VERMONT DEPARTMENT OF PUBLIC SERVICE – CLEAN HEAT STANDARD ASSESSMENT OF THERMAL SECTOR CARBON REDUCTION POTENTIAL IN VERMONT

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EXECUTIVE SUMMARY

To support the implementation of the Affordable Heat Act, which became law on May 11, 2023, Act 18 requires the Vermont Department of Public Service to conduct and complete a potential study with the overall objective to assess and quantify the technical, economic, and max achievable potential for thermal sector resources. NV5, in partnership with Energy Environmental Economics ("E3"), completed a thermal sector potential study analyzing Technical, Maximum Achievable, Act 18 Optimized and Economic potential to develop a comparison to the legal obligations of the thermal sector portion of the requirements of the Global Warming Solutions Act ("GWSA").

This report presents:

- **Technical Potential**, which represents a theoretical maximum for emissions reductions from individual measures.

- **Maximum Achievable Potential**, which represents the total potential of clean heat measures including interactive effects and non-financial market barriers.

- **Act 18 Optimized Potential,** which presents optimized results that prioritize cost efficient lifecycle emissions reductions and that help meet the specific policy priorities in Act 18. These requirements include the portion of clean heat credits going to low- and moderate-income households and declining carbon intensity requirements for clean fuels.

- **Economic Potential,** which quantifies the portion of the Optimized Potential that passes the Vermont Societal Cost Test.

Figure E1 below shows the thermal sector emissions for each year in the analysis period for the Act 18 Optimized scenario. As shown, the scenario meets the GWSA targets in both 2030 and 2050. This scenario resulted in $9,623 million in societal costs and $11,737 million in societal benefits for a total of $2,114 million in societal net benefits. Note that this analysis focuses on societal costs and is not meant as an implementation plan analyzing actual program costs needed to implement Act 18. In an actual program, significant participation can be achieved without incentives that cover the full cost of the measures. In addition, there are large existing funding streams available from federal and other state and local programs, such as from the IRA, tax credits, and Energy Efficiency Utilities, that can contribute to GWSA target achievement. While this study focuses on the impacts of a program in isolation to support Act 18, Section 5.3 of the report estimates an additional $1.5 billion available from these other funding sources through 2049.

Figure E1: Act 18 Optimized Net RCI Emissions and GWSA Targets

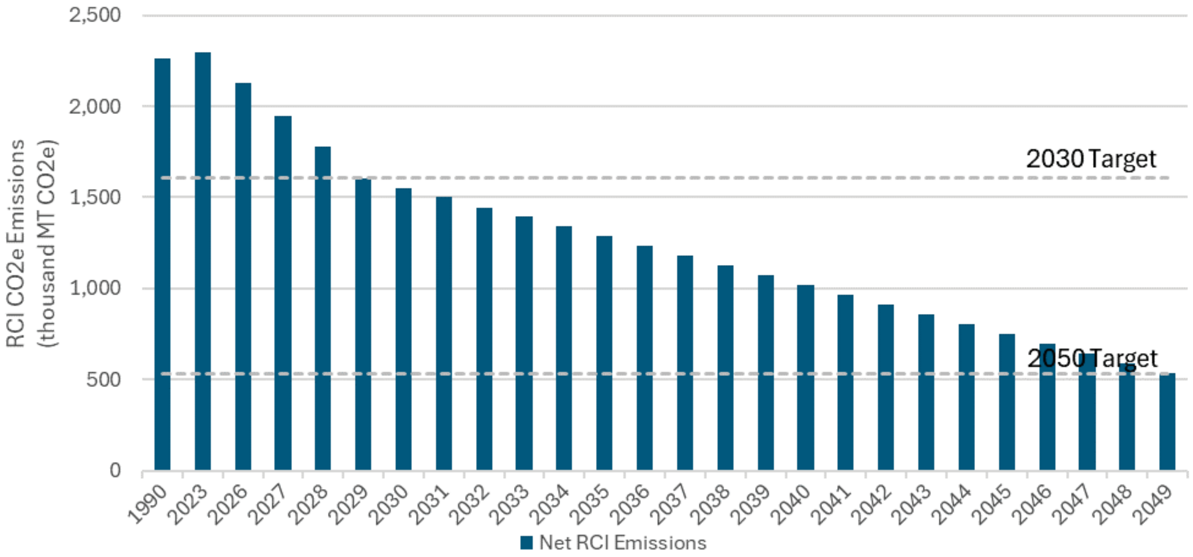
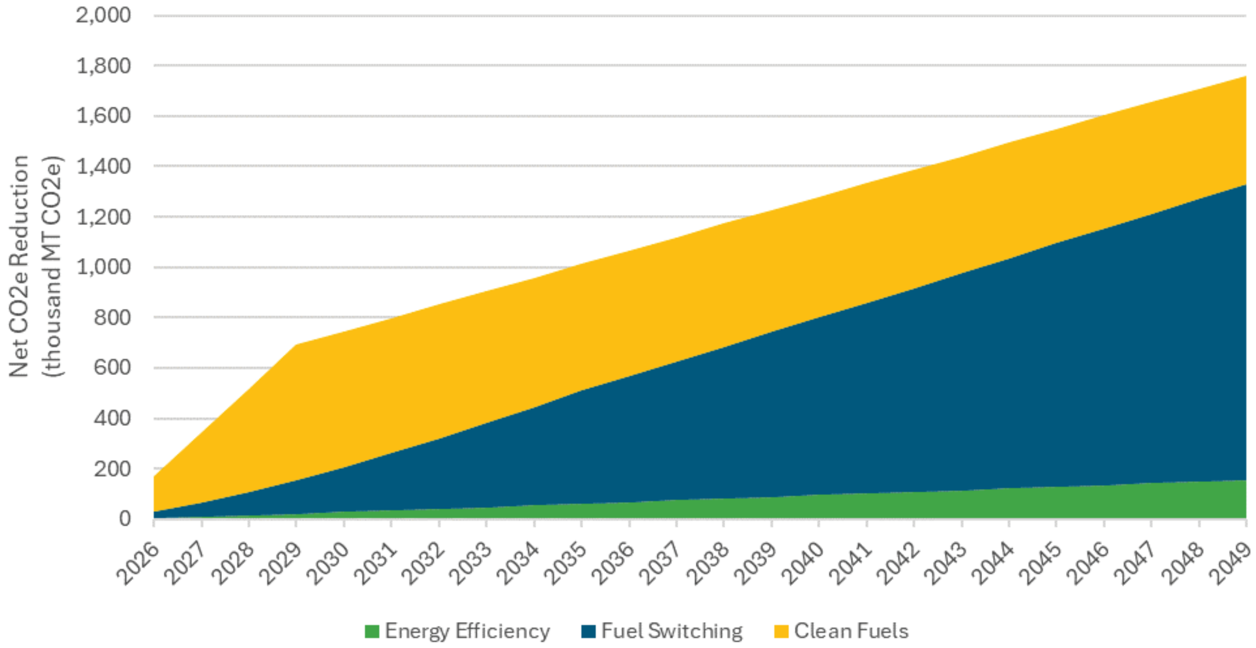


Figure E2 below shows the CO2e emissions reductions by measure type for the optimized scenario. As presented, the 2030 GWSA target is heavily reliant on clean fuels, which have low costs per lifetime lifecycle emissions reductions, particularly compared to fuel switching. However, the contribution from fuel switching steadily ramps up over time, and it is the most significant contributor to the 2050 goal.

Figure E2: Act 18 Optimized Cumulative Annual GWSA Emissions Reduction by Measure Type



In addition, this report includes a supplemental analysis looking at Vermont's workforce's capacity to support the extra demand likely to be generated by Act 18. This analysis examines the gap between the current workforce capacity and the workforce potentially needed to support the activity required in the Act 18 Optimized scenario. The results show significant variation in this gap from measure to measure, with the most significant deficit in the weatherization workforce—a highly labor-intensive opportunity compared to equipment installations and clean fuels. See Section 3.0 of the report for more details.

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1.0 BACKGROUND

The Clean Heat Standard ("CHS"), created under Act 18, requires obligated entities to reduce greenhouse gas emissions attributable to the Vermont thermal sector by retiring required amounts of clean heat credits to meet the thermal sector portion of the greenhouse gas emission reduction obligations of the Global Warming Solutions Act[1]. Obligated parties include Vermont Gas, entities that import fuel oil and propane for ultimate consumption within the State, or entities that produce, refine, manufacture, or compound heating fuel within the State for ultimate consumption within the State. A clean heat credit is defined by Act 18 as "a tradeable, nontangible commodity that represents the amount of greenhouse gas reduction attributable to a clean heat measure." Clean heat measures are fuel delivered and technologies installed to end-use customers in Vermont that reduce greenhouse gas emissions from the thermal sector.

This report presents the results of the potential study required by Section 8125(e)(1)(A) of Act 18, estimating the technical, economic, and maximum achievable potential for greenhouse gas reduction in Vermont from the Clean Heat Standard. The results include a comparison to the legal obligations of the thermal sector portion of the requirements of the Global Warming Solutions Act ("GWSA").[2] The potential study also includes an evaluation of market conditions for the delivery of clean heat measures within the State relative to the current, business as usual and future workforce characteristics to meet the obligations of the GWSA.

The scope of the potential study analysis is the "thermal sector" which is the same as the Residential, Commercial and Industrial Fuel Use ("RCI") sector used in the Vermont Greenhouse Gas Emissions Inventory and Forecast ("Inventory"). The RCI sector includes greenhouse gas emissions mainly from building energy use, and emissions in this sector are mostly from fuel oil, propane, and natural gas used for heating buildings, heating water, and cooking.[3]

It is important to note that while the CHS is designed as a tool to meet the requirements of the GWSA, Act 18 defines the value of clean heat credit in terms of *lifecycle* CO2e emission reductions inclusive of emissions from feedstock production and transportation, fuel production and distribution, and use of the finished fuel. However, GWSA achievement is assessed with the VT Inventory which, with certain exceptions, only considers the use phase of energy commodities consumed within Vermont. As quantifying the thermal sector potential relative to GWSA requirements is a primary objective of this study, unless otherwise noted, the values presented herein are consistent with VT Inventory methods of emissions accounting.

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[1] https://legislature.vermont.gov/Documents/2024/Docs/ACTS/ACT018/ACT018%20As%20Enacted.pdf

[2] 10 V.S.A. § 578(a)(2) and (3)

[3] For the purposes of this study, kerosene consumption has been included in the fuel oil totals and treated as fuel oil with respect to costs and emissions factors. Given that kerosene it typically more expensive than fuel oil per MMBtu, this analytical simplification may slightly penalize the fuel switching economics of buildings heated with kerosene as the baseline fuel.

2.0 METHODOLOGY

2.1 TYPES OF POTENTIAL CALCULATED

Technical Potential

The Technical Potential represents the theoretical maximum potential for greenhouse gas reduction, with no consideration of economic or market barriers. For example, in a region with 100,000 oil heated homes, the Technical Potential for an oil-to-electric fuel switch measure would represent the costs and savings associated with all 100,000 homes installing heat pumps. For clean fuels, the Technical Potential is the lesser of the technical availability of the renewable fuels/biofuels or the total usage of the baseline fuel. For this study, the Technical Potential assumes all technologically feasible measures could be installed instantaneously where, for the purposes of quantifying impacts relative to GWSA targets, the resulting emissions reductions persist over the entire 24-year analysis period (2026–2049). The exception to this is the treatment of biofuels and renewable fuels which, as they are assumed to have a one-year measure life, must be implemented annually to yield persisting emissions reductions. The technical potential results therefore reflect the measure-level Technical Potential without any consideration of competing measures (i.e., mutual exclusivity) and measure interactions. These results provided a useful steppingstone to developing the Maximum Achievable and Act 18 Optimized scenarios, as described below.

Maximum Achievable Potential

The Maximum Achievable potential reflects the total potential that is possible assuming the existence of idealized implementation programs offering financial incentives covering the full incremental costs of the measures. This is examined by applying measure adoption curves that recognize that adoption does not occur instantaneously, and that, even without out-of-pocket incremental costs, technologies will not achieve 100% adoption. The Maximum Achievable potential looks at the total potential of all measures and therefore includes the impacts of measure competition (i.e., mutual exclusivity) and measure interactions. For this study, the Maximum Achievable potential does not screen out measures for cost-effectiveness and assumes non-incentive program costs (e.g., administration, marketing, technical assistance, and evaluation) of 3% for biofuel measures and 15% for energy efficiency and fuel switching measures as a percentage of total estimated incentives. Incentives are assumed to cover the full incremental costs of the measures. As the vast majority of the modeled energy efficiency and fuel switching measures in the analysis are modeled as time-discretionary retrofits, the incremental costs equal the total installed costs as the base case option is to take no action. Total installed costs include the total estimated equipment and labor costs a participant would pay for the installation of clean heat measures. For biofuels and renewable fuels, incremental costs were calculated as the difference in cost between the baseline fuel and the clean fuel.

The Maximum Achievable potential assumes all the measures that could be implemented are implemented, regardless of economics or whether the GWSA targets have already been met. It assumes that energy efficiency measures are implemented first, then fuel switching, and that clean fuels serve the remainder of baseline fossil fuel load that isn't addressed by these measures.

Act 18 Optimization Potential

The Act 18 Optimized potential scenario optimized results to prioritize program cost efficient lifetime lifecycle emissions reductions and to meet other policy priorities in Act 18 – primarily the requirements around the minimum portion of credits coming from low- and moderate- income households. To optimize for cost-effectiveness, we eliminated adoption of the most expensive measures, on an incentive $/lifetime lifecycle emission reduction basis, until the 2050 GWSA targets are met. This resulted in a significant reliance on clean fuels in the early years of the analysis period, as these measures are less expensive than most efficiency and fuel switching measures on an incentive $/lifetime lifecycle emissions reduction basis and even cheaper when using the GWSA accounting. That said, there are significant emissions in areas that can't be addressed by clean fuels: primarily that 1) renewable propane is considered unavailable due to its very low current production rate with renewable diesel,[4] and 2) limits on technical availability of biomethane, and blending limits on hydrogen, as replacements for natural gas. Due to these limitations, additional contributions from weatherization and fuel switching are needed to meet the GWSA 2050 target. Note also that, even though we evaluated $/lifetime lifecycle emissions reduction and cost-effectiveness using an effective useful life (EUL), we assume that fuel switches would persist once the original fuel switching equipment, like a heat pump, needs replacement. In other words, we assume once someone electrifies their thermal loads, they decommission their existing fossil fuel heating system and do not switch back to fossil heat in the future. See the results section for more detail.

Economic Potential

In a typical Maximum Achievable potential for energy efficiency, measures that do not pass the relevant cost test are screened out of the potential. However, because the Clean Heat Standard and GWSA do not have explicit cost-effectiveness requirements, the cost-effectiveness screen is only applied to the Maximum Achievable and Act 18 Optimized potential to estimate the portion of the identified potential that is economic vs. uneconomic according to the VT Societal Cost Test. Components of the VT Societal Cost Test can be found in Table 1 below. Note that this scenario is for reporting purposes only (i.e., opportunities are not removed from the analysis based on societal cost-effectiveness). While not documented in the table below, the cost-benefit analysis also accounts for avoided future capital costs in cases where a participant would have needed to purchase new baseline equipment had they not replaced their equipment prior to failure (sometimes referred to as the "deferred replacement credit"). Note that the Income-eligible Non-Energy Benefits (beyond the base 15% adder for Non-Energy Benefits), Weatherization Health Benefits, and Electric Risk Discounts were not applied as the appropriate application of these values is uncertain for Clean Heat measures. In addition, these impacts would be applied to electric load building from fuel switching as well as decreases in electricity and fuel consumption and would therefore partially offset each other as the

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[4] Currently, 4.5 million gallons per year of propane are as byproduct alongside renewable diesel production, primarily in California or Louisiana (https://afdc.energy.gov/fuels/propane-renewable), corresponding to approximately 0.5 TBTU/yr nationally. A population-weighted share of today's renewable propane would yield around 10,000 MMBTU/yr for VT, which corresponds to about 0.1% of the state's total LPG consumption (https://www.eia.gov/state/seds/sep_sum/html/pdf/sum_use_tx.pdf). While renewable diesel and sustainable aviation fuel production are expected increase and the value proposition for renewable propane or renewable LPG are quite strong, the volumes of either fuel are not likely to increase substantially within the next decade (https://www.nrel.gov/docs/fy23osti/83755.pdf).

Income-eligible Non-Energy Benefits and Weatherization Health Benefits adders are applied to both increased and decreased electricity/fuel consumption.

Benefits	**Costs**
Avoided Electric & Natural Gas Energy Supply Cost	Measure Cost (over baseline)
Avoided Electric Generation Capacity Supply Costs	Increased electric and/or fuel consumption (if any)
Avoided Electric Transmission & Distribution Costs	O&M Costs (if any)
Avoided Fuel Savings	Electric Risk Discount (5% reduction to measure cost)
Additional Resource Savings (i.e. water savings, O&M benefits)	
Externalities (i.e. compliance costs for SO2, NOX emissions, and the value of reduced greenhouse gas emissions)	
Non-Energy Benefits (15% adder to energy benefits)	
Income-eligible Non-Energy Benefit (Additional 15% adder to energy benefits)	
Weatherization Health Benefit (2.5% market rate and 7.7% income-eligible measure cost added to NPV of benefits)	

Table 1: VT Societal Cost Test Components

2.2 DATA COLLECTION

To ensure the quality and reliability of this study, NV5 conducted systematic research to identify and collect relevant, current sources of data to support assumptions used in the potential study analysis.

The following principal data sources were used:

- ANR Lifecycle Emissions[5]

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[5] Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2021, https://climatechange.vermont.gov/climateactionoffice/greenhouse-gas-inventory.

- Avoided Costs from the Vermont Societal Cost Test[6]
- Vermont EEU customer counts and sales[7]
- Vermont heat pump installation data[8]
- Vermont Technical Reference Manuals[9]
- Vermont marginal grid emissions[10]
- Residential and Commercial baseline market assessments[11]
- Vermont EEU load forecasts[12]
- Systems Analysis on Biomass Gasification to Carbon-Negative Hydrogen[13]
- Supplemental data from other jurisdictions

2.3 STEPS IN CALCULATING POTENTIAL

2.3.1 Step 1: Forecast and Disaggregate the Baseline Energy Load

Establishing Applicability Groups

The first step in this study was to split the existing energy consumption into different groups that may be applicable to certain technologies, or that may have different propensities to adopt. For example, a ductless mini-split heat pump is only applicable to homes without current ductwork, as we assume people would otherwise install a ducted central heat pump. In addition, people who heat with fuel oil will have different economics from fuel switching, as well as different average baseline MMBtu usage, than people who heat with natural gas.

For the efficiency and fuel switching measures, we split the number of homes (residential) or number of square footage (commercial and industrial) into the following categories:

- Residential:
    - Home Type (Mobile, Single Family, Multi-Family)
    - Income Level (Low, Moderate, Market Rate)
    - Baseline Fuel Type (Fuel Oil, Natural Gas, Propane, Wood)
    - Baseline Heating System Type (Ducted, Non-Ducted)

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[6] VT PUC Approved EEU Cost-Effectiveness Screening Values. https://epuc.vermont.gov/?q=downloadfile/615689/160095

[7] BED, EVT and VGS Territory 2024 Rate Calculations provided by the Department.

[8] Historical VT territory heat pump installations provided by the Department.

[9] Efficiency Vermont Technical Reference Manual (TRM) Program Year 2023 and VT Act 56 Tier III Technical Advisory Group 2023 Annual Report.

[10] AESC 2024 marginal generation plus upstream forecast, modified by VT's RES requirements, with renewable resource mix as modeled by SEA scenario 2 variant 5 using upstream emissions factors provided by ERG to ANR to enable the inventory plus upstream draft.

[11] https://publicservice.vermont.gov/efficiency/evaluations-and-studies.

[12] 2021 VELCO Zonal Load Forecast.

[13] https://www.nrel.gov/bioenergy/assets/pdfs/03-nrel-carbon-neg-wksp-plenary-june-2023-weiland.pdf

- Commercial and Industrial:
    - Building Type (Small/Medium, Large)
    - Baseline Fuel Type (Fuel Oil, Natural Gas, Propane, Wood)
    - Baseline Heating System (Boiler, Furnace)

We use a combination of data from the US Census and data from the recent Vermont Baseline Studies to divide the number of homes and commercial square footage into the appropriate groups. We further estimate the average space heating and water heating usage per household/square foot using data from EIA's Residential Energy Consumption Survey ("RECS") and Commercial Buildings Energy Consumption Survey ("CBECS"), combined with data from the VT baseline studies, and reconciled to the overall usage from VT's 2023 Greenhouse Gas Emissions Inventory. This usage was used as a basis for savings in the measure characterizations (for example, a full heating electrification measure will save the entire heating usage of the baseline system).

Applicability for clean fuels is comparatively straightforward. Each type of clean fuel has a specific baseline fuel that it can replace without significantly changing the end use equipment. For example, the applicability of advanced renewable diesel is Vermont's entire annual fuel oil usage. Note that some fuels can only be blended into the baseline fuel in a limited amount before issues arise in the end use equipment. For example, it is assumed hydrogen can only be blended up to 7% by energy content or 20% by volume in today's natural gas systems. It is also assumed older fuel oil systems can only tolerate biodiesel blends of up to 20%. These blending assumptions impact total applicability.

New Construction

Although New Construction cannot help to reach the GWSA targets (since it contributes to load growth and sequestration attributable to timber use in long lived structures is not included in the RCI or total values of the VT Inventory), new construction that achieves emissions reductions relative to a standard baseline will be eligible for clean heat credits under Act 18, and were thus included in this analysis. For this analysis, we forecast the amount of new construction based on past trends. We assume that any new construction building receiving clean heat credits will be all-electric, and thus not add any fossil fuel load.

2.3.2 Step 2: Measure Characterization

2.3.2.1 Efficiency Measures

All measures included in the potential study were characterized with respect to GHG emission reductions, energy savings, costs, applicability, effective useful life and building type. Due to the scope and timeline of this project, installed measures represent what is commercially available in the market today and where supporting baseline and market data currently exist.

In addition to the clean heat standard potential study, the Vermont Public Utility Commission and Opinion Dynamics are also developing clean heat measure characterizations to assist the Commission and Technical Advisory Group in establishing credit values for those measures.[14] During the measure

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[14] https://puc.vermont.gov/node/2816

characterization stage, NV5 worked with Opinion Dynamics on measure list coordination in attempt to align both project's respective measure lists.

The 2023 Vermont Technical Reference Manual (TRM) was the primary source of the measure characterization effort for traditional measure groups (e.g. insulation, air sealing, heat pumps and heat pump water heaters). The Tier III Technical Advisory Group TRM, which supports energy transformation measures that reduce fossil fuel consumption, and the Vermont Gas TRM were also used as supplemental measure sources.[15,16] [17]

While the prescriptive savings algorithms presented in these TRMs may be adequate to quantify the savings for some measures, they do not cover all savings opportunities, and do not fully define all the variables needed to calculate average savings (as opposed to savings in specific buildings and applications). To supplement the Vermont specific data, we drew upon our existing library of measure characterizations, evaluation data from similar jurisdictions, and additional literature review. All data points drawn from non-Vermont sources were calibrated to current Vermont energy codes, equipment standards, and market trends.

For each measure, fuel type, and building type, the following datapoints were characterized:

- Total Installed Cost[18]
- Total Incremental Cost
- Electric and fuel impacts
- Total lifecycle emissions
- Total GWSA emissions
- Measure Life
- Percent of the market that has not already adopted the measure
- Technical feasibility for installing the measure

Measure inputs are summarized in Appendix A.

2.3.2.2 Emerging Fuels Measures

The following low-carbon pathways were modeled by NV5:

- Biodiesel ("BD") and renewable diesel ("RD") made from waste fats and oils and purpose-grown oil crops
- Advanced RD from Fischer-Tropsch of agricultural, forestry, or municipal solid waste
- Renewable natural gas (RNG) from anaerobic digestion of animal waste, landfill waste municipal solid waste, or food waste

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[15] https://publicservice.vermont.gov/sites/dps/files/documents/Efficiency%20Vermont%202022%20Savings%20Verification%20TRM.pdf

[16] https://publicservice.vermont.gov/document/2023-tier-iii-trm-characterizations

[17] Note that the Vermont TRM also includes discount factors for weatherization measures to account for observed differences in engineering savings calculations compared to measured savings. These discounts were used in this study, applied equally to low and moderate income.

[18] Note that costs associated with electric upgrades to support fuel switching were excluded from the analysis

- RNG from gasification of food, agricultural, or forestry waste
- Green hydrogen from grid or emission-free electricity, with local and distant modes of production

Fuel Potentials

NV5 has estimated biofuel potentials through various methods. The first set of methods is based on surveys of current market conditions and/or knowledge of engineering limitations on fuel availability. These non-cost methods typically result in fixed technical biofuel potential across most of the modeling period, as market and policy conditions external to Vermont are not explicitly considered. The second method recognizes that there are competing uses of limited biofuel feedstocks. This second method, using E3's Biofuel Module, allocates feedstocks competitively to biofuel production, often resulting in varying biofuel potential across the modeling period as the relative costs of each production pathway change.

In addition, NV5 draws a distinction between in-state and out-of-state potential. It is typically assumed that Vermont has access to all of its in-state potential for biofuel production, owing to its leadership with regards to Clean Heat policy, its promotion of in-state wood consumption, and its limited natural gas interconnection to the broader United States gas system. In short, these factors indicate that in-state resources are unlikely to be exported to other states or to Canada to a significant extent. Out-of-state potential is more likely to be influenced by shifts in US and Canadian Clean Heat and transportation policy. Where Vermont sources biofuels is likely to shift over time, the dynamics of which are challenging to granularly forecast. To that end, NV5 estimated a generic out-of-state biofuel potential using simplified assumptions, as described below.

Non-Cost Biofuel Potentials

Oil-based BD and RD are assumed to be mature, scalable fuel pathways. Since Vermont residential, commercial, and industrial ("RCI") fuel oil consumption is small relative to national BD and RD consumption, NV5 considered the practically accessible BD and RD availability for Vermont to be equal to today's RCI fuel oil consumption, derived from the Energy Information Agency's ("EIA") State Energy Data System ("SEDS").[19] This potential is assumed to be entirely out-of-state, consistent with the VT Inventory.

Green hydrogen is an emerging clean fuel - there is little current green hydrogen production and essentially no transportation infrastructure today in the northeastern United States. Given its nascent status in the region, NV5 assumed that green hydrogen is unavailable to Vermont until 2028. After that, total green hydrogen potential was limited to 7% by energy or 20% by volume blending into Vermont's local distribution gas systems.[20] Hydrogen was assumed to be produced from one of two sources:

- In-State. This entailed small-scale hydrogen production sited within or close to local gas distribution systems.

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[19] State Energy Data System: Vermont. Energy Information Agency. https://www.eia.gov/state/seds/?sid=Vermont

[20] Hydrogen Blending into Natural Gas Pipeline Infrastructure: Review of the State of Technology. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy23osti/81704.pdf

- Out-of-State. Hydrogen that can be delivered to Vermont via pipeline from outside of the state. Given the size of the Vermont market, this would likely require a more substantial build-out of hydrogen infrastructure both upstream and within New England to be feasible. For modeling purposes, it was assumed that additional green hydrogen will be produced in Western Pennsylvania with wind resources, stored in salt caverns in Western Pennsylvania, and transported in dedicated hydrogen pipelines to Vermont.

In-state anaerobic digestion potential is derived from the Vermont Gas Systems' ("VGS") RNG potential study.[21] NV5 used the total RNG potentials for landfill gas, wastewater gas, animal manure gas in Addison, Chittenden, and Franklin Counties within 5 miles of existing distribution and transmission lines. For animal manure, the potential used was that from clusters of 1,000 cows or more located within a five-mile drive of a digester hosting farm.

Total woody biomass potentials were based on the 2022 Update to the Wood Heat Use in Vermont report.[22] These woody biomass potentials were allocated to the woody biomass categories and sectors based on historic wood consumption data from the Vermont Agency of Natural Resources Draft Vermont Greenhouse Gas Emissions Inventory and Forecast report. As a result, firewood and wood pellet consumption was allocated to the residential subsector, while wood chips were allocated to a mixture of the commercial and industrial subsectors.

Biofuel Potentials via the Biofuels Module

All other biofuel potentials, including all advanced RD, all gasification-based RNG, and out-of-state anaerobic digestion potential, were estimated using NV5's Biofuels Module. This model allocates biomass feedstocks to final fuels by minimizing net cost, where the net cost is defined as the difference between the total production cost of the renewable fuel and the cost of the fossil fuel that it could replace. The results of this optimization determined the maximum fuel availability in Vermont of each final fuel. The study assumed that anaerobic digestion RNG will be available throughout the entirety of the study period, while RNG produced via thermal gasification and advanced RD will only be available starting in 2030 due to the current low rate of gasification commercialization.

All advanced RD and gasification RNG feedstocks are derived from the 2016 Billion-Ton Report.[23] The "Basecase, all energy crops", "Medium housing, low energy demands", and "Waste and other residues" scenarios were used to construct feedstock potentials for these pathways. As noted above, food, agricultural, municipal solid, and forestry wastes were included from each of these scenarios.

Out-of-state anaerobic digestion RNG feedstocks were sourced from the 2019 American Gas Foundation Renewable Sources of Natural Gas study.[24] This study estimates the potential of common feedstocks for RNG production at a state level. While the study's scenarios assume that feedstock availability will rise over time, plateauing around 2040, it only provided numeric data for 2040 for each state. As a result, NV5 selected the Low Potential scenario as the source of feedstock availability, since

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[21] https://vgsvt.com/wp-content/uploads/2024/02/VGS-2024-Integrated-Resource-Plan.pdf

[22] https://fpr.vermont.gov/forest/wood-energy

[23] https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

[24] https://gasfoundation.org/wp-content/uploads/2019/12/AGF-2019-RNG-Study-Full-Report-FINAL-12-18-19.pdf

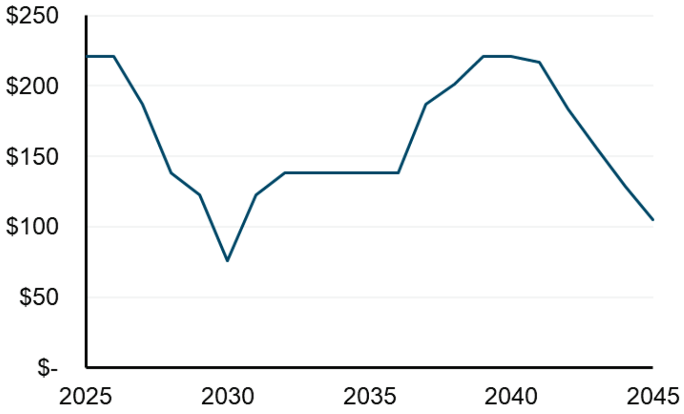
it would likely provide a middle-of-the-road estimate, being somewhat optimistic in the short term and conservative in the long term.

For all feedstocks, NV5 selected only those from states east of the Mississippi to be representative of out-of-state potential. As noted above, the geographic sources of biofuels will heavily depend on US state and Canadian provincial policy, natural gas transmission interconnection, the type of biofuel, and other factors. These factors will change over time, resulting in fuel being derived from different places as well. As a result, these states represent a reasonable representation of generic out-of-state biofuel feedstock. Finally, NV5 derated feedstock potentials to capture that there will be other demands for biofuels outside of Vermont and in non-heating sectors of the economy. In recognition that Vermont is an early mover in Clean Heat policy, the fraction of the total east-of-Mississippi feedstock was estimated to be twice Vermont's population-weighted share from 2025-2030. This fraction ramps down to Vermont's population-weighted share by 2035 and remains at that level to the end of the study period.

Fuel Costs

The cost of low-carbon fuels today is often influenced by California's Low-Carbon Fuel Standard ("LCFS") and the national Renewable Fuel Standard ("RFS") markets. Since these markets may yield high revenues for low-carbon fuel producers, selling those fuels to another market may result in lower revenues. These producers may sell their fuels at prices consistent with revenues from LCFS and RFS to reduce or eliminate those lost revenues. NV5's modeling thus incorporated LCFS and RFS market price forecasts, assuming those prices would impact the cost of Clean Heat resources available to Vermonters in the near term. LCFS and RFS market price forecasts were derived from the publicly available LCFS 2023 Standardized Regulatory Impact Assessment ("SRIA") and from an internal review of the RFS credit market.[25]

Figure 1: CARB-Modeled LCFS credit price (2021 $/MT Co2e)



NV5 used the above SRIA-estimated credit price trajectory for LCFS-eligible renewable fuels, which include oil-based BD and RD, advanced RD, and RNG. This trajectory was based on the modeled effect

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[25] https://ww2.arb.ca.gov/sites/default/files/2023-09/lcfs_sria_2023_0.pdf

of several LCFS policy amendments that have been proposed in CA on credit prices, the most important of which for this study are listed here:

- Increasing the stringency of the emission factor reduction targets to 30% by 2030 and requiring further emissions reductions to 90% by 2045
- Eliminating avoided methane crediting for animal manure and landfill gas pathways by 2040
- Requiring that biomethane is physically delivered to California; and
- Allowing indirect crediting for low-carbon hydrogen if it is injected into the national pipeline network

The analysis reflected these policies in the following respective ways:

- Using the emission factor target trajectory to estimate the LCFS credits a given fuel would produce if the fuel were sold to California as an LCFS-compliant fuel. These hypothetical credits were multiplied by credit price trajectory to estimate the lost expected revenue from the LCFS market;
- Assuming that the per-MMBTU cost to Vermont for animal manure or landfill RNG was the production cost of these pathways after 2040. The avoided methane credit drives a substantial amount of the low carbon intensities for these pathways. Eliminating this credit by 2040 as the SRIA suggests would substantially reduce possible revenues from the LCFS market. Since the focus of this study is 2026-2029, this assumption will not likely impact near-term conclusions about potential and cost-effectiveness of these pathways, despite significant uncertainty in the state of renewable fuel markets beyond 2040.
- While the SRIA does not specify a timeline for enforcing biomethane deliverability, we assume that biomethane accessible to Vermont will not be considered to be deliverable to California after 2030;
- The LCFS policy will not likely have any impacts on the cost of hydrogen in Vermont because it is unlikely that hydrogen supply available in Vermont could plausibly be delivered to California.

Producers of LCFS- and/or RFS-eligible fuels may work with intermediary wholesalers to bring their fuels to these markets, and thus may not receive the full credit values as revenue. In addition, fuel producers may be willing to sell fuel at lower prices via long-term contracts than would be fetched in more volatile transportation markets. To represent these dynamics, the study scaled down the credit prices for these fuels by a multiplier, which, in turn produced a range of fuel costs for Vermont. NV5 used a 50%-100% multiplier for LCFS credit revenues and a 60%-100% multiplier for RFS credit revenues. As a point of comparison, the lower range of these multipliers result in a $10-$20/MMBTU "adder" for RNG relative to natural gas in 2025, depending on the fuel feedstock, which is comparable to VGS's RNG adder tariff of $14-$16/MMBTU in 2024.

Woody biomass costs were derived from the most recent PUC approved 2021 New England Avoided Energy Supply Costs ("AESC").[26] Cord wood was used for firewood costs and pellet costs were used for wood pellets. Wood chip costs were assumed to be the average of cord wood and pellet costs.

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[26] https://www.synapse-energy.com/avoided-energy-supply-costs-new-england-aesc

Data from the California Energy Commission's Challenge of Retail Gas in California's Low Carbon Future report was used to support the green hydrogen production cost analysis.[27] This data was used to produce a bottom-up cost estimate of hydrogen production from electrolysis using dedicated renewables. It includes costs of transportation from and storage near the site of production and tax credits, such as the 45V hydrogen production tax credit and 45Z transportation fuel tax credit. Further, it includes assumptions on cost declines based on learning rates derived from a review of historical industrial learning rates.

Fuel Scenarios

NV5 estimated two renewable fuel scenarios. Scenario 1 results in higher per-MMBTU fuel costs but overall lower emission factors, driven by higher LCFS market revenues. In contrast, Scenario 2 results in lower per-MMBTU fuel costs but higher emission factors. Below is a table summarizing the parameters used in these scenarios.

Scenario	Cost Assumptions	Emission Assumptions
1	50% and 100% multiplier on LCFS and RFS revenues, respectively	Median emission factor for LCFS-eligible pathways
2	50% and 60% multiplier on LCFS and RFS revenues, respectively	Median emission factor for LCFS-eligible pathways

Table 2: Fuel Scenarios

For the purposes of integrating the identified biofuels and renewables fuels potentials with energy efficiency and fuel switching measures, the lower price scenario (Scenario 2) is assumed. The low-price scenario assumes higher emission factors avoiding the very optimistic emission factors for manure-based RNG. The low-price scenario also assumes less competition with the LCFS and RFS markets. Current biodiesel costs in the US suggest that costs today are closer to the low end of the scale, rather than the high end. This suggests that the LCFS has a lower impact nationwide on biodiesel. Furthermore, a high proportion of California's transportation natural gas demands are already being met with existing RNG. Any incremental RNG production is unlikely to be sold to California. These two observations together suggest that the low-price scenario is more likely to be representative of the future. Prices and availability by fuel and pathway for Scenario 2 are presented in Appendix G.

Networked Geothermal Heat Pumps

The technical feasibility screening for networked geothermal in residential areas was defined based on household density thresholds, informed by a Home Energy Efficiency Team Inc. ("HEET") and Buro Happold 2019 Geothermal Networks Feasibility Study (GeoMicroDistrict).[28] Vermont has a large share of low-density residential areas that are more suitable for individual heat pumps, since the cost of maintaining a large distribution network with relatively low capacity imposes a significant economic

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[27] https://www.energy.ca.gov/publications/2019/challenge-retail-gas-californias-low-carbon-future-technology-options-customer

[28] https://www.burohappold.com/projects/geomicrodistrict-feasibility-study/

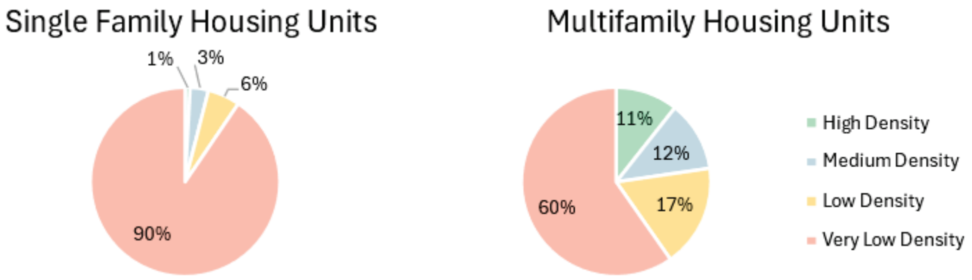
challenge. The referenced study recommends residential density thresholds across three classifications – high, medium, and low, providing the following definitions for each:

- Very low density: less than one household per acre
- Low density: One to two households per acre
- Medium density: Two to four households per acre
- High density: More than four households per acre

The study assumes that 10%, 25%, 50% and 75% of housing units in very low, low, medium, and high-density areas, respectively, can convert to a networked geothermal system. The assumptions are driven by the cost challenge of installing and maintaining a shared network loop with low capacity and low heating diversity; higher density areas with more multi-use buildings would be more likely to be suitable for these systems.

The Vermont Open Geodata Portal was used by NV5 to characterize Vermont's building stock using these density thresholds, since it includes 2020 Decennial Census data at the census tract level for Vermont.[29] The distribution of housing types at a census tract level, was sourced from the American Community Survey 5-Year Estimates Data Profiles, Selected Housing Characteristics.[30] Household density thresholds, land use, and housing data were thus combined to develop estimates of household density for the state of Vermont, as shown in Figure 2 below.

Figure 2: Calculated distribution of density levels for single family and multifamily households in Vermont.



Technical feasibility screening for networked geothermal for commercial buildings was defined based on commercial building types. This determination of feasibility involved assessing factors that contribute to the likelihood of participation such as load profiles aimed to reduce peak system capacity and cooling loads to balance the loop and reduce the overall system cost, as seen in grocery stores.

The data for commercial building area by typology was determined using NREL's ComStock dataset for Vermont.[31] Table 3 shows a qualitative ranking of feasibility by building type, based on the factors discussed above. The study assumes that networked geothermal is technically feasible in 25%, 50%, and 75% of the buildings for weights 1, 2, and 3 respectively. As shown in the figure below, about 40%

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[29] https://geodata.vermont.gov/

[30] https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/

[31] https://comstock.nrel.gov/page/datasets

of Vermont's commercial building space has a weighting; the rest are assumed to be not suitable for networked geothermal.

Building Type	Relative Weights
Education	2
Warehouse and Storage	2
Mercantile	1
Office	1
Food Service	3
Lodging	2
Healthcare	2

Table 3: Technical Potential Weights by Commercial Building Type

(Note: Higher weights represent higher feasibility, determined by heating and cooling load diversity)

Costs of networked geothermal systems are uncertain and variable, given the nascency of this technology. The GeoMicroDistrict4 study, along with utility pilot project budgets from existing pilots in Massachusetts (Eversource) was used to inform the assumed individual household GSHP, internal distribution, and weatherization costs (totaling to $5,600/heating ton) and total utility shared network infrastructure installation costs ($16,000/heating ton).

For this assessment, the GeoMicroDistrict study is the source of system-wide heating and cooling efficiencies, with annual average co-efficient of performance ("COP") of 5.0 and 6.0 respectively. These values are assumed to factor in the performance variations due to operating conditions, ground temperatures, and building distribution systems.

2.3.3 Step 3: Develop Technical, Economic, and Maximum Achievable

2.3.3.1 Technical Potential

Once the measures are fully characterized, measure level Technical Potential for the residential measures can be estimated using the following equation:

$$Technical\ Potential = Savings_{per\_home} \times Applicable_{homes} \times \%\ Technically\ Feasible\ \times \%\ Not\ Complete$$

This same equation can be applied to costs and other impacts to derive a full set of Technical Potential results. In general, a similar equation is used for the commercial and industrial sectors where savings and applicability are characterized in terms of building floorspace and MMBtu of baseline fuel, respectively. We look at Technical Potential at a measure level and as a snapshot in time. Interactive effects, mutual exclusivity, and adoption curves are introduced for the Maximum Achievable scenario.

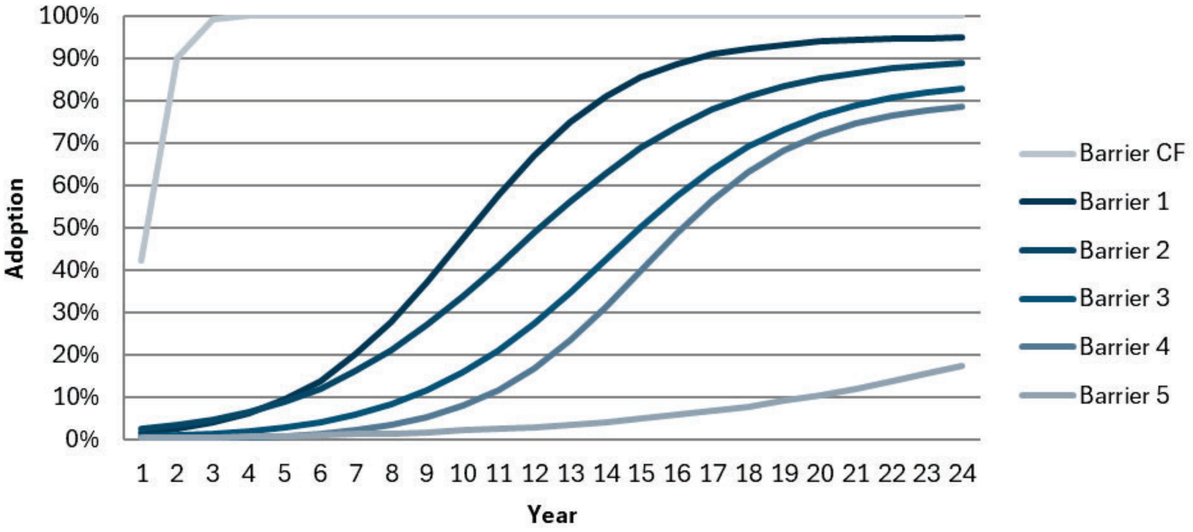
2.3.3.2 Maximum Achievable Potential

The Technical Potential is used largely as a steppingstone to the Maximum Achievable potential. As discussed earlier, this scenario represents an estimate of the maximum GHG reductions available, given non-financial barriers preventing adoption of each measure. Adoption curves are used to reflect that not all homes that technically can adopt measure will actually do so, and that those who do adopt will do so over many years. Further, Maximum Achievable potential is an aggregate estimate, rather than separate measure level estimates, so adjustments were needed to account for measure interactions and mutual exclusivity. A cost adder was also included at the portfolio level to account for non-incentive costs associated with implementing the Clean Heat measures (e.g., administration, marketing, technical assistance, and evaluation). These costs are discussed in Section 5.

Adoption Curves

This study assumes typical "S" Curves for adoption, based on the Bass Diffusion Model which is widely used to estimate potential adoption of new technologies. Under this curve, there is slow growth in the early years, as usage is restricted to early adopters, then a period of mass adoption where consumer acceptance accelerates, followed by a leveling off as late adopters continue to slowly change their consumption patterns. For this study, we assume that the parameters of the "S" Curve (max adoption, how long it takes to get to max adoption, etc.) are dependent on the level of barriers, from one to five, of the measure and on the current adoption of the measure. Note that workforce was not included as a barrier in our adoption curves. Further discussion on workforce can be found in section 3.0. The graph below shows the shape of the adoption curves by barrier level of the measure. A higher barrier number indicates more barriers to a given opportunity and the "CF" barrier curve was specifically applied to clean fuels adoption. Adoption my measure is presented in Appendix B.

Figure 3 Generic Adoption Curves



Mutual Exclusivity

Since Maximum Achievable is an aggregate estimate, it needs to account for mutual exclusivity and interactions between measures. To handle mutual exclusivity, we bundled measures into mutual exclusivity groups. In each group, only one of the measures could be installed. For example, any given household can only implement one of the following four electrification measures:

- Ductless Air Source Heat Pump – Full Replacement
- Ductless Air Source Heat Pump - Partial Replacement
- Air-to-Water Heat Pump
- Ground Source Heat Pump

In these cases, total adoption for the entire exclusivity group was based on the adoption curve of the measure with the lowest barrier level. Next, we defined a distribution showing the percentage of the total adoption for the group as a whole that is allocated to each individual measure. For example, in one year, 7% of homes with hydronic fossil fuel heating convert to heat pumps, and the distribution defines that ground source heat pumps make up 5% of the adoption group. In this case, 0.35% of applicable homes would install ground source heat pumps in that year. The distribution described above is based on several factors, including barrier level, the economics of the measure, and the total greenhouse gas emissions reduction of the measure.

Interactions

There are significant interactions between Clean Heat measures in this analysis. For example, an envelope improvement reduces the total fossil fuel savings from a partial fuel switch to heat pump, which reduces the potential available from clean fuels. To address these interactive effects, a loading order was developed for measures that are not mutually exclusive but impact the same end use. This loading order is defined as efficiency first, then fuel switching, and then clean fuels. Within the category of efficiency, we generally assume that lower-barrier, less capital-intensive measures, such as smart thermostats, are installed before more expensive measures, such as air sealing and insulation. We adjust savings for each measure with interactions by applying a multiplier to the savings based on the % savings of the measure before it. For example, if a smart thermostat saves 5% of the total heating load, then a multiplier of 95% is applied to adjust the savings for weatherization. We make further adjustments based on the maximum adoption of the measure to account for the fact that while there will be a lot of overlap between people who get thermostats and people who get envelope upgrades, there will be a fraction that only does one or the other.

Clean Fuel Carbon Intensity Requirements

Act 18 requires that any clean fuel have a carbon intensity value of less than 80 g/MJ in 2025, 60 g/MJ in 2030, and 20 g/MJ in 2050 relative to a statutorily defined carbon intensity of Number 2 fuel oil (“No. 2 heating fuel”) of 100 grams per mega joule (g/MJ).[32] The Maximum Achievable potential scenario (and the Act 18 Optimized scenario discussed below) screens out any clean fuels at the pathway level that do not meet these requirements. In practice, this had a very minor impact, as only

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[32] While Act 18 explicitly deems the carbon intensity value of No. 2 fuel to be 100, this analysis interprets the requirements to be relative to the lifecycle emissions value for No. 2 fuel oil assumed in this study.

one fuel pathway (“In-State | Advanced Renewable Diesel | