VERMONT

Agency of Natural Resources

Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2022

July 2025

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Table of Contents

List of Tables

List of Figures

Note to Readers

The *Vermont Greenhouse Gas Emissions Inventory and Forecast* reports are now comprised of two components to help make the report more accessible to readers. 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 affecting 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. Impacts of climate change are being felt here in the Northeastern U.S., including damage to communities and natural ecosystems.[2] Understanding Vermont's contribution to climate pollution from both a local and global perspective, by identifying and quantifying greenhouse gas emissions, by sources and sectors, is critical to our on-going efforts to reduce emissions. 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, in a manner that is consistent with other jurisdictions, and helps inform decisions on future mitigation strategies and pathways.

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 modified, as necessary, with each updated inventory release based on currently available data sources, global warming potential values, or changes to methodologies.

This report provides emissions estimates, as well as general information and emissions trends for each sector. While calculation methodologies and data that have been used to generate emissions estimates in the inventory are briefly described in the sections below, methodologies and data used to inform this inventory are provided in detail in the *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies* companion 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 carbon dioxide (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

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[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 of 2020): https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT153/ACT153%20As%20Enacted.pdf

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 Section 3.1 below and the companion *Methodologies* document.

This inventory includes official estimates for the years 1990 through 2022. Overall emissions in 2022 were 8.09 $MMTCO_2e$, which reflects a slight decrease from 2021 levels as shown in Figure 1, with variability within each sector. Also represented are estimates of GHG emissions by sector going back to the 1990 and 2005 statutory base years against which Vermont's emissions are measured (Figure 1).

Projecting future emissions totals 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. 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)[6] process and which will continue to be updated by the Climate Action Office. 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.

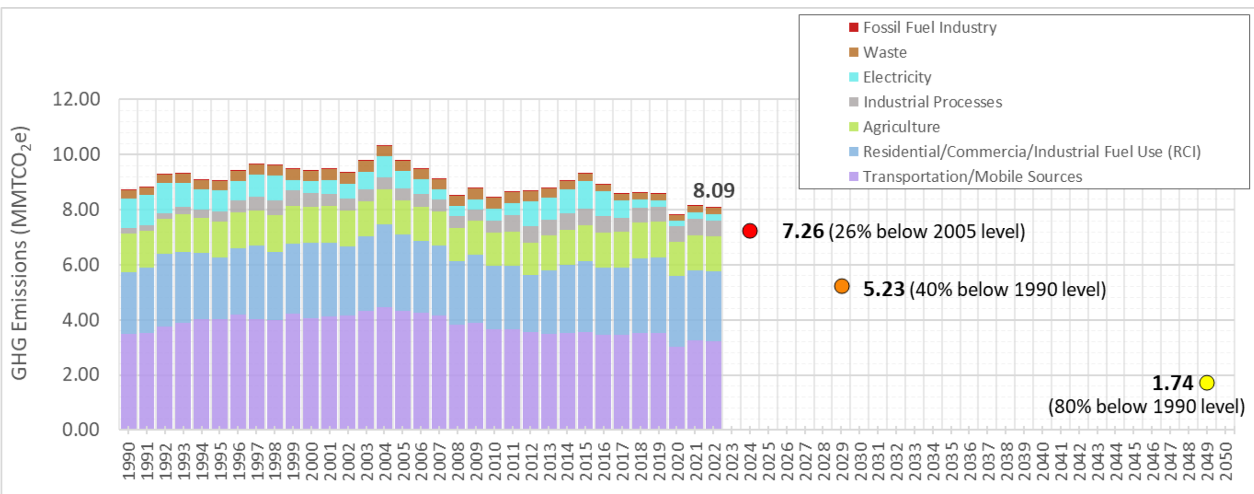

Figure 1:Vermont statewide greenhouse gas emissions levels and mandated reduction targets as defined in 10 V.S.A. § 578.

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

[6] Vermont Climate Action Plan: [Read the Plan | Climate Change in Vermont]

Assessment Report (AR5)[7] per IPCC inventory guidelines, which are the AR5 100-year values. 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; values are generated using methods and datasets discussed in the *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies*[8] companion document. This report includes estimates for the years 1990 – 2022 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 emissions reductions required by the Global Warming Solutions Act.

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 geographic, 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 rest of the country on average, which is likely due to the rural nature of the state, the prominence of dairy agriculture, Vermont's colder climate 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 emitting electricity in the Vermont portfolio.

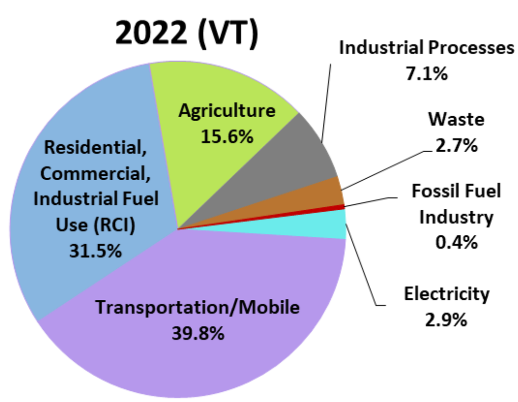

Figure 2: Vermont GHG percent contributions by sector.

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

[8] Vermont Agency of Natural Resources - *Vermont Greenhouse Gas Emissions Inventory and Forecast – Methodologies:* _Methodology_Vermont_Greenhouse_Gas_Emissions_Inventory_1990-2022_Final.pdf

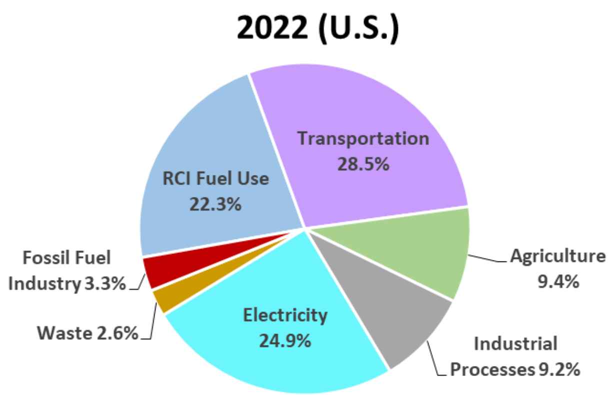

Figure 3: U.S. GHG percent contributions by sector. Data for the U.S. contributions by sector has been reallocated to match the Vermont sector categories in this report as closely as possible.

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 contributed from each sector and how those emissions are changing over time. This information can be important for informing and prioritizing policymaking related to specific sources within each sector and subsector.

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 the GHG inventory is calculated using the gross sector totals. Additional details related to each sector can be found in the sections below; additional information on the calculation methodologies and data sources used to calculate the emissions totals for each sector are provided in the accompanying Methodologies document.

Emissions of biogenic carbon dioxide, which are produced from the burning, breaking down, or processing of biogenic material[9], are not included in the overall gross sectoral totals in the

[9] "Biogenic materials," are non-fossilized and biodegradable organic materials originating from modern or contemporarily grown plants, animals, or microorganisms (including products, by-products, residues, and wastes from agriculture, forestry, and related industries, as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes, including gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material). These feedstocks do not include materials such as peat, coal, petroleum, natural gas, and other products that are derived from biologic materials but are considered non-renewable during the time frame relevant to policymaking. (U.S. EPA Framework for Assessing Biogenic CO2 Emissions from Stationary Sources, November 2014.)

inventory per the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[10] as well as the 2019 refinement to those guidelines.[11] 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 Methodologies document.

2.1.1 Transportation/Mobile Sources

The transportation and mobile sources sector consists of estimates of greenhouse gas emissions attributed to the movement of people and goods through and around Vermont. The totals include emissions from the combustion of gasoline and diesel sold in Vermont for on road vehicles and non-road equipment, and the use of aviation gasoline and jet fuel for aircraft (Table 1). It is important to note that some fraction of the transportation fuel sold in Vermont will be burned outside of the boundaries of Vermont. Likewise, vehicles visiting or passing through Vermont may rely on fuel sold outside of Vermont. The use of gasoline and diesel by on road vehicles in Vermont is the largest source of emissions in this sector (Table 2), with light duty gasoline vehicles (e.g., cars, SUVs and small pickup trucks) being the largest source category within the on road vehicle fleet (Table 3).

