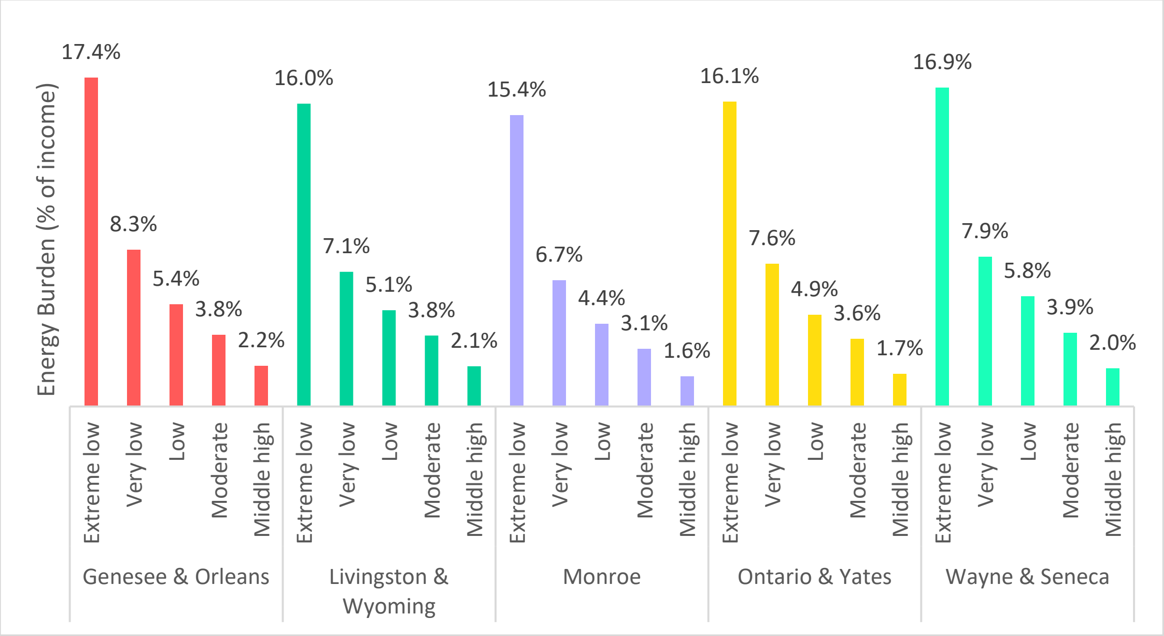
Older buildings – those built before 2000 – emit slightly more per household compared to new buildings. This is unsurprising, given that newer buildings are built under the NY State Energy Conservation Construction Code, which underwent significant updates in 2002 and boosted energy efficiency.

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, though 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.

Despite using less energy, the energy burden – the share of household income spent on energy bills – on lower-income households tends to be high. Figure 2-11 through Figure 2-14 show the energy burden across different groups – income, race, disability and Spanish/Hispanic/Latino ethnicity – using 2019 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.

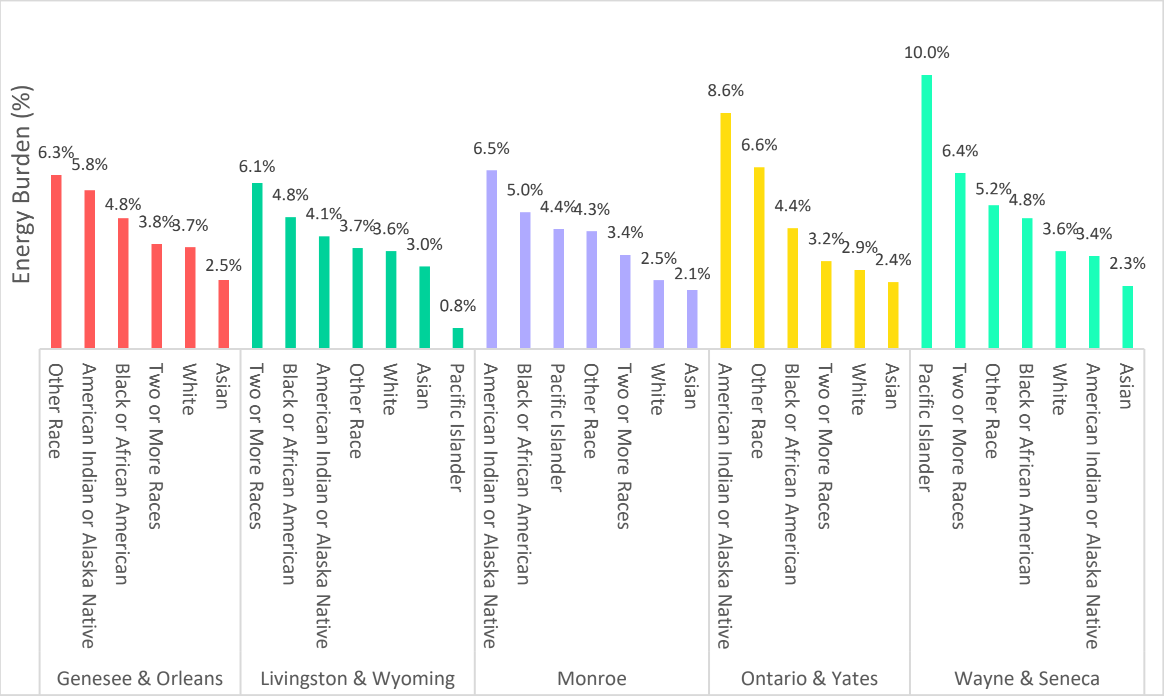
The energy cost burden can be high, especially in older, poorly insulated homes using inefficient heating systems. While there are financial incentives from utilities and state agencies to switch to electric heat pumps and to weatherize the home, it can be challenging for those living in rental units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

Figure 2-11: *Energy Cost Burden by County and Income Group in 2019*



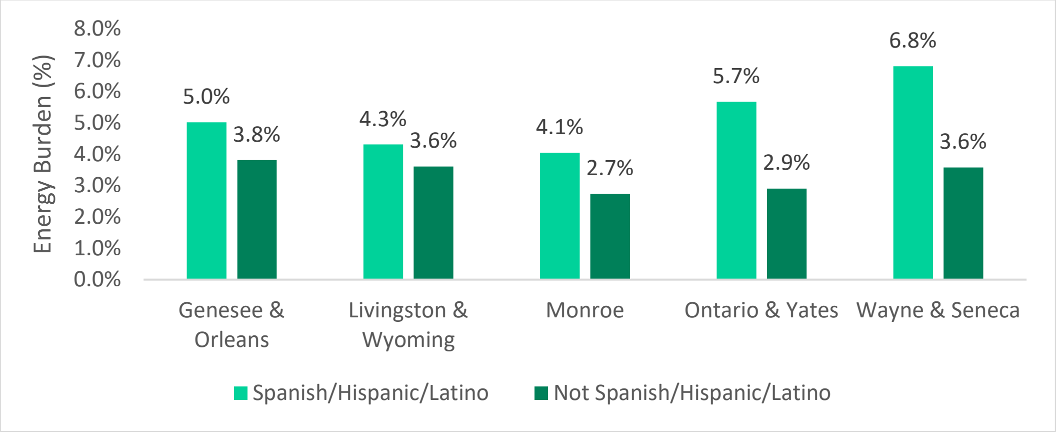
Source: US Census Bureau (2020a)

Figure 2-12: *Energy Cost Burden by County and Race in 2019*



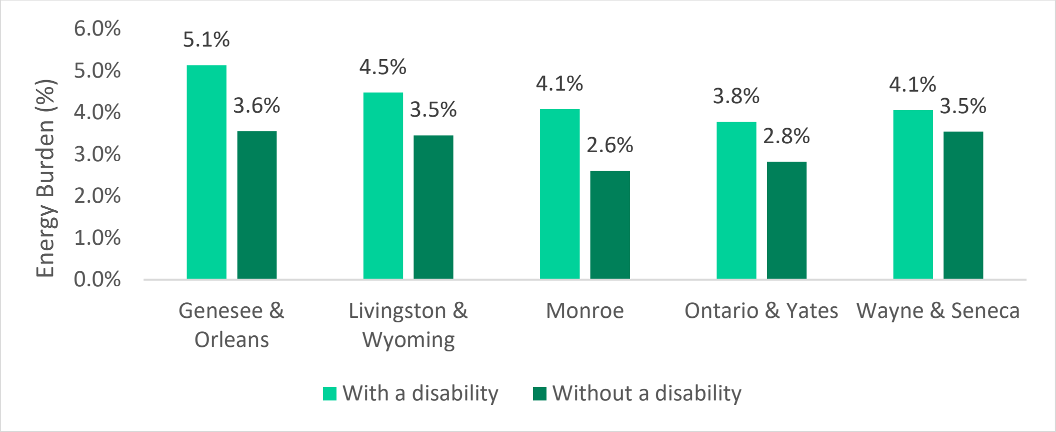
Source: US Census Bureau (2020a)

Figure 2-13: *Energy Cost Burden by County and Spanish/Hispanic/Latino Origin in 2019*



Source: US Census Bureau (2020a)

Figure 2-14: *Energy Cost Burden by County and Disability in 2019*



Source: US Census Bureau (2020a)

2.3.2 Commercial emissions

Energy data for the commercial sector was limited to natural gas and electricity. As shown in Figure 2-15, the emissions share was split 50/50 between the two fuels in recent history, except for 2018, when natural gas emissions jump to 59% of total commercial emissions. As discussed in the section on the residential sector (Section 2.3.1), this jump coincides with Rochester's increased heating degree-days in the months of March, April and October in 2018 (NYSERDA, 2021a), suggesting that households in the region 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.

