VERMONT

Agency of Natural Resources

Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2021

July 2024

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Note to Readers

The Greenhouse Gas Emissions Inventory and Forecast reports are now comprised of two components to help make the report more accessible for public consumption. This component of the report estimates greenhouse gas (GHG) emissions levels by sector, and includes important considerations related to emission estimates. The companion document *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies* discusses the specific sector by sector methodologies and datasets utilized in the calculations in greater depth. The *Methodologies* document will be updated with each inventory release as necessary when improvements to methods or datasets occur.

For additional information and resources on climate action in Vermont from adaptation and resilience to mitigation pathways and strategies, please visit our website: https://climatechange.vermont.gov/.

Executive Summary

Overall concentrations of greenhouse gases (GHGs) in the earth's atmosphere continue to increase due to human caused emissions and are already affecting many weather and climate extremes in all regions around the world[1]. Greenhouse gases absorb solar radiation and trap heat energy in the atmosphere, which warms the planet. Global warming is already having impacts here in the Northeastern U.S. [2], including impacts to communities and natural ecosystems, many of which are already marginalized or disproportionately impacted. Understanding Vermont's contribution to this problem from both a local and global perspective, by identifying and quantifying greenhouse gas emissions from the sources and sectors which are responsible, is a critical first step in reducing emissions that contribute to global warming. The goal of this inventory is to provide an understanding of emissions sources in Vermont in a way that enables the tracking of emissions levels through time and to help inform decisions on future mitigation strategies and pathways that is consistent with other jurisdictions.

The Vermont Greenhouse Gas Emissions Inventory and Forecast reports are required pursuant to Vermont statute 10 V.S.A. § 582[3]. The Inventory quantifies historic 1990 and 2005 baseline GHG levels and tracks changes in emissions through time to determine progress toward the state's GHG reduction requirements in 10 V.S.A. § 578[4], which were updated with the passage of the Global Warming Solutions Act (GWSA)), (Act 153) in 2020.[5] The emissions reduction requirements of the GWSA are 26% below 2005 levels by January 1, 2025, 40% below 1990 levels by January 1, 2030, and 80% below 1990 levels by January 1, 2050. Historic inventory values are updated as necessary with each updated inventory release based on updates to data sources, global warming potential values, or changes to methodologies.

The methodologies and data used to inform this inventory are provided in detail in the *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies* companion document. This report provides emissions estimates, as well as general information and emissions trends for each sector. Updates to data and methodologies in this current GHG Inventory include a change in the source of data for fossil fuel use in the Residential/Commercial/Industrial Fuel Use (RCI) sector, which also impacted totals in the Transportation/Mobile sources sector, as well as the data source for onroad diesel use in the transportation sector. Methodologies were also updated for closed landfill estimates in the Waste sector, and for estimates of emissions from ozone depleting substances (ODS) substitutes in the Industrial Processes sector. Additional detail on calculation

[1] Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC): Climate Change 2021 – The Physical Science Basis: https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf

[2] Whitehead, J.C., E.L. Mecray, E.D. Lane, L. Kerr, M.L. Finucane, D.R. Reidmiller, M.C. Bove, F.A. Montalto, S. O'Rourke, D.A. Zarrilli, P. Chigbu, C.C. Thornbrugh, E.N. Curchitser, J.G. Hunter, and K. Law, 2023: Ch. 21. Northeast. In: Fifth National Climate Assessment. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. https://doi.org/10.7930/NCA5.2023.CH21

[3] Vermont Statute 10 V.S.A. § 582: https://legislature.vermont.gov/statutes/section/10/023/00582

[4] Vermont Statute 10 V.S.A. § 578: https://legislature.vermont.gov/statutes/section/10/023/00578

[5] Vermont Legislature - Global Warming Solutions Act (Act 153): https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT153/ACT153%20As%20Enacted.pdf

methodologies and data that have been used to generate emissions estimates in the inventory, as well as these updates, are briefly described in the sections below but are discussed in greater detail in the companion Methodology document.

The emissions totals in this inventory report are accounted for in a gross framework within each sector, meaning that the individual sectors do not account for any sequestration of CO_2 from the atmosphere. The Land-use, Land Use Change, and Forestry (LULUCF) sector includes this sequestration component for the other sectors, but estimates of biogenic CO_2 emissions are included as supplemental information in several sectors for tracking purposes. For further discussion on the accounting of biogenic CO_2 and the LULUCF sector please refer to the Methodology document.

This inventory includes official estimates for the years 1990 through 2021. Overall emissions in 2021 were 8.28 $MMTCO_2e$, which was an overall increase from 2020 levels as shown in Figure 1, with variability within each sector. Much of this increase was due to a rebound from the depressed emissions levels in 2020 stemming from the COVID-19 pandemic, but small emissions increases were seen in the electricity sector and the industrial processes sector as well as several other sectors.

Five- and ten-year projected emissions totals are provided and have been taken directly from modeling work that was completed as part of the Vermont Climate Action Plan (CAP) process and which will continue to be updated by the Climate Action Office. Estimating emissions totals in future years is a complex undertaking and is not the focus of this report, which utilizes historical data to estimate emissions totals from activities that have already occurred. Because significant work to project emissions estimates into the future has already been completed, this inventory includes those projections rather than attempting to calculate separate values.

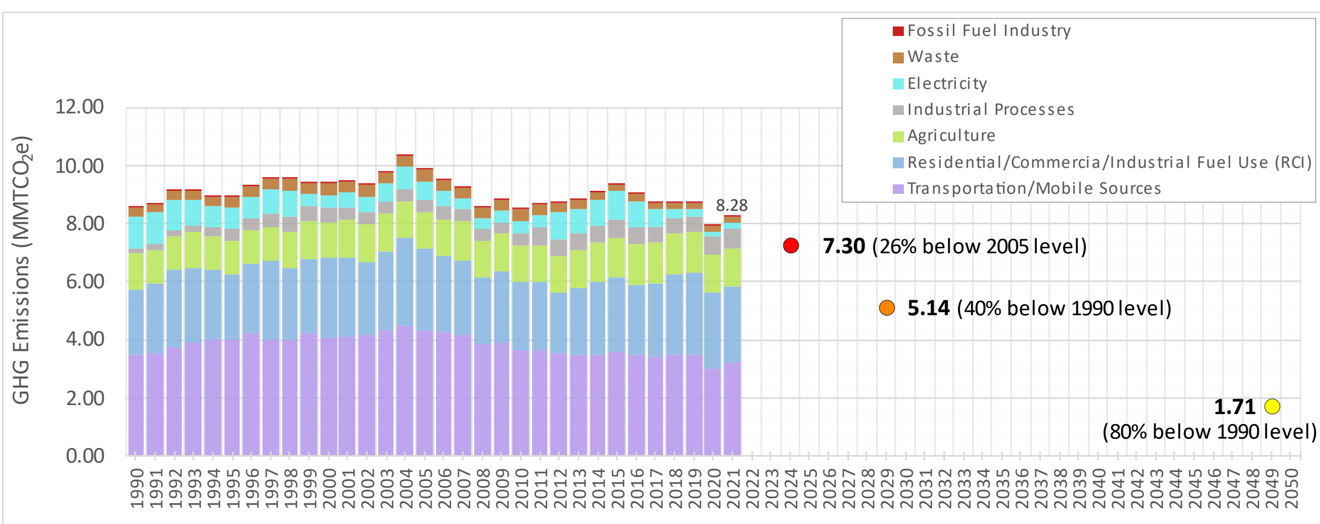

Figure 1: Vermont statewide greenhouse gas emissions levels and mandated reduction targets as defined in 10 V.S.A. § 578.

1. Introduction

The *Vermont Greenhouse Gas Emissions Inventory and Forecast* (GHG Inventory) provides estimates of the amount of human caused (anthropogenic) greenhouse gas emissions produced within the state of Vermont in units of million metric tons of carbon dioxide (CO_2) equivalent ($MMTCO_2e$). The global warming potential (GWP) values have been updated from the previous report to match those used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5)[6] per IPCC inventory guidelines, which are the AR5 100-year values. This update has the largest impact on sectors where methane (CH_4) is the predominant gas, such as the agriculture and waste sectors. Estimates of emissions using the AR5 20-year GWP values are available for select years in the companion methodology document. The GHG Inventory estimates and tracks the levels of greenhouse gas emissions for the state as accurately and consistently as possible through time and are generated using methods and datasets discussed in the *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies*[7] companion document. This report includes estimates for the years 1990 – 2021 and supersedes estimates included in previous reports. Including data that is both complete and as current as possible is important to help understand Vermont's progress towards required emissions reductions levels.

1.1 Vermont and the U.S. GHG Comparisons

When comparing sectoral contributions from Vermont to the U.S. as a whole, differences are expected due to different social, economic, and cultural realities. Some of the major differences are that Vermont has a higher percentage of emissions from transportation, thermal use in buildings (RCI), and agriculture than the country, which is likely due to the rural nature of the state and the disproportionate use of heating fuels during the winter months. It also has a significantly lower percentage of emissions from electricity generation (Figure 2 and Figure 3) due to the large amounts of low- or no-carbon electricity in the Vermont portfolio.

[6] Intergovernmental Panel on Climate Change (IPCC) – Fifth Assessment Report (AR5): https://www.ipcc.ch/assessment-report/ar5/

[7] Vermont Agency of Natural Resources - *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies:* *https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/_Methodology_Vermont_Greenhouse_Gas_Emissions_Inventory_1990-2020_Final.pdf*

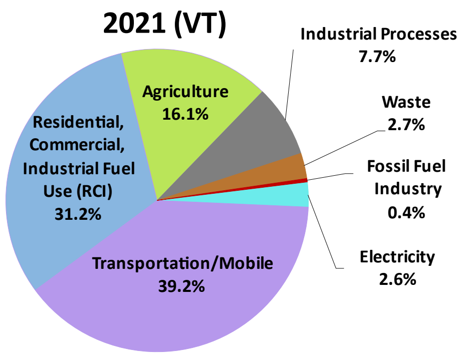

Figure 2: Vermont GHG percent contributions by sector.

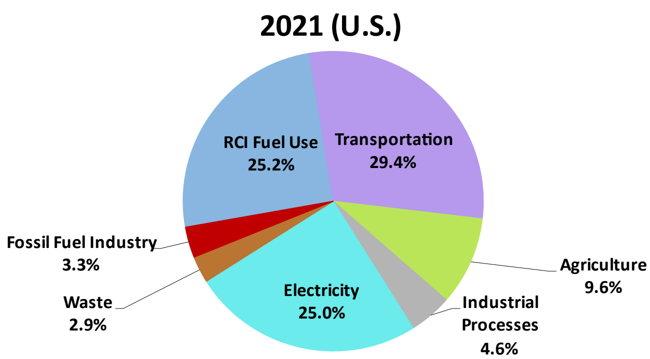

Figure 3: U.S. GHG percent contributions by sector. Data for the U.S. contributions by sector has been reallocated to match the Vermont sector categories in this report as closely as possible.