The transportation and mobile sources sector historically has been the highest emitting sector in Vermont, although it was surpassed by the Residential/Commercial/Industrial Fuel Use (RCI) sector in the 2020 Inventory. This decline in transportation sector emissions in 2020 (Figure 4) was largely due to the COVID-19 pandemic and the resulting reductions in travel. In 2021 statewide VMT (Figure 5) and sales of gasoline (Figure 6) both rebounded. VMT continued to increase in 2022, while sales of gasoline and diesel remained relatively flat. 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 earlier 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. Recently, a new dataset became available and 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 non-road diesel fuel between sectors also contributed to the switch that reestablished the Transportation/Mobile

[10] IPCC (2006) - *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/
[11] 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

sources sector as the highest emitting sector in the state. For additional details on this change in dataset and allocation of fuels, please see the companion *Methodologies* document.

Table 1: Mobile source contributions by fuel type.

Sector	Emissions in MMTCO$_2$e						
	1990	**2005**	**2010**	**2019**	**2020**	**2021**	**2022**
Transportation/Mobile Sources (MMTCO2e)	**3.48**	**4.33**	**3.67**	**3.50**	**3.02**	**3.24**	**3.22**
Motor Gasoline (Onroad and Nonroad) (CO_2)	2.54	3.05	2.63	2.42	2.01	2.19	2.19
Diesel (Onroad) (CO2)	0.41	0.70	0.63	0.65	0.61	0.66	0.64
Diesel (Nonroad) (CO_2)	0.31	0.33	0.25	0.30	0.29	0.26	0.26
Jet Fuel & Aviation Gasoline (CO_2)	0.08	0.13	0.07	0.07	0.06	0.09	0.09
Other sources (CO_2, CH_4, N_2O)	0.14	0.13	0.09	0.06	0.05	0.05	0.04
Ethanol (biogenic CO_2)*	0.00	0.01	0.17	0.17	0.14	0.16	0.16
Biodiesel (biogenic CO_2)*	0.00	0.00	0.00	0.02	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)[12].

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)[10].

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%

[12] 2020 National Emissions Inventory (NEI) Data: https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data. The triennial 2023 NEI inventory year is in progress and will not be published until March 2026.

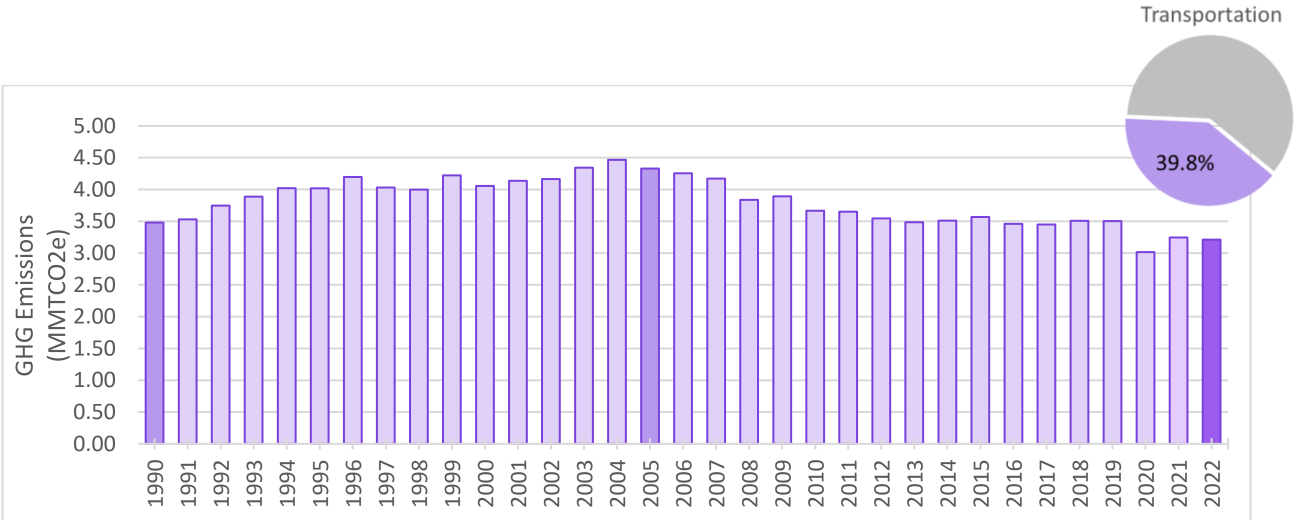

Figure 4: Vermont GHG emissions from transportation/mobile sources sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

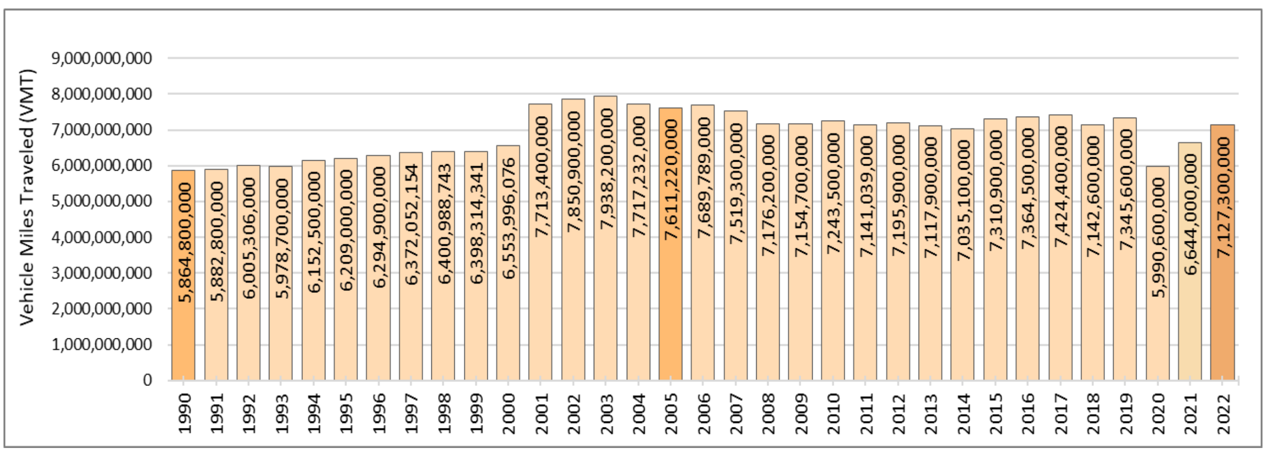

Figure 5: Vehicle miles traveled in Vermont by year (Source: VTrans), 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

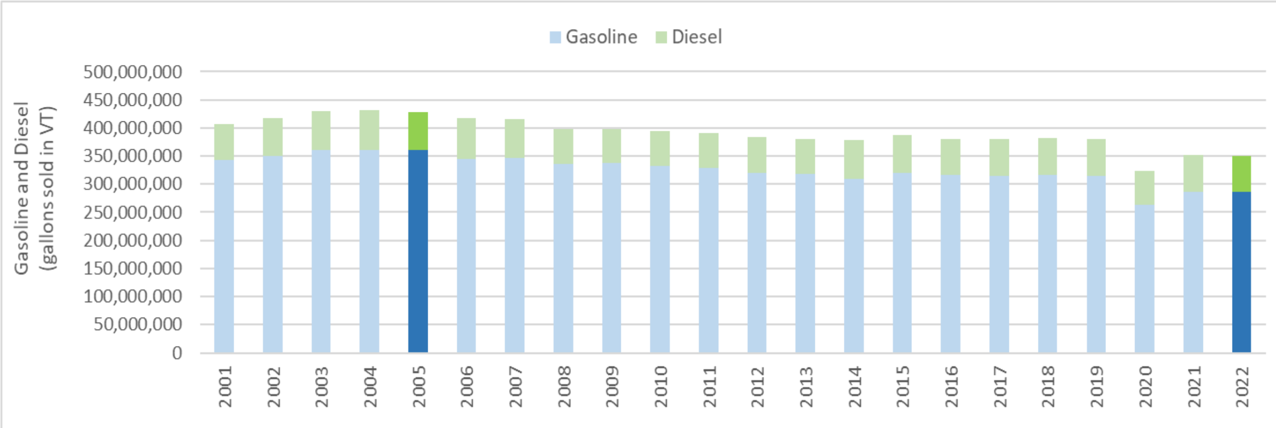

Figure 6: Gallons of gasoline and diesel sold in Vermont by year (Source: Joint Fiscal Office), 2001-2022; current inventory year (2022) and the 2005 baseline year are highlighted.