Figure 2-15: *Historical and Projected Emissions in the Commercial Sector by Fuel (results in GWP20)*

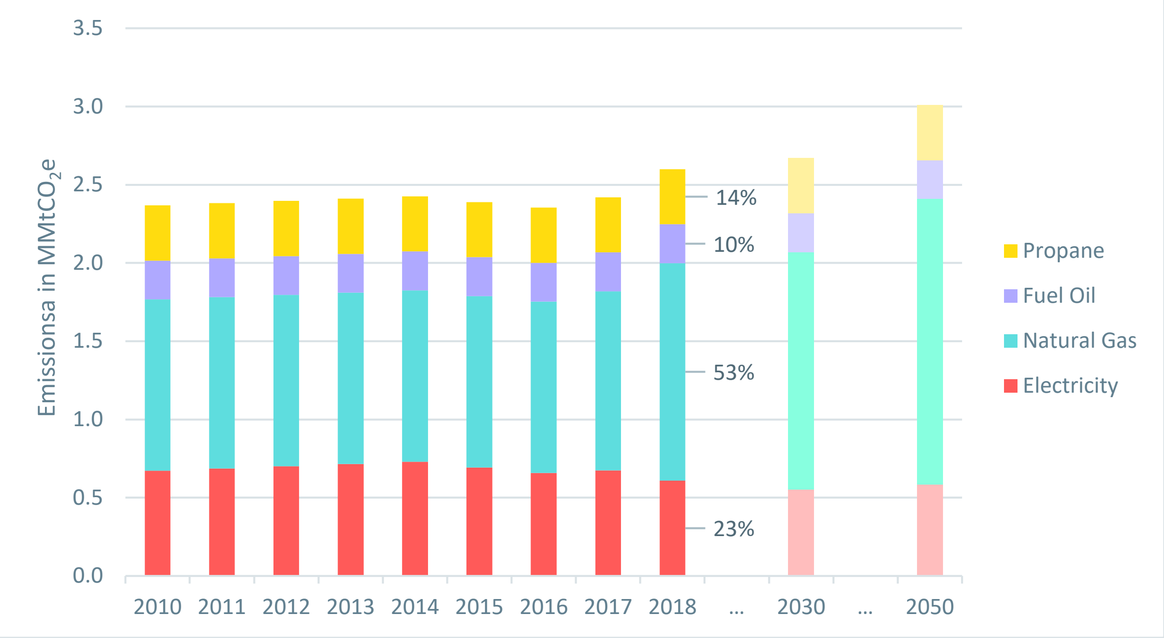


Table 2-8: *Commercial Sector Emissions by Fuel (results in GWP20)*

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	1.10	46	1.39	53	1.52	57	1.82	61
Natural gas	0.67	28	0.61	23	0.55	21	0.58	19
Propane	0.35	15	0.35	14	0.35	13	0.35	12
Fuel oil	0.25	10	0.25	10	0.25	9	0.25	8
Gross emissions total (commercial)	**2.37**	**100**	**2.60**	**100**	**2.67**	**100**	**3.01**	**100**
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 energy use 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 (of which Genesee-Finger Lakes is a part) are provided in Table 2-9, Figure 2-16 and Figure 2-17. 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.

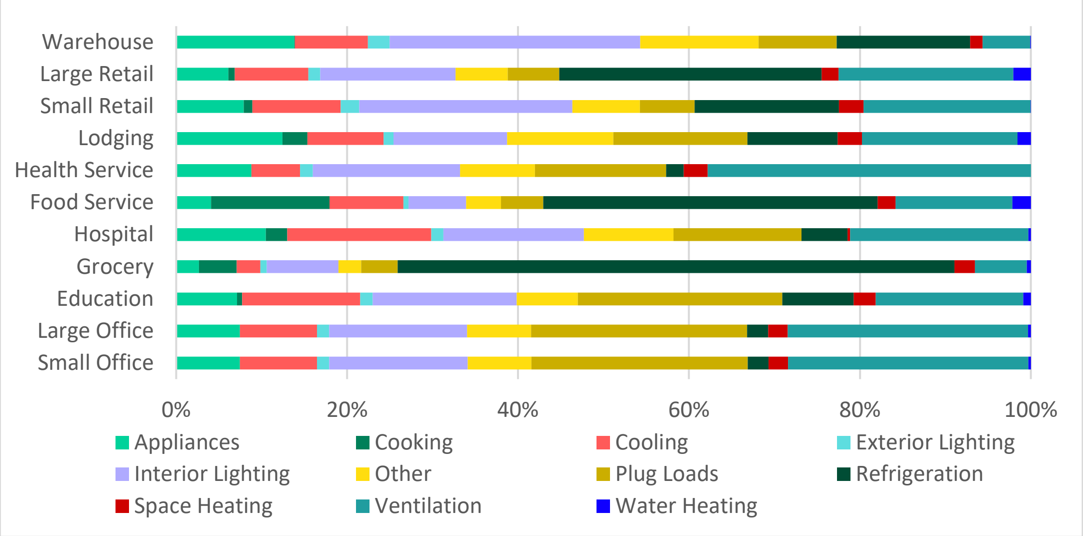
Table 2-9: *Share of Commercial Buildings and Energy Usage in Upstate New York*

Commercial Sub-sector	Medium / Large Bldgs	Small Bldgs	Electric Sales	Natural Gas Sales	Fuel Oil Sales	Propane Sales
Totals	**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%**

Note: Medium and large buildings use more than 75 MWH/year. Small buildings use less than 75 MWH/year.

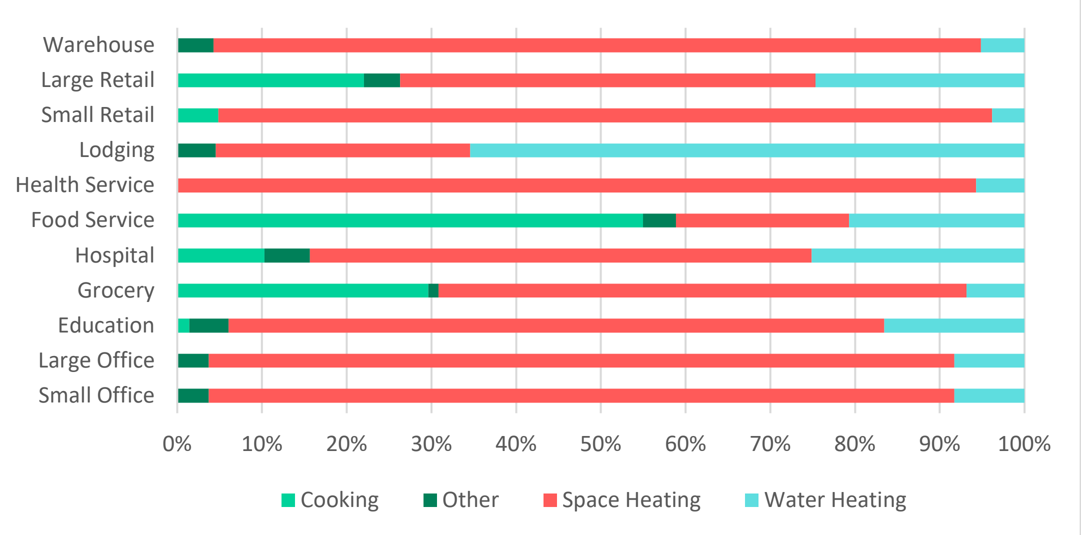
Source: NYSERDA (2019a)

Figure 2-16: *Electricity Usage by Commercial Sub-sector and End Use for Upstate NY*



Source: NYSERDA (2019a)

Figure 2-17: *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 2-18 shows the industries and industrial processes that are the most emissions-intensive (including both energy and non-energy emissions). In 2010, the category of 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 has since grown to 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 2-19 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 are electricity, natural gas and diesel. Using data from the US EIA's *Manufacturing Energy Consumption Survey,* Figure 2-20 and Table 2-10 breaks down the end uses of the fuels. 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 industrial processes
- **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 2-20 shows data for the Northeast, which contains the Genesee-Finger Lakes region. Most fuel is used directly for industrial processes, with the exception of coal, which is used for generating heat indirectly.

Figure 2-18: *Historical and projected emissions in the industrial sub-sectors (results in GWP20)*

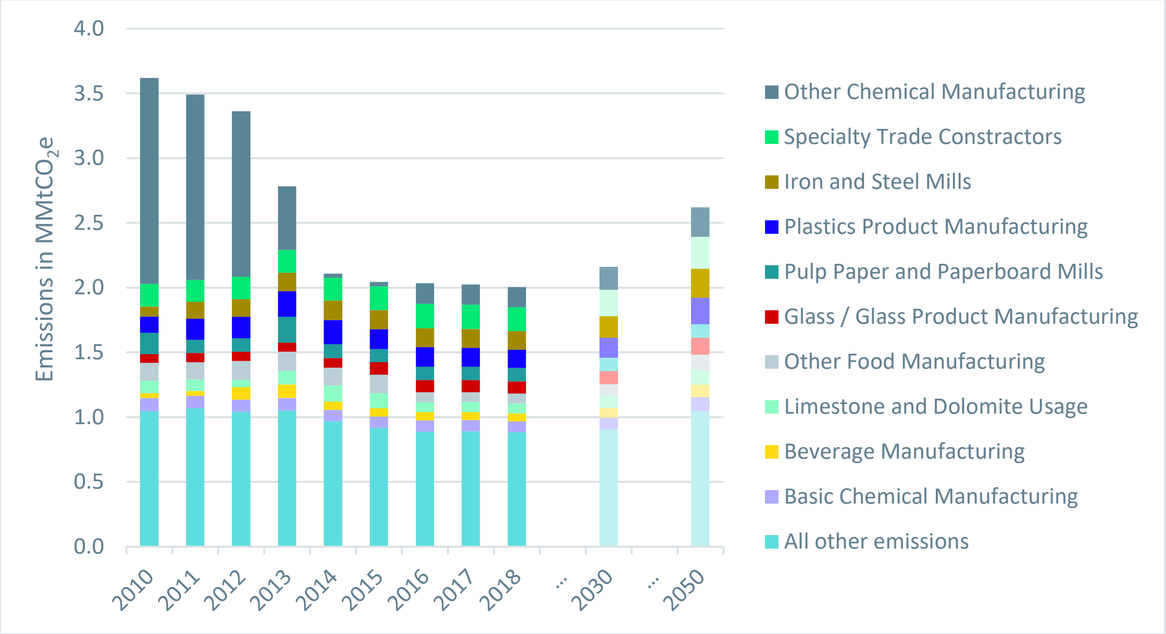


Figure 2-19: *Historical and Projected Emissions in the Industrial Sector by Fuel (results in GWP20)*