2 Vermont GHG Emissions by Sector

2.1 Overview

The GHG Inventory tracks greenhouse gas emissions by economic sector through time. Utilizing this sector-based accounting framework provides an understanding of the portion of the total statewide GHG emissions for which each sector is responsible and how those emissions totals are changing over time. This information can be important for prioritizing and informing policy decision-making related to specific sources within each sector and subsector, however, which broader economic sector the emissions are bucketed in is not as important as understanding the specific contributing sources.

The sectors in this report include transportation/mobile sources, residential/commercial/industrial (RCI) fuel use, agriculture, industrial processes, electricity consumption, waste, and the fossil fuel industry. The land-use, land use change, and forestry (LULUCF) sector is also included in the report, but no sequestration is incorporated into the gross sector totals. Figure 4 below shows the estimates of GHG emissions by sector back to the 1990 baseline. Additional details related to each sector can be found in the sections below and additional information on the calculation methodologies and data sources used to calculate the emissions totals for each sector are in the accompanying methodology document.

Emissions of biogenic carbon dioxide, which are produced from the burning, breaking down, or processing of biologically-based material, are not included in the overall gross sectoral totals in the inventory per the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[8] as well as the 2019 refinement to those guidelines[9]. Those biogenic emissions are instead captured in the LULUCF sector through changes in land use and the amount of stored carbon on the landscape (carbon stocks and fluxes). Estimates of emissions of biogenic CO_2 have been included as additional information by sector where applicable and where the data exist. A more detailed explanation of the accounting decisions and calculations for biogenic emissions in Vermont is included in the Methodology document.

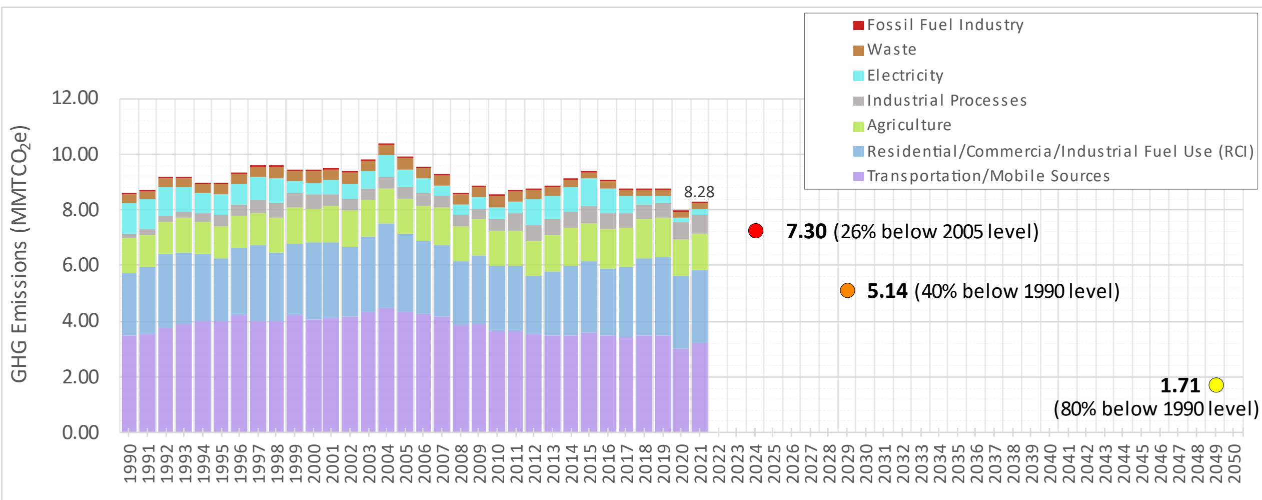

Figure 4: Total and sector-specific GHG emissions in Vermont, 1990-2021 with targets.

2.1.1 Transportation/Mobile Sources

The transportation and mobile sources sector consists of estimates of greenhouse gas emissions related to people and goods moving through and around Vermont. The totals include emissions from the combustion of fuels used in cars and trucks on Vermont roads, the use of aviation gasoline and jet fuel for aircraft, and emissions from other non-road equipment (Table 1). The use of gasoline and diesel by vehicles on the roads of Vermont is the largest source of emissions in the sector (Table 2), with light duty gasoline vehicles being the largest source category within the onroad vehicle fleet (Table 3).

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[8] IPCC (2006) - *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/
[9] IPCC (2019) - *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

The transportation and mobile sources sector has consistently been the highest emitting sector in Vermont. In the previous GHG Inventory report it was surpassed by the Residential/Commercial/Industrial Fuel Use (RCI) sector in 2020. This change in hierarchy was short lived because the drop in transportation sector emissions in 2020 (Figure 5) was due to the COVID-19 pandemic and the resulting reductions in vehicle miles traveled (VMT) and lower sales of gasoline in the state, and historical values were also impacted by the use of an updated dataset allowing for reallocation of a volume of fuel described below. In 2021 statewide VMT (Figure 6) and sales of gasoline (Figure 7) both rebounded. Although gasoline sales and VMT were still below pre-pandemic levels, GHG emissions in the Transportation/Mobile Sources sector are once again the highest emitting sector in the state. Emissions totals in this sector depend on a number of complex factors including travel behaviors, fuel prices, vehicle consumer choices, vehicle fuel efficiency standards, and electrification policies and initiatives which are difficult to predict.

In previous versions of the GHG Inventory diesel fuel used by several nonroad mobile sources (such as construction equipment and logging equipment) was included within the industrial subsector of the Residential/Commercial/Industrial (RCI) Fuel Use sector. In this iteration of the GHG Inventory, however, a new dataset is being utilized that allows for the separation of the diesel use in nonroad equipment within the RCI sector and so it is now being included in the Transportation/Mobile Sources sector. The reallocation of this volume of fuel from the RCI sector to the Transportation/Mobile sector has been projected backwards through time and so has changed historical values in both sectors back to 1990. This reallocation in nonroad diesel fuel between sectors also contributed to the switch that reestablished the Transportation/Mobile sources sector as the highest emitting sector in the state (both in 2021 and in the revised 2020 values). For additional details on this change in dataset and allocation of fuels, please see the companion methodology document.

Table 1: Mobile source contributions by fuel type.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2010	2019	2020	2021
Transportation/Mobile Sources (MMTCO2e)	**3.48**	**4.33**	**3.67**	**3.50**	**3.02**	**3.24**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.54	3.05	2.63	2.42	2.01	2.19
Diesel (Onroad) (CO2)	0.41	0.70	0.63	0.65	0.61	0.66
Diesel (Nonroad) (CO_2)	0.31	0.33	0.25	0.30	0.29	0.26
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.13	0.07	0.07	0.06	0.09
Other sources (CO_2, CH_4, N_2O)	0.14	0.13	0.09	0.06	0.05	0.05
Ethanol (biogenic CO_2)*	0.00	0.01	0.17	0.17	0.14	0.16
Biodiesel (biogenic CO_2)*	0.00	0.00	0.00	0.02	0.02	0.02

** biogenic totals not included in gross total estimates*

Table 2: Percent contribution to transportation emissions from onroad and nonroad sources (2020 NEI)[10].

Transportation Subsector (NEI)	Percent Contribution (2020)
Onroad Gasoline and Diesel	68%
Nonroad Gasoline and Diesel	32%

Table 3: Percent contribution to onroad transportation emissions by vehicle type (2020 NEI)[9].

Onroad Transportation Subsector (2020 NEI)	Percent Contribution (2020)
Light-duty Gasoline Vehicles	85%
Heavy-duty Gasoline Vehicles	1%
Light-duty Diesel Vehicles	2%
Heavy-duty Diesel Vehicles	12%

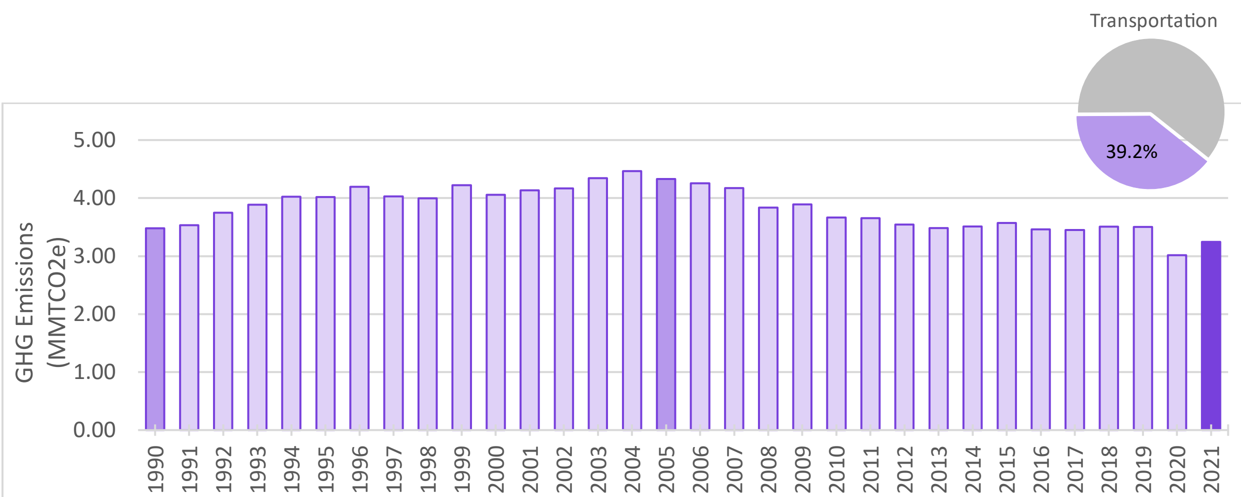

Figure 5: Vermont GHG emissions from transportation/mobile sources sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

[10] 2020 National Emissions Inventory (NEI) Data: https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data