2.1.2 Residential/Commercial/Industrial (RCI) Fuel Use

The majority of greenhouse gas emissions from the Residential/Commercial/Industrial (RCI) 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 these fuel volumes have been reassigned to the Transportation/Mobile Sources sector projected backwards through time in both sectors back to 1990.

The largest share of emissions in the RCI sector comes from residential fuel use at 52.9% in 2022. This is followed by the commercial subsector at 34.7% and the industrial subsector at 12.5% (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. Fluctuations of emissions levels in this sector (Figure 7) 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*[13]. RCI sector emissions totals have been plotted with heating degree days (HDD) in Figure 8, 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.

[13] 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

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 Methodologies document.

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

Sector	Emissions in $MMTCO_2e$						
	1990	**2005**	**2010**	**2019**	**2020**	**2021**	**2022**
Residential/ Commercial/ Industrial (RCI) Fuel Use	**2.25**	**2.78**	**2.31**	**2.75**	**2.57**	**2.56**	**2.55**
Residential - Oil, Propane, Natural Gas, and other	1.26	1.53	1.24	1.44	1.26	1.25	1.25
Residential - Wood (CH_4, N_2O)	0.07	0.08	0.09	0.10	0.11	0.09	0.09
Commercial - Oil, Propane, Natural Gas, and other	0.54	0.66	0.59	0.86	0.83	0.89	0.88
Commercial - Wood (CH_4, N_2O)	0.002	0.001	0.001	0.003	0.002	0.003	0.003
Industrial - Oil, Propane, Natural Gas and Other	0.38	0.52	0.39	0.35	0.36	0.32	0.32
Industrial - Wood (CH_4, N_2O)	0.004	0.004	0.002	0.002	0.002	0.002	0.002
Residential - Wood (biogenic CO_2)*	0.83	0.95	1.10	1.30	1.36	1.20	1.20
Commercial - Wood (biogenic CO_2)*	0.03	0.01	0.01	0.04	0.02	0.04	0.04
Industrial - Wood (biogenic CO_2)*	0.29	0.27	0.16	0.17	0.13	0.14	0.15
Renewable Natural Gas (RNG)*	0.000	0.000	0.000	0.001	0.002	0.005	0.008

** biogenic totals not included in gross total estimates*

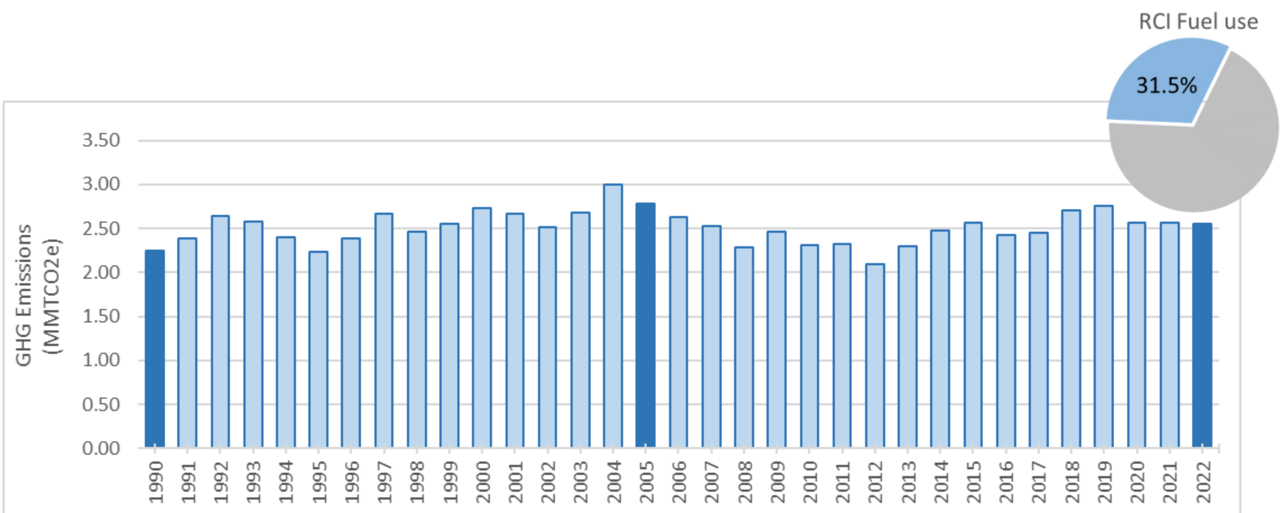

Figure 7: Vermont GHG emissions from the RCI sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

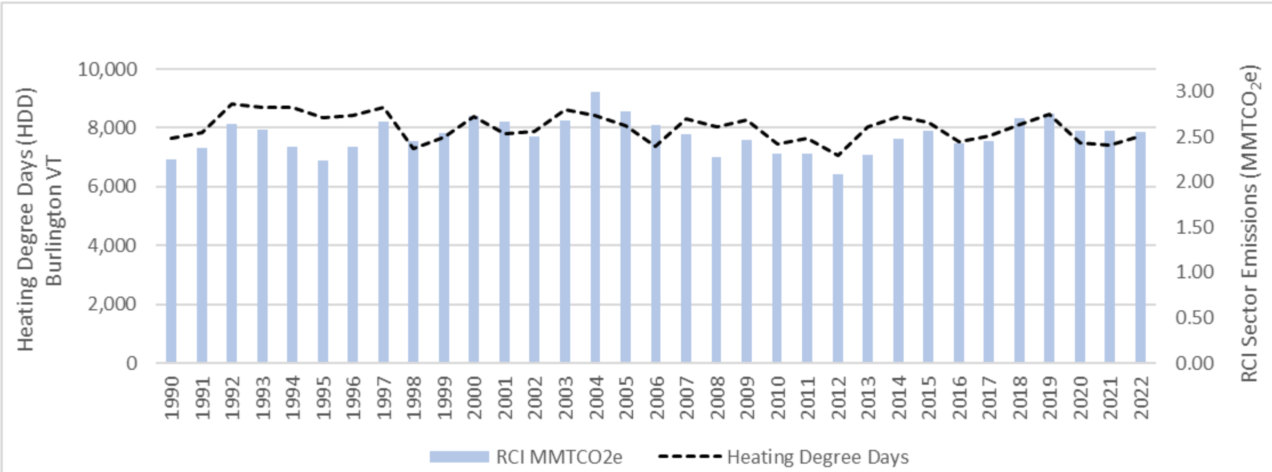

Figure 8: Vermont RCI sector emissions in MMTCO$_2$e plotted with the heating degree days (the difference between 65 degrees and a day's average temperature if below 65 degrees) from 1990 – 2022.

Table 5: GHG emissions contributions by fuel type and subsector within the RCI sector (2022).