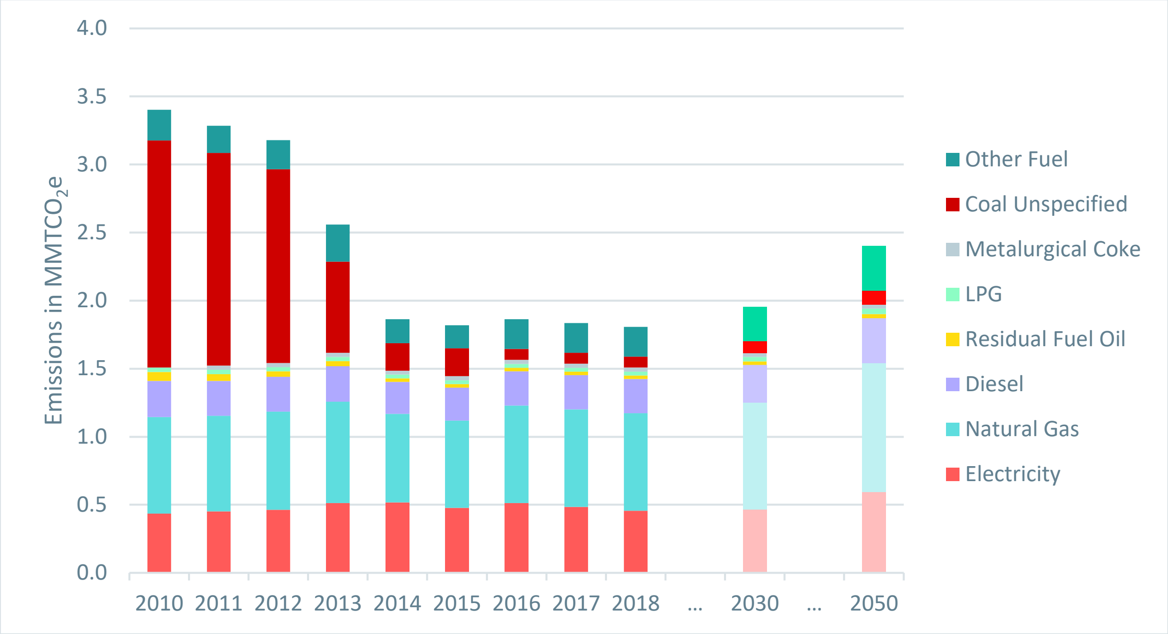
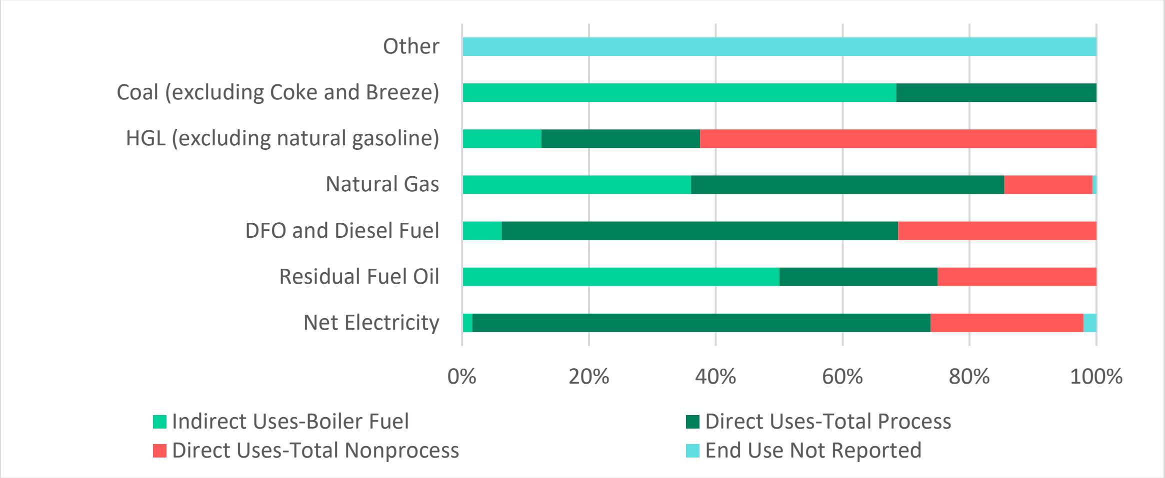


Table 2-10: *Industrial Sector Emissions by Fuel (results in GWP20)*

Sector – Industrial	**-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**
Energy emissions	**3.40**	**94**	**1.81**	**90**	**1.95**	**90**	**2.40**	**92**
Electricity	0.44	12	0.46	23	0.47	22	0.59	23
Natural Gas	0.71	20	0.72	36	0.78	36	0.95	36
Diesel	0.26	7	0.25	13	0.28	13	0.33	13
Residual Fuel Oil	0.07	2	0.02	1	0.03	1	0.03	1
LPG	0.03	1	0.03	2	0.03	2	0.04	2
Metallurgical Coke	0.00	0	0.03	1	0.03	1	0.03	1
Coal Unspecified	1.67	46	0.08	4	0.09	4	0.10	4
Other Fuel	0.23	6	0.22	11	0.25	12	0.33	13
Non-energy emissions	**0.22**	**6**	**0.20**	**10**	**0.21**	**10**	**0.22**	**8**
Gross emissions total (industrial)	**3.62**	**100**	**2.00**	**100**	**2.16**	**100**	**2.62**	**100**
Net emission removal	n/a		n/a		n/a		n/a	
Biogenic CO$_2$	0		0		0		0	
Net emissions total (industrial)	**3.62**		**2.00**		**2.16**		**2.62**	

Figure 2-20: *Industrial Energy Breakdown by Fuel and End-use for the Northeastern US*



Source: US EIA 2018 Manufacturing Energy Consumption Survey *(2021)*

2.3.4 Agricultural emissions

Figure 2-21 and Table 2-11 presents the historical and projected 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 (40%) and manure management (30%). 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 2-12, most enteric fermentation emissions in the region originate 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 affects the level of methane 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 account for 19% of agricultural emissions. Residue emissions are generated when the residue left behind after a harvest decomposes. According to Table 2-13, alfalfa has the highest level of residue emissions, followed by soybeans. While soybeans are produced at a fraction of the volume of alfalfa in the region, soybeans are much more emissions-intensive, producing the most metric tons of carbon dioxide equivalent ($MtCO_2e$) per metric ton of crop yield among the crops evaluated here.

Figure 2-21: *Historical and Projected Emissions in the Agricultural Sector (results in GWP20)*

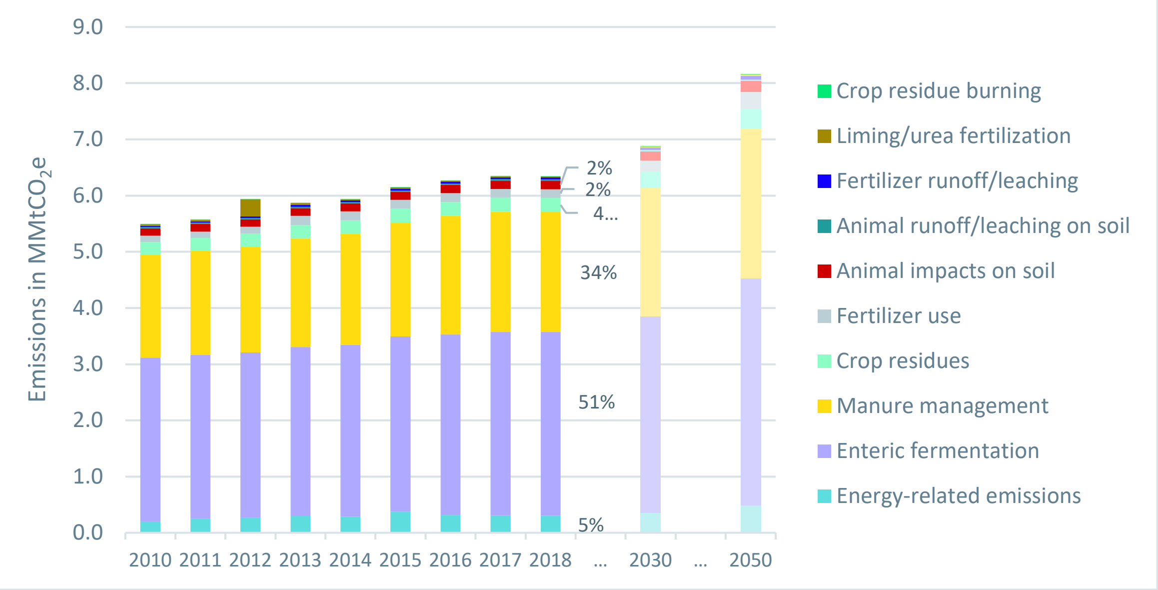


Table 2-11: *Agricultural Sector Emissions (results in GWP20)*

Sector – Agricultural	**-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**
Energy emissions	**0.20**	**4**	**0.31**	**5**	**0.36**	**5**	**0.49**	**6**
Non-energy emissions	**5.29**	**96**	**6.03**	**95**	**6.52**	**95**	**7.67**	**94**
Enteric fermentation	2.91	53	3.26	51	3.49	51	4.04	49
Manure management	1.83	33	2.14	34	2.29	33	2.67	33
Crop residues	0.22	4	0.25	4	0.29	4	0.37	4
Fertilizer use	0.11	2	0.16	2	0.20	3	0.29	4
Animal impacts on soil	0.13	2	0.15	2	0.16	2	0.19	2
Animal runoff/ leaching on soil	0.02	0	0.03	0	0.03	0	0.03	0
Fertilizer runoff/ leaching	0.02	0	0.03	0	0.04	1	0.06	1
Liming/urea fertilization	0.03	1	0.02	0	0.02	0	0.03	0
Crop residue burning	0.00	0	0.00	0	0.00	0	0.00	0
Gross emissions total (agricultural)	**5.49**	**100**	**6.34**	**100**	**6.88**	**100**	**8.16**	**100**
Net emission removal	n/a		n/a		n/a		n/a	
Biogenic CO$_2$	0		0		0		0	
Net emissions total (agricultural)	**5.49**		**6.34**		**6.88**		**8.16**	

Table 2-12: *2018 Livestock Emissions (results in GWP20)*

Animal	**Livestock (heads)**	**Enteric Fermentation (ktCO$_2$e)**	**Manure Management (ktCO$_2$e)**	**Soil Animals (ktCO$_2$e)**	**Soil Animal Runoff / Leaching (ktCO$_2$e)**	**Total Emissions (ktCO$_2$e)**	**MtCO$_2$e per head**
Dairy Cows	161834	2234.1	2110.3	146.2	24.6	4515.3	27.901
Beef Cows	14184	119.4	2.2	n/a	n/a	121.6	8.576
Calves	192040	890.0	5.9	n/a	n/a	895.9	4.665
Goat	3852	1.5	0.1	n/a	n/a	1.6	0.407
Sheep	22852	15.8	1.2	1.4	0.2	18.6	0.814
Swine	22963	2.6	15.4	2.2	0.3	20.5	0.892
Llama	2080	1.3	0.1	0.1	0.0	1.5	0.730
Layers	178749	n/a	1.8	0.5	0.1	2.4	0.013
Pullets	1896	n/a	0.0	0.0	0.0	0.0	0.011
Broilers	9665	n/a	0.0	0.0	0.0	0.0	0.003
Roosters	194	n/a	0.1	0.0	0.0	0.1	0.332
Total	**610,309**	**3264.8**	**2137.1**	**150.4**	**25.2**	**5577.5**	**9.139**