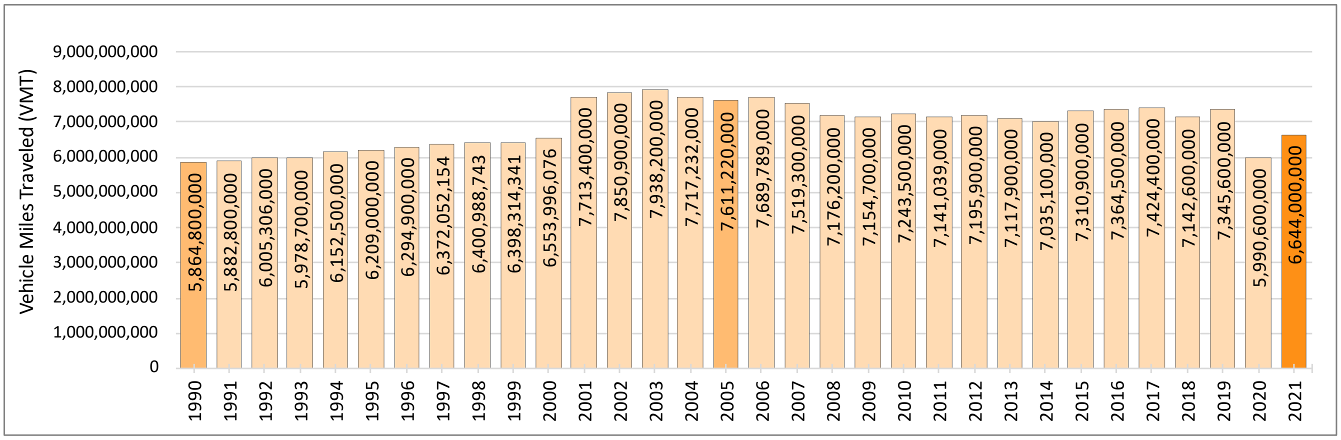

Figure 6: Vehicle miles traveled in Vermont by year (Source: VTrans). Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

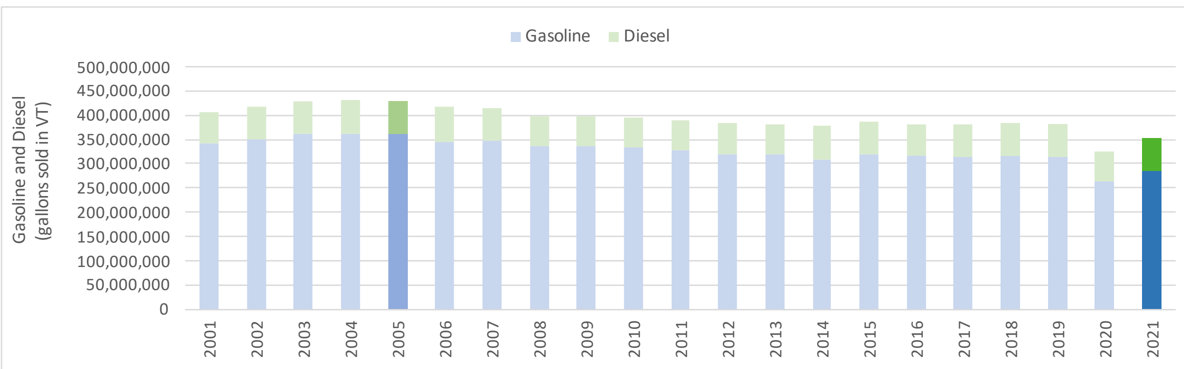

Figure 7: Gallons of gasoline and diesel sold in Vermont by year (Source: Joint Fiscal Office). Years from 2001-2021 are included with 2021 and the 2005 baseline year highlighted.

2.1.2 Residential/Commercial/Industrial (RCI) Fuel Use

The majority of greenhouse gas emissions from the Residential/Commercial and Industrial Fuel Use sector are related to the use of fossil fuels for space heating, water heating, and cooking, in residential, commercial, and industrial buildings. Emissions are mostly CO_2 from the use of fuel oil, propane, and natural gas but also include methane (CH_4) and nitrous oxide (N_2O) from burning fossil fuels and wood (Table 4). The industrial portion of the RCI sector previously included the use of diesel fuel in several nonroad categories such as farm use, off-highway construction, and logging operations, however with the integration of a new dataset from the Vermont Department of Taxes it is now possible to move this volume of fuel to the Transportation/Mobile Sources sector.

The largest share of emissions in the RCI sector comes from residential fuel use at nearly 53% in 2021. This is followed by the commercial subsector at just under 35% and the industrial subsector at 12.6% (Table 5). Emissions from fuel oil in the residential subsector is the highest emitting source within the sector overall, followed by residential propane and then by the use of natural gas in the commercial subsector (Table 5). Fluctuations of emissions levels in this sector

(Figure 8) are caused mainly by winter heating season demands, but are also impacted by fuel prices, weatherization initiatives, fuel switching, and increased efficiency of appliances. Additional analysis related to fossil fuel heating use in Vermont has been completed and is available in a report *Analyzing Changes in Fossil Heating Fuel Use in Vermont, 2018-2023*[11]. RCI sector emissions totals have been plotted with heating degree days (HDD) in Figure 9, which are used as an indicator of average winter temperatures, to help illustrate the relationship between GHG emissions in the RCI sector and fluctuations in winter temperatures.

Table 4: GHG emissions from the RCI sector by subsector and fuel type.

Sector	Emissions in $MMTCO_2e$					
	1990	**2005**	**2010**	**2019**	**2020**	**2021**
Residential/ Commercial/ Industrial (RCI) Fuel Use	**2.25**	**2.79**	**2.31**	**2.77**	**2.59**	**2.57**
Residential - Oil, Propane, Natural Gas, and other	1.26	1.53	1.25	1.46	1.28	1.26
Residential - Wood (CH_4, N_2O)	0.07	0.08	0.09	0.10	0.11	0.09
Commercial - Oil, Propane, Natural Gas, and other	0.54	0.66	0.59	0.86	0.83	0.89
Commercial - Wood (CH_4, N_2O)	0.00	0.00	0.00	0.00	0.00	0.00
Industrial - Oil, Propane, Natural Gas and Other	0.38	0.52	0.39	0.35	0.37	0.32
Industrial - Wood (CH_4, N_2O)	0.00	0.00	0.00	0.00	0.00	0.00
Residential - Wood (biogenic CO_2)*	0.83	0.95	1.10	1.30	1.36	1.20
Commercial - Wood (biogenic CO_2)*	0.03	0.01	0.01	0.04	0.02	0.04
Industrial - Wood (biogenic CO_2)*	0.29	0.27	0.16	0.17	0.13	0.14
Renewable Natural Gas (RNG)*	0.000	0.000	0.000	0.001	0.002	0.005

** biogenic totals not included in gross total estimates*

As discussed previously, biogenic emissions are not included in the gross emissions totals in this inventory. The biogenic CO_2 values from the burning of wood (shown in Table 4) are included here for informational purposes. The methodology used for calculating these totals, as well as the IPCC guidance related to biogenic emissions, is discussed in the companion methodology document.

[11] Energy Action Network (EAN): Analyzing Changes in Fossil Heating Fuel Use in Vermont 2018-2023 (2024): https://eanvt.org/wp-content/uploads/2024/06/Thermal-fuels-research-paper-June-20-2024-1.pdf

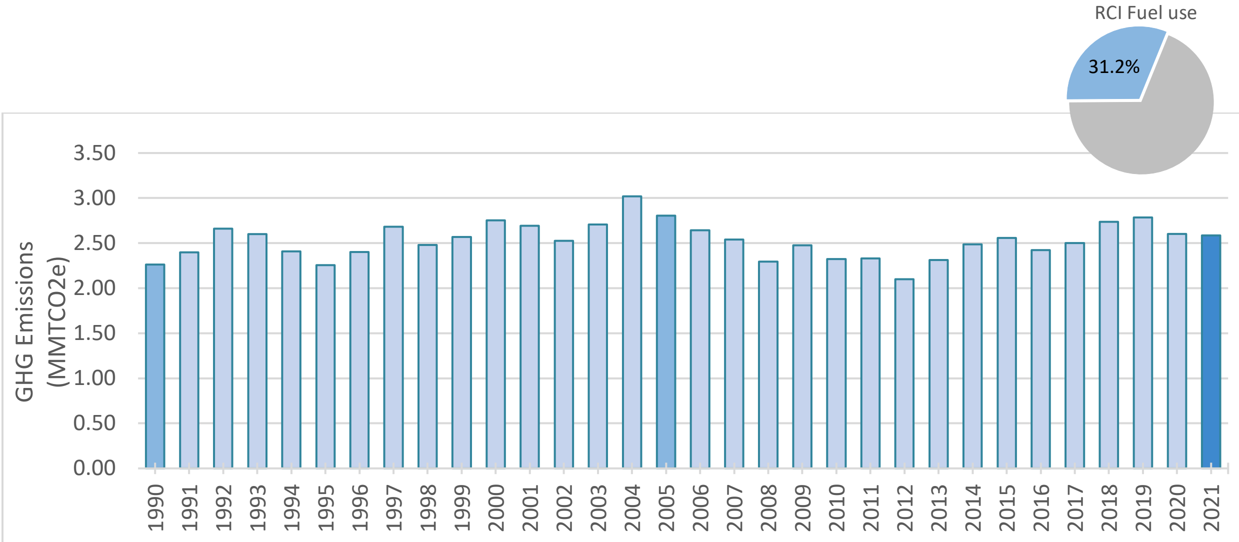

Figure 8: Vermont GHG emissions from the RCI sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

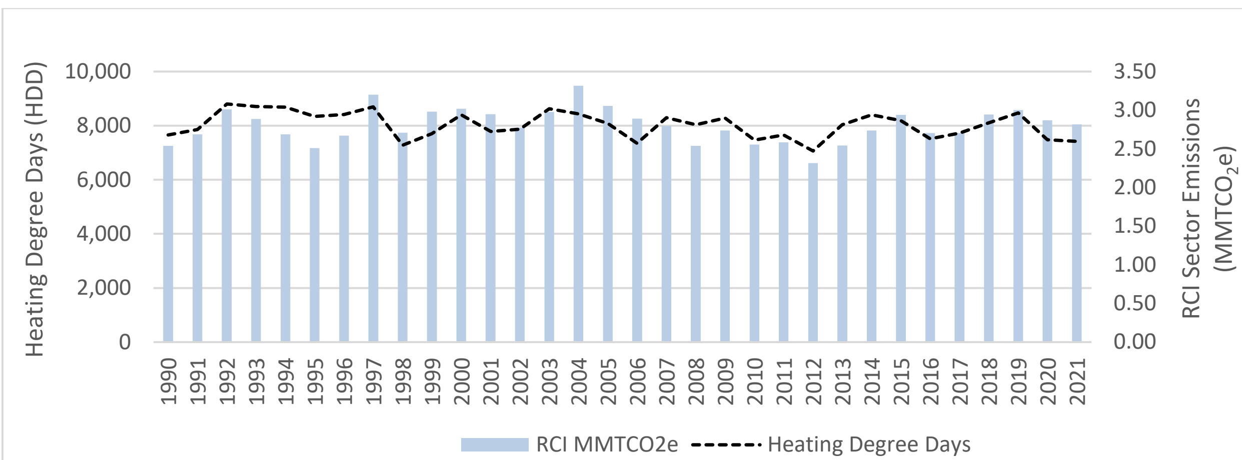

Figure 9: Vermont RCI sector emissions in $MMTCO_2e$ plotted with the heating degree days (the difference between 65 degrees and a day's average temperature if below 65 degrees) from 1990 – 2021.

Table 5: GHG emissions contributions by fuel type and subsector within the RCI sector (2021).