RCI Breakdown by Subsector and by Fuel (2022)	Subsector	Emissions (MMTCO$_2$e)	Percent of Subsector Total	Percent of Total by Subsector
Fuel Oil	Residential	0.58	43.0%	52.9%
Propane	Residential	0.43	31.9%	
Natural Gas	Residential	0.21	15.8%	
Wood (CH_4 + N_2O)	Residential	0.09	7.0%	
Kerosene	Residential	0.03	2.3%	
Total	**Residential**	**1.35**	**100%**	
Fuel Oil	Commercial	0.20	22.8%	34.7%
Propane	Commercial	0.22	24.6%	
Natural Gas	Commercial	0.40	45.7%	
Wood (CH_4 + N_2O)	Commercial	0.003	0.3%	
Other	Commercial	0.058	6.6%	
Total	**Commercial**	**0.88**	**100%**	
Fuel Oil	Industrial	0.15	46.7%	12.5%
Propane	Industrial	0.01	2.3%	
Natural Gas	Industrial	0.11	35.3%	
Wood (CH_4 + N_2O)	Industrial	0.002	0.7%	
Other	Industrial	0.048	15.1%	
Total	**Industrial**	**0.32**	**100%**	
Grand Total	**All**	**2.55**		**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 remained relatively stable in recent years (Figure 9).

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 conservation tillage practices (e.g., 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.

Recently, ANR worked with the Agency of Agriculture Food and Markets (AAFM) and a consultant to investigate available tools and datasets to enable more holistic accounting 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 practicable. Additional information related to data and emissions from the agriculture sector in the state can be found in the Vermont Carbon Budget report[14] and information about the calculation methodologies for the sector and recommendations from the Agricultural Tool Review study can be found in the companion Methodologies document.

[14] 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$_2$e						
	1990	**2005**	**2010**	**2019**	**2020**	**2021**	**2022**
Agriculture	**1.40**	**1.23**	**1.21**	**1.30**	**1.24**	**1.25**	**1.26**
Enteric Fermentation (CH_4, N_2O*)*	*0.82*	*0.76*	*0.74*	*0.78*	*0.76*	*0.75*	*0.75*
Manure Management (CH_4, N_2O*)*	*0.18*	*0.13*	*0.11*	*0.10*	*0.10*	*0.09*	*0.10*
Agricultural Soils (CH_4, N_2O*)*	*0.40*	*0.33*	*0.34*	*0.39*	*0.33*	*0.35*	*0.32*
Liming and Urea Fertilization (CO_2*)*	*0.00*	*0.00*	*0.01*	*0.04*	*0.05*	*0.06*	*0.10*

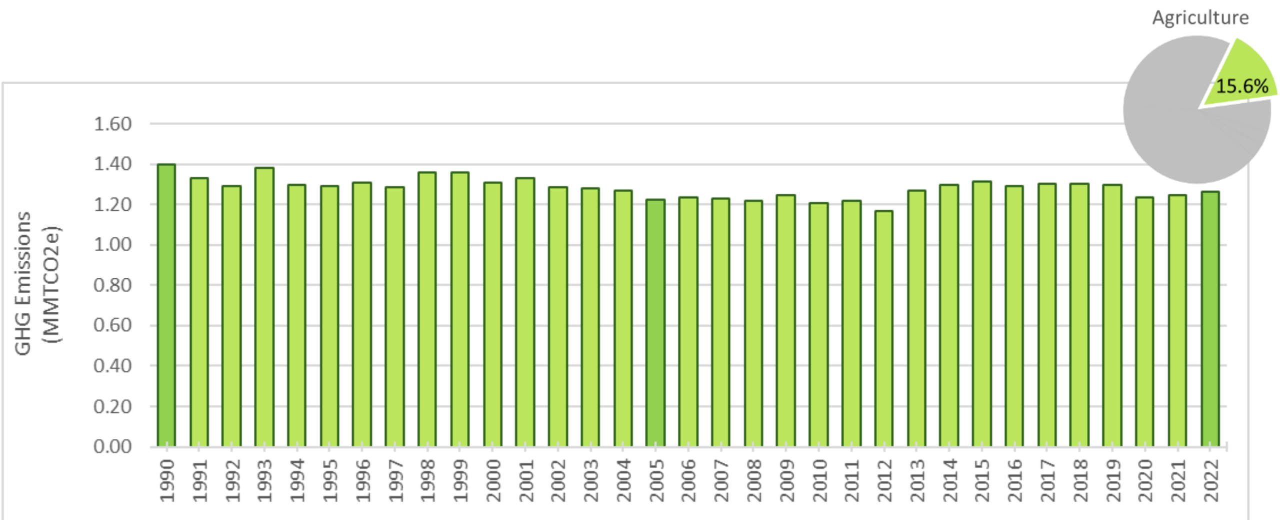

Figure 9: Vermont GHG emissions from the agriculture sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

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[15], 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 95% of the total (Table 7). Emissions estimates from the IP sector for 2022 decreased slightly from 2021 with emissions from ODS substitutes increasing slightly and semiconductor manufacturing decreasing (Figure 10).

[15] EPA Greenhouse Gas Reporting Program: https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp

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)[16] 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.

The manufacturing of semiconductors is a complex process that requires the use of 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.

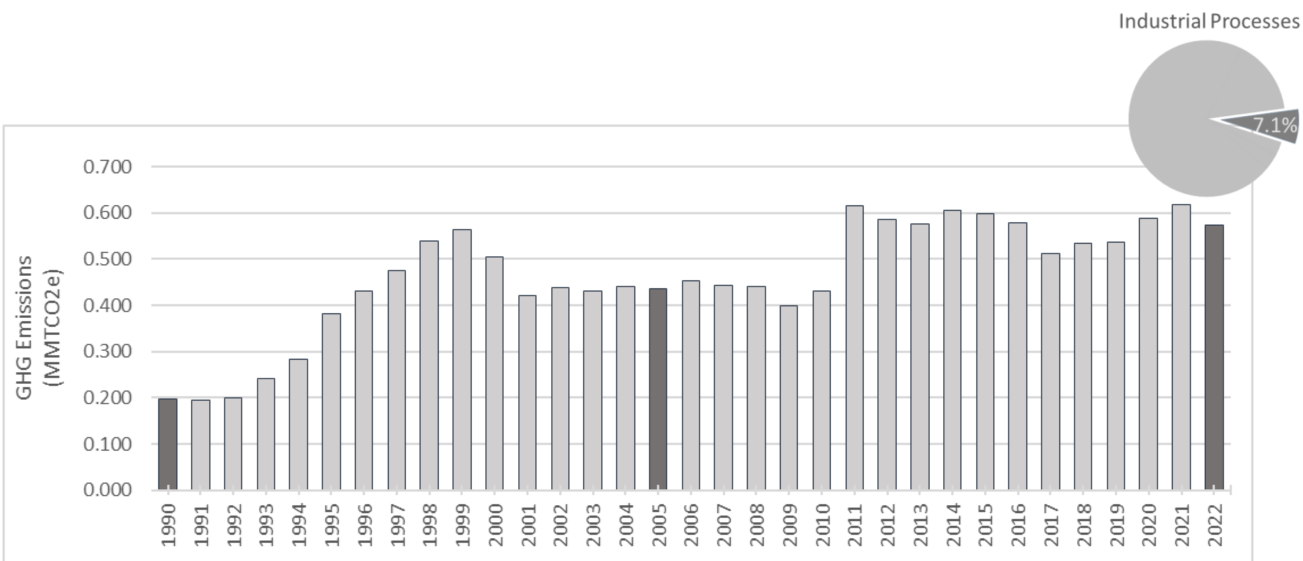

Figure 10: Vermont GHG emissions from the industrial processes sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

[16] Vermont Act 65: https://legislature.vermont.gov/Documents/2020/Docs/ACTS/ACT065/ACT065%20As%20Enacted.pdf

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

Sector	Emissions in $MMTCO_2e$						
	1990	2005	2010	2019	2020	2021	2022
Industrial Processes	**0.20**	**0.44**	**0.43**	**0.54**	**0.59**	**0.62**	**0.57**
ODS Substitutes (HFCs, PFCs, NF_3 SF_6)	0.00	0.19	0.22	0.29	0.33	0.34	0.35
Electric Utilities (SF_6)	0.04	0.02	0.01	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	0.19
Limestone & Dolomite Use (CO_2)	0.00	0.03	0.02	0.02	0.02	0.02	0.02
Soda Ash Use (CO_2)	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Urea Consumption (CO_2)	0.00	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.[17] 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. 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 Methodologies document.

The electricity sector continues to be one of Vermont's lowest emitting sectors (Appendix A) and accounted for approximately 3% of statewide emissions in 2022. 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[18] portion of Vermont's electricity portfolio (Table 8). Vermont's low emissions totals from the electricity sector are due mainly to our reliance on hydroelectric and renewable energy 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 11) in recent years can be attributed to distribution

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

[18] Describes the average emissions characteristics of the electricity generation that remains after specific claims of renewable energy or other generation types have been allocated to individual consumers or other defined loads.

utilities meeting and exceeding Renewable Energy Standard (RES)[19] 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[20]

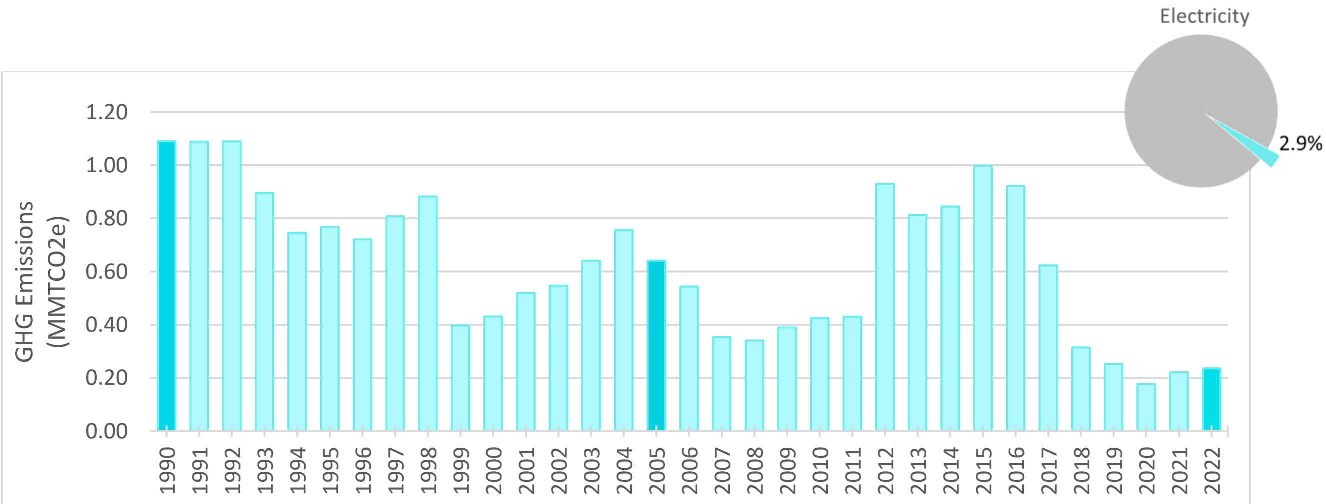

Figure 11: Vermont GHG emissions from the electricity sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

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	2022
Electricity Consumption	**1.09**	**0.64**	**0.43**	**0.25**	**0.18**	**0.22**	**0.24**
Coal	0.00	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	0.00
Oil	0.01	0.01	0.04	0.00	0.00	0.00	0.00
Wood (CH_4, N_2O)	0.003	0.014	0.015	0.012	0.013	0.014	0.012
Residual System Mix	1.03	0.616	0.365	0.240	0.164	0.207	0.224
Wood Combustion (Biogenic CO_2 at the stack)*	0.30	1.07	0.94	0.80	0.86	0.94	0.80

** Biogenic CO_2 emissions are not included in totals*[21]

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

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

[21] 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 total approximately 0.80 $MMTCO_2e$ in 2022 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 companion Methodologies document.

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 subsectors remained flat from 2016 to 2022 (Figure 12), and the waste sector remains one of the smallest emitting sectors at 2.7% of the statewide total. As in the previous version of the GHG Inventory, 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. Emissions from the solid waste sector have remained stable for the last several years (Table 9). Vermont's Universal Recycling law (Act 148)[22] in 2012 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.

<table>
<tr><th rowspan="2">Sector</th><th colspan="7">Emissions in MMTCO$_2$e</th></tr>
<tr><th>1990</th><th>2005</th><th>2010</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th></tr>
<tr><td>Waste</td><td>0.29</td><td>0.37</td><td>0.39</td><td>0.23</td><td>0.22</td><td>0.23</td><td>0.22</td></tr>
<tr><td>Solid Waste (CH_4, N_2O)</td><td>0.24</td><td>0.31</td><td>0.32</td><td>0.16</td><td>0.15</td><td>0.15</td><td>0.15</td></tr>
<tr><td>Fugitive LFG</td><td rowspan="3">0.24</td><td rowspan="3">0.31</td><td>0.18</td><td>0.07</td><td>0.07</td><td>0.08</td><td>0.08</td></tr>
<tr><td>Reported landfill gas totals (from LFGTE* equipment)</td><td>0.03</td><td>0.08</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>Closed landfills</td><td>0.11</td><td>0.08</td><td>0.07</td><td>0.07</td><td>0.07</td></tr>
<tr><td>Composting (CH_4, N_2O)</td><td>0.00</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>Wastewater (CH_4, N_2O)</td><td>0.05</td><td>0.06</td><td>0.06</td><td>0.06</td><td>0.06</td><td>0.06</td><td>0.06</td></tr>
</table>

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

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

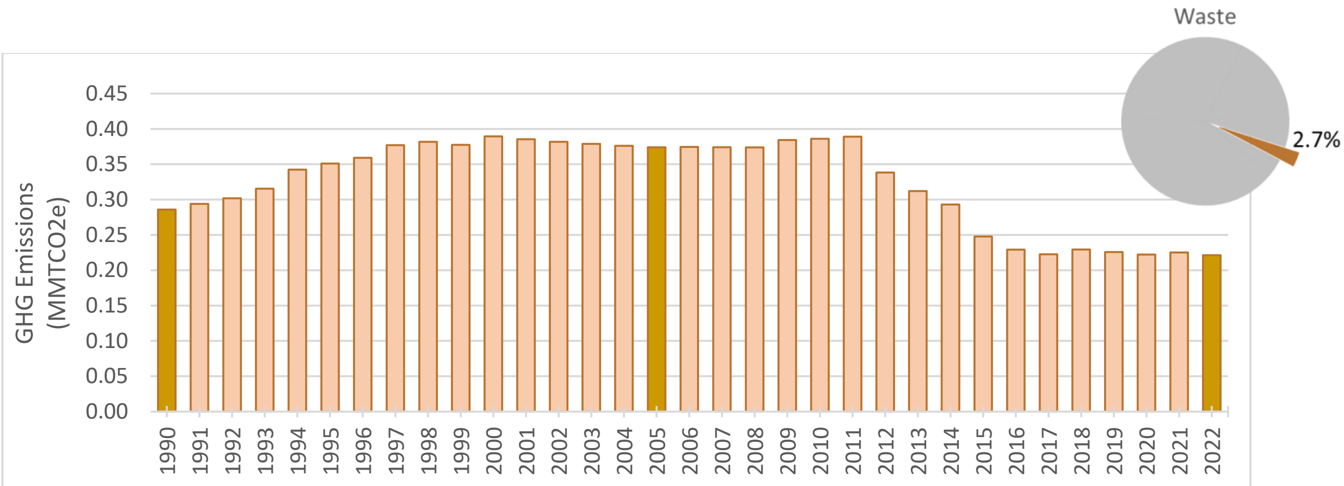

Figure 12: Vermont GHG emissions from the waste sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

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 and fugitive emissions from the transmission and distribution pipelines and connected services in Vermont. The emissions related to the combustion of 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 13). This offsetting effect has led to stable emissions levels in this sector in the last several years (Table 10) after the increase seen from the extension of Vermont Gas services to Addison County.

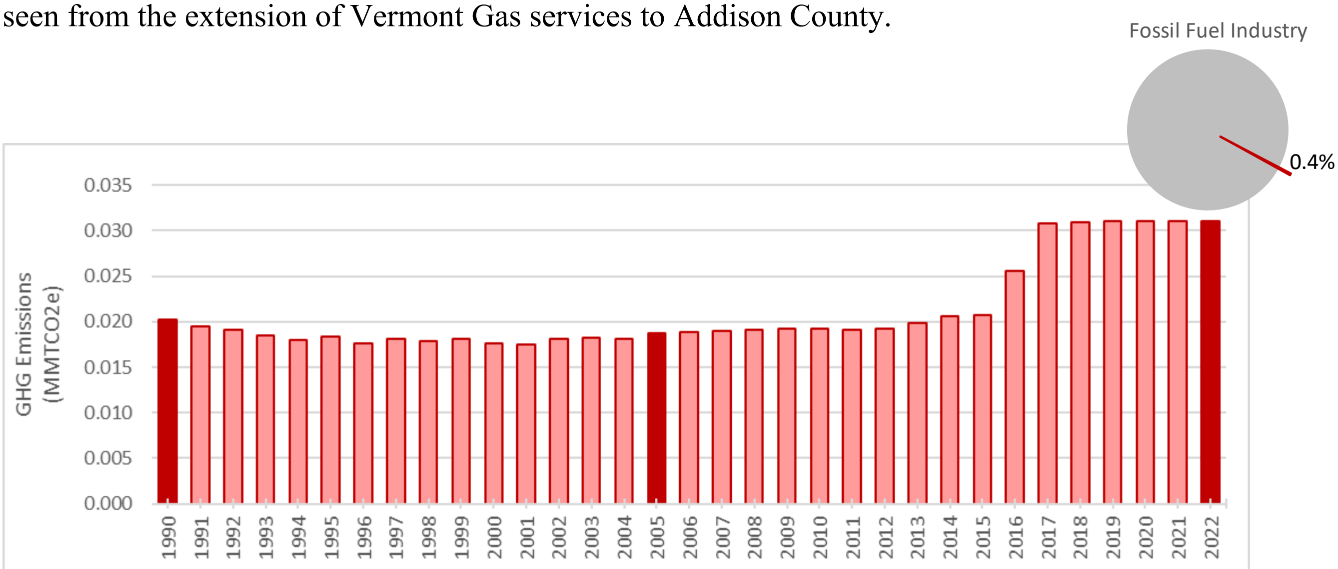

Figure 13: Vermont GHG emissions from the fossil fuel industry sector, 1990-2022; current inventory year (2022) and the 1990 and 2005 baseline years are highlighted.

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

Sector	Emissions in $MMTCO_2e$						
	1990	2005	2010	2019	2020	2021	2022
Fossil Fuel Industry	**0.020**	**0.019**	**0.019**	**0.031**	**0.031**	**0.031**	**0.031**
Natural Gas Distribution (CH_4)	0.008	0.003	0.004	0.005	0.005	0.005	0.005
Natural Gas Transmission (CH_4)	0.013	0.016	0.016	0.026	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 *Methodologies* document.

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

The Land Use, Land Use Change, and Forestry (LULUCF) sector accounts for carbon emissions and sequestration based on the maintenance and conversion of various land use types, including forestland, cropland, grassland, settlements (developed land), and wetlands. Vegetated areas such as forests sequester carbon through photosynthesis, storing it in plant material and soil. Therefore, maintaining or increasing vegetation, such as preserving forests or converting annual cropland to grassland, enhances carbon sequestration. Conversely, converting vegetated land to less or non-vegetated uses typically leads to carbon emissions or reduced sequestration capacity.

Estimating GHG emissions and sequestration from the LULUCF sector is complex, as it requires tracking annual changes in carbon stocks and fluxes across diverse landscapes at a statewide level. Historically, due to data limitations and the complexity of carbon cycling, the inventory included only above-ground forest biomass as a supplemental indicator of forest sequestration. More recently, the U.S. Environmental Protection Agency (EPA) released state-level estimates of emissions and sinks from land use and land use conversions beyond forests[23]. These were generated by downscaling national estimates from the National Inventory Report[24] to the state level and have now been incorporated into the inventory to provide a more complete view of the

[23] EPA State GHG Emissions and Removals: https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals
[24] EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022 :https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022.

LULUCF sector. Additional data sources, such as the Vermont Carbon Budget[25], inform estimates of sequestration from harvested wood products, and wetlands and waterbodies. Carbon storage from landfilled yard trimmings and food scraps is estimated using Vermont's diversion and disposal data[26]. Detailed information on data sources and methodologies is available in the companion Methodologies report.

Overall, Vermont's LULUCF sector functions as a net carbon sink, sequestering more carbon than it emits. Forests that remain forests account for the majority of this sequestration, as shown in Table 11. Figure 14 shows that Vermont's carbon sequestration offset approximately 70% of gross emissions in 2022, with an average offset of 74% from 1990 to 2002. The steady decline in sequestration shown in Figure 14 can be attributed to both the aging of forests, since older forests tend to sequester carbon at a lower rate, despite storing more overall, and the continued loss of forestland. Optimizing forest sequestration and storage requires maintaining structural diversity, including trees of various ages, species, and sizes, along with canopy gaps, standing dead trees, and downed logs. Settlements that remain settlements are the second-largest category of carbon sequestration, largely due to the benefits provided by urban trees.[27]

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**	**2022**
Net Forest Carbon Flux	**(8.84)**	**(8.20)**	**(7.62)**	**(7.06)**	**(6.83)**	**(6.60)**	**(6.29)**	**(6.23)**	**(6.17)**	**(6.11)**
Aboveground Biomass	(4.46)	(4.31)	(4.22)	(4.20)	(4.26)	(4.21)	(4.13)	(4.11)	(4.10)	(4.08)
Belowground Biomass	(0.79)	(0.76)	(0.76)	(0.76)	(0.77)	(0.75)	(0.74)	(0.74)	(0.73)	(0.73)
Deadwood	(1.03)	(1.03)	(1.00)	(0.95)	(0.87)	(0.81)	(0.75)	(0.72)	(0.70)	(0.68)
Litter	(0.22)	(0.17)	(0.12)	(0.09)	(0.06)	(0.02)	0.01	0.02	0.02	0.03
Soil (Mineral)	(0.55)	(0.49)	(0.42)	(0.34)	(0.26)	(0.18)	(0.13)	(0.12)	(0.11)	(0.10)
Soil (Organic)	(0.29)	(0.22)	(0.15)	(0.10)	(0.06)	(0.02)	0.00	0.00	0.00	0.00
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)	(0.56)
Forest Remaining Forest Land (Forest Carbon Flux)	(9.18)	(8.56)	(8.00)	(7.46)	(7.26)	(7.08)	(6.79)	(6.73)	(6.67)	(6.61)
Land Converted to Forestland (Forest Carbon Flux)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Forestland Converted to Land (Forest Carbon Flux)	0.45	0.47	0.50	0.52	0.54	0.59	0.61	0.61	0.61	0.61
Agricultural Soil Carbon Flux	**0.42**	**0.41**	**0.46**	**0.33**	**0.39**	**0.35**	**0.35**	**0.33**	**0.32**	**0.32**
Aboveground Biomass	0.35	0.35	0.35	0.34	0.33	0.29	0.27	0.27	0.27	0.27
Belowground Biomass	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
Deadwood	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Litter	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10
Soil (Mineral)	(0.14)	(0.17)	(0.11)	(0.24)	(0.16)	(0.16)	(0.13)	(0.14)	(0.15)	(0.14)
Soil (Organic)	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.02
Cropland Remaining Cropland (Ag Soil Carbon Flux)	(0.07)	(0.07)	(0.05)	(0.05)	(0.07)	(0.04)	(0.05)	(0.07)	(0.09)	(0.10)
Land Converted to Cropland (Ag Soil Carbon Flux)	0.12	0.14	0.15	0.15	0.15	0.16	0.17	0.18	0.19	0.19
Grassland Remaining Grassland (Ag Soil Carbon Flux)	(0.04)	(0.05)	(0.04)	(0.14)	(0.03)	(0.05)	(0.02)	(0.03)	(0.00)	(0.04)
Land Converted to Grassland (Ag Soil Carbon Flux)	0.41	0.39	0.39	0.36	0.34	0.27	0.24	0.25	0.23	0.24
Land Converted to Settlements	0.45	0.49	0.53	0.55	0.57	0.58	0.58	0.57	0.58	0.58
Settlements Remaining Settlements	(0.36)	(0.37)	(0.38)	(0.40)	(0.44)	(0.45)	(0.47)	(0.47)	(0.47)	(0.47)
Wetland and Waterbodies	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
LULUCF Net CO_2 Flux (including Harvested Wood Products)	**(8.34)**	**(7.68)**	**(7.01)**	**(6.59)**	**(6.31)**	**(6.12)**	**(5.84)**	**(5.81)**	**(5.75)**	**(5.70)**

[25] Vermont Carbon Budget Report: https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Carbon%20Budget%20for%20Vermont%20Sept%202021.pdf
[26] 2022 Diversion and Disposal Report | Department of Environmental Conservation
[27] AGuideToForestCarbon.pdf

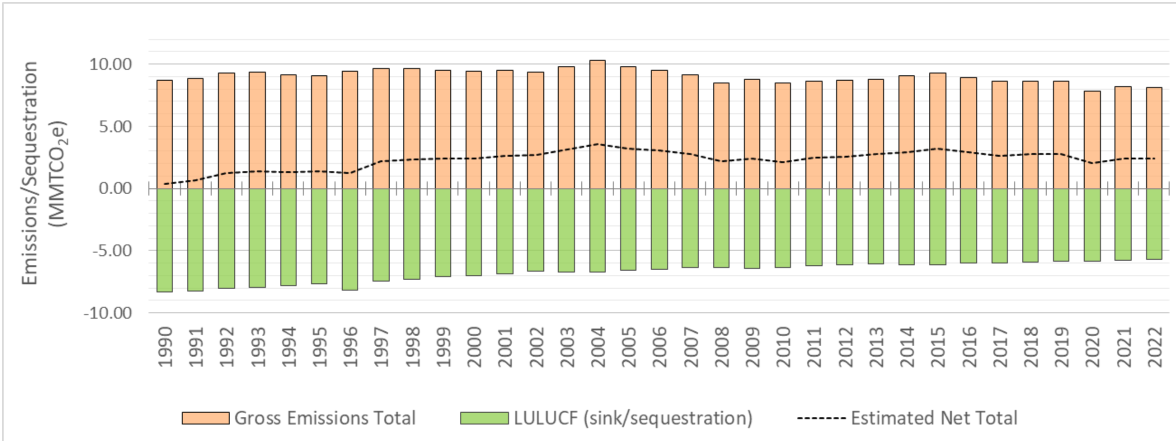

Figure 14: Estimated gross emissions, total sequestration, and net GHG levels in Vermont, 1990-2022.

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; 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 remains challenging given the complexity of the systems involved and there is currently no consensus 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, such as belowground biomass, deadwood, litter, and forest soils. 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[28] 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 credit for the renewability of the resource.

4 Emissions Forecasts

4.1 Estimated GHG Emissions Levels for 2026 and 2031

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 future years requires making many assumptions related to our natural environment, built environment, and society at large which are difficult to predict.

In support of development the initial 2021 Vermont Climate Action Plan (CAP)[29] and the 2022 Comprehensive Energy Plan (CEP)[30] ANR commissioned an emissions modeling study.[31] Since then the emissions model developed for that study has undergone several revisions including a comprehensive update in support of the 2025 Vermont CAP. This inventory incorporates values directly from that modeling effort as the 5- and 10-year projections described in 10 V.S.A. § 582(c). The emission projections in Table 12 include values from the most recent update to the emissions model baseline/business as usual (BAU) scenario, which assumes only currently enacted policies to reduce emissions will be in place in the modeled out years.[32]

The model results indicate that without additional initiatives beyond what Vermont has already in place the state's current climate policies, as reflected in the BAU scenario, will be unable to reduce GHG emissions enough to achieve the 2030 requirement of the Global Warming Solutions Act.

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[28] Biogenic Carbon Footprint Calculator – World Wildlife Federation: https://files.worldwildlife.org/wwfcmsprod/misc/climate_forest/Biogenic_Carbon_Footprint_Calculator_2020.xlsx
[29] Vermont Climate Action Plan: https://climatechange.vermont.gov/readtheplan
[30] Vermont Comprehensive Energy Plan: https://publicservice.vermont.gov/about-us/plans-and-reports/department-state-plans/2022-plan
[31] 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

[32] Note that values in Table 12 utilize the AR5 100-year GWP values and reflect the requirements of the updated Renewable Energy Standard

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

Sector	2026	2031
Agriculture	1.21	1.18
Electricity generation	0.29	0.07
Natural Gas Transmission and Distribution	0.03	0.03
Transportation	3.15	2.71
Industrial Processes	0.59	0.62
Residential/Commercial/Industrial Fuel Use (RCI)	2.20	2.03
Waste	0.22	0.22
Total	**7.69**	**6.87**

5 Conclusion

The 1990-2022 *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, track progress towards Vermont's mandated emissions levels and provide insights into which sectors to prioritize for mitigation policies. Total GHG emissions for 2022 declined from 2021 levels primarily due to slightly lower emissions from the Transportation, RCI, and Industrial Processes sectors. Vermont's greenhouse gas emissions levels in the coming years will depend on many factors including the implementation of key 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 approach taken by the Agency of Natural Resources for this annual in-boundary inventory seeks to maintain consistency with how emissions are being tracked by other states in the region, as well as IPCC guidelines. The GHG Inventory is based on data availability and the most current understanding of the various methods and tools to estimate GHG emissions from each sector.

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	2022
:tricity 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**	**0.24**
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	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	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	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	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	0.22
idential / Commercial / Industrial (RCI) Fuel Use	**2.25**	**2.24**	**2.73**	**2.78**	**2.62**	**2.52**	**2.28**	**2.46**	**2.31**	**2.32**	**2.09**	**2.30**	**2.47**	**2.56**	**2.43**	**2.45**	**2.71**	**2.75**	**2.57**	**2.56**	**2.55**
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	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	0.73
Oil, Propane & Other Petroleum	1.84	1.78	2.17	2.26	2.12	1.97	1.74	1.92	1.78	1.77	1.57	1.69	1.81	1.82	1.68	1.70	1.85	1.89	1.75	1.74	1.72
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	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	1.39
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**	**3.51**	**3.02**	**3.25**	**3.22**
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	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	0.96	0.90	0.92	0.90
Irocarbon 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	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	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	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	0.02
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	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**	**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	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	0.03
Industrial Processes	**0.20**	**0.38**	**0.51**	**0.44**	**0.45**	**0.44**	**0.44**	**0.40**	**0.43**	**0.62**	**0.59**	**0.58**	**0.61**	**0.60**	**0.58**	**0.51**	**0.53**	**0.54**	**0.59**	**0.62**	**0.57**
ODS Substitutes	0.00	0.06	0.14	0.19	0.20	0.21	0.23	0.23	0.22	0.23	0.25	0.28	0.32	0.31	0.31	0.27	0.30	0.29	0.33	0.34	0.35
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	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	0.19
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	0.02	0.02
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	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	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**	**0.22**
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	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	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	0.06
Agriculture	**1.40**	**1.29**	**1.31**	**1.23**	**1.23**	**1.23**	**1.22**	**1.25**	**1.21**	**1.22**	**1.17**	**1.27**	**1.30**	**1.31**	**1.29**	**1.30**	**1.30**	**1.30**	**1.24**	**1.25**	**1.26**
Enteric Fermentation	0.82	0.78	0.82	0.76	0.76	0.77	0.77	0.77	0.74	0.77	0.75	0.78	0.77	0.77	0.78	0.79	0.79	0.78	0.76	0.75	0.75
Manure Management	0.18	0.16	0.15	0.13	0.13	0.13	0.12	0.12	0.11	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.10
Agricultural Soils	0.40	0.35	0.33	0.33	0.34	0.34	0.33	0.35	0.34	0.33	0.31	0.38	0.40	0.40	0.37	0.37	0.38	0.39	0.33	0.35	0.32
Liming and Urea Fertilization	0.00	0.00	0.00	0.00	0.00	0.00	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	0.10
TOTAL GROSS EMISSIONS	**8.72**	**9.07**	**9.44**	**9.81**	**9.50**	**9.12**	**8.51**	**8.79**	**8.44**	**8.64**	**8.68**	**8.78**	**9.04**	**9.31**	**8.94**	**8.59**	**8.63**	**8.60**	**7.85**	**8.16**	**8.09**
Land-use, Land Use Change, and Forestry (LULUCF)	**-8.34**	**-7.68**	**-7.01**	**-6.59**	**-6.46**	**-6.38**	**-6.33**	**-6.39**	**-6.31**	**-6.18**	**-6.10**	**-6.03**	**-6.11**	**-6.12**	**-6.00**	**-5.98**	**-5.90**	**-5.84**	**-5.81**	**-5.75**	**-5.70**
Estimated Net Emissions Total	**0.38**	**1.39**	**2.43**	**3.22**	**3.04**	**2.74**	**2.18**	**2.40**	**2.13**	**2.46**	**2.58**	**2.74**	**2.94**	**3.19**	**2.94**	**2.61**	**2.74**	**2.76**	**2.04**	**2.40**	**2.40**

[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 2022	Key Category in 2022?
Electricity Supply & Demand (Consumption - based)						
Coal	0.00%	No	0.00%	No	0.00%	No
Natural Gas	0.53%	No	0.00%	No	0.00%	No
Oil	0.16%	No	0.11%	No	0.00%	No
Wood (CH4, N2O)	0.03%	No	0.14%	No	0.15%	No
Residual System Mix	11.75%	Yes	6.27%	Yes	2.76%	Yes
Residential/ Commercial/ Industrial (RCI) Fuel Use						
Coal	0.23%	No	0.02%	No	0.00%	No
Oil, Propane, & Other Petroleum	21.19%	Yes	23.22%	Yes	21.66%	Yes
Natural Gas	3.66%	Yes	4.48%	Yes	8.97%	Yes
Wood (CH4, N2O)	0.82%	No	0.81%	No	1.21%	Yes
Transportation/Mobile						
Motor Gasoline (Onroad and Nonroad) (CO2)	29.07%	Yes	30.97%	Yes	26.89%	Yes
Diesel (Onroad and Nonroad) (CO2)	8.23%	Yes	10.42%	Yes	11.02%	Yes
Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO2)	0.05%	No	0.03%	No	0.04%	No
Jet Fuel & Aviation Gasoline (CO2)	0.88%	No	1.36%	Yes	1.08%	No
Non-Energy Consumption - Lubricants (CO2)	0.25%	No	0.19%	No	0.16%	No
All Mobile (CH4, N2O)	1.34%	No	1.06%	No	0.29%	No
Fossil Fuel Industry						
Natural Gas Distribution	0.09%	No	0.03%	No	0.06%	No
Natural Gas Transmission	0.14%	No	0.16%	No	0.32%	No
Industrial Processes						
ODS Substitutes	0.01%	No	1.92%	Yes	4.33%	Yes
Electric Utilities (SF6)	0.49%	No	0.19%	No	0.09%	No
Semiconductor Manufacturing (HFC, PFC & SF6)	1.69%	Yes	1.99%	Yes	2.33%	Yes
Limestone & Dolomite Use	0.00%	No	0.28%	No	0.30%	No
Soda Ash Use	0.07%	No	0.05%	No	0.00%	No
Urea Consumption	0.00%	No	0.01%	No	0.00%	No
Waste Management						
Solid Waste (CH4, N2O)	2.72%	Yes	3.15%	Yes	1.86%	Yes
Composting	0.01%	No	0.07%	No	0.12%	No
Wastewater	0.54%	No	0.59%	No	0.74%	No
Agriculture						
Enteric Fermentation	9.36%	Yes	7.74%	Yes	9.22%	Yes
Manure Management	2.04%	Yes	1.36%	No	1.19%	No
Agricultural Soils	4.61%	Yes	3.34%	Yes	3.90%	Yes
Liming and Urea Fertilization	0.03%	No	0.04%	No	1.21%	No

Appendix C: Vermont Key Category Analysis by Trend Assessment

Sector	Subsector	Trend Assessment (1990-2022)	% Contribution To The Trend (1990-2022)	Cumulative Total (1990-2022)
Electricity Supply & Demand	Residual System Mix	1.33	27%	27%
Residential/ Commercial/ Industrial (RCI) Fuel Use	Natural Gas	0.68	14%	41%
Transportation/Mobile	Motor Gasoline (Onroad and Nonroad) (CO2)	0.59	12%	53%
Industrial Processes	ODS Substitutes	0.58	12%	64%
Transportation/Mobile	Diesel (Onroad and Nonroad) (CO2)	0.29	6%	70%
Agriculture	Liming and Urea Fertilization	0.16	3%	73%
Transportation/Mobile	All Mobile (CH4, N2O)	0.16	3%	77%
Residential/ Commercial/ Industrial (RCI) Fuel Use	Oil, Propane, & Other Petroleum	0.15	3%	80%
Waste Management	Solid Waste (CH4, N2O)	0.14	3%	83%
Agriculture	Agricultural Soils	0.14	3%	85%
Agriculture	Manure Management	0.14	3%	88%
Agriculture	Enteric Fermentation	0.11	2%	90%
Electricity Supply & Demand	Natural Gas	0.08	2%	92%
Industrial Processes	Semiconductor Manufacturing (HFC, PFC & SF6)	0.07	1%	93%
Industrial Processes	Electric Utilities (SF6)	0.06	1%	95%
Residential/ Commercial/ Industrial (RCI) Fuel Use	Wood (CH4, N2O)	0.05	1%	96%
Industrial Processes	Limestone & Dolomite Use	0.04	1%	96%
Residential/ Commercial/ Industrial (RCI) Fuel Use	Coal	0.03	1%	97%
Electricity Supply & Demand	Oil	0.02	0%	97%
Fossil Fuel Industry	Natural Gas Transmission	0.02	0%	98%
Waste Management	Wastewater	0.02	0%	98%
Transportation/Mobile	Jet Fuel & Aviation Gasoline (CO2)	0.02	0%	99%
Electricity Supply & Demand	Wood (CH4, N2O)	0.02	0%	99%
Waste Management	Composting	0.01	0%	99%
Transportation/Mobile	Non-Energy Consumption - Lubricants (CO2)	0.01	0%	100%
Industrial Processes	Soda Ash Use	0.01	0%	100%
Fossil Fuel Industry	Natural Gas Distribution	0.00	0%	100%
Transportation/Mobile	Hydrocarbon Gas Liquids, Residual Fuel, Natural Gas (CO2)	0.00	0%	100%
Industrial Processes	Urea Consumption	0.00	0%	100%
Electricity Supply & Demand	Coal	0.00	0%	100%