Table 2-13: *2018 Crop Emission (results in GWP20)*

Crop	Crop Production (metric tons)	Crop Residues ($ktCO_2e$)	Crop Residue Burning ($ktCO_2e$)	Total Emissions ($ktCO_2e$)	$MtCO_2e$ per Metric Ton
Alfalfa	1249.3	136.6	n/a	136.6	109.3
Corn for grain	925.0	18.1	0.0	18.1	19.6
All wheat	124.7	3.7	0.0	3.7	29.6
Barley	3.1	0.1	0.0	0.1	33.3
Sorghum for grain	0.4	0.0	n/a	0.0	64.2
Oats	6.9	0.2	n/a	0.2	23.9
Rye	2.3	0.1	n/a	0.1	29.9
Soybeans	186.2	90.6	0.1	90.7	487.2
Dry edible peas	1.3	0.6	n/a	0.6	440.9
Red clover	0.0	0.0	n/a	0.0	150.9
Crimson clover	0.0	0.0	n/a	0.0	134.4
Total	**2499.3**	**249.9**	**0.1**	**250.0**	**100.0**

2.3.5 Transport emissions

Among all sectors, transport comprises the highest share of emissions in the region. As shown in Figure 2-22 and Table 2-14, light passenger trucks and cars dominate transport emissions, alongside a fair share of emissions from heavy duty combination trucks. Based on Figure 2-23 and Figure 2-24, between the various fuels, gasoline accounts for 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 2-22: *Historical and Projected Emissions in the Transport Sector by Vehicle Type (results in GWP20)*

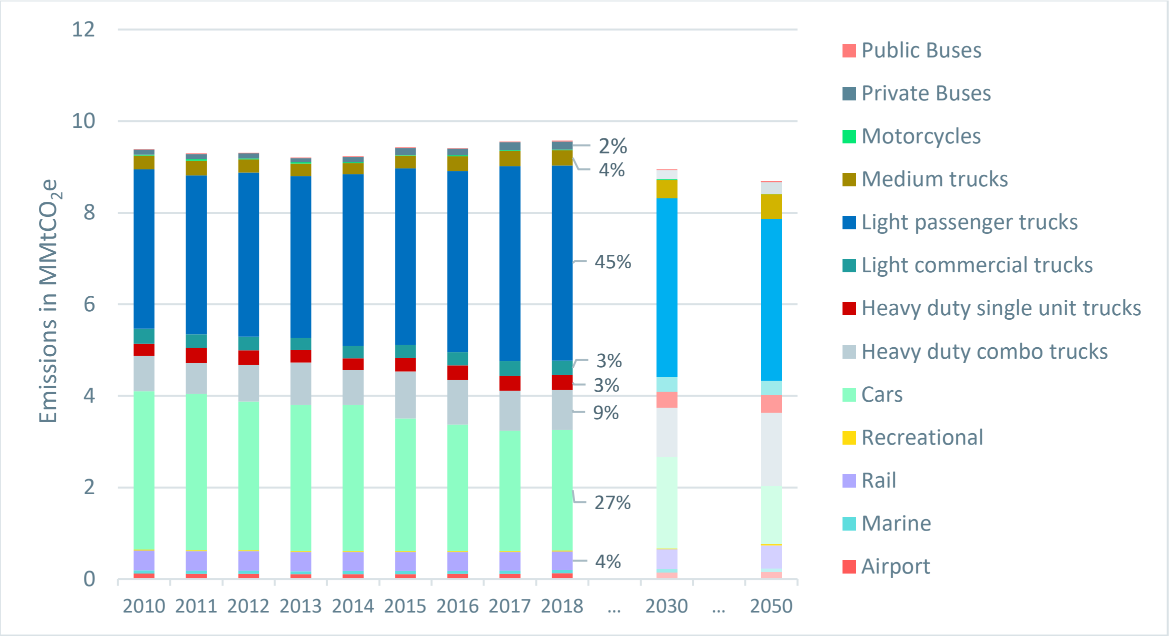


Table 2-14: *Transport Sector Emissions (results in GWP20)*

Sector – Transport	**-Historical-**				**-Baseline Projection-**			
	2010		**2018**		**2030**		**2050**	
	MMtCO₂e	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**
On road	**8.75**	**93**	**8.95**	**93**	**8.27**	**92**	**7.93**	**91**
Cars	3.46	37	2.63	27	1.99	22	1.27	15
Heavy duty combo trucks	0.77	8	0.88	9	1.09	12	1.61	18
Heavy duty single unit trucks	0.27	3	0.32	3	0.34	4	0.38	4
Light commercial trucks	0.33	3	0.32	3	0.32	4	0.32	4
Light passenger trucks	3.48	37	4.26	45	3.91	44	3.53	41
Medium trucks	0.30	3	0.34	4	0.39	4	0.53	6
Motorcycles	0.02	0	0.01	0	0.01	0	0.01	0
Private Buses	0.11	1	0.18	2	0.20	2	0.26	3
Public Buses	0.02	0	0.01	0	0.02	0	0.02	0
Off road	**0.62**	**7**	**0.60**	**6**	**0.65**	**7**	**0.73**	**8**
Airport	0.12	1	0.13	1	0.15	2	0.16	2
Marine	0.07	1	0.07	1	0.07	1	0.08	1
Rail	0.43	5	0.40	4	0.43	5	0.50	6
Non road	**0.02**	**0**	**0.02**	**0**	**0.03**	**0**	**0.03**	**0**
Recreational	0.02	0	0.02	0	0.03	0	0.03	0
Gross emissions total (transport)	**9.39**	**100**	**9.57**	**100**	**8.95**	**100**	**8.69**	**100**
Net emission removal	n/a		n/a		n/a		n/a	
Biogenic CO_2	0.35		0.35		0.30		0.26	
Net emissions total (transport)	**9.05**		**9.22**		**8.65**		**8.44**	

Figure 2-23: *Historical and Projected Emissions in the Transport Sector by Fuel (results in GWP20)*

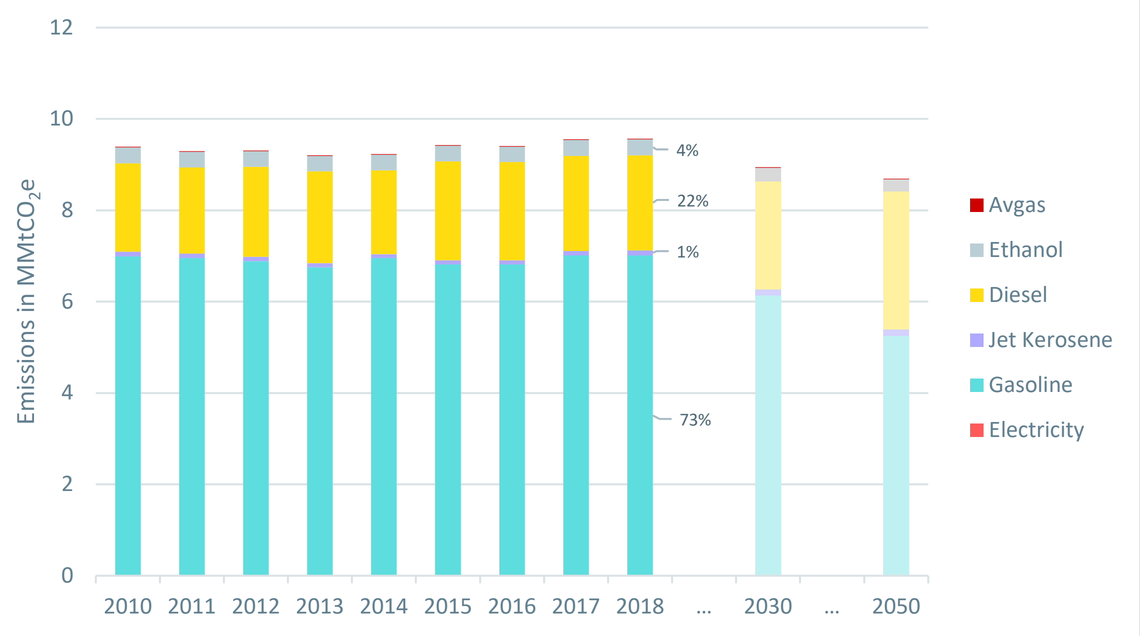
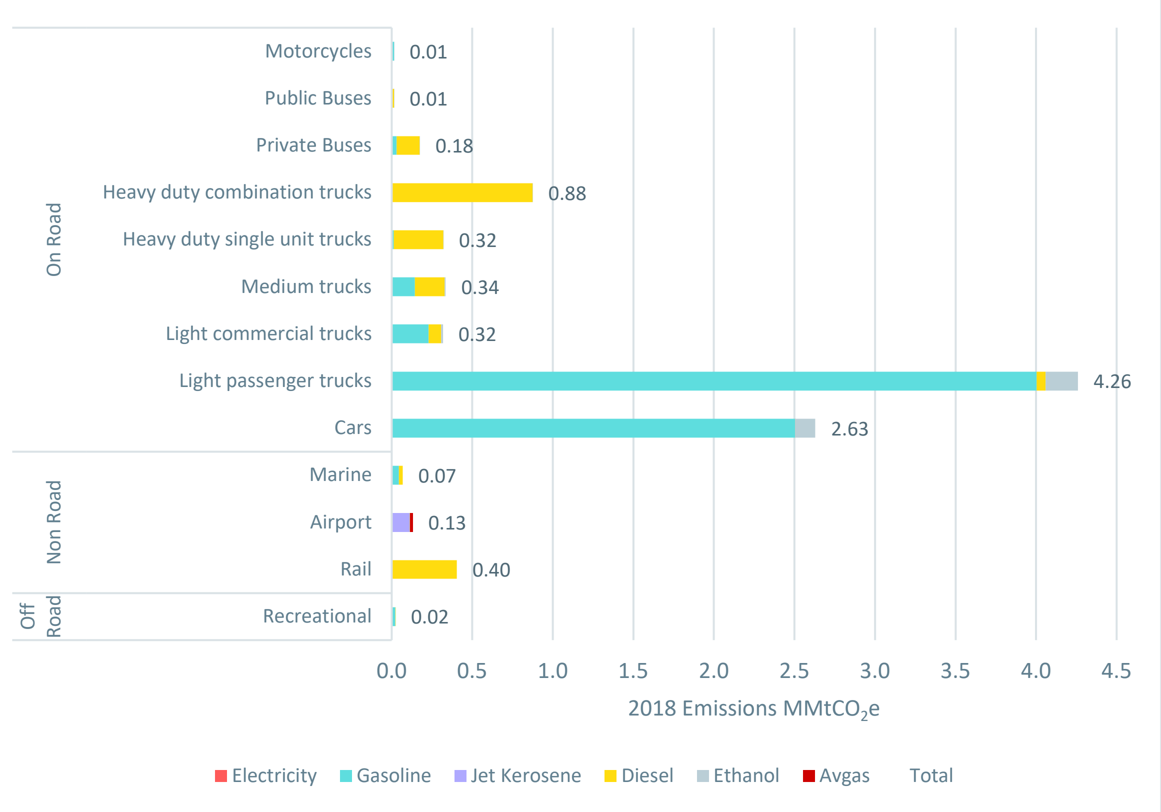


