RESEARCH PAPER

Analyzing changes in fossil heating fuel use in Vermont, 2018-2023

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Executive Summary

Vermont's thermal sector—also referred to as the residential, commercial, and industrial (RCI) fuel use sector—is responsible for more than one-third of the state's total greenhouse gas (GHG) emissions. The majority of thermal sector emissions are related to the direct combustion of fossil fuels in buildings, largely for space and water heating. Specifically, fuel oil, propane, and fossil gas are responsible for the vast majority—over 90%—of GHG emissions in Vermont's thermal sector.

Between 2018 and 2023, total annual sales of these fossil heating fuels decreased by 12%, according to data from the Vermont Department of Taxes. The decline was largely driven by a 22% reduction in sales of fuel oil, in addition to a 9% reduction in fossil gas sales. Propane sales, on the other hand, increased by just over 4%.

Over this time, Vermont's winters have been getting warmer, reducing demand for fossil fuels for space heating. Specifically, annual heating degree days in 2023 were nearly 8% lower than in 2018. Given that the majority of fuel oil, propane, and fossil gas consumption in Vermont is related to space heating, we estimate that warmer winter temperatures are the single largest factor contributing to the reduction in fuel sales over this time period, accounting for approximately half of the observed decline.

In addition to the effect of warmer winters, several other factors likely played a role, including increased adoption of electrification, efficiency, and other pollution reduction measures. Specifically, Vermont is beginning to see the results of increased adoption of high-efficiency electric heat pumps over the last several years, which we estimate may be responsible for nearly one-third of the observed decrease in fossil heating fuel sales. Additionally, improvements in the average efficiency of fossil fuel heating equipment, as well as increased adoption of heat pump water heaters and home weatherization, have likely played a role.

Recent reductions in fossil heating fuel use will help bring Vermont closer to meeting its legally-mandated emissions reduction targets, but the data show that much more progress is still needed. Vermont's Global Warming Solutions

Act (GWSA) established legal obligations for the state to reduce its GHG emissions by at least:

- 26% below 2005 levels by 2025,
- 40% below 1990 levels by 2030,
- and 80% below 1990 levels by 2050.

In order to meet the January 1, 2025 target for thermal sector emissions, Vermont would need to achieve a nearly 9% reduction in annual emissions from 2023 to 2024. Given insufficient adoption and utilization of cleaner heating measures to date, the possibility of meeting this sectoral target for 2024 will, at this point, likely depend on whether and to what degree the winter warming trend continues through the end of the 2024 heating season. Looking ahead to Vermont's 2030 and 2050 emissions reduction obligations, confidently achieving the thermal sector GHG pollution reduction targets will require reducing dependence on fossil fuels via significantly increased heat pump adoption, weatherization, and other durable, non-weather dependent pollution reduction measures.

I. Introduction

From 2018 to 2023 total annual sales of fossil heating fuels (primarily fuel oil, fossil gas,[1] and propane) in Vermont declined by 12%. Within this overall reduction, however, changes in the sales of different heating fuels varied widely. The largest decline was in sales of fuel oil,[2] which fell by 22%. Meanwhile, propane sales actually *increased,* by about 4%. Fossil gas sales declined by 9%.

Vermont annual fossil heating fuel sales, 2018–2023

	Sales of fuel oil, kerosene, other (gallons)	Propane sales (gallons)	Fossil gas sales (MMcf)	Total heating fuel sales (MMBtus)
2018	142,760,715	105,640,210	13,750	43,678,368
2019	144,042,019	112,071,541	13,882	44,580,738
2020	138,113,813	96,992,594	13,043	41,511,478
2021	125,390,288	110,776,478	13,255	41,229,465
2022	121,538,893	114,116,456	13,463	41,216,983
2023	111,123,798	110,130,821	12,519	38,432,014
% change (2018–2023)	**-22.16%**	**+4.25%**	**-8.95%**	**-12.01%**

Sources: Fuel oil and propane: Vermont Department of Taxes; Fossil gas: VGS; Conversion factors for energy content: EIA.

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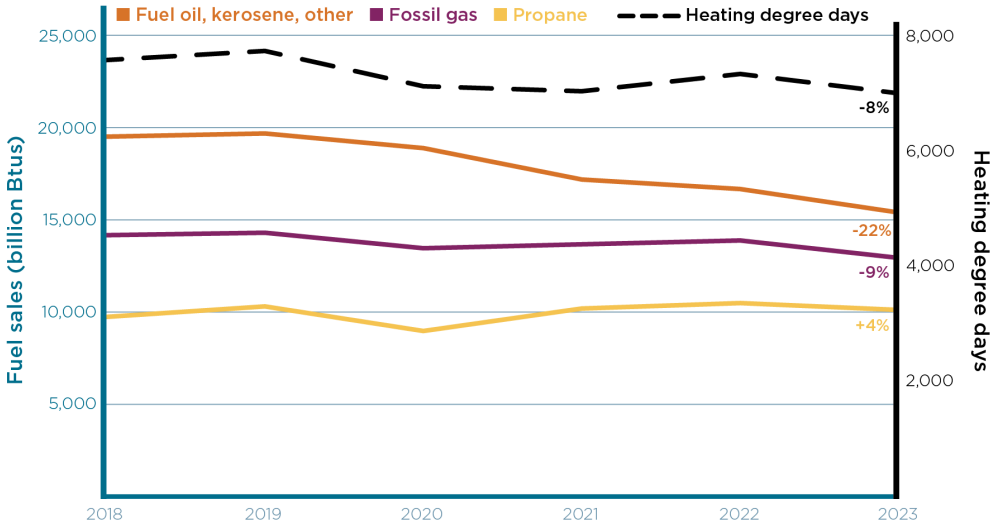
This paper explores the reasons behind overall and fuel-specific changes in fossil heating fuel use in Vermont between 2018 and 2023. Analysis begins with 2018, the first year of fossil heating fuel sales data from the Vermont Department of Taxes available at the time of writing. The analysis ends with 2023, the most recent year for which full annual data is available from the Vermont Department of Taxes.

[1] Fossil gas is also sometimes referred to as "natural gas", "utility gas", "fossil natural gas", "pipeline gas", "fracked gas", "methane", or "gas."

[2] Fuel oil totals as reported by the Tax Department technically also include sales of kerosene. However, kerosene sales are a very small fraction of this category. Specifically, as of 2020, EIA reported kerosene sales to only be about 2.6% of combined fuel oil and kerosene sales in Vermont. That is why in this report we refer simply to fuel oil rather than the more exact but longer "Fuel oil, kerosene, and other."

The decrease in total fossil heating fuel sales is particularly notable because it occurred over a period of time when Vermont's residential building stock was increasing by about 0.53% per year, or a total increase of about 2.7% between 2018 and 2023.[3] We estimate that this increased the total heating load of the state by about 1.4% (given that residential fuel use is only a portion – about 52% – of total Residential, Commercial, and Industrial (RCI) fuel use).[4]

VT fossil heating fuel sales and heating degree days, 2018–2023



Sources: Heating fuel sales data: Vermont Department of Taxes, 2024; VGS, 2024. Fuel heat content conversion factors: U.S. Energy Information Administration, 2023. Heating degree days: NOAA Climate Prediction Center, 2023.

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Based on available data and assumptions provided by state sources, we calculated the expected effect of a variety of factors on the observed decrease in fossil heating fuel sales.[5] Based on those calculations, the following factors are likely most responsible, listed in order of magnitude:

- Decrease in Heating Degree Days (HDD) (i.e., warmer winters) (±50% of observed decrease)
- Increased adoption of cold climate heat pumps (CCHPs). (±28% of observed decrease)

[3] Vermont Department of Taxes. Annual reports from property valuation and review, 2018 - 2023. Note: While new construction is likely more energy efficient than existing homes, that is likely partially offset by the increasing average square footage of new homes.
[4] Note: Grand List data from the Vermont Department of Taxes show that the total number of commercial and industrial properties in Vermont has been essentially flat over the same period.
[5] For more information about the inputs and assumptions utilized, please see the Excel workbook that accompanies this paper.

Other quantifiable factors of smaller magnitude:

- Increasing average equipment efficiency of residential fossil boilers and furnaces (±7% of observed decrease)
- Comprehensive residential weatherization (±5% of observed decrease)
- Increased adoption of heat pump water heaters (HPWH) (±3% of observed decrease)

Other possible factors (difficult to quantify):

- Fuel switching from fossil fuels to wood
- Changing efficiency of commercial and industrial buildings
- Changing efficiency of commercial and industrial fossil fuel equipment
- Consumer response to high fuel prices (lowering of thermostats)

Next, we consider possible reasons for differential changes in the sales of different types of fossil heating fuels (fuel oil, propane, and fossil gas).

We conclude with consideration of the implications of the observed reduction in fossil heating fuel sales for the Global Warming Solutions Act (GWSA) and the Affordable Heat Act.