RCI Breakdown by Subsector and by Fuel (2021)	Subsector	Emissions ($MMTCO_2e$)	Percent of Subsector Total	Percent of Total by Subsector
Fuel Oil	Residential	0.61	44.9%	52.8%
Propane	Residential	0.42	30.6%	
Natural Gas	Residential	0.20	15.0%	
Wood (CH_4 + N_2O)	Residential	0.09	7.0%	
Kerosene	Residential	0.03	2.5%	
Total	**Residential**	**1.36**	**100%**	
Fuel Oil	Commercial	0.21	23.7%	34.7%
Propane	Commercial	0.21	23.6%	
Natural Gas	Commercial	0.41	45.8%	
Wood (CH_4 + N_2O)	Commercial	0.00	0.3%	
Other	Commercial	0.06	6.5%	
Total	**Commercial**	**0.90**	**100%**	
Fuel Oil	Industrial	0.15	46.9%	12.6%
Propane	Industrial	0.01	3.1%	
Natural Gas	Industrial	0.10	29.6%	
Wood (CH_4 + N_2O)	Industrial	0.00	0.6%	
Other	Industrial	0.06	19.7%	
Total	**Industrial**	**0.32**	**100%**	
Grand Total	**All**	**2.59**		**100.0%**

2.1.3 Agriculture

Greenhouse gas emissions from the agriculture sector include estimates of CH_4 and N_2O from agricultural practices and activities in Vermont. These emissions come from the digestive processes of animals, managing manure, application of fertilizers, and processes related to agricultural soils. Carbon dioxide emissions from this sector are almost entirely biogenic, and so are not included in the sector totals, with the exception of liming and urea fertilization (Table 6). Total emissions from the sector have declined slightly in the last two years (Figure 10), by about 6% between 2019 and 2021.

Agriculture sector emissions totals in the GHG Inventory do not currently account for any sequestration (removal of CO_2 from the atmosphere) by vegetation, storage in agricultural soils, or any emissions benefits from agricultural management practices such as no till or cover cropping. This is because the components of the agricultural sector related to sequestration and land use change are being captured in the Land-Use, Land-use Change, and Forestry (LULUCF) sector and due to the limitations of the currently utilized accounting methodology. These processes and practices are intricately linked to agriculture but because of the current accounting framework the associated sources and sinks are not tied directly to the agriculture sector of the GHG Inventory itself.

Many Vermont farmers are already working to reduce emissions from their farms by adopting agricultural conservation practices to reduce tillage and fertilizer use and these practices have benefits for both GHG emissions and water quality. ANR worked with the Agency of Agriculture Food and Markets (AAFM) on a project where a consultant investigated the available tools and datasets to enable more accurate accounting and a more holistic picture of greenhouse gas emissions and sinks associated with the agriculture sector in Vermont. This project has been completed and recommendations related to datasets and modifications to methodologies, especially to better incorporate emissions impacts from existing agricultural management practices, will be coordinated with AAFM and incorporated into future inventories to the extent possible. Additional information related to data and emissions from the agriculture sector in the state can be found in the Vermont Carbon Budget report[12] and information about the calculation methodologies for the sector and recommendations from the Agricultural Tool Review study can be found in the companion methodology document.

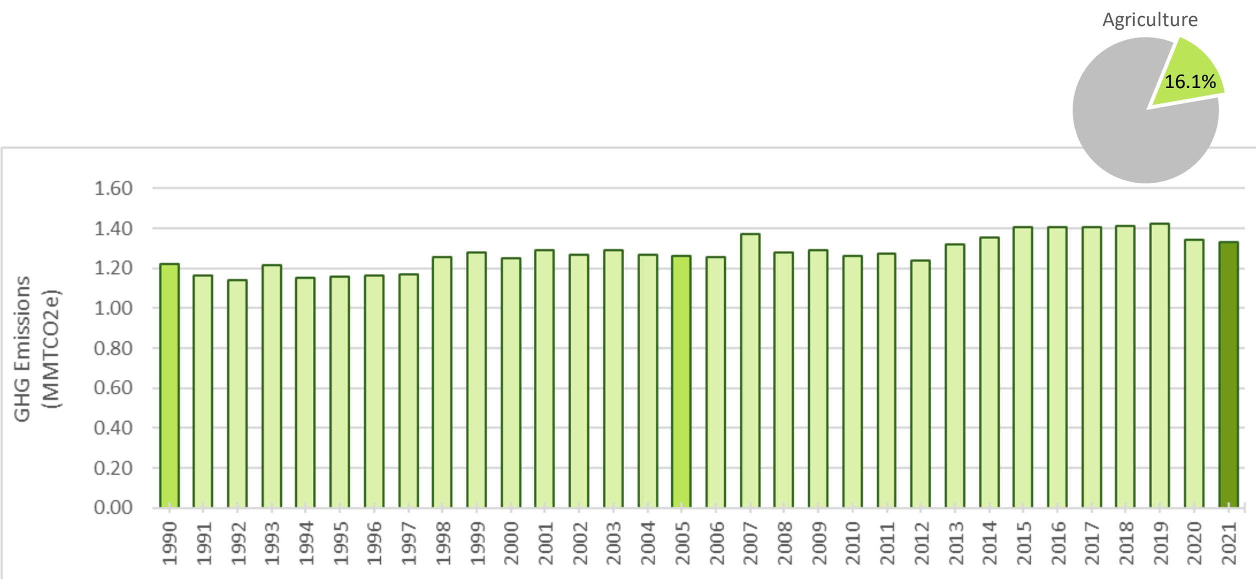

Figure 10: Vermont GHG emissions from the agriculture sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years.

[12] Vermont Carbon Budget Report: https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Carbon%20Budget%20for%20Vermont%20Sept%202021.pdf

Table 6: GHG emissions contributions of subsectors within the agriculture sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2010	2019	2020	2021
Agriculture	**1.22**	**1.26**	**1.26**	**1.42**	**1.34**	**1.33**
Enteric Fermentation (CH_4, N_2O)	*0.76*	*0.69*	*0.67*	*0.70*	*0.67*	*0.67*
Manure Management (CH_4, N_2O)	*0.18*	*0.34*	*0.35*	*0.39*	*0.37*	*0.36*
Agricultural Soils (CH_4, N_2O)	*0.29*	*0.23*	*0.24*	*0.29*	*0.25*	*0.25*
Liming and Urea Fertilization (CO_2)	*0.00*	*0.00*	*0.01*	*0.04*	*0.05*	*0.06*

2.1.4 Industrial Processes

The Industrial Processes (IP) sector of the GHG Inventory includes emissions related to industrial manufacturing occurring in Vermont, as well as the use of high global warming potential (GWP) gases in a number of end uses and applications. Many of the high emitting manufacturing categories usually included in the IP sector of a state's GHG inventory, such as the production of chemicals and materials like lime, ammonia, nitric acid, cement, iron, and steel, are not occurring in Vermont. The state does not have very many large manufacturing facilities, which is evidenced by the fact that there are fewer than a dozen facilities in the state that currently report to EPA's Greenhouse Gas Reporting Program [13], which requires reporting by any facilities that emit more than 25,000 metric tons of CO_2e annually. Emissions of gasses from ozone depleting substances (ODS) substitutes and the manufacturing of semiconductors tend to be very potent in terms of their ability to warm the planet (high GWP) and dominate emissions from the sector, making up around 94% of the total (Table 7). Emissions estimates from the IP sector have increased by roughly 15% between 2019 and 2021 due to increased emissions from both ODS substitutes and semiconductor manufacturing (Figure 11).

ODS substitutes are gases that are used mainly in refrigeration equipment, air conditioning equipment, aerosol propellants, and foams. These gases were incorporated into equipment as substitutes to replace gases that deplete the ozone layer. A number of these replacement gases (ODS substitutes), mainly hydrofluorocarbons (HFCs), are very potent planet warming gases with high GWPs and their use and leakage into the atmosphere is a driver of global warming. The phase out and replacement of these ODS substitute gases with lower GWP alternatives is underway in Vermont through the passage of Act 65 (2019) [14] and Act 121 (2022) [15], which prohibits the use of high-GWP HFCs in certain end uses. However, the overall use of these gases is still growing as the use of additional refrigeration and air conditioning increases.

[13] EPA Greenhouse Gas Reporting Program: https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp
[14] Vermont Act 65: https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT065/ACT065%20As%20Enacted.pdf
[15] Vermont Act 121: https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT065/ACT065%20As%20Enacted.pdf

The manufacturing of semiconductors is a complex process that requires the use of very high GWP gases including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). These gases are used in the plasma etching and chemical vapor deposition process, as well as in heat transfer fluids. Emissions can be mitigated by adding destruction devices at specific times and locations within the manufacturing process to combust some of the high GWP gases before they are released to the atmosphere, and by finding alternatives for the gases used in the processes themselves.

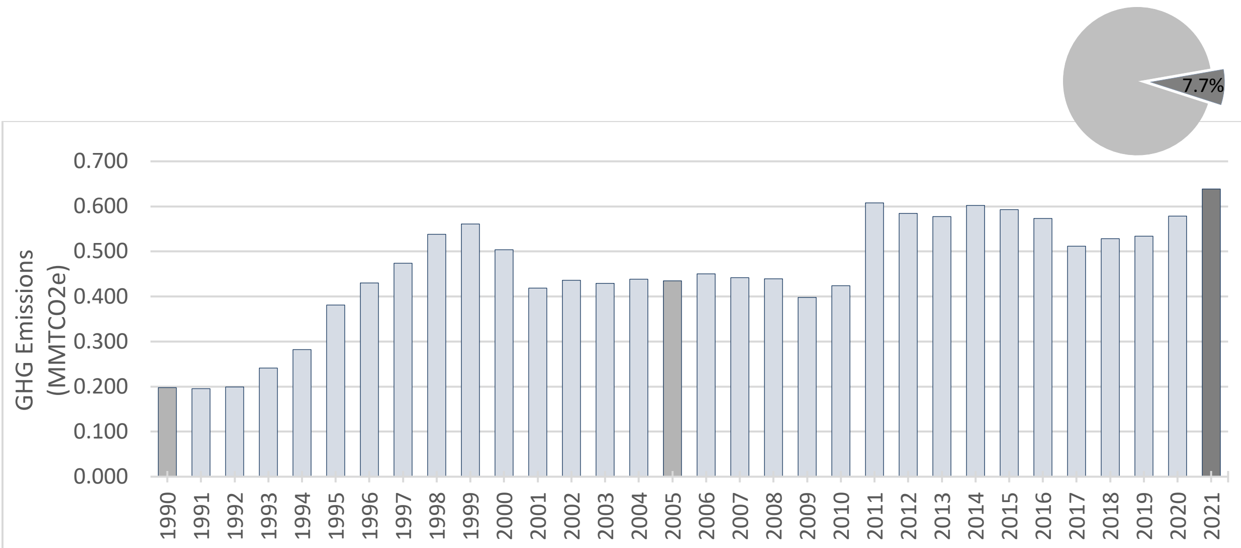

Figure 11: Vermont GHG emissions from the industrial processes sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

Table 7: GHG emissions contributions of subsectors with the industrial processes sector.