Figure 2-24: *2018 Transport Emissions by Vehicle Type and Fuel (results in GWP20)*



2.3.6 Waste emissions

Combined energy and non-energy emissions from the solid waste and wastewater sectors are presented in Figure 2-25 and Table 2-15. As discussed in the methodology, these emissions are from large emitters in the sector. The emissions appear to be decreasing over time. This may 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 2-25: *Historical and Projected Solid Waste and Wastewater Emissions by Large Facilities (results in GWP20)*

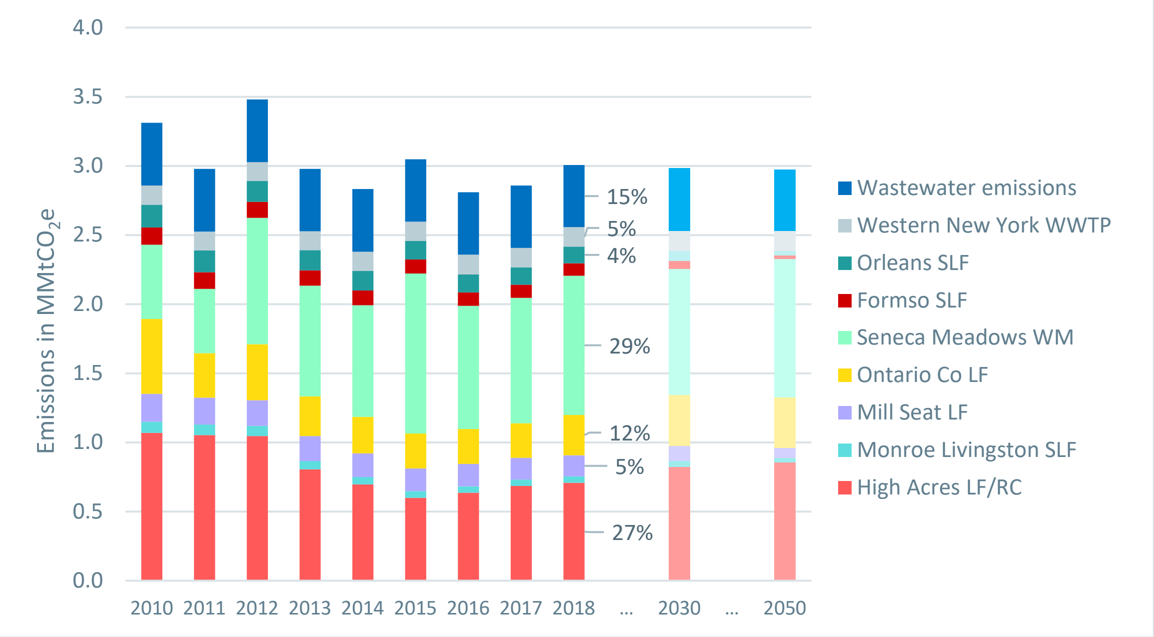


Table 2-15: *Waste Sector Emissions (results in GWP20)*

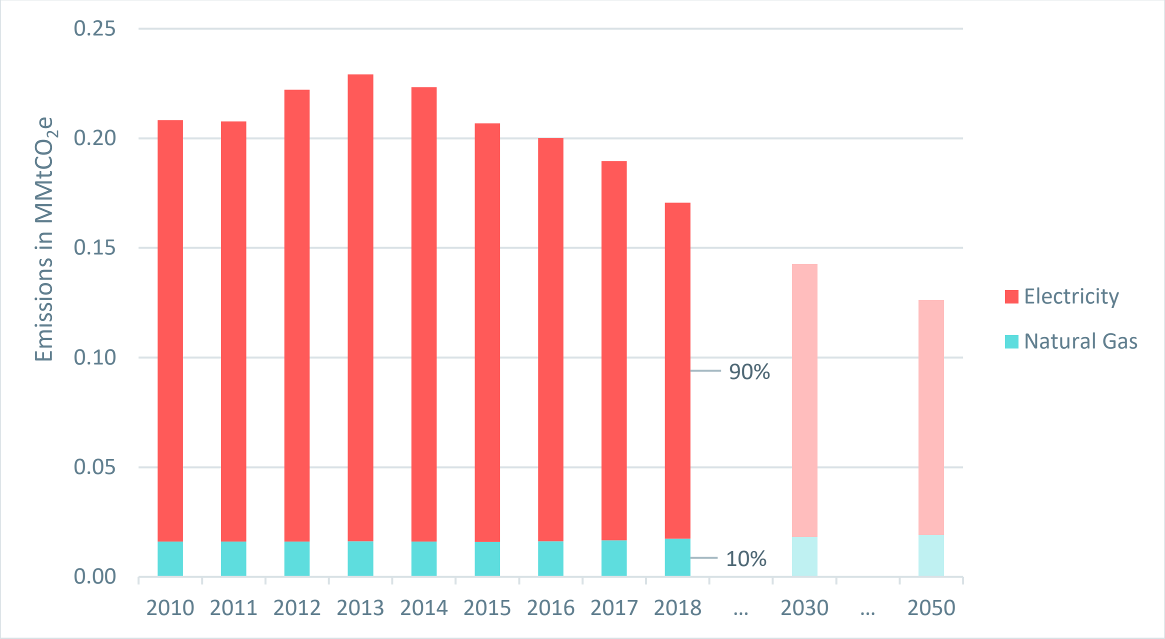
Sector – Waste	**-Historical-**				**-Baseline Projection-**			
	2010		**2018**		**2030**		**2050**	
	MMtCO₂e	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**	**MMtCO₂e**	**% of total**
Solid Waste	**2.72**	**82**	**2.42**	**80**	**2.39**	**80**	**2.39**	**80**
High Acres LF/RC	1.07	32	0.71	24	0.83	28	0.86	29
Monroe Livingston SLF	0.08	2	0.05	2	0.04	1	0.03	1
Mill Seat LF	0.20	6	0.15	5	0.11	4	0.07	2
Ontario Co LF	0.54	16	0.29	10	0.37	12	0.37	12
Seneca Meadows WM	0.54	16	1.01	33	0.91	31	1.00	34
Formso SLF	0.12	4	0.09	3	0.06	2	0.03	1
Orleans SLF	0.16	5	0.12	4	0.07	2	0.03	1
Wastewater	**0.59**	**18**	**0.59**	**20**	**0.60**	**20**	**0.59**	**20**

Sector – Waste	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
Western New York WWTP	0.14	4	0.14	5	0.14	5	0.14	5
Wastewater emissions	0.45	14	0.45	15	0.46	15	0.44	15
Gross emissions total (waste)	**3.31**	**100**	**3.01**	**100**	**2.98**	**100**	**2.97**	**100**
Net emission removal	n/a		n/a		n/a		n/a	
Biogenic CO_2	0.20		0.25		0.27		0.35	
Net emissions total (waste)	**3.11**		**2.76**		**2.71**		**2.62**	

2.3.7 Transmission losses and fugitive emissions

As shown in Figure 2-26 and Table 2-1, emissions from electricity transmission losses contributed to 0.15 $MMtCO_2e$ in 2018 compared to fugitive emissions from natural gas pipelines at only 0.02 $MMtCO_2e$. The projection shows that the rate of loss from transmission lines will decline from 7.0% in 2018 to 4.6% in 2050, contributing to the major decrease in transmission losses over time. Natural gas consumption is not expected to grow significantly in the future, so fugitive emissions will remain roughly the same.

Figure 2-26: *Historical and Projected Transmission Losses and Fugitive Emissions (results in GWP20)*



2.3.8 Land use emissions and removals

The land use sector is the main source of removals in the region. In 2018, about 1.1 MMtCO$_2$e was removed by existing forests, followed by 0.4 MMtCO$_2$e from urban trees. Emissions removals from forests are projected to decline to 0.9 MMtCO$_2$e by 2050 due to deforestation.

Forest converted to land for settlement or agriculture is the main source of emissions in the land use sector at 0.2 MMtCO$_2$e in 2018, remaining at this level through 2050.

Figure 2-27: *Historical and Projected Land Use Emissions and Removals (results in GWP20)*

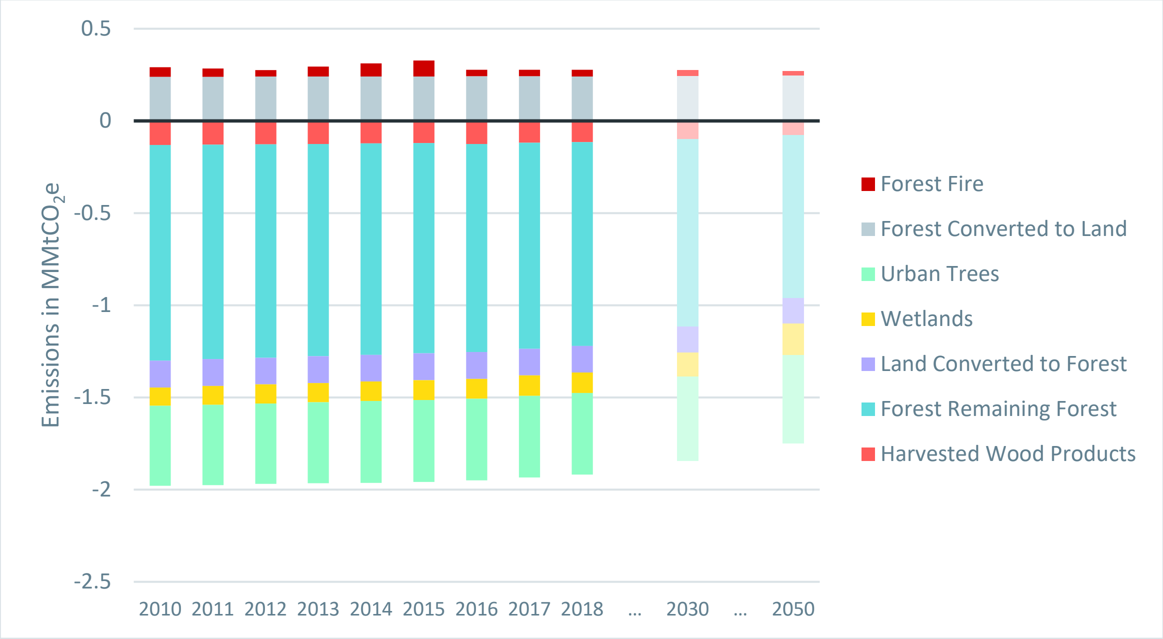


Table 2-16: *Land use sector emissions and removals (results in GWP20)*

Sector – Land Use	-Historical-				-Baseline Projection-			
	2010		2018		2030		2050	
	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total	$MMtCO_2e$	% of total
Land use emissions	**0.29**	**100**	**0.28**	**100**	**0.27**	**100**	**0.27**	**100**
Forest Converted to Land	0.24	82	0.24	87	0.24	89	0.25	91
Forest Fire	0.05	18	0.04	13	0.03	11	0.02	9
Gross emissions total (land use)	**0.29**	**100**	**0.28**	**100**	**0.27**	**100**	**0.27**	**100**
Land use removals	**-1.98**		**-1.92**		**-1.84**		**-1.75**	
Harvested Wood Products	-0.13	7	-0.12	6	-0.10	5	-0.08	4
Forest Remaining Forest	-1.17	59	-1.11	58	-1.02	55	-0.88	51
Land Converted to Forest	-0.15	7	-0.14	8	-0.14	8	-0.14	8
Wetlands	-0.10	5	-0.11	6	-0.13	7	-0.17	10
Urban Trees	-0.43	22	-0.44	23	-0.46	25	-0.48	27
Biogenic CO_2	n/a		n/a		n/a		n/a	
Net emissions total (land use)	**-1.69**		**-1.64**		**-1.57**		**-1.48**	

2.4 Priority areas for emission reductions

A summary of the top 15 sources of regional emissions in 2018 is given in Table 2-17, reflecting 82% of the region’s emissions. These sources of emissions should be prioritized for climate action.

Table 2-17: *Top 15 Sources of Emissions in 2018 (results in GWP20)*

Sector	Subsector	Subsector Emissions ($MMtCO_2e$)	Share of Emissions (%)
Transport	Light passenger trucks	4.3	16
Agricultural	Enteric fermentation (animal digestive processes)	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

Sector	Subsector	Subsector Emissions ($MMtCO_2e$)	Share of Emissions (%)
Waste	High Acres Landfill and Recycling Center	0.6	2
Commercial	Electricity consumption	0.5	2
Waste	Wastewater	0.5	2
Transport	Rail	0.4	2
Commercial	Propane consumption	0.4	1
Total		**22.0**	**82**

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. The following section outlines some of the elements to be included in a future iteration of the inventory.

3.1 Addressing data gaps

While the current version of the model includes all major sectors and fuel types, several data gaps are identified that need to be addressed in a future iteration of the inventory. We do not expect that these gaps will significantly change the findings presented in the emissions inventory, but filling them will ensure completeness.

- **Calibrate energy demands using data for multiple years**. Currently, county-level electricity and natural gas consumption in residential, commercial and industrial sector are calibrated using 2013 data, while all other fuels in the residential sector use 2017 data and gasoline sales data encompasses 1995 to 2017. Multiple years of data on the historical energy consumption for all sectors and fuels are needed to ensure the modeled usage matches actual consumption.
- **Population estimates including climate refugees from within America and elsewhere.** The Genesee-Finger Lakes is considered a climate refuge, yet the population projection used for the current analysis does not include increased migration from climate refugees into the region.
- **Street lighting.** It is unclear if the commercial energy use reported by utilities in the UER includes street lighting.
- **Bottom-up calculation of solid waste emissions.** Currently, the model only includes large solid waste facilities located within the region. A bottom-up calculation of solid waste generated by households, commercial and institutional entities and industry would ensure a complete inventory of those emissions. This would also help with analyzing the emissions reduction potential of diverting waste.
- **HCFC-22 production.** As of January 1, 2020, the US EPA mandates 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 the inventory can 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 about its energy consumption. The biggest bitcoin facility is the Greenidge plant, which started operation after 2018. Since the Greenidge Generation facility is connected to the grid, we assume its emissions are already captured in the electricity emissions factor described in Section 1.2.3.2, though this needs to be verified.
- **Emissions from behind-the-meter energy generation in industry and agriculture.** The data source use to estimate energy demands in the industrial and agricultural sectors provides electricity as "net electricity". 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. It is unclear how much fossil fuel is used to generate electricity on site at these facilities.
- **Upstream emissions of fossil fuel imports for electricity generation.** The electricity emission factors from eGRID does not consider upstream emissions of fossil fuel imports. In a future iteration of the study, an estimate of upstream emissions should be made based on the share of natural gas, coal, diesel and other fossil fuels in the electricity generation mix.
- **Airplane travel (cruise) emissions.** Emissions related to airplane travel (cruise emissions) has not been incorporated at the time of writing this report. The US Bureau of Transportation Statistics appears to possess 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 of those flights.
- **Consumption emissions from goods and services.** Consumption emissions are upstream emissions occurring from the manufacturing or production of energy or goods produced outside of the region. While the inventory includes upstream emissions for fossil fuel production, it does not include emissions from the manufacturing of goods outside the region. This analysis would require data on the type and amount of goods being brought into the region (e.g. cars, appliances, food) and the emissions resulting from the production of those goods. This data is generally difficult to find at a sub-national scale.
- **Community Choice Aggregation.** Community Choice Aggregation, or CCA, is a policy that enables local governments to procure energy supply service (mainly renewable energy) and distributed energy resources (DER) – like rooftop solar – for eligible energy customers in the community. When the initial model was developed, CCA was sparsely used across the region, but has since been implemented in several major cities, such as Rochester, Geneva, Pittsford and more. The emissions factor for electricity will need to be updated to account for the reduction in emissions from the use of CCAs.

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 and help identify targeted emissions reduction policies. Sectors to update and add further detail include:

- Further disaggregating commercial sector by subsector and end use using NYSERDA's 2018 report on the *Commercial Statewide Baseline Study of New York State*
- Disaggregating industrial sector by end use
- Disaggregating "other" residential energy demands beyond air conditioning, space heating and water heating
- Including multiple years of data for residential energy intensity
- Including multiple years of data for rail, marine and airport sub-sectors

4 References

A.B. A08429: Climate Leadership and Community Protection Act, (2019). https://nyassembly.gov/leg/?default_fld=&leg_video=&bn=A08429&term=2019&Summary=Y&Actions=Y&Text=Y

ACEEE. (2020). *Energy Burdens in Rochester*. American Council for an Energy-Efficient Economy. https://www.aceee.org/sites/default/files/pdfs/aceee-01_energy_burden_-_rochester.pdf

Bhattacharyya, S. C. (2011). Energy Demand Forecasting. In S. C. Bhattacharyya, *Energy Economics* (pp. 107–133). Springer London. http://link.springer.com/10.1007/978-0-85729-268-1_5

City of Rochester. (2019). *Climate Change Resilience Plan*. https://www.cityofrochester.gov/CCRP/

Climate Watch. (2022). *Data Explorer*. https://www.climatewatchdata.org/data-explorer

Cornell Program on Applied Demographics. (2017). *NY County profiles*. https://pad.human.cornell.edu/profiles/index.cfm

Eastern Research Group. (2020). *2017 National Emissions Inventory: Aviation Component*. US Environmental Protection Agency. https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/point/2017Aircraft_main_25june2020.pdf

ERG. (2021). *Technical Documentation: Estimating Energy Sector Greenhouse Gas Emissions Under New York State's Climate Leadership and Community Protection Act*. Eastern Research Group, Inc. https://www.dec.ny.gov/docs/administration_pdf/energyghgerg.pdf

FAA. (2021). *Economic Values for Evaluation of FAA Investment and Regulatory Decisions: Section 3—Aircraft capacity and utilization factors*. US Federal Aviation Administration. https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost

GFLRPC. (2013). *Finger Lakes Regional Sustainability Plan*. https://www.gflrpc.org/finger_lakes_regional_sustainability_plan.php

Howarth, R. W. (2020). Methane emissions from fossil fuels: Exploring recent changes in greenhouse-gas reporting requirements for the State of New York. *Journal of Integrative Environmental Sciences*, *17*(3), 69–81. https://doi.org/10.1080/1943815X.2020.1789666

IPCC. (2001). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories: Aircraft Emissions*. Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_5_Aircraft.pdf

IPCC. (2003). *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. Institute for Global Environmental Strategies. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

IPCC. (2006a). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

IPCC. (2006b). *IPCC Road Transport Default Emission Factors. 2006 IPCC Guidelines, Volume 2 (Energy), Chapter 3 (Mobile Combustion)* (2006 IPCC Guidelines for National Greenhouse Gas Inventories). Intergovernmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

IPCC. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://www.ipcc.ch/report/ar5/wg1/

IPCC. (2018). *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Cambridge University Press. https://www.ipcc.ch/sr15/chapter/spm/

IPCC. (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IPCC. https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Kartha, S., Kemp-Benedict, E., Ghosh, E., Nazareth, A., & Gore, T. (2020). *The Carbon Inequality Era*. Stockholm Environment Insitute and Oxfam International. https://www.sei.org/publications/the-carbon-inequality-era/

Landsberg, H. H., Resources for the Future, & National Science Foundation (U.S.) (Eds.). (1974). *Energy and the social sciences: An examination of research needs*. Resources for the Future.

Leverenz, H. L., Tchobanoglous, G., & Darby, J. L. (2010). *Evaluation of Greenhouse Gas Emissions from Septic Systems*. Water Environment Research Foundation. https://decentralizedwater.waterrf.org/documents/DEC1R09/DEC1R09.pdf

McMillan, C. (2019). *2018 Industrial Energy Data Book*. National Renewable Energy Laboratory. https://doi.org/10.7799/1575074

MRLC. (2022). *2019 National Land Cover Database (CONUS)*. https://www.mrlc.gov/data

New York City Department of Housing Preservation and Development. (2021). *Affordable Housing: Area Median Income*. https://www1.nyc.gov/site/hpd/services-and-information/area-median-income.page

NYDPS. (2021). *New York Generation Attribute Tracking System*. https://nygats.ny.gov/ng/Report/getdto_view_Report_PublicEDPLabel

NYSDEC. (2017). *Directory of Primary Wood-Using Industry in New York State*. New York State Department of Environmental Conservation. https://www.dec.ny.gov/docs/lands_forests_pdf/directory17.pdf

NYSDEC. (2019). *2019 MSW Landfill Capacity Chart*. https://www.dec.ny.gov/chemical/23723.html

NYSDEC. (2022a). *2021 NYS GHG Emissions Report: Sectoral Report #4–Waste*. New York State Department of Environmental Conservation. https://www.dec.ny.gov/docs/administration_pdf/ghgwaste21.pdf

NYSDEC. (2022b). *2021 Statewide GHG Emissions Report: Summary Report*. New York State Department of Environmental Conservation. https://www.dec.ny.gov/docs/administration_pdf/ghgsumrpt21.pdf

NYSERDA. (2015). *New York Community and Regional GHG Inventory Guidance*. https://climatesmart.ny.gov/fileadmin/csc/documents/GHG_Inventories/ghgguide.pdf

NYSERDA. (2017). *Patterns and Trends: New York State Energy Profiles, 2001–2015*. New York State Energy Research and Development Authority. file:///C:/Users/SEI/Downloads/2001-2015-patterns-and-trends.pdf

NYSERDA. (2019a). *Commercial Statewide Baseline Study of New York State*. New York State Energy Research and Development Authority. https://www.nyserda.ny.gov/About/Publications/Building-Stock-and-Potential-Studies/Commercial-Statewide-Baseline-Study

NYSERDA. (2019b). *Patterns and Trends: New York State Energy Profiles, 2002–2016*. New York State Energy Research and Development Authority. file:///C:/Users/SEI/Downloads/2002-2016-Patterns-and-Trends.pdf

NYSERDA. (2021a). *Monthly Cooling and Heating Degree Day Data*. New York State Energy Research and Development Authority. https://www.nyserda.ny.gov/about/publications/ea-reports-and-studies/weather-data/monthly-cooling-and-heating-degree-day-data

NYSERDA. (2021b). *Patterns and Trends: New York State Energy Profiles, 2003–2017*. New York State Energy Research and Development Authority. file:///C:/Users/SEI/Downloads/2003-2017-Patterns-and-Trends.pdf

Ruggles, S., Flood, S., Foster, S., Goeken, R., Pacas, J., Schouweiler, M., & Sobek, M. (2021). *IPUMS USA: Version 11.0. Amercian Community Survey Data from 2010 to 2019*. https://doi.org/10.18128/D010.V11.0

Southern Research Institute. (2007). *NYSERDA Clean Diesel Technology: Non-Road Field Demonstration Program—Development of the 2002 Locomotive Survey for New York State*. New York State Energy Research and Development Authority. file:///C:/Users/SEI/Downloads/locomotive-survey-clean-diesel-technology.pdf

UNDESA. (2019). *World Population Prospects Data Query—Total Population by Sex*. United Nations Department of Economic and Social Affairs. https://population.un.org/wpp/DataQuery/

US Census Bureau. (n.d.). *County Business Patterns 1986–2019 & Nonemployer Statistics 1997–2018*. United States Census Bureau. Retrieved July 9, 2021, from https://www.census.gov/data/developers/data-sets/cbp-nonemp-zbp.html

US Census Bureau. (2019). *American Housing Survey (AHS)*. United States Census Bureau. https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00000&s_year=2019&s_tablename=TABLE1&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1

US Census Bureau. (2020a). *American Community Survey 1-Year Data (2005–2019)*. United States Census Bureau. https://www.census.gov/data/developers/data-sets/acs-1year.html

US Census Bureau. (2020b). *Evaluation Estimates*. United States Census Bureau. https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates.html

US Census Bureau. (2021). *American Community Survey 5-Year Data*. United States Census Bureau. https://www.census.gov/data/developers/data-sets/acs-5year.2019.html

US EIA. (2018). *2015 Residential Energy Consumption Survey (RECS)*. US Energy Information Administration. https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption#undefined

US EIA. (2021). *2018 Manufacturing Energy Consumption Survey (MECS)*. US Energy Information Administration. https://www.eia.gov/consumption/manufacturing/data/2018/#r5

US EPA. (2017). *State Inventory and Projection Tool* [Data and Tools]. US Environmental Protection Agency. https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool

US EPA. (2019a). *2017 NEI LTO Database*. US Environmental Protection Agency. https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/point/2017Aircraft_NEIEPA_LTOs_19aug2019.accdb

US EPA. (2019b). *Specification Sheet: Rail 2017 National Emissions Inventory*. US Environmental Protection Agency. https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/point/2017Rail_main_21aug2019.pdf

US EPA. (2020a). *2017 National Emissions Inventory (NEI) Data* [Other Policies and Guidance]. US Environmental Protection Agency. https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data

US EPA. (2020b). *EPA CMV model*. https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/nonpoint/EPA%20CMV%20Model%20V5.pptx

US EPA. (2021a). *EGRID2019 Summary Tables*. US Environmental Protection Agency. https://www.epa.gov/sites/default/files/2021-02/documents/egrid2019_summary_tables.pdf

US EPA. (2021b). *Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2019*. US Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019

US EPA. (2021c). *MOtor Vehicle Emission Simulator 3 (MOVES3)*. https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

US FTA. (2022). *National Transit Database*. US Federal Transportation Administration. https://www.transit.dot.gov/ntd/ntd-data

US HUD. (2020). *FY 2020 Income Limits Documentation System*. https://www.huduser.gov/portal/datasets/il.html#2020

USDA. (2022). *USDA/NASS QuickStats Ad-hoc Query Tool: Inventory of Cattle*. https://quickstats.nass.usda.gov/

USGS. (2019). *USGS Cement MIS Archive, December 2019, Table T4P4. Clinker Production, by District. January-December 2018*. http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb

USGS. (2020). *USGS 2016 Mineral Yearbook*. US Geographical Survey. https://d9-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/myb1-2016-stonc.pdf

Vespa, J., Medina, L., & Armstrong, D. M. (2020). *Demographic Turning Points for the United States: Population Projections for 2020 to 2060* (No. P25-1144; Current Population Reports). U.S. Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf

APPENDIX A

Emission factors

Appendix A. Emission Factors

Table A-1: 2019 Emission factors for fuel combustion

Sector	Fuel	CO_2		CH_4		N_2O	
Electricity	Coal	95.63	kg/MMBtu	0.7	g/GJ	3.6	g/GJ
Electricity	Distillate fuel	74.14	kg/MMBtu	0.9	g/GJ	0.4	g/GJ
Electricity	Natural gas	52.91	kg/MMBtu	1	g/GJ	0.3	g/GJ
Electricity	Petroleum coke	102.12	kg/MMBtu	0.7	g/GJ	3.6	g/GJ
Electricity	Residual fuel	75.09	kg/MMBtu	0.8	g/GJ	0.3	g/GJ
Electricity	Wood	103.14	kg/MMBtu	11	g/GJ	7	g/GJ
Residential	Coal	95.74	kg/MMBtu	300	g/GJ	1.5	g/GJ
Residential	Distillate fuel	74.14	kg/MMBtu	10	g/GJ	0.6	g/GJ
Residential	Kerosene	73.19	kg/MMBtu	10	g/GJ	0.6	g/GJ
Residential	LPG	62.88	kg/MMBtu	5	g/GJ	0.1	g/GJ
Residential	Natural gas	52.91	kg/MMBtu	5	g/GJ	0.1	g/GJ
Residential	Wood	103.14	kg/MMBtu	300	g/GJ	4	g/GJ
Residential	Electricity	50.03	kg/MMBtu	3.53	g/GJ	0.38	g/GJ
Commercial	Coal	95.74	kg/MMBtu	10	g/GJ	1.5	g/GJ
Commercial	Distillate fuel	74.14	kg/MMBtu	10	g/GJ	0.6	g/GJ
Commercial	Kerosene	73.19	kg/MMBtu	10	g/GJ	0.6	g/GJ
Commercial	LPG	62.88	kg/MMBtu	5	g/GJ	0.1	g/GJ
Commercial	Natural gas	52.91	kg/MMBtu	5	g/GJ	0.1	g/GJ
Commercial	Residual fuel	75.09	kg/MMBtu	10	g/GJ	0.6	g/GJ
Commercial	Wood	103.14	kg/MMBtu	300	g/GJ	4	g/GJ
Commercial	Electricity	50.03	kg/MMBtu	3.53	g/GJ	0.38	g/GJ

Sector	Fuel	CO_2		CH_4		N_2O	
Industrial	Asphalt and road oil	75.35	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Coal: coking	93.83	kg/MMBtu	10	g/GJ	1.5	g/GJ
Industrial	Coal: other	95.59	kg/MMBtu	10	g/GJ	1.5	g/GJ
Industrial	Distillate fuel	74.14	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Kerosene	73.19	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	LPG	62.88	kg/MMBtu	1	g/GJ	0.1	g/GJ
Industrial	Lubricants	74.07	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Miscellaneous petroleum products	74.47	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Natural gas	52.91	kg/MMBtu	1	g/GJ	0.1	g/GJ
Industrial	Petroleum coke	102.12	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Residual fuel	75.09	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Special naphthas	72.38	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Waxes	72.60	kg/MMBtu	3	g/GJ	0.6	g/GJ
Industrial	Wood	93.87	kg/MMBtu	30	g/GJ	4	g/GJ
Industrial	Electricity	50.03	kg/MMBtu	3.53	g/GJ	0.38	g/GJ
Transportation—On road	Motor gasoline	71.35	kg/MMBtu	25	g/GJ	8	g/GJ
Transportation—On road	Distillate	74.14	kg/MMBtu	3.9	g/GJ	3.9	g/GJ
Transportation—On road	Natural gas	52.91	kg/MMBtu	5[1]	g/GJ	0.1[1]	g/GJ
Transportation—On road	Electricity	50.03	kg/MMBtu	3.53	g/GJ	0.38	g/GJ
Transportation—Aviation	Aviation gasoline	69.15	kg/MMBtu	60	g/GJ	0.9	g/GJ
Transportation—Aviation	Jet fuel	72.23	kg/MMBtu	0	g/GJ	2.5	g/GJ
Transportation—Railroad	Distillate fuel	74.14	kg/MMBtu	0.25	g/kg	0.08	g/kg
Transportation—Military	Distillate fuel	74.14	kg/MMBtu	2.01	g/kg	0.054	g/kg
Transportation—Military	Residual fuel oil	75.09	kg/MMBtu	0.31	g/kg	0.088	g/kg
Transportation—Bunker vessel	Distillate fuel	74.14	kg/MMBtu	2.01	g/kg	0.054	g/kg

Sector	Fuel	CO_2		CH_4		N_2O	
Transportation—Bunker vessel	Residual fuel oil	75.09	kg/MMBtu	0.31	g/kg	0.088	g/kg
Transportation—Other nonroad	Distillate fuel	74.14	kg/MMBtu	0.295	g/kg	0.274	g/kg
Transportation—Other nonroad	Industrial/commercial equipment: gasoline—4 stroke	71.35	kg/MMBtu	1.09	g/kg	0.6	g/kg
Transportation—Other nonroad	Construction/mining equipment: equipment gasoline—4 stroke	71.35	kg/MMBtu	1.085	g/kg	0.597	g/kg
Transportation—Other nonroad	Airport equipment gasoline—4 stroke	71.35	kg/MMBtu	1.39	g/kg	0.764	g/kg
Transportation—Other nonroad	Construction/mining equipment: equipment gasoline—4 stroke	71.35	kg/MMBtu	1.085	g/kg	0.597	g/kg
Transportation—Other nonroad	Construction/mining equipment: equipment gasoline—4 stroke	71.35	kg/MMBtu	1.085	g/kg	0.597	g/kg
Transportation—Other nonroad	Lawn and garden equipment: residential gasoline—4 stroke	71.35	kg/MMBtu	0.98	g/kg	0.537	g/kg
Transportation—Other nonroad	Ships and boats: gasoline—4 stroke	71.35	kg/MMBtu	0.802	g/kg	0.003	g/kg
Transportation—Other nonroad	Recreational equipment: gasoline—4 stroke	71.35	kg/MMBtu	1.54	g/kg	0.795	g/kg

Source: US EPA (2021b) and IPCC (2006b) as cited in ERG (2021)

Note: Emission factors for fuels labelled as “electricity” are multiplied by utility factor per Table 1-3 in Section 1.2.3.2. The emission factors for CO_2 in the original data source were given as CO_2-C. This was converted to CO_2 using the molecular weight ratio of 44/12.

[1] Assumed to have the same emission factor as natural gas in the commercial sector

Table A-2: 2019 upstream emission factors

Sector	CO_2 (g/MMBtu)	CH_4 (g/MMBtu)	N_2O (g/MMBtu)
Natural gas	12 131	357	0.14
Diesel/distillate fuel	15 164	121	0.26
Coal	3300	364	0.10
Kerosene/jet fuel	10 071	109	0.17
Gasoline (E85)	5097	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)

Note: The emission factors for CO_2 in the original data source were given as CO_2-C. This was converted to CO_2 using the molecular weight ratio of 44/12.

APPENDIX B

Orebed Analytics report on industrial and agricultural energy demands

APPENDIX C

Agricultural non-energy calculations and assumptions

Appendix C. Agricultural non-energy calculations and assumptions

Enteric fermentation

The calculation of methane emissions from enteric fermentation are described in Table 1-20.

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:

$$\mathbf{CH_4 = [H]*[TAM]*[VS]*[MPE]*[WMCF]*[ConCH4]}$$

Where:
[H] = Livestock heads from USDA (2021)
[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 management and feeding practices.

Table C-3: *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/day]	Max. Potential Emissions [m^3 CH_4/kg VS]	Weighted methane conversion factors [fraction]
Dairy	Not applicable	7.9	0.24	0.309
Beef	Not applicable	4.6	0.17	0.009
Calves	123	7.7	0.17	0.009
Goat	64	9.5	0.17	0.009
Sheep’ (average of all categories)	53	8.3	0.28	0.006
Swine’ (average of all categories)	83	5.5	0.48	0.165
Llama[1]	53	8.3	0.28	0.006

Animal	Typical Animal Mass [kg]	Volatile Solids [kg VS/head/day]	Max. Potential Emissions [m^3 CH_4/kg VS]	Weighted methane conversion factors [fraction]
Layers	2	11	0.39[2]	0.049
Pullets	2	10	0.39	0.049
Broilers	1	17	0.39	0.015
Roosters[2]	2	11	0.39	0.049

[1] Values assumed by SEI to be same as sheep

[2] Values assumed by SEI 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 (N_2O) from manure management are as follows:

$$N_2O = (([K\text{-}Nitrogen]*[\%AN])*E1 + ([K\text{-}Nitrogen]*[\%OT])*E2) * [ConN_2O]$$

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 N_2O-N/kg N)
[E2] = 0.02 = emissions factor for solid storage, drylot, and other systems (kg N_2O-N/kg N)
[ConN_2O] = conversion from N_2O to N_2

Table C-4: *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/day]	Manure in anaerobic system or lagoon [%]	Manure in solid storage, drylot or other [%]
Dairy	not applicable	0.43	43	40
Beef	not applicable	0	43	40
Calves	123	0	43	40
Goat	64	0	0	0
Sheep (average of all categories)	53	0.45	0	50
Swine (average of all categories)	83	0.55	53	0
Llama[1]	53	0.45	0	50
Layers	2	0.79	5	0.5

Animal	Typical Animal Mass [kg]	Nitrogen Excreted [kg NEx/head/day]	Manure in anaerobic system or lagoon [%]	Manure in solid storage, drylot or other [%]
Pullets	2	0.79	5	0.5
Broilers	1	0.96	0	100
Roosters[2]	2	1.1	5	95

[1] Values assumed by SEI to be same as sheep

[2] Values assumed by SEI to be same as chickens

Animal manure on agricultural soils

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

$$\mathbf{N_2O = (([K\text{-}Nitrogen]*0.2*E3 + ([K\text{-}Nitrogen]*[\%P])*E4 + ([K\text{-}Nitrogen]*[\%M] + [K\text{-}Nitrogen]*[\%S])*(1\text{-}0.2)*E5) * [ConN_2O]}$$

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 NH_3 and NOx [kg N_2O 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]
[$ConN_2O$] = conversion from N_2O to N_2

Table C-5: *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/day]	Manure on Pastures [%]	Manure managed [%]	Manure spread on ground [%]
Dairy	na	0.44	14	83	3
Beef	na	0	100	0	0
Calves	123	0	100	0	0
Goat	64	0	100	0	0
Sheep (average of all categories)	53	0.45	50	50	0
Swine (average of all categories)	83	0.55	41	54	0

Animal	Typical Animal Mass [kg]	Nitrogen Excreted [kg NEx/head/day]	Manure on Pastures [%]	Manure managed [%]	Manure spread on ground [%]
Llama[1]	53	0.45	50	50	0
Layers	2	0.79	0	100	0
Pullets	2	0.79	0	100	0
Broilers	1	0.96	0	100	0
Roosters[2]	2	1.1	0	100	0

[1] Values assumed to be same as sheep

[2] Values assumed to be same as chickens

Livestock runoff and leaching onto agricultural soils

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

$$\mathbf{N_2O = [K\text{-}Nitrogen] * 0.3 * E6 * [ConN_2O]}$$

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 N_2O N/kg N]
[ConN_2O] = Conversion from N_2O to N_2

See Table 4-3 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):

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

[P] = crop production [kg] from USDA (2021)
[RR] = residue crop mass ratio
[FD] = residue dry matter fraction
[FA] = fraction residue applied
[NR] = nitrogen content of residue
[NB] = 0.0 = nitrogen content of aboveground biomass for nitrogen-fixing crop production
E7 = 0.01 = emission factor (kg N_2O N/kg N)

[$ConN_2O$] = conversion from N_2O to N_2

Table C-6: *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

Plant residue burning (nitrous oxide emissions)

Based on the methodology from the US EPA State Inventory Tool (2017) for the module tab labeled “soils plant residue burning”, this is the equation to calculate emissions from burning residues to clear and prepare the field for the next cropping cycle:

$$N_2O = [P]*[RR]*[FB]*[FD]*[BE]*[CE]*[NC]*E9*[ConN_2O]$$

[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] = nitrogen content
E9 = 0.007 = ag soils burning N_2O to N emissions ratio [N_2O/N]
[$ConN_2O$] = conversion from N_2O to N_2

Table C-7: *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:

$$CH_4 = [P]*[RR]*[FB]*[FD]*[BE]*[CE]* [CC]*E10*[ConCH_4]$$

[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] = carbon content
E10 = 16/12 = ag soils burning CH_4 to carbon emissions ratio [CH_4/C]
[ConCH_4] = conversion from CH_4 to C

Table C-8: *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] = nitrogen 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 N_2O N/kg N]
E12 = 0.01 = emission factor for ag soils plant indirect [kg N_2O N/kg N]

County-level fertilizer consumption is estimated by taking the statewide fertilizer consumption (US EPA, 2017) and allocating it to each county based on fertilizer expenditures from USDA (2021) (See FERTILIZER TOTALS, INCL LIME & SOIL CONDITIONERS - EXPENSE, MEASURED IN $).

Table C-9: *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] = nitrogen 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 N_2O N/kg N]

County-level fertilizer consumption is estimated by taking the statewide fertilizer consumption (US EPA, 2017) and allocating it to each county based on fertilizer expenditures from USDA (2021) (See FERTILIZER TOTALS, INCL LIME & SOIL CONDITIONERS - EXPENSE, MEASURED IN $). See Table 4-7 for the data used for the remaining variables.

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:

$$\mathbf{CO_2 = [A]*EF*[ConCO_2]}$$

Where:
[A] = amount applied to soil [metric tons]
EF = emission Factors [tons C/tons applied]
[$ConCO_2$] = 12/44 = Weight conversion from C to CO_2

Table C-10: *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

Visit us

SEI Headquarters

Linnégatan 87D
Box 24218
104 51 Stockholm Sweden
Tel: +46 8 30 80 44
info@sei.org

Måns Nilsson
Executive Director

SEI Africa

World Agroforestry Centre
United Nations Avenue Gigiri
P.O. Box 30677 Nairobi 00100 Kenya
Tel: +254 20 722 4886
info-Africa@sei.org

Philip Osano
Centre Director

SEI Asia

Chulalongkorn University
Henri Dunant Road Pathumwan
Bangkok 10330 Thailand
Tel: +66 2 251 4415
info-Asia@sei.org

Niall O'Connor
Centre Director

SEI Latin America

Calle 71 # 11–10
Oficina 801
Bogotá Colombia
Tel: +57 1 6355319
info-LatinAmerica@sei.org

David Purkey
Centre Director

SEI Oxford

Oxford Eco Centre
Roger House Osney Mead
Oxford OX2 0ES UK
Tel: +44 1865 42 6316
info-Oxford@sei.org

Ruth Butterfield
Centre Director

SEI Tallinn

Arsenal Centre
Erika 14
10416 Tallinn Estonia
Tel: +372 6276 100
info-Tallinn@sei.org

Lauri Tammiste
Centre Director

SEI York

University of York
Heslington
York YO10 5NG UK
Tel: +44 1904 32 2897
info-York@sei.org

Sarah West
Centre Director

SEI US Main Office

11 Curtis Avenue
Somerville MA 02144-1224 USA
Tel: +1 617 627 3786
info-US@sei.org

Michael Lazarus
Centre Director

SEI US Davis Office

501 Second Street
Davis CA 95616 USA
Tel: +1 530 753 3035

SEI US Seattle Office

1402 Third Avenue Suite 925
Seattle WA 98101 USA
Tel: +1 206 547 4000

SEI Stockholm Environment Institute

sei.org
@SEIresearch @SEIclimate