II. The reasons for changes in fossil heating fuel sales, 2018-2023

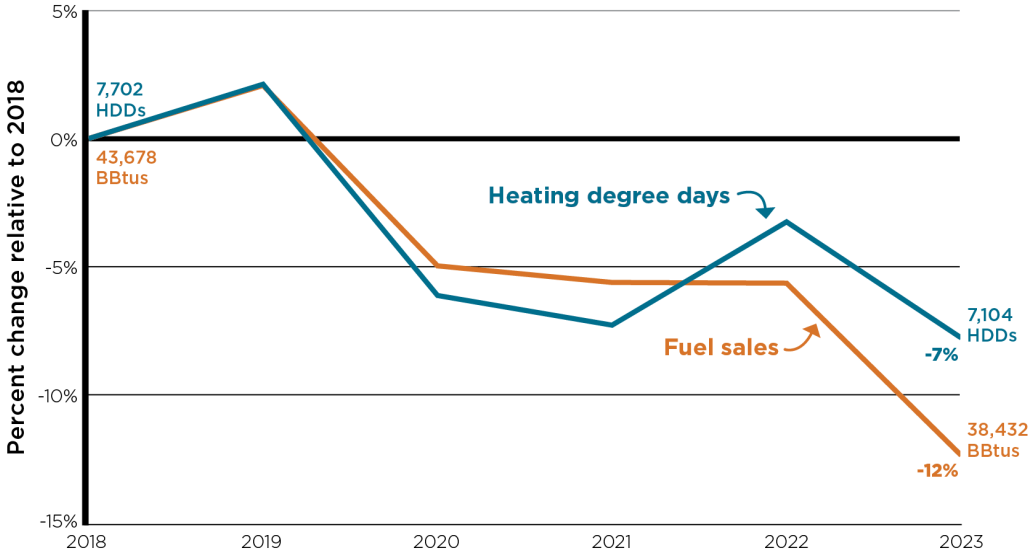
a) Warmer winters are the single largest factor behind a reduction in fossil heating fuel sales

The single largest factor in the decline of fossil heating fuels over the past six years has been lower demand for heating, driven by warmer winters. Heating degree days are a measure that compares the mean outdoor temperature on a given day to a standard temperature of 65 degrees Fahrenheit. For instance, a day with an average temperature of 30 degrees would be a 35 heating degree day. Combined over the course of a year, total heating degree days tell us how relatively warm or cold a year was, as well as the overall heating need for that year.

Comparing 2018 and 2023, annual heating degree days in Vermont declined by 7.76%, from 7,702 to 7,104. Fewer heating degree days lowers fossil fuel use

for space heating. However, not all fossil heating fuels are used for space heating. Propane and fossil gas (and, to a lesser extent, fuel oil) are also used for water heating and cooking. Meanwhile fuel oil and fossil gas are also used in industrial activities that are not space-heating related.[6] Therefore, we estimate that about 77% of fossil fuel sales in the thermal sector — the share related to space heating — would be affected by heating degree days while the remaining ~23% are more insulated from changes in heating degree days. Our analysis found that warmer winters alone likely explain about 50% of the observed decline in total combined annual heating fuel sales.

Percent change in fossil heating fuel sales and heating degree days in VT, relative to 2018



Sources: Heating fuel sales data: Vermont Department of Taxes, 2024; VGS, 2024. Fuel heat content conversion factors: U.S. Energy Information Administration, 2023. Heating degree days: NOAA Climate Prediction Center, 2023.

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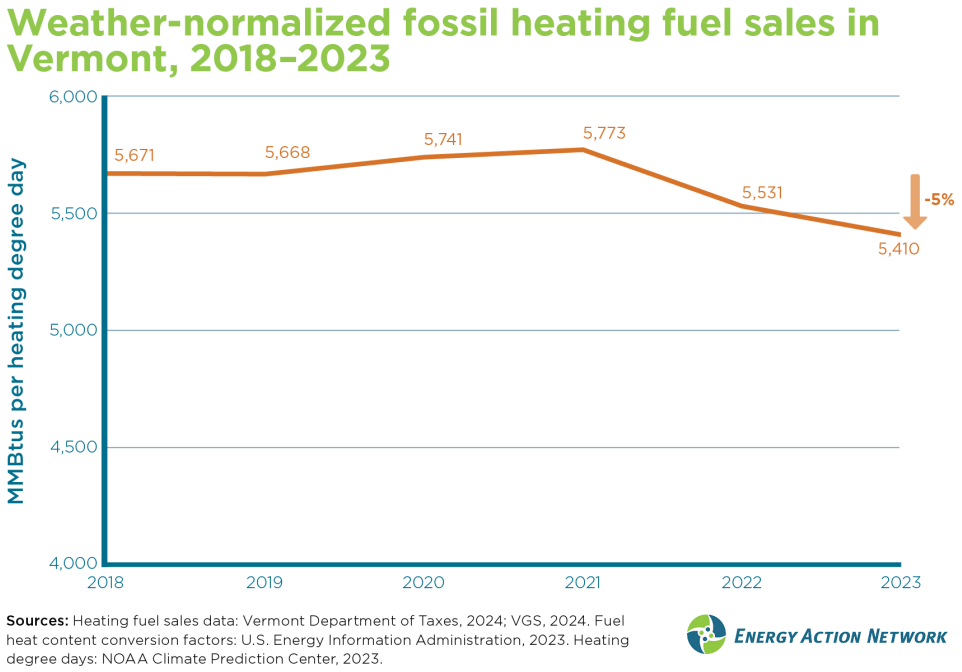
While warmer winters and lower heating demand, as measured by heating degree days, explain much of the decline in fossil fuel heating use, they don't explain all of it. Normalizing fossil heating fuel sales by heating degree day reveals a decline in fossil heating fuel sales in 2022 and 2023 not attributable

[6] Estimate based on an assumption that 85% of residential fuel use, 80% of commercial fuel use, and 40% of industrial fuel use is for space heating purposes. Given limited measured data on fossil fuel end uses in Vermont buildings, particularly in the commercial and industrial sectors, this should be considered an approximate estimate. It is important to note that as heat pump adoption increases and more heating load shifts to electricity, the share of fossil fuel use related to space heating will decrease.

to weather. This demonstrates that additional factors beyond declining heating degree days in Vermont are having impacts on fossil fuel sales.



Sources: Heating fuel sales data: Vermont Department of Taxes, 2024; VGS, 2024. Fuel heat content conversion factors: U.S. Energy Information Administration, 2023. Heating degree days: NOAA Climate Prediction Center, 2023.

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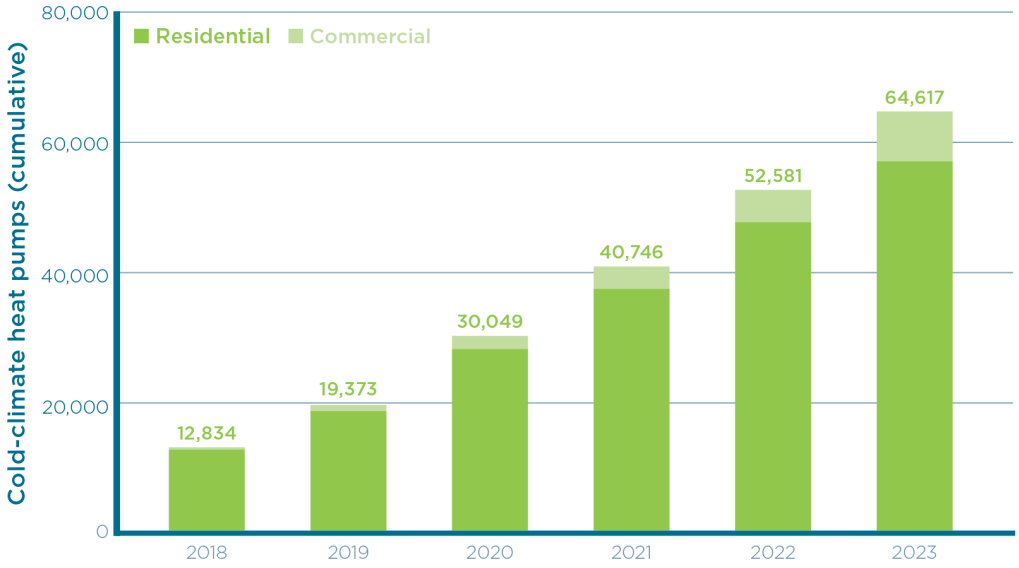
b) Electric heat pumps and wood are displacing some fossil heating fuel use

From 2018 to 2023, the cumulative number of CCHPs installed in Vermont grew from 12,834 to 64,617, based on energy efficiency program data.[7] This represents an increase of over 400% in a five-year period.

[7] Source: Efficiency Vermont, 2024; Burlington Electric Department (BED), 2024. Note: Heat pump totals include all units for which Efficiency Vermont or BED incentives were received. There may be a small number of residential heat pump installations not captured in this data, but the programs apply incentives as an instant discount via distributors and therefore capture the vast majority of sales. Additionally, these data do not include commercial heat pumps installed prior to 2018, when tracking began.

Cold-climate heat pumps in Vermont, 2018–2023



Sources: Efficiency Vermont, 2023; Burlington Electric Department, 2023.
Note: Heat pump totals represent the number of outdoor units installed, not the number of individual indoor heads. The data include residential and commercial installations of high efficiency single head and multi-head cold climate heat pumps, air-to-water heat pumps, and centrally ducted heat pumps that meet the program criteria for efficient performance.

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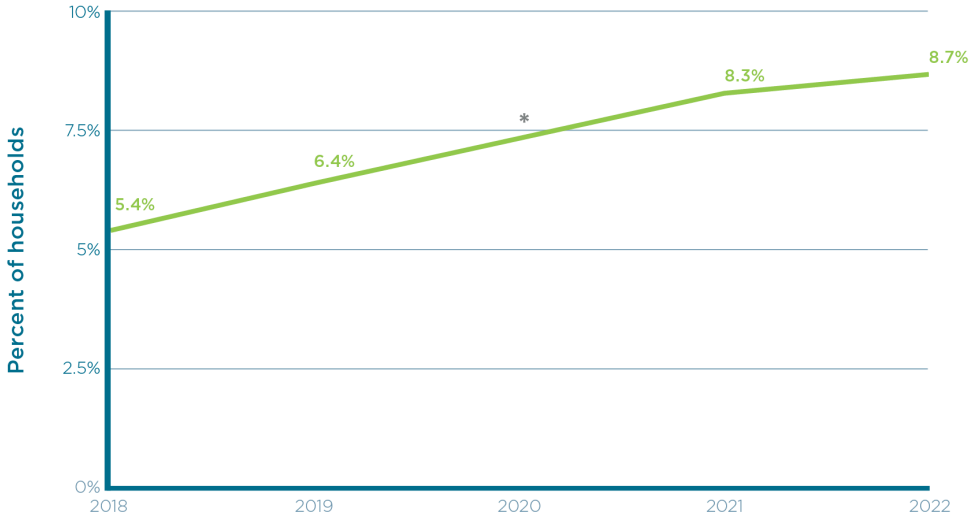
Beyond rebate data that shows increasing sales of CCHPs, Vermont households are also self-reporting greater use of electricity as their primary heating fuel. In the 2018 American Community Survey, 5.4% of Vermont households reported electricity (including both electric resistance and electric heat pumps) as their primary heating fuel. As of 2022, that number had climbed to 8.7%.[8] Additionally, a study by the Vermont Department of Public Service found that the share of homes in Vermont that rely on heat pumps as their primary heating system increased from less than 1% in 2015 to around 3% in 2020/2021.[9]

[8] Some portion of these numbers include electric resistance heating systems, not just heat pumps. However, based on sales/rebate data, it is likely that heat pumps made up the vast majority of the increase from 2018 to 2022. Additionally, electric resistance heat is now mostly prohibited in Vermont as a primary space heating source. This is another reason that this increase can likely be directly attributed to CCHPs.

[9] NMR, EFG, and Itron for the Vermont Department of Public Service, 2020 Vermont Single-Family Existing Homes Baseline Study, 2023. Note: Single-family homes (defined in the PSD study to include detached homes, two-unit attached homes, and manufactured homes) make up 83% of occupied housing units in Vermont.

We estimate that the significant adoption of heat pumps across Vermont is likely the second leading factor, after warmer winters, that has driven the reduction in fossil heating fuel sales. Specifically, given the sales of different heat pump types and associated energy savings assumptions from Efficiency Vermont's Demand Resource Plan (DRP) and the Efficiency Vermont Technical Reference Manual (TRM), the scale of CCHP adoption between 2018 to 2023 would be expected to result in a reduction of 1,444,140 MMBtu worth of fossil heating fuel, or about 28% of the total observed decline (5,246,354 MMBtu) in fossil heating fuel sales.[10]

Share of Vermont households reporting electricity as their primary heating fuel



Source: U.S. Census Bureau, American Community Survey 1-year estimates, 2018-2022.
Note: Data is self-reported. *: ACS 1-year estimates not available for 2020 due to the pandemic. This graph assumes linear growth between the 2019 and 2021 estimates.

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The exact scale of the effect of heat pumps in reducing fossil heating fuel use is an estimate that we have less confidence in than others, given the lack of certainty about how much fossil fuel use heat pumps are displacing, on average, across Vermont. Anecdotal information suggests that some heat pumps in Vermont are being used solely or primarily for cooling, especially in VGS territory, and therefore are not achieving the scale of fossil fuel displacement that is possible. Whether the TRM provides an appropriate

[10] Fuel use savings calculated based on 51,783 additional heat pumps installed in Vermont between 2018 and 2023. Assumed breakdown of heat pump types: 86% ductless (76% single-head and 24% multi-head), 12% ducted, 1% air-to-water, 0.4% ground-source (based on Efficiency Vermont DRP). Estimated amount of fossil fuel displacement varied by heat pump type and was calculated based on assumptions outlined in the 2023 Efficiency Vermont Technical Reference Manual. Note: For the purpose of this analysis, heat pumps installed during 2023 were calculated as providing a full year of fossil fuel displacement. This caveat also applies to HPWHs and weatherization in 2023. The actual amount of fossil fuel displacement from 2023 installations is likely lower, given that some of these installed measures were only present for a fraction of that year.

average statewide assumption for fossil fuel displacement per unit is a question worthy of continued evaluation.

Beyond heat pumps for space heating, installations of heat pump water heaters (HPWHs) have also increased over the last several years, displacing fossil fuels used for water heating. Specifically, as of 2022, 17,053 high-efficiency residential heat pump water heaters were installed in Vermont, nearly doubling from 2018 when only 9,460 heat pump water heaters were in operation.[11]

Assuming the same number of HPWHs were installed in 2023 as in 2022, we estimate that the increase in the adoption of HPWHs across Vermont has contributed to about 3% of the observed reduction in fossil heating fuel sales, comparing 2018 and 2023. Specifically, given sales of HPWHs and savings assumptions from the TRM, the installation and use of HPWHs over the six-year period would be expected to result in a reduction of 163,743 MMBtu worth of fossil heating fuel, or about 3% of the total observed decline (5,246,354 MMBtu) in fossil heating fuel sales.[12]

c) The relationship between fossil heating fuel prices and sales

Another variable that could be present is that during times of high fossil heating fuel prices, as in 2022, there is historical evidence of Vermonters reducing fossil fuel use in favor of wood heating.[13] This can happen either when a home or building already has both types of heating systems and the owner or occupant changes the balance between their supplemental or backup heating sources toward wood or when an owner adds new wood heating equipment to reduce or replace fossil fuel use.

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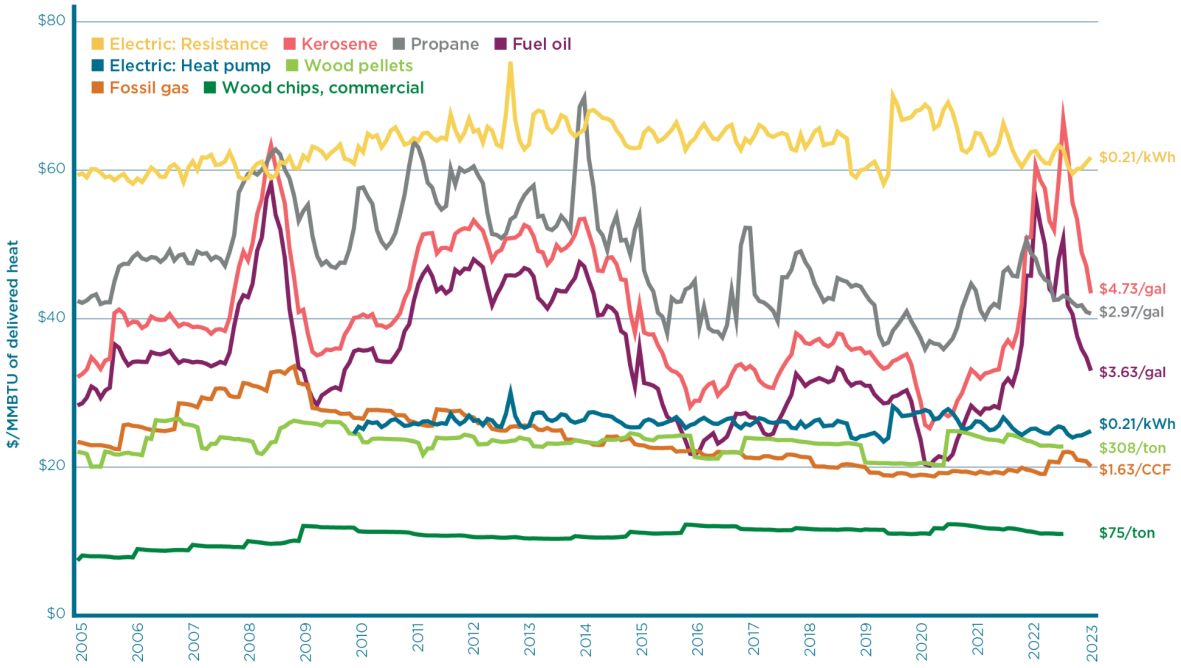
[11] Efficiency Vermont, 2024; Burlington Electric Department, 2024. Note: Heat pump water heater totals include all residential units for which Efficiency Vermont or BED incentives were received. There may be a small number of installations not captured in this data. See more on EAN Vermont Energy Dashboard, 2024. Note: 2023 data are not yet available; for purposes of this analysis annual installations for that year were assumed to be the same as the previous year.

[12] Note: we have more confidence in the projections of fossil fuel reductions associated with the installation and use of HPWHs as compared to CCHPs, since HPWHs are full replacements of fossil fuel water heating equipment, whereas CCHPs are often used in a supplemental way, displacing only some portion of fossil fuel use for space heating, the amount of which varies widely and for which it is more difficult to establish confident estimates.

[13] VEIC for the Clean Energy Development Fund at the Vermont Department of Public Service, "2022 Update: Wood Heat Use in Vermont," 2024.

Cost comparison of different heating fuel options over time (in May 2023 dollars)



Sources: Fuel Oil, Propane, Kerosene: VT Department of Public Service, Fuel Price Report 2023. Fossil gas: VGS, 2023. Electricity: EIA, 2023. Wood Chips, Wood Pellets: Biomass Energy Research Center, 2023. **Notes:** Electricity prices presented here are a statewide average. Electricity prices vary by utility territory. The reason propane is more expensive per MMBTU than fuel oil but less expensive on a per gallon basis is because propane has a lower energy content per gallon. Propane's energy content is only 66% that of fuel oil, by gallon (EIA). Prices reflect data availability at time of publication: through November 2022 for wood fuels and through May 2023 for all others. Prices adjusted for inflation using the Consumer Price Index from the U.S. Bureau of Labor Statistics.

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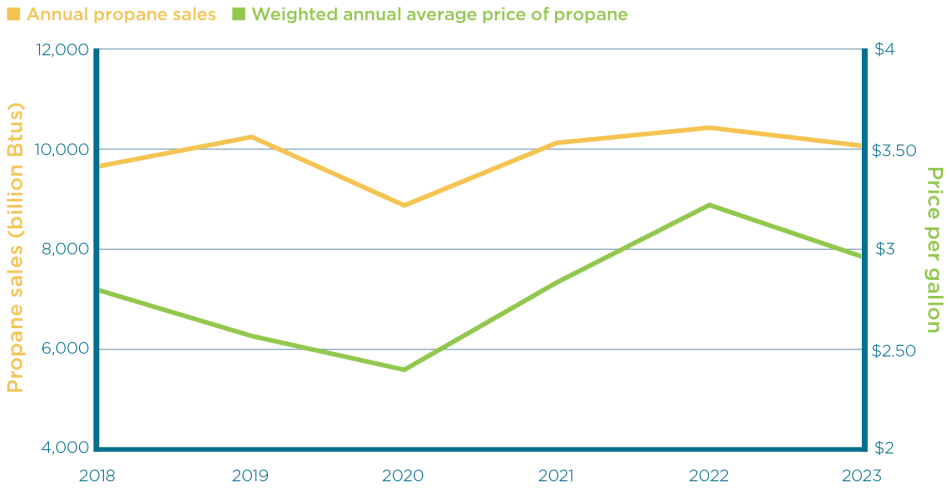
Unfortunately, we are not aware of consistent annual data regarding sales of cord wood or wood pellets, or of wood stoves or pellet stoves, between 2018 and 2023. However, it is important to note that greater use of wood heating likely played some role in the reduction in fossil fuel use between 2018 and 2023. Specifically, there is data to suggest an increase in cord wood and wood pellet sales over this general time period, as estimated in the 2022 update to the "Wood Heat Use in Vermont" report prepared by VEIC.

Beyond reducing or ending dependence on fossil fuels by virtue of moving to other heating options, some (small) portion of the observed decline in fossil heating fuel sales could also have happened as a result of Vermonters turning down the thermostat to use less fuel when fossil heating fuel prices were relatively high, as fuel oil, kerosene, and propane were in 2022.

However, historically the price elasticity of demand has been fairly inelastic for fossil heating fuels, with demand remaining relatively steady regardless of price changes. Although the price elasticity of demand for fossil heating fuels is likely becoming more elastic as alternative heating options achieve greater visibility and maturity in the market, it is nevertheless telling that when fossil heating fuel prices were near historic highs in 2022, their sales were *higher* than they were in 2023, when prices were lower.

As seen in the graphs on the right, there have been multiple years in which fuel oil and propane sales have declined at the same time as their prices were declining. There have also been multiple years in which propane demand increased even as propane prices were increasing. If prices were the primary variable driving demand, we would expect to see an inverse relationship, i.e., demand declining as prices go up and vice versa. Such an inverse relationship is not consistently or predictably apparent in the available data. In summary, the

Propane: Annual average prices vs. sales volumes



Sources: Vermont Department of Taxes, 2024; Vermont Department of Public Service, Retail Prices of Heating Fuels, 2024.

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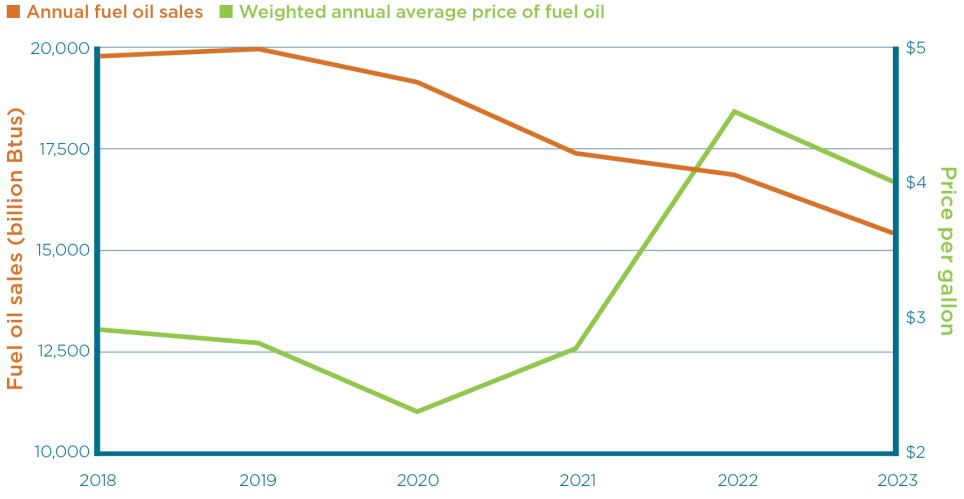
Fuel oil: Annual average prices vs. sales volumes



Sources: Vermont Department of Taxes, 2024; Vermont Department of Public Service, Retail Prices of Heating Fuels, 2024.

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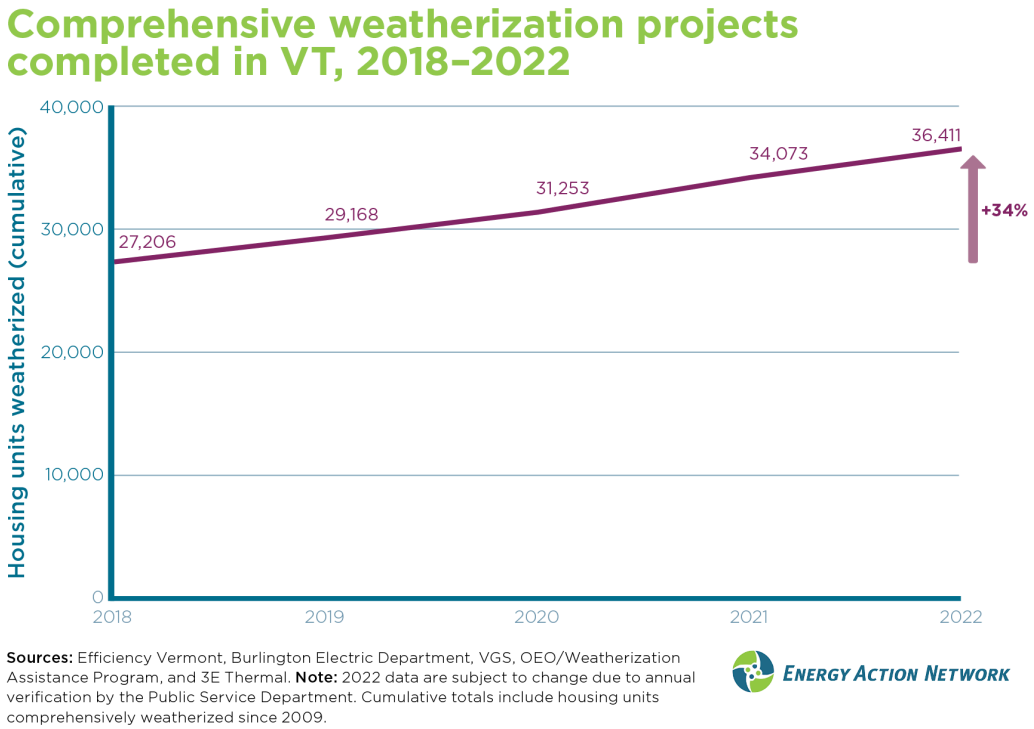
primary variable leading to higher heating fuel sales in 2022 as compared to 2023 was not fuel prices but rather a colder winter with more heating degree days.

d) The role of building and appliance efficiency improvements (weatherization and heating equipment)

Between 2018 and 2022, an average of roughly 2,000 Vermont homes per year were "comprehensively weatherized."[14] Altogether, these projects increased the total number of Vermont homes that have been comprehensively weatherized from 27,206 in 2018 to 36,411 as of 2022—an increase of 34%.



Given the number of Vermont homes weatherized from 2018 - 2022 (and assuming the same number of weatherization projects are completed in 2023 as in 2022) and assuming average energy savings and associated fossil fuel reductions per project as estimated by the Public Service Department, home

[14] "Comprehensively weatherized" refers to projects that achieve average fuel use reductions of at least 25%, consistent with Vermont Public Service Department program criteria and statutory guidance in 10 V.S.A. § 581.

weatherization is potentially responsible for about 4.6% of the observed decline in fossil fuel heating (238,940 out of 5,246,354 MMBtu).[15]

Beyond building efficiency, another type of efficiency that could also be playing a small role in the reduction of fossil heating sales is appliance or equipment efficiency.

Each year, an estimated 10,000 Vermont households replace space heating equipment (primarily boilers and furnaces) and an estimated 20,000 Vermont households replace water heaters.[16] Even when fossil equipment is not replaced with more efficient and cleaner heat pump technology, new fossil fuel boilers, furnaces, and water heaters often have combustion efficiencies that are improvements upon the legacy units they are replacing.

The average efficiency of residential fossil fuel boilers and furnaces (weighted by the prevalence of each type of equipment in Vermont) increased from about 85.9% in 2015 to 87.3% in 2020.[17] If we assume this same rate of increasing efficiency for the period of 2018 to 2023, improved efficiency of residential heating equipment would be responsible for approximately 7% of the total reduction in fossil heating fuel sales (368,172 of 5,246,354 MMBtu).

It is likely that there have also been improvements in fossil fuel heating equipment efficiency in the commercial and industrial sectors. Commercial and industrial buildings also undergo weatherization and building efficiency improvements. However, due to limitations in data availability and inconsistency of data reporting over time, we do not attempt to quantify the potential effect of either of these factors in the commercial and industrial sectors on changing fossil heating fuel sales in this paper.

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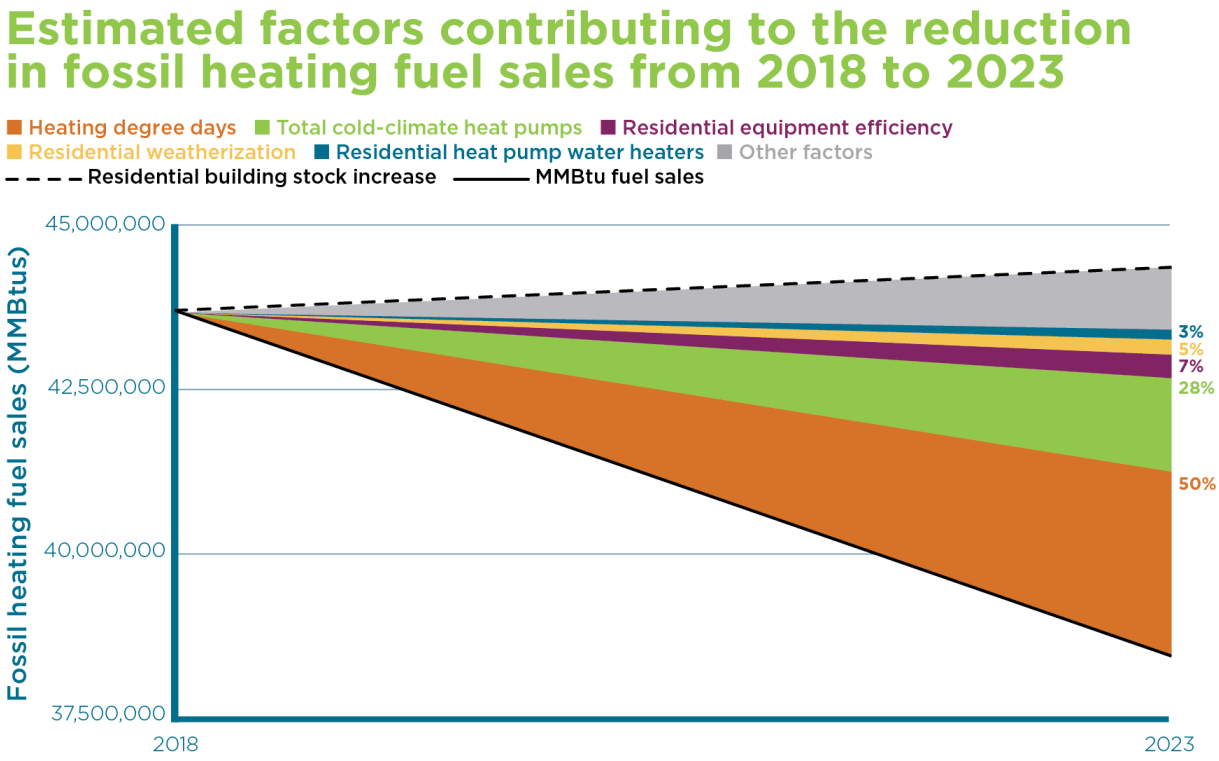
[15] Fuel savings calculated based on a projection of 11,506 additional weatherization projects completed between 2018 and 2023 (note: 2023 data are not yet available; for purposes of this analysis, annual weatherization projects for that year were assumed to be the same as the previous year). Estimate assumes an average annual household heating load of 82.8 MMBtu and an average fuel use reduction of 25% (as reported by the VT Department of Public Service's 2024 Annual Energy Report). MMBtu savings = (82.8 MMBtu x 25%) x 11,506

[16] Estimates derived based on the number of households in Vermont (~260,000) and assumed lifetimes of 12 years for water heaters, 15 years for fossil furnaces, and 25 years for fossil boilers (2021 Efficiency Vermont Technical Reference User Manual). Approximately 72% of Vermont households are single-family homes.

[17] NMR, EFG, and Itron for the Vermont Department of Public Service, 2020 Vermont Single-Family Existing Homes Baseline Study, 2023.

e) Summary of estimated factors in the reduction of fossil heating fuel sales, 2018-2023

Taking each of these factors into account, we can estimate their expected effect on the decrease in fossil heating fuel sales, both individually and collectively, comparing 2018 to 2023. The graph below illustrates the estimated scale of each factor relative to the overall reduction in fossil heating fuel sales.



Note: wedges represent the estimated share of the reduction that each factor may be responsible for, comparing 2018 to 2023 fossil heating fuel sales. The wedges are not meant to suggest that each factor was affecting fuel sales in a linear manner over the time period.

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III. What declining fossil heating fuel sales mean for Vermont's thermal sector GHG emissions

2020 is the most recent year that official statewide greenhouse gas (GHG) inventory data has been published for Vermont. In that year, combustion of fuel oil, kerosene, propane, and fossil gas accounted for 93% of emissions in

the thermal (a.k.a. Residential, Commercial, and Industrial, or RCI fuel use) sector.

Although the Vermont GHG Inventory has not yet been published for 2021, 2022, or 2023, fossil heating fuel sales data from the Tax Department provides most of the information needed to develop an initial estimate for thermal sector, or RCI, emissions in Vermont over the past few years. While total annual fossil heating fuel use (as measured in MMBtus delivered by total fuel oil, propane, and fossil gas sales) declined by about 12% comparing 2023 to 2018, emissions have likely declined by slightly more than 12%. This is because, within that overall drop in fossil heating fuels, different fuels (with different emissions intensities) are seeing differential changes in sales.

Specifically, fuel oil sales declined by about 22% comparing 2023 to 2018. Comparing the same years, propane sales actually increased, by 4%. Fuel oil produces more GHG emissions per MMBtu than propane (74.2 kg of CO_2e per MMBtu of fuel oil vs. 63.1 kg of CO_2e for propane).[18] Because of this differential change in heating fuel sales by fuel type, while sales of total fossil heating fuels, as measured by MMBtus provided, declined by 12% overall, total *emissions* from fossil heating fuel sales have declined by about 13%.

a) Why did propane sales increase while fuel oil sales declined significantly?

The reason(s) for the differential changes in sales of different types of fossil heating fuels are not fully known. While further research is warranted, there are several plausible factors that may help explain the shift away from fuel oil and toward propane, in particular.

One possible contributing factor may be the new regulations on fuel tanks, designed to prevent fuel oil and kerosene spills, that were put in place by the Agency of Natural Resources in 2017. The regulation focused on above-ground storage tanks (ASTs) and was fully implemented by July of 2020.[19]

Between 2018 and 2023, 3,821 residential and commercial fuel tanks were "red-tagged" for being at imminent risk of a fuel spill and were subsequently

[18] EPA, Emissions Factors for Greenhouse Gas Inventories, 2023.
[19] Vermont Agency of Natural Resources, 2017.

removed, repaired, or replaced to be brought into compliance.[20] Another 1,358 fuel tanks that were red-tagged during the same time period have yet to be reported as having been brought into compliance.[21] It is likely that some share of this latter total have not been removed from the red-tag list simply because the customer switched fuel providers and/or fuel systems, and not necessarily because a repair or a replacement didn't happen.[22]

For fuel oil customers whose above-ground fuel tanks had been red-tagged and subsequently removed or replaced, propane may have been seen as an attractive alternative. And, whether precipitated by red-tagging or not, there are several reasons why a household or business might make the switch from fuel oil to propane.

First, unlike with fuel oil, propane providers commonly rent propane tanks, allowing customers to avoid the up-front purchase cost of a new fuel tank for fuel oil.

Second, propane tanks can be stored outside without the gelling that occurs with fuel oil at low temperatures.[23] An outdoor location also allows propane tanks to be sized larger (up to 500 or even 1,000 gallon tanks) than is common for indoor fuel oil tanks (which most commonly have 275 gallons of fuel storage capacity).[24] This can lengthen the amount of time between fill-ups for propane customers: in some instances, home or building owners are able to go a full heating season with a full large-sized propane tank, avoiding the mid-winter fill-ups (when prices are higher and delivery conditions not as favorable) that are often necessary with fuel oil tanks.

Third, after weatherization, reduced air exchange can make it so that oil furnaces or boilers will no longer draft properly, causing a safety issue. In this instance, propane can be attractive as a sealed combustion equipment option. For instance, it is common for homes weatherized through the Weatherization Assistance Program (WAP) to switch from fuel oil to propane.

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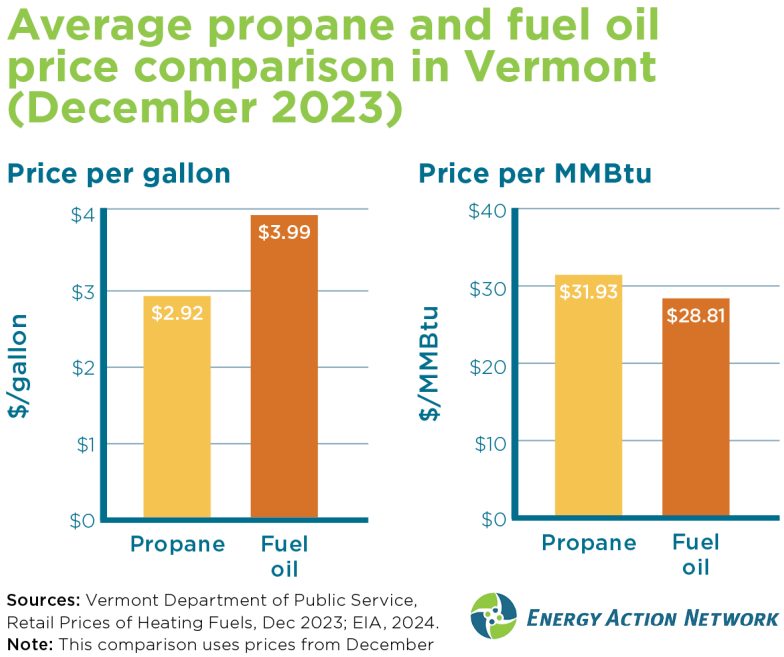
[20] Vermont Department of Environmental Conservation (DEC), 2024.
[21] Vermont DEC. See: https://anrweb.vt.gov/DEC/ERT/RedTaggedAST.aspx
[22] Conversation with Kristin Schultz, Vermont DEC, April 25, 2024.
[23] While kerosene is a low-temperature alternative to fuel oil that can be stored outside, it is usually more expensive than either fuel oil or propane, both on a per gallon and per Btu basis.
[24] Additionally, if a propane tank leaks, it results in gas going into outdoor air versus a leak from a fuel tank, which results in fuel oil on the ground at someone's home or business, likely necessitating more troublesome and expensive clean up.

Fourth, when a fuel tank and/or a fuel oil furnace or boiler is at the end of its life, some fuel dealers who sell both fuel oil and propane are reported to encourage their fuel oil customers to switch to propane.[25] A driving factor in this sales pitch is understood to be that there are usually larger profit margins for fuel dealers in selling propane as compared to fuel oil.

It is possible that some consumers are also influenced to switch to propane from fuel oil based on per gallon price comparisons. However, it is important to note that per gallon prices are an incomplete and misleading comparison between these two fuels.

Specifically, while the per gallon retail price for propane has historically been lower than the per gallon retail price for fuel oil, the price per delivered MMBtu – or the price for the same amount of delivered heat – has historically been *higher* for propane. This is because the energy content in a gallon of propane is much lower—only 66%—than that of a gallon of fuel oil.[26] Hopefully, switches from fuel oil to propane are not being driven by consumers being misled by a lower price per gallon, because they are actually very likely to pay *more* for the same amount of heat relative to fuel oil, given the lower energy content of propane and historic retail price comparisons between the two fuels.



Sources: Vermont Department of Public Service, Retail Prices of Heating Fuels, Dec 2023; EIA, 2024.
Note: This comparison uses prices from December 2023 for illustration. The relationship shown here has been generally consistent over time.

However, anecdotal information suggests that some customers are able to purchase propane at prices well below the retail rate. The reason for this may

[25] Interview with former executive of a Vermont fuel provider, April 3, 2024.
[26] U.S. Energy Information Administration, Monthly Energy Review: Appendix A, 2024.

be due, in part, to less price volatility for wholesale propane as compared to wholesale fuel oil. This is reported to allow fuel dealers to use future contracts to account for less risk in propane prices. Generally, there is also a much larger difference between wholesale and residential prices for propane vs. for fuel oil.[27]

Some of the larger gap between wholesale and residential prices for propane is likely also due to higher costs facing propane providers for infrastructure, equipment, and delivery, as compared to fuel oil. The differences in wholesale price volatility between propane and fuel oil, as well as the larger price differential between wholesale and residential prices of propane, may allow propane providers a greater degree of price discrimination, leading to greater variation in what is actually charged to different propane customers depending on a number of factors, including what volume of fuel they are purchasing and over what period of time.

Finally, when it comes to new construction, propane is reported to be a more attractive option than fuel oil to home builders because of its multi-use versatility. Specifically, propane can provide space heating, water heating, cooking, and/or be connected to a fireplace whereas fuel oil is most commonly used just for space heating.[28]

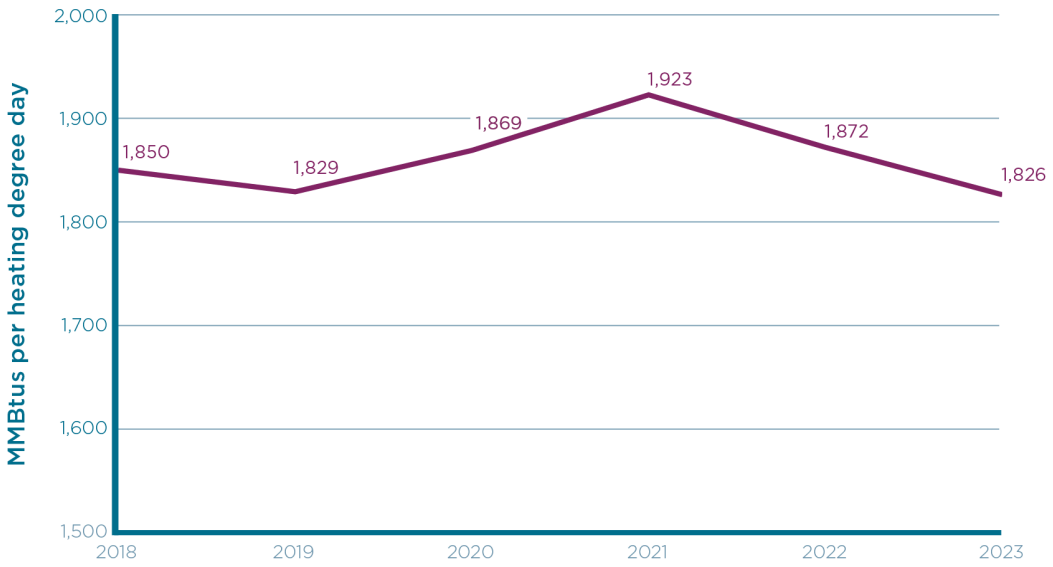
b) Fossil gas sales declined even with more customers

Fossil gas sales declined about 9% between 2018 and 2023. At first, this seems right in line with what we would expect due to warmer winters and fewer heating degree days alone (an 8% decline in HDDs over the same period), all else being equal. Indeed, when looking at weather-normalized fossil gas sales from 2018 to 2023, as shown in the graph on page 21, they are essentially unchanged.

[27] For example, for the week of April 8th, 2024 the wholesale price of propane was $1.09, compared to a residential price of $3.55 – a difference of $2.46 per gallon. In contrast, during the same week, the wholesale price of fuel oil was $3.30, compared to a residential price of $4.09 – a difference of only 79 cents per gallon. See: https://www.eia.gov/dnav/pet/pet_pri_wfr_a_EPLLPA_PWR_dpgal_w.htm and https://www.eia.gov/dnav/pet/PET_PRI_WFR_DCUS_SVT_W.htm

[28] Interview with former executive of a Vermont fuel provider, April 3, 2024.

Weather-normalized fossil gas sales in Vermont, 2018–2023



Sources: Fossil gas sales: VGS, 2024; Fuel heat content conversion factors: U.S. Energy Information Administration, 2023. Heating degree days: NOAA Climate Prediction Center, 2023.

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However, all else was not equal: the VGS customer base increased by about 5% during this same period, growing from 52,748 customers in 2018 to 55,637 customers in 2023. This period of time also saw the VGS pipeline network increase by 3%, from 972 miles in 2018 to 1,005 miles in 2023.[29] The increase in the VGS customer base over this period would include both existing homes and buildings that switched from fuel oil or propane to fossil gas as well as new construction.

For this reason, the decline in fossil gas sales that we might have expected to occur solely from fewer heating degree days does not fully explain the trend of fossil gas sales over the period. Given an increasing number of customers during the same time, factors beyond warmer winters are likely also contributing to fossil gas sales trends, especially the weather-normalized decline visible in 2022 and 2023. Those other factors likely include some combination of increasing use of heat pumps and HPWHs, additional weatherization, and increasing equipment efficiency.

[29] VGS, 2024.

Interestingly, Burlington saw much more significant declines in fossil gas sales than other parts of VGS territory. Specifically, fossil gas sales declined by 19% in Burlington from 2018 to 2023, compared to the 9% decline in overall fossil gas sales in Vermont.[30] The main reason for this lies in large differences between residential and commercial fossil gas consumption in Burlington. 75% of fossil gas use in Burlington is by commercial customers, while only about 25% is by residential customers. While sales of fossil gas to residential customers were roughly in line with the decline in heating degree days comparing 2018 to 2023 (a 9% reduction), sales to commercial customers, where most fossil gas is used, declined by 21%.[31]

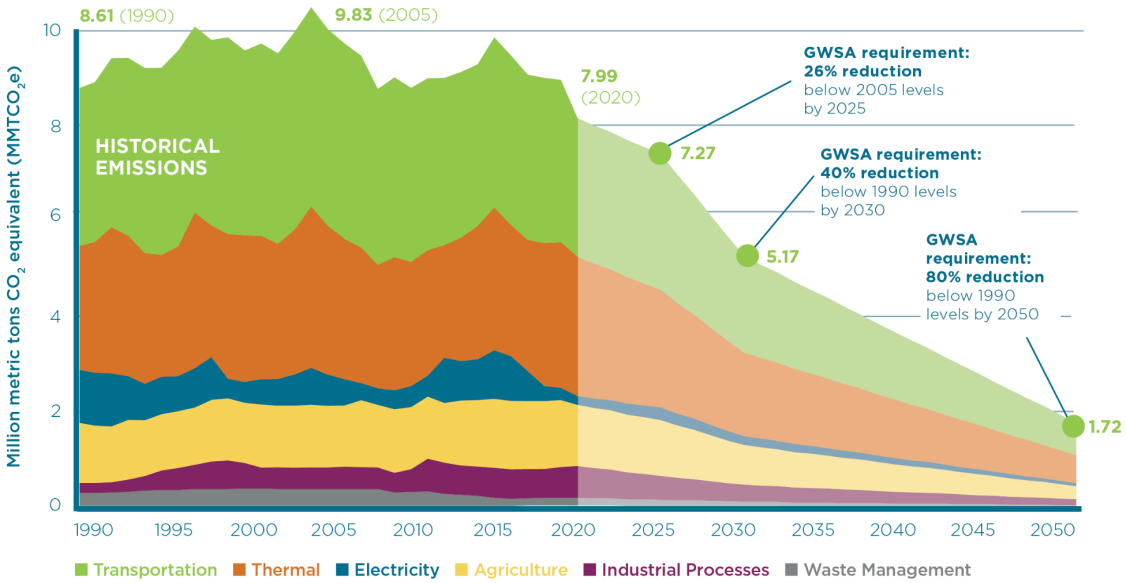
IV. Implications for compliance with Vermont legal obligations for emissions reduction

a) Global Warming Solutions Act (GWSA) compliance

The Global Warming Solutions Act (Act 153 of 2020) established legal obligations for Vermont to reduce its statewide GHG emissions by at least 26% below 2005 levels by January 1, 2025; by at least 40% below 1990 levels by 2030; and by at least 80% below 1990 levels by 2050. These targets represent Vermont doing our part toward international, science-based commitments made by the United States, including the Paris Climate Agreement.

[30] Burlington Electric Department, Net Zero Energy Update, 2023.
[31] Burlington Electric Department, 2024.

Vermont's historical GHG emissions and future requirements



Source: Vermont Agency of Natural Resources, Vermont GHG Emissions Inventory and Forecast: 1990-2020, 2023. **Notes:** There is a small amount of emissions from the "fossil fuel industry" category (i.e. fugitive emissions from fossil gas pipelines in VT), accounting for 0.3% of Vermont's overall emissions in 2020, that does not show up on this graph. The ANR projections for 2025 and 2030 are from Vermont's 1990-2020 GHG inventory, published in 2023, and reflect a business-as-usual scenario, including the impact of ACCII.

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To assess the relative responsibility of each sector in achieving statewide emissions reduction requirements, the Vermont Climate Council established 2018 as the reference year for determining sectoral proportionality (the most recent year for which GHG emissions were available at the time of the Initial Climate Action Plan).[32] In 2018, the thermal sector was responsible for one-third of Vermont's greenhouse gas emissions.

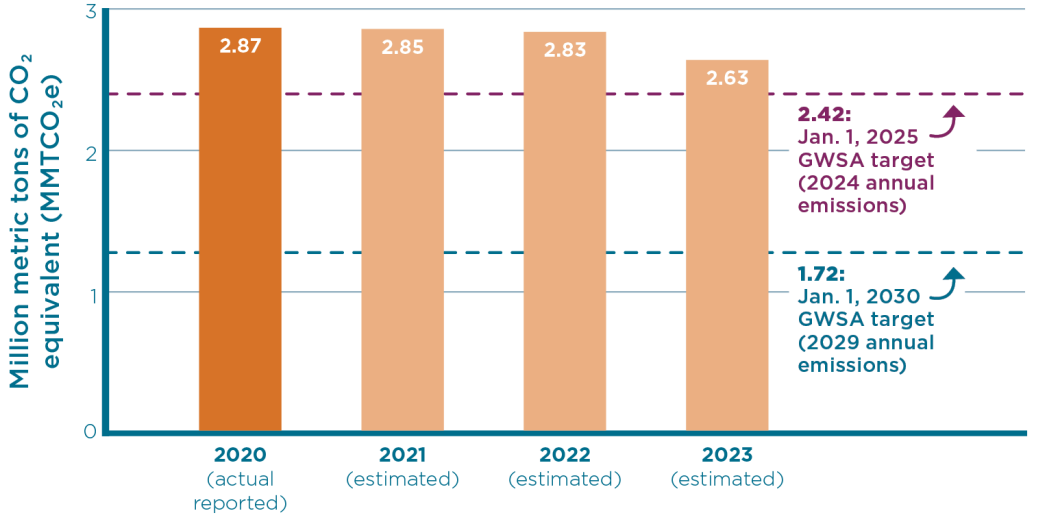
To comply with the GWSA's January 1, 2025 deadline, the economy-wide maximum amount of GHG pollution allowed for Vermont in 2024 is 7.27 million metric tons of CO_2-equivalent ($MMTCO_2e$). One-third of that total is 2.42 $MMTCO_2e$. Therefore, 2.42 $MMTCO_2e$ is the target for thermal sector emissions to fall at or below in 2024.

Using 2023 fossil heating fuel sales volumes, appropriate emissions factors by fuel type, and historical data, we can interpolate an initial estimate of 2023

[32] See October 2021 Vermont Climate Council Memo and October 2021 Vermont Climate Council meeting minutes.

GHG emissions from the thermal sector: 2.63 $MMTCO_2e$.[33] If that estimate is correct, it would mean that Vermont would need to see a reduction of another 0.21 $MMTCO_2e$ in thermal sector emissions in 2024 to meet the thermal sectoral proportional reduction target to help achieve GWSA compliance by January 1, 2025. This would represent an 8% decline in thermal sector emissions from 2023 to 2024.

Vermont GHG emissions in the thermal sector



Sources: For 2020 emissions: Vermont Agency of Natural Resources, "Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990-2020," 2023. For 2021-2023 emissions estimates: Vermont Department of Taxes, VGS, and EIA emissions factors. For 2024 emissions: Vermont Global Warming Solutions Act, 2020, Vermont Climate Council, October 26, 2021.

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There is only one instance in the last twenty years of Vermont GHG inventory data of a year to year decline in thermal sector emissions of this magnitude or higher: a 10% decline from 2011 to 2012. And while greater emissions reductions are possible to achieve with increasing amounts of weatherization and efficient electric or renewable heating use, we are not yet seeing those activities occur at a scale and pace that would correspond with the required levels of pollution reduction.

[33] Estimate based on CO_2e emissions factors from the U.S. EPA. 2023 emissions based on sales of fuel oil, propane, and fossil gas for heating were equivalent to 2.45 $MMTCO_2e$. A multiplier of 1.073 was applied to account for the ~7% of emissions from other sources (2.45 X 1.073 = 2.63 $MMTCO_2e$).

Historical Vermont GHG emissions and future sector targets

	ACTUAL REPORTED EMISSIONS ($MMTCO_2e$)				EMISSIONS TARGETS ($MMTCO_2e$)	
	1990	**2005**	**2018**	**2020**	**2025**	**2030**
Transportation	3.25	4.05	3.40	2.85	2.80	1.99
Thermal	2.54	3.06	2.94	2.87	2.42	1.72
Electricity	1.09	0.64	0.31	0.18	0.26	0.18
Fossil fuel industry	0.02	0.02	0.03	0.03	0.02	0.02
Agriculture	1.24	1.27	1.40	1.26	1.15	0.82
Industrial processes	0.21	0.44	0.59	0.65	0.49	0.35
Waste management	0.27	0.35	0.16	0.16	0.13	0.09
Total	**8.61**	**9.83**	**8.83**	**7.99**	**7.27**	**5.17**

Sources: Vermont Agency of Natural Resources, "Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990–2020," 2023; Vermont Global Warming Solutions Act, 2020. Vermont Climate Council, October 26, 2021.

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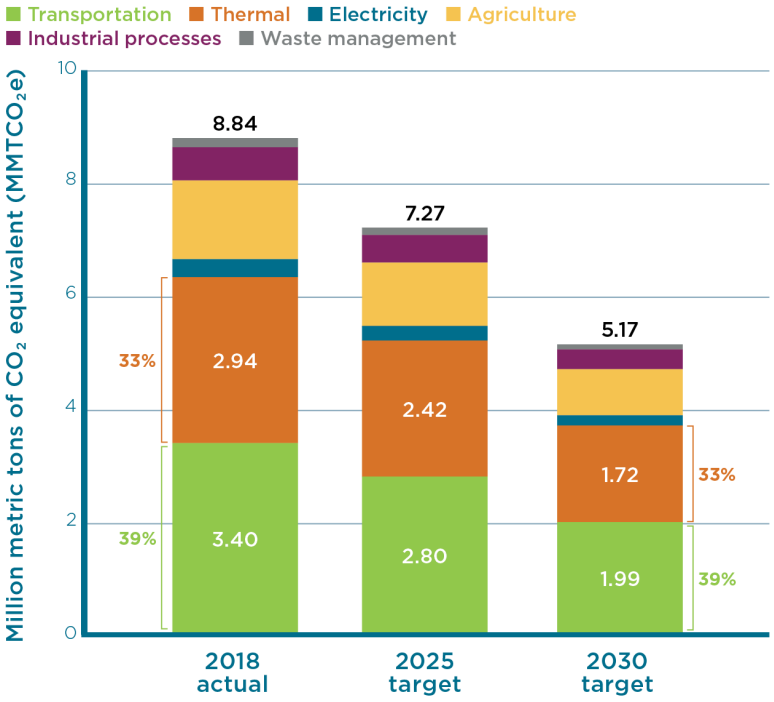
Given recent trends, whether Vermont meets the first thermal sector target in alignment with the GWSA is likely to depend on how relatively warm or cold the 2024 heating season is. Initial data for January and February 2024 suggest that Vermont has a chance to record its warmest heating season ever (note that "meteorological winters" span calendar years – December, January, and February – whereas the 2024 heating season will include the beginning and end of the calendar year, primarily January-March, for which temperatures are known, and

Vermont GWSA emissions reduction targets: Sectoral proportionality



Sources: Vermont Agency of Natural Resources, "Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990-2020," 2023; Vermont Global Warming Solutions Act, 2020. Vermont Climate Council, October 26, 2021. **Note:** There is a small amount of emissions from the "fossil fuel industry" category (i.e. fugitive emissions from fossil gas pipelines in VT) that does not show up on this graph.

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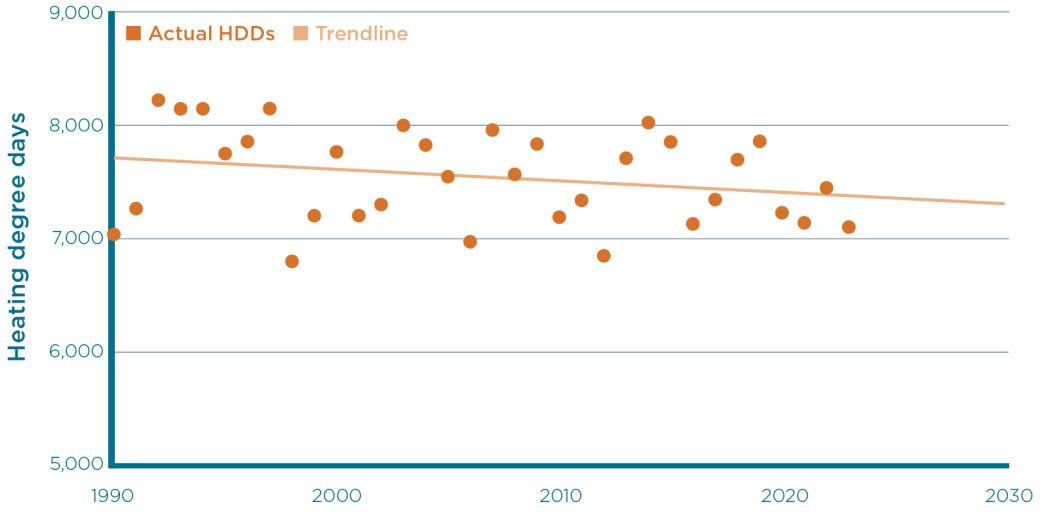
then October-December, for which temperatures are not yet known).[34]

It is worth noting that Vermont's efforts to reduce climate pollution and do our part to address climate disruption are, ironically, being aided by the very global heating that we are working to do our part to help minimize. However, relying on warmer winters to reduce emissions from fossil heating fuel use is not a sustainable strategy. While there is a general warming trend affecting Vermont winters, what that means for temperatures—and therefore fuel use—in any given year is still subject to variation and unpredictability. To be less dependent on the whims of weather—so that we are not counting on record-breaking warm winters to meet thermal sector emissions reduction targets—more concerted efforts to help customers install and properly operate heat pumps for both space and water heating and complete weatherization projects will be necessary to achieve more predictable and durable emissions reductions.

Vermont annual heating degree days, 1990–2023



Source: NOAA Climate Prediction Center, Vermont population-weighted heating degree day data, 1990-2023.

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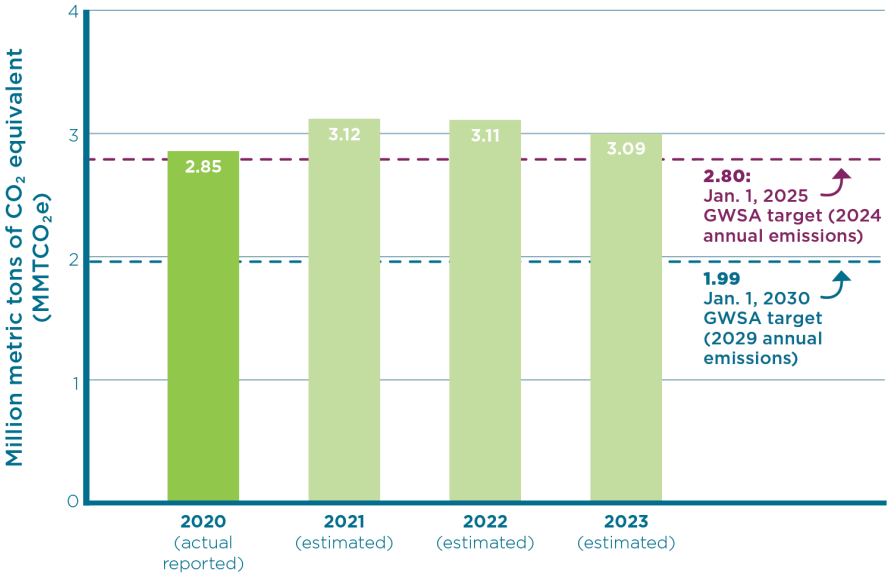
While it is technically possible that the thermal sector could meet its sectoral emissions target by January 1, 2025, other heavily polluting sectors are even less likely to do so, making meeting Vermont's statewide emissions reduction obligation for 2025 exceedingly unlikely.

[34] Vermont Public, "Record warm winter all but guaranteed for parts of Vermont, New York," 2024.

Specifically, the transportation sector is the other major source of climate pollution in Vermont (responsible for 36% of GHG emissions in 2020). We anticipate that 2023 transportation emissions, interpolated from gasoline and diesel fuel sales from that same year, are likely to be approximately 3.09 $MMTCO_2e$.[35]

Vermont GHG emissions in the transportation sector



Sources: For 2020 emissions: Vermont Agency of Natural Resources, "Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990-2020," 2023. For 2021-2023 emissions estimates: Vermont Department of Taxes and EIA emissions factors. For 2024 emissions: Vermont Global Warming Solutions Act, 2020, Vermont Climate Council, October 26, 2021.

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To meet the sectoral proportionality target for the transportation sector in 2024 – i.e., for the transportation sector to do its part toward meeting the first GWSA compliance deadline – transportation sector emissions would need to be 2.80 $MMTCO_2e$. That would represent a 10% decline in emissions in just one year.

Historically, the only instance of such a steep decline in transportation emissions occurring was from 2019 to 2020, when transportation emissions plummeted 15% due to the vehicle miles traveled reductions associated with the COVID-19 pandemic. The next largest year to year decline in Vermont transportation emissions was by 8%, from 2007 to 2008, during the Great Recession.

Again, the way to achieve more predictable and durable declines in emissions is not to count on unlikely (and harmful) events such as recessions and pandemics—it is to transition away from fossil fuel use by scaling more efficient and electric transportation options. Right now, EV adoption and

[35] Estimate based on CO_2 emissions factors from the U.S. EPA. 2023 emissions based on sales of gasoline and diesel for transportation were equivalent to 2.97 $MMTCO_2e$. A multiplier of 1.041 was applied to account for the ~4% of emissions from other sources (2.97 X 1.041 = 3.09 $MMTCO_2e$).

other fossil fuel reduction measures are not occuring at the scale and pace necessary to meet near term emissions reduction obligations.

There is, however, one sector where emissions are likely to be below their sectoral proportionality target by January 1, 2025: the electricity sector. To meet its sectoral proportionality target for the first GWSA compliance deadline (Jan. 1, 2025), the electricity sector would have to be below 0.26 $MMTCO_2e$ in annual emissions for 2024. As of the latest Vermont GHG Inventory and Forecast, in 2020, the electricity sector accounted for 0.18 $MMTCO_2e$, already .08 $MMTCO_2e$ below its January 1st, 2025 sectoral target.

This anticipated "extra" reduction would help offset a lack of emissions reduction progress in other sectors, but only to a relatively small degree because the electricity sector is a relatively small contributor to Vermont's GHG emissions. With every other sector likely to be at or above its proportional share of emissions in 2024, another .08 $MMTCO_2e$ is a fairly small "surplus" of reductions to make up for the expected deficits in needed reductions across the other sectors.

b) Implications for Clean Heat Standard compliance

Thermal sector emissions reduction requirements are referenced in the Affordable Heat Act (Act 18 of 2023), with the expectation that the thermal sector will meet its proportional share of emissions reduction to contribute to the 2030 GWSA obligation. By January 1, 2030—which means 2029's annual emissions total—the maximum thermal sector-wide emissions threshold is 1.72 $MMTCO_2e$. That would be a 35% decline in thermal sector emissions, comparing estimated 2023 thermal sectoral emissions to the 2029 annual sectoral proportionality target.

If we were to see the same degree of warming from 2024-2029 that we saw from 2018-2023, the result would be only an 8% decline in thermal sector emissions from warming alone. That said, there is a fair amount of variation along that trend line (see graph on page 26) and 2029 could easily be a warmer *or* a colder than average winter.

In order to achieve thermal sector emissions reduction targets without relying primarily on an abnormal amount of winter warming, significantly more

displacement and/or replacement of fossil heating fuels (i.e., via weatherization, cold climate heat pumps, heat pump water heaters, etc.) will be necessary. These non-fossil fuel heating solutions are the best way to confidently and durably achieve emissions reductions in the thermal sector, no matter what the weather-dependent heating needs in Vermont will be going forward.