Sector	Emissions in $MMTCO_2e$					
	1990	**2005**	**2010**	**2019**	**2020**	**2021**
Industrial Processes	**0.20**	**0.43**	**0.42**	**0.53**	**0.58**	**0.64**
ODS Substitutes (HFCs, PFCs, NF_3 SF_6)	0.00	0.19	0.21	0.29	0.32	0.33
Electric Utilities (SF_6)	0.04	0.02	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs, NF_3 SF_6)	0.15	0.20	0.17	0.21	0.23	0.24
Limestone & Dolomite Use (CO_2)	0.00	0.03	0.02	0.02	0.02	0.05
Soda Ash Use (CO_2)	0.01	0.01	0.00	0.00	0.00	0.00
Urea Consumption (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00

2.1.5 Electricity Consumption

The electricity sector includes emissions associated with all electricity used by Vermonters and is the only sector in the inventory where emissions that occur outside of the boundaries of the state are accounted for. This is because in Vermont we consume more than three times as much electricity as we generate in state[16]. In addition, it makes sense to account for out of state production in Vermont's inventory because of the interconnected nature of the New England electric grid. Although out-of-state generation is included in the totals, emissions estimates are still only for emissions that occur at the point of generation of Vermont's purchased electricity portfolio and do not include estimates of any emissions that occur "upstream" of the generation sources themselves. For example, the emissions from combustion occurring in a natural gas fired powerplant supplying electricity to Vermont that is in another state in the region would be counted, but the emissions from the extraction and transport of the natural gas to the generation facility would not be included. Electricity generated by renewable sources is assumed to have zero emissions within this accounting framework. Additional information on the methodologies for estimating emissions in the electric sector can be found in the companion methodology document.

The electricity sector continues to be one of the lowest emitting sectors in the state (Appendix A) and accounted for 2.6% of statewide emissions in 2021. In contrast, nearly 25% of the nation's GHG emissions are from the electricity sector. The majority of electricity sector emissions were from the residual system mix portion of Vermont's electricity portfolio (Table 9). Vermont's low emissions totals from the electricity sector are due mainly to our reliance on hydroelectric and nuclear generation. In the last several years roughly 60% to 70% of the electricity in Vermont has been from hydroelectric generation, with electricity and renewable energy certificates (RECs) from Hydro-Québec (HQ) being over half of that total. Declines in emissions in the electric sector (Figure 12) can be attributed to distribution utilities meeting and exceeding Renewable Energy Standard (RES)[17] requirements for their electricity portfolios. Modifications to the Renewable Energy Standard (Act 179) were passed by the Vermont legislature in June 2024. Act 179 contains more ambitious requirements for in-state renewable energy generation and requires utilities to provide 100% renewable electricity to their customers by 2035[18].

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[16] Energy Information Administration (EIA) – State Profile and Energy Estimates: https://www.eia.gov/state/?sid=VT

[17] Vermont Public Utility Commission – Renewable Energy Standard: https://puc.vermont.gov/electric/renewable-energy-standard

[18] No. 179. An act relating to the Renewable Energy Standard: https://legislature.vermont.gov/Documents/2024/Docs/ACTS/ACT179/ACT179%20As%20Enacted.pdf

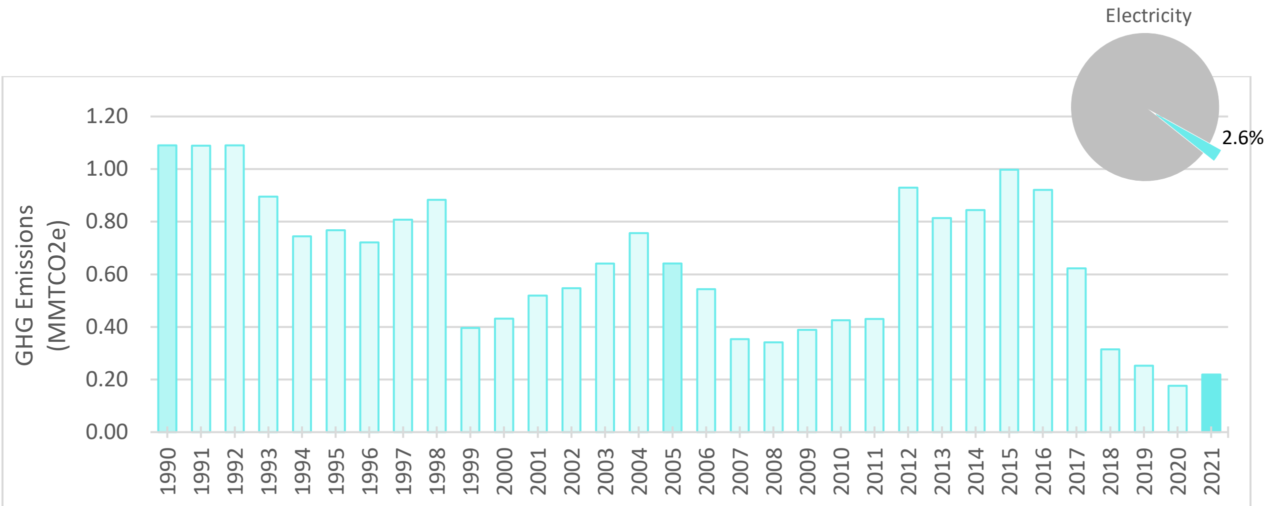

Figure 12: Vermont GHG emissions from the electricity sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

Table 8: GHG emissions contributions by fuel and system mix in the electric sector.

Sector	Emissions in $MMTCO_2e$					
	1990	2005	2010	2019	2020	2021
Electricity Consumption	**1.09**	**0.64**	**0.43**	**0.25**	**0.18**	**0.22**
Coal	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.01	0.00	0.00	0.00
Oil	0.01	0.01	0.04	0.00	0.00	0.00
Wood (CH_4, N_2O)	0.00	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.62	0.36	0.24	0.16	0.21
Wood Combustion (Biogenic CO_2 at the stack)*	0.30	1.07	0.94	0.80	0.86	0.94

** Biogenic CO_2 emissions are not included in totals*[19]

2.1.6 Waste

Emissions of greenhouse gases associated with the waste sector include CH_4 and N_2O from both solid waste and wastewater. These emissions come from wastewater treatment systems, landfills, and composting. Carbon dioxide emissions from the waste sector are considered biogenic and are not included in the sector totals, per IPCC guidelines. Total emissions from both the solid waste and wastewater sectors remained flat from 2020 to 2021 (Figure 13), and the

[19] Biogenic emissions from wood combustion for the generation of electricity are not included in the Inventory totals. This includes emissions from the two main wood biomass electric generation facilities in the state, McNeil and Ryegate. Biogenic CO_2 emissions from these two facilities are significant, totaling approximately 0.94 $MMTCO_2e$ in 2021, but are not accounted for in the Inventory both because the emissions are biogenic and because the RECs produced by these two facilities are sold almost exclusively outside of Vermont. Additional information related to the accounting of biogenic CO_2 can be found in the Methodology document.

waste sector remains one of the smallest emitting sectors at 2.7% of the statewide total. Emissions estimates for the sector were updated in this inventory report based on a methodology change related to accounting for emissions from closed landfills around the state. This update was enabled by newly acquired data related to landfill open dates, closure dates, and the estimated total amount of waste in the landfill. This change resulted in an increase in emissions from the solid waste sector (Table 10), which was also impacted by the update to the GWP value for CH_4. Vermont's Universal Recycling law (Act 148)[20] has helped to reduce the amount of landfill gas produced in the solid waste sector by banning recyclable materials, leaf and yard debris, and food scraps from landfills. However, the total emissions from the solid waste subsector are variable as they depend on the overall amount of waste deposited into the landfill in a given year.

Table 9: GHG emissions contributions within the waste sector.

Sector	Emissions in $MMTCO_2e$					
	1990	**2005**	**2010**	**2019**	**2020**	**2021**
Waste	**0.52**	**0.68**	**0.70**	**0.38**	**0.37**	**0.38**
Solid Waste (CH_4, N_2O)	0.24	0.31	0.32	0.16	0.15	0.15
Reported landfill gas totals (from LFGTE equipment)*	*0.24*	*0.31*	*0.21*	*0.08*	*0.07*	*0.08*
Closed landfills			*0.11*	*0.08*	*0.07*	*0.07*
Composting (CH_4, N_2O)	0.00	0.01	0.01	0.01	0.01	0.01
Wastewater (CH_4, N_2O)	0.05	0.06	0.06	0.06	0.06	0.06

** Landfill gas to energy (LFGTE) equipment*
*** Historical combined totals utilize previous calculations that incorporated closed landfills*

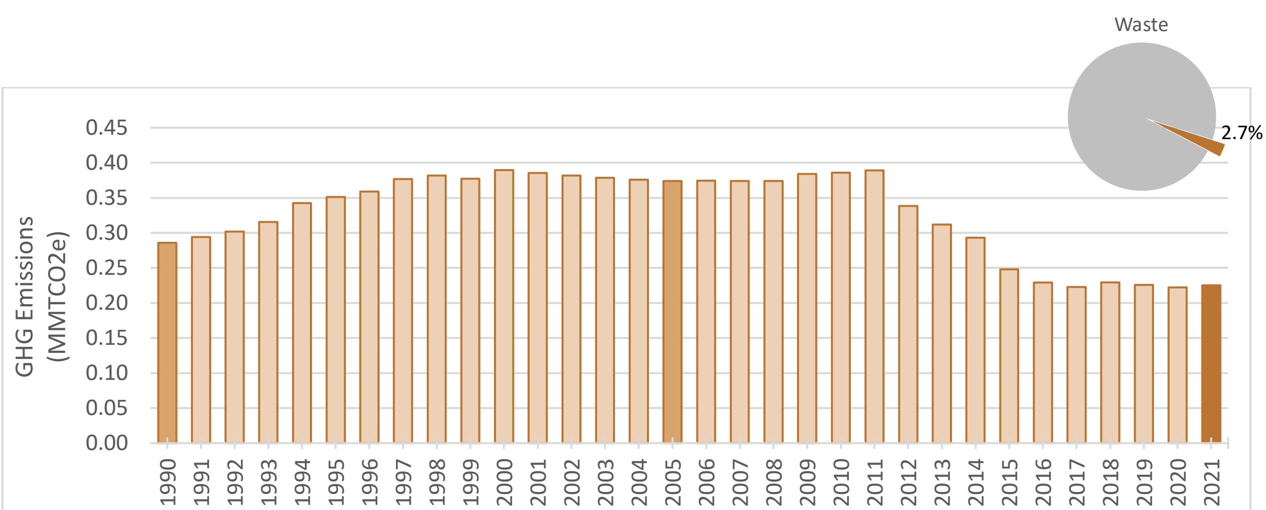

Figure 13: Vermont GHG emissions from the waste sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

[20] Vermont Department of Environmental Conservation – Universal Recycling Law: https://dec.vermont.gov/waste-management/solid/universal-recycling

2.1.7 Fossil Fuel Industry

Emissions of greenhouse gases from the fossil fuel industry sector account for the emissions of CH_4 from natural gas leaks, or fugitive emissions from the transmission and distribution pipelines and connected services in Vermont. The emissions related to the combustion of the natural gas are captured within other sectors in this inventory. Total emissions from the Fossil Fuel Industry sector account for only 0.4% of the statewide total. Emissions fluctuations in this sector are a balance between the addition of new natural gas services and lines, and the associated leakage, with the replacement of older and more leak prone pipe and service types with pipes and services made from newer and less leak prone materials (Figure 14). This offsetting effect has led to stable emissions levels in this sector in the last several years (Table 11) after the increase seen from the extension of Vermont Gas services to Addison County.

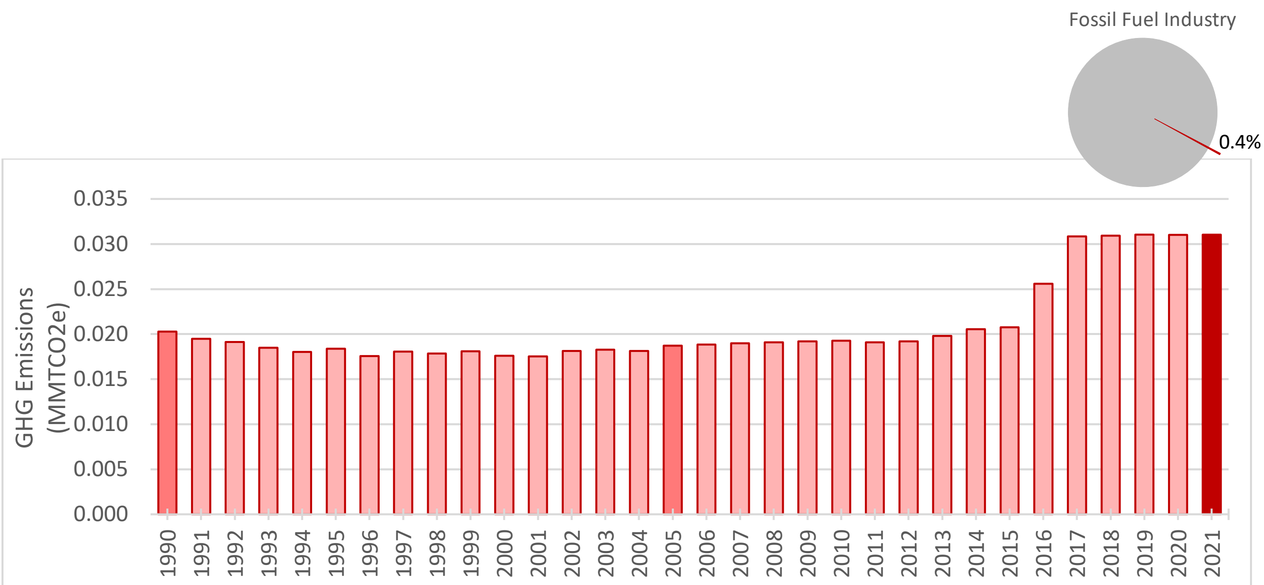

Figure 14: Vermont GHG emissions from the fossil fuel industry sector. Years from 1990-2021 are included with 2021 and the 1990 and 2005 baseline years highlighted.

Table 10: GHG emissions contributions within the fossil fuel industry sector.

Sector	Emissions in $MMTCO_2e$					
	1990	**2005**	**2010**	**2019**	**2020**	**2021**
Fossil Fuel Industry	**0.020**	**0.019**	**0.019**	**0.031**	**0.031**	**0.031**
Natural Gas Distribution (CH_4)	0.008	0.003	0.004	0.005	0.005	0.005
Natural Gas Transmission (CH_4)	0.013	0.016	0.016	0.026	0.026	0.026

3 Additional Emissions Inventory Components

A discussion of emissions and sinks from sectors or portions of sectors that are not included in the gross inventory totals are provided below. For additional explanation of why certain emissions and sinks are not accounted for in the total gross emissions for Vermont, please refer to the companion methodology document.

3.1 Land Use, Land-Use Change, and Forestry (LULUCF)

Greenhouse gas emissions and sequestration resulting from either the changing or maintaining of certain land uses as well as the cycling and storage of carbon within the forests and agricultural lands of Vermont is a critical but complicated component in understanding a holistic picture of GHG emissions in the state. Forests and other vegetation sequester CO_2 from the atmosphere and convert it into stored biological material through the process of photosynthesis, in essence removing or negating GHG emissions that have been released into the atmosphere by incorporating it into plants. Some of that sequestered carbon is also then transferred to soils for potentially longer-term storage in forests, agricultural lands, wetlands, and other land types. Changes to land use can impact the carbon stored on a landscape, either causing it to be emitted as CO_2 if the stored biologic material is burned or breaks down, or to potentially increase sequestration or storage depending upon the change of land use or specific practice. Managing and maintaining natural working lands (NWL) and conserving forests and other natural ecosystems is crucial to both increase resilience to climate change, and to allow these systems to both retain and potentially sequester and store additional carbon.

Accurately estimating the emissions and sequestration (sinks) of greenhouse gases from the LULUCF sector is challenging because it relies on the quantification of annual changes in the amount of carbon contained on, and moving through, landscapes annually at a statewide level. Due to the complexity of quantifying changes in carbon stocks and fluxes from carbon cycling through systems and ecosystems and the lack of reliable data, historical inventory reports only included information related to above ground forest biomass as an indicator of sequestration by forests as supplemental information in the GHG Inventory. As data and analysis from the Forest Inventory and Analysis (FIA)[21] program improved, data was incorporated into the GHG Inventory specifically related to forests[22] to more accurately track emissions and sequestration from forests. EPA has since released estimates of state-level emissions and sinks from land use conversions for land use types besides forests[23] which have now also been included in the GHG Inventory to provide a more holistic view of the LULUCF sector. These most recent land use change and forestry estimates were generated by the EPA by downscaling estimates calculated

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[21] Forest Inventory and Analysis (FIA) Program: https://www.fia.fs.usda.gov/

[22] Walters, Brian F.; Domke, Grant M.; Greenfield, Eric J.; Smith, James E.; Ogle, Stephen M. 2023. Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2021: Estimates and quantitative uncertainty for individual states, regional ownership groups, and National Forest System regions. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2023-0020

[23] EPA State GHG Emissions and Removals: https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals

for the National Inventory Report[24]. Estimates of the changes in carbon on the landscape (fluxes) and carbon emitted and sequestered by forests are shown in Table 11. The LULUCF sector in Vermont is a large emissions sink overall, meaning that it sequesters far more CO_2 than is emitted within the sector, but the annual sequestration has been declining steadily since 1990, as can be seen in the green bars in Figure 15 below. Sequestration in the state is dominated by forests as seen in Table 11. The declining sequestration over time mirrors the loss of forested land in the state[25]. Additional information related to the LULUCF sector estimates can be found in the Methodology document.

Table 11: Emissions and sinks for select years from the LULUCF sector in Vermont.

Land-Use, Land use change, and Forestry (LULUCF)	Emissions/Sequestration in $MMTCO_2e$								
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**	**2021**
Forest Carbon Flux (Forest Land Remaining Forest Land)	(9.60)	(9.04)	(8.46)	(7.84)	(7.61)	(7.25)	(6.96)	(6.91)	(6.85)
Aboveground Biomass	*(5.00)*	*(4.89)*	*(4.80)*	*(4.73)*	*(4.78)*	*(4.61)*	*(4.53)*	*(4.52)*	*(4.50)*
Belowground Biomass	*(0.96)*	*(0.94)*	*(0.92)*	*(0.91)*	*(0.92)*	*(0.89)*	*(0.87)*	*(0.87)*	*(0.86)*
Deadwood	*(1.20)*	*(1.18)*	*(1.13)*	*(1.05)*	*(0.93)*	*(0.86)*	*(0.78)*	*(0.75)*	*(0.73)*
Litter	*(0.21)*	*(0.19)*	*(0.17)*	*(0.16)*	*(0.14)*	*(0.14)*	*(0.13)*	*(0.12)*	*(0.12)*
Soil (Mineral)	*(0.73)*	*(0.62)*	*(0.50)*	*(0.38)*	*(0.28)*	*(0.14)*	*(0.09)*	*(0.09)*	*(0.08)*
Soil (Organic)	-	-	-	-	-	-	-	-	-
Drained Organic Soil	-	-	-	-	-	-	-	-	-
Total wood products and landfills	*(1.50)*	*(1.22)*	*(0.94)*	*(0.61)*	*(0.56)*	*(0.61)*	*(0.56)*	*(0.56)*	*(0.56)*
Land Converted to Forest Land	(0.27)	(0.27)	(0.27)	(0.27)	(0.26)	(0.26)	(0.26)	(0.26)	(0.26)
Cropland Remaining Cropland (Ag soil carbon flux)	(0.18)	(0.20)	(0.10)	(0.15)	(0.15)	(0.10)	(0.09)	(0.11)	(0.10)
Land Converted to Cropland	0.35	0.39	0.38	0.38	0.38	0.42	0.43	0.43	0.43
Grassland Remaining Grassland	(0.04)	(0.05)	(0.04)	(0.01)	(0.01)	0.04	0.01	(0.00)	0.01
Land Converted to Grassland	(0.03)	(0.05)	(0.04)	(0.03)	0.00	(0.03)	(0.02)	(0.02)	(0.02)
Wetlands Remaining Wetlands	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Land Converted to Wetlands	0.00	0.00	0.00	0.00	-	-	-	-	-
Settlements Remaining Settlements	(0.42)	(0.41)	(0.42)	(0.45)	(0.48)	(0.49)	(0.49)	(0.51)	(0.51)
Land Converted to Settlements	0.43	0.45	0.48	0.50	0.53	0.56	0.57	0.57	0.57
LULUCF Net CO_2 Flux (w/ harvested wood products)	**(9.77)**	**(9.19)**	**(8.50)**	**(7.88)**	**(7.61)**	**(7.11)**	**(6.80)**	**(6.83)**	**(6.75)**

** Note that parentheses indicate net sequestration.*

[24] EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020
[25] Vermont Forest Parks and Recreation – Vermont Forest Carbon Inventory: https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Climate_Change/Files/VermontForestCarbonInventory_Mar2021.pdf

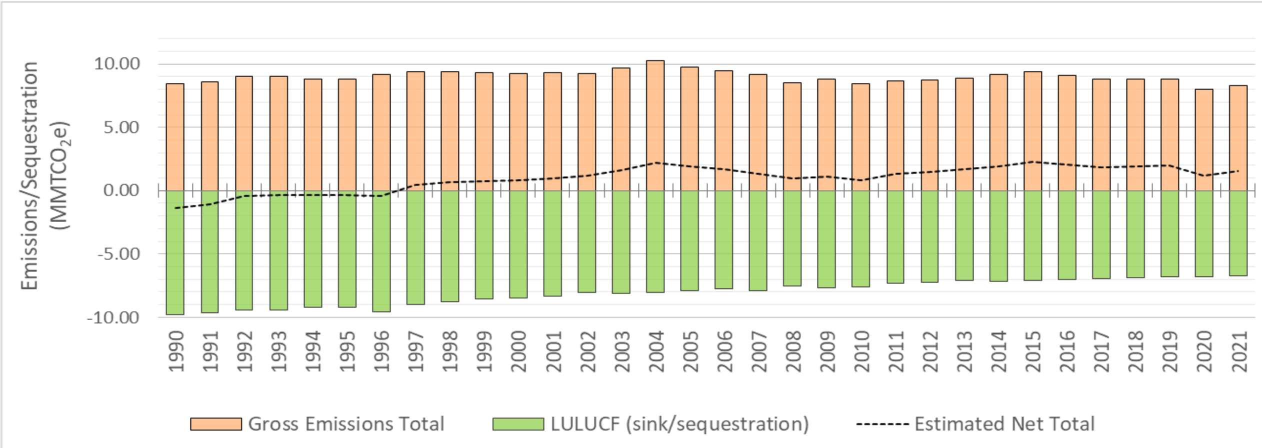

Figure 15: Estimated gross emissions, total sequestration, and net GHG levels in Vermont from 1990-2021.

3.2 Biogenic CO_2

Emissions of biogenic CO_2 related to the combustion or breaking down of biologically based materials are directly tied to the LULUCF sector as described above. Wood use for energy is the largest source of human-caused biogenic CO_2 emissions in Vermont, but those emissions are not included in the inventory totals within each individual sector because the carbon (and releases of CO_2) from that wood is captured in the changes in carbon on the landscape and in the forests of Vermont in the LULUCF sector per IPCC guidelines. Estimating the carbon and CO_2 fluxes from changes in land use and from forests on a statewide scale is not an exact science, nor are there currently accurate data on the total amount of wood cut, imported, or combusted annually in Vermont to compare the LULUCF carbon flux estimates against. Biogenic CO_2 estimates have been included in several of the inventory sectors in this report as supplemental information and to help provide a sense of scale of these emissions and the transfer of carbon to and from the landscape and to track these changes over time. How to appropriately account for biogenic CO_2 is not an easy question to answer given the complexity of the systems involved and there is currently no consensus even within scientific literature as to the best approach.

3.3 Biogenic Carbon Footprint Calculator and GWP_{bio}

The biogenic carbon footprint calculator utilizes a calculation that includes the incorporation of biogenic carbon in wood-based products with a time dependent impacts from a pulse of CO_2 caused by the combustion of biomass (GWP_{bio}). GWP_{bio} attempts to account for the atmospheric impacts of the pulse of CO_2 emitted when biomass is combusted while also taking into account that harvesting is often followed by the regrowth of trees over time. There are many factors that influence the values for GWP_{bio} that can make it either higher or lower, including the rotation periods for the harvested biofuels and impacts on other forest carbon pools. The values have a large range depending on the various factors but can be close to zero (carbon neutrality) or reach levels greater than that of fossil fuels. Values for GWP_{bio} and the incorporation of those values into other frameworks have evolved over time. The Biogenic Carbon Footprint calculator[26] utilizes GWP_{bio} but expands upon that idea to incorporate wood that is harvested and put into longer term storage (harvested wood products). This idea of GWP_{bio} and the Biogenic Carbon Footprint calculator is one additional framework for understanding emissions from biogenic carbon dioxide that could be explored in more detail which acknowledges that CO_2 emissions from the combustion of wood are real and impactful while providing some credit for the renewability of the resource.

4 Emissions Forecasts

4.1 Estimated GHG Emissions Levels for 2026 and 2031

As is seen in this inventory report, emissions of greenhouse gases come from a variety of different sectors and processes, and are influenced by many factors including the economy, markets, state and federal policies and regulations, personal and consumer choices, as well as unforeseen events. Estimating what greenhouse gas emissions totals will be in a future year requires making many assumptions related to our natural environment, built environment, and society at large which are difficult to predict.

A model (Vermont Pathways[27]) was created and is being maintained for Vermont which estimates GHG emissions by sector through 2050. Its primary purpose was to help inform the Vermont Climate Action Plan (CAP)[28] and the Comprehensive Energy Plan (CEP)[29]. Since a large amount of work, research, and process has gone into the creation of that model, this inventory incorporates values directly from that modeling effort as the 5 and 10 year projections described in 10 V.S.A. § 582(c). That model will continue to be updated and modified to inform the upcoming Climate Action Plan Update process. The projections in Table 12 include values from a 2023 update[30] to the business as usual (BAU) baseline scenario, which are estimates of emissions levels assuming similar trends continue into the future without any new policies to reduce emissions. With the expected updates to the modeling for the next CAP process, the values in this report will likely change as data and assumptions are modified and improved. It should be noted that values in Table 12 have been updated to utilize the AR5 100-year GWP values and to include the expected effects of adopting the Advanced Clean Cars II and Advanced

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[26] Biogenic Carbon Footprint Calculator – World Wildlife Federation: https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx
[27] Vermont Pathways 2.0, Energy Futures Group February 2022 https://climatechange.vermont.gov/sites/climatecouncilsandbox/files/2022-03/Pathways%20Analysis%20Report_Version%202.0.pdf
[28] Vermont Climate Action Plan: https://climatechange.vermont.gov/readtheplan
[29] Vermont Comprehensive Energy Plan: https://publicservice.vermont.gov/about-us/plans-and-reports/department-state-plans/2022-plan
[30] Vermont Thermal Analysis Final Report: https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/1990-2021_GHG_Inventory_Uploads/VT_Thermal_Analysis_Final_Report.pdf

Clean Trucks[31] regulations as well as the impacts of retrofits attributable to Inflation Reduction Act Funding, but that they do not yet reflect impacts related to the Affordable Heat Act (Clean Heat Standard)[32] or the passage of the updated Renewable Energy Standard[18].

Although 2021 emissions from VT Pathways are approximately 6% below the 2021 inventory emissions, the model results still indicate that there will likely be a significant gap between Vermont's current trajectory and the 2030 requirement.

Table 12: GHG emissions projections from Pathways modeling in $MMTCO_2e$

Sector	2026	2031
Agriculture	1.33	1.34
Electricity generation	0.20	0.16
Transportation	2.86	2.37
Industrial Processes	0.57	0.59
Residential/Commercial/Industrial Fuel Use (RCI)	2.11	1.77
Waste	0.14	0.14
Total	**7.21**	**6.37**

5 Conclusion

The 1990-2021 Vermont Greenhouse Gas Emissions Inventory and Forecast report provides both current and historical estimates of GHG emissions in Vermont. Historical emissions totals, which are updated with each new release as appropriate and necessary, serve as baseline values to track progress towards Vermont's mandated emissions levels and provide insights into which sectors to prioritize for mitigation policies. Total GHG emissions for 2021 rebounded from the COVID-19 impacts seen in 2020 but remain below the pre-COVID 2019 levels. Vermont's greenhouse gas emissions levels in the coming years will depend on many factors including the implementation of policies and regulations, Federal and State standards and funding support for programs, overall societal and economic changes, and the weather and climate themselves.

This inventory report is one way to understand GHG emissions associated with Vermont and the actions of Vermonters. The approaches taken by the Agency of Natural Resources for this annual in-boundary inventory attempt to maintain consistency with other states in the region, as well as IPCC guidelines, and are based on data availability and the most current understanding of the various methods and tools to estimate GHG emissions. ANR will continue to keep apprised of additional frameworks for understanding GHG emissions to maintain a broad understanding of issues and to help inform policy decisions.

[31] Vermont Department of Environmental Conservation - Vermont Low Emission Vehicle and Zero Emission Vehicle Rules (2022): https://dec.vermont.gov/sites/dec/files/aqc/laws-regs/documents/Chapter_40_LEV_ZEV_rule_adopted.pdf
[32] Vermont Legislature – Act 18 (2023) – Affordable Heat Act: https://legislature.vermont.gov/Documents/2024/Docs/ACTS/ACT018/ACT018%20As%20Enacted.pdf

Appendix A – Vermont Historic Greenhouse Gas Emissions by Sector [33]

Sector	Million Metric Tons CO_2 Equivalent: $MMTCO_2e$																			
	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Electricity Supply & Demand (consumption based)	**1.09**	**0.77**	**0.43**	**0.64**	**0.54**	**0.35**	**0.34**	**0.39**	**0.43**	**0.43**	**0.93**	**0.81**	**0.84**	**1.00**	**0.92**	**0.62**	**0.31**	**0.25**	**0.18**	**0.22**
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.05	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00
Oil	0.01	0.01	0.06	0.01	0.02	0.02	0.03	0.04	0.04	0.04	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Wood (CH_4 & N_2O)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Residual System Mix	1.03	0.75	0.35	0.62	0.51	0.31	0.29	0.34	0.36	0.37	0.90	0.78	0.81	0.96	0.90	0.60	0.30	0.24	0.16	0.21
Residential / Commercial / Industrial (RCI) Fuel Use	**2.26**	**2.25**	**2.75**	**2.80**	**2.64**	**2.54**	**2.29**	**2.48**	**2.32**	**2.33**	**2.10**	**2.31**	**2.49**	**2.56**	**2.42**	**2.50**	**2.74**	**2.79**	**2.60**	**2.59**
Coal	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	0.32	0.38	0.49	0.44	0.42	0.47	0.45	0.45	0.44	0.45	0.43	0.51	0.57	0.64	0.64	0.65	0.75	0.75	0.71	0.72
Oil, Propane & Other Petroleum	1.85	1.79	2.19	2.28	2.14	1.99	1.75	1.94	1.79	1.79	1.58	1.70	1.82	1.82	1.67	1.75	1.88	1.92	1.78	1.77
Wood (CH_4 & N_2O)	0.07	0.08	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.10
Wood combustion (biogenic CO_2 - not included in gross totals)	1.15	1.24	1.11	1.23	1.26	1.22	1.21	1.23	1.28	1.32	1.32	1.37	1.43	1.43	1.44	1.47	1.52	1.51	1.52	1.38
Transportation	**3.48**	**4.02**	**4.06**	**4.33**	**4.25**	**4.17**	**3.84**	**3.89**	**3.67**	**3.65**	**3.55**	**3.49**	**3.51**	**3.57**	**3.46**	**3.45**	**3.51**	**3.50**	**3.02**	**3.24**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.54	2.74	3.00	3.05	2.92	2.94	2.73	2.69	2.63	2.59	2.52	2.49	2.42	2.48	2.44	2.42	2.44	2.42	2.01	2.19
Diesel (Onroad and Nonroad) (CO_2)	0.72	1.07	0.84	1.02	1.05	0.99	0.90	0.91	0.88	0.90	0.87	0.85	0.93	0.94	0.86	0.90	0.95	0.95	0.89	0.92
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.06	0.07	0.13	0.16	0.14	0.11	0.21	0.07	0.08	0.08	0.07	0.08	0.08	0.09	0.06	0.07	0.07	0.06	0.09
Non-Energy Consumption - Lubricants (CO_2)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
All Mobile (CH_4, N_2O)	0.12	0.13	0.12	0.10	0.10	0.09	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Ethanol + Biodiesel (biogenic CO2 - not included in gross totals)	0.00	0.00	0.00	0.01	0.02	0.03	0.13	0.18	0.17	0.17	0.18	0.20	0.19	0.19	0.22	0.22	0.19	0.19	0.17	0.18
Fossil Fuel Industry	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
Natural Gas Distribution	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas Transmission	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Industrial Processes	**0.20**	**0.38**	**0.50**	**0.43**	**0.45**	**0.44**	**0.44**	**0.40**	**0.42**	**0.61**	**0.58**	**0.58**	**0.60**	**0.59**	**0.57**	**0.51**	**0.53**	**0.53**	**0.58**	**0.64**
ODS Substitutes	0.00	0.05	0.14	0.19	0.20	0.21	0.23	0.23	0.21	0.23	0.24	0.29	0.32	0.31	0.31	0.27	0.30	0.29	0.32	0.33
Electric Utilities (SF_6)	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Semiconductor Manufacturing (HFCs, PFCs & SF_6)	0.15	0.26	0.31	0.20	0.22	0.20	0.18	0.13	0.17	0.34	0.31	0.25	0.23	0.24	0.22	0.21	0.20	0.21	0.23	0.24
Limestone & Dolomite Use	0.00	0.03	0.02	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.01	0.02	0.02	0.05
Soda Ash Use	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**0.29**	**0.35**	**0.39**	**0.37**	**0.37**	**0.37**	**0.37**	**0.38**	**0.39**	**0.39**	**0.34**	**0.31**	**0.29**	**0.25**	**0.23**	**0.22**	**0.23**	**0.23**	**0.22**	**0.23**
Solid Waste	0.24	0.30	0.33	0.31	0.31	0.31	0.31	0.32	0.32	0.33	0.27	0.25	0.23	0.18	0.16	0.15	0.16	0.16	0.15	0.15
Composting	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Wastewater	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Agriculture	**1.22**	**1.16**	**1.25**	**1.26**	**1.26**	**1.37**	**1.28**	**1.29**	**1.26**	**1.27**	**1.24**	**1.32**	**1.36**	**1.40**	**1.41**	**1.41**	**1.41**	**1.42**	**1.34**	**1.33**
Enteric Fermentation	0.76	0.72	0.75	0.69	0.69	0.69	0.70	0.69	0.67	0.69	0.68	0.70	0.69	0.69	0.70	0.71	0.71	0.70	0.67	0.67
Manure Management	0.18	0.19	0.27	0.34	0.33	0.34	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.37	0.39	0.38	0.39	0.39	0.37	0.36
Agricultural Soils	0.29	0.24	0.23	0.23	0.23	0.23	0.23	0.25	0.24	0.23	0.22	0.27	0.29	0.30	0.27	0.27	0.28	0.29	0.25	0.25
Liming and Urea Fertilization	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.01	0.01	0.00	0.00	0.01	0.03	0.05	0.05	0.05	0.04	0.04	0.05	0.06
TOTAL GROSS EMISSIONS	**8.56**	**8.95**	**9.40**	**9.86**	**9.54**	**9.27**	**8.59**	**8.85**	**8.51**	**8.70**	**8.76**	**8.84**	**9.11**	**9.39**	**9.04**	**8.75**	**8.76**	**8.75**	**7.97**	**8.28**
Land-use, Land Use Change, and Forestry (LULUCF)	**-9.77**	**-9.19**	**-8.50**	**-7.88**	**-7.77**	**-7.86**	**-7.55**	**-7.67**	**-7.61**	**-7.33**	**-7.25**	**-7.12**	**-7.19**	**-7.11**	**-7.05**	**-6.94**	**-6.87**	**-6.80**	**-6.83**	**-6.75**
Estimated Net Emissions Total	**-1.21**	**-0.24**	**0.91**	**1.98**	**1.78**	**1.41**	**1.03**	**1.18**	**0.90**	**1.38**	**1.51**	**1.72**	**1.92**	**2.28**	**1.99**	**1.81**	**1.89**	**1.95**	**1.14**	**1.53**

[33] Totals may not sum exactly due to independent rounding.

Appendix B: Vermont Key Category Analysis by Scale Assessment.

Sector	Scale 1990	Key Category in 1990	Scale 2005	Key Category in 2005	Scale 2020	Key Category in 2021
Electricity Supply & Demand (Consumption - based)						
Coal	0.00%	No	0.00%	No	0.00%	No
Natural Gas	0.54%	No	0.00%	No	0.00%	No
Oil, Propane, & Other Petroleum	0.17%	No	0.11%	No	0.00%	No
Wood (CH_4, N_2O)	0.03%	No	0.14%	No	0.15%	No
Residual System Mix	12.00%	Yes	6.24%	Yes	2.50%	Yes
Residential/ Commercial/ Industrial (RCI) Fuel Use						
Coal	0.23%	No	0.02%	No	0.00%	No
Natural Gas	21.63%	Yes	23.14%	Yes	21.33%	Yes
Oil, Propane, & Other Petroleum	3.73%	Yes	4.46%	Yes	8.71%	Yes
Wood (CH_4, N_2O)	0.84%	No	0.81%	No	1.20%	No
Transportation/Mobile						
Motor Gasoline (Onroad and Nonroad) (CO_2)	29.68%	Yes	30.87%	Yes	26.44%	Yes
Diesel (Onroad and Nonroad) (CO_2)	8.40%	Yes	10.38%	Yes	11.07%	Yes
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.05%	No	0.03%	No	0.04%	No
Jet Fuel & Aviation Gasoline (CO_2)	0.89%	No	1.36%	No	1.07%	No
Non-Energy Consumption - Lubricants (CO_2)	0.25%	No	0.19%	No	0.16%	No
All Mobile (CH_4, N_2O)	1.37%	No	1.06%	No	0.43%	No
Fossil Fuel Industry						
Natural Gas Distribution	0.09%	No	0.03%	No	0.06%	No
Natural Gas Transmission	0.15%	No	0.16%	No	0.32%	No
Industrial Processes						
ODS Substitutes	0.01%	No	1.89%	Yes	4.02%	Yes
Electric Utilities (SF_6)	0.50%	No	0.19%	No	0.10%	No
Semiconductor Manufacturing (HFC, PFC & SF_6)	1.73%	Yes	1.99%	Yes	2.92%	Yes
Limestone & Dolomite Use	0.00%	No	0.28%	No	0.60%	No
Soda Ash Use	0.07%	No	0.05%	No	0.05%	No
Urea Consumption	0.00%	No	0.01%	No	0.02%	No
Waste Management						
Solid Waste (CH_4, N_2O)	2.78%	Yes	3.14%	Yes	1.83%	Yes
Wastewater	0.01%	No	0.07%	No	0.17%	No
Agriculture						
Enteric Fermentation	8.86%	Yes	6.98%	Yes	8.04%	Yes
Manure Management	2.05%	Yes	3.48%	Yes	4.30%	Yes
Agricultural Soils	3.35%	Yes	2.31%	Yes	3.02%	Yes
Liming and Urea Fertilization	0.03%	No	0.04%	No	0.74%	No

Appendix C: Vermont Key Category Analysis by Trend Assessment

Sector	Subsector	Trend Assessment (1990-2021)	Contribution to the trend (1990 - 2021)	Cumulative total (1990-2021)
Electricity Supply & Demand	Residual System Mix	2.90	0.26	0.26
Residential/ Commercial/ Industrial (RCI) Fuel Use	Natural Gas	1.42	0.13	0.39
Industrial Processes	ODS Substitutes	1.18	0.11	0.50
Transportation/Mobile Sources	Diesel (Onroad and Nonroad) (CO_2)	0.70	0.06	0.56
Agriculture	Manure Management	0.13	0.01	0.58
Transportation/Mobile Sources	All Mobile (CH_4, N_2O)	0.29	0.03	0.60
Waste	Solid Waste (CH_4, N_2O)	0.31	0.03	0.63
Agriculture	Enteric Fermentation	0.64	0.06	0.69
Electricity Supply & Demand	Natural Gas	0.16	0.02	0.70
Industrial Processes	Semiconductor Manufacturing (HFCs, PFCs, SF_6, NF_3)	0.33	0.03	0.73
Residential/ Commercial/ Industrial (RCI) Fuel Use	Oil, Propane, & Other Petroleum	0.75	0.07	0.80
Transportation/Mobile Sources	Motor Gasoline (Onroad and Nonroad) (CO_2)	1.24	0.11	0.92
Industrial Processes	Electric Utilities (SF_6)	0.12	0.01	0.93
Residential/ Commercial/ Industrial (RCI) Fuel Use	Wood (CH_4, N_2O)	0.11	0.01	0.94
Transportation/Mobile Sources	Jet Fuel & Aviation Gasoline (CO_2)	0.04	0.00	0.94
Industrial Processes	Limestone & Dolomite Use	0.18	0.02	0.96
Agriculture	Agricultural Soils	0.21	0.02	0.98
Residential/ Commercial/ Industrial (RCI) Fuel Use	Coal	0.07	0.01	0.98
Electricity Supply & Demand	Oil	0.05	0.00	0.99
Fossil Fuel Industry	Natural Gas Transmission	0.00	0.00	0.99
Electricity Supply & Demand	Wood (CH_4, N_2O)	0.03	0.00	0.99
Waste	Wastewater	0.05	0.00	1.00
Transportation/Mobile Sources	Non-Energy Consumption - Lubricants (CO_2)	0.03	0.00	1.00
Transportation/Mobile Sources	Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO_2)	0.00	0.00	1.00
Fossil Fuel Industry	Natural Gas Distribution	0.01	0.00	1.00
Industrial Processes	Soda Ash Use	0.01	0.00	1.00
Industrial Processes	Urea Consumption	0.00	0.00	1.00
Electricity Supply & Demand	Coal	0.00	0.00	1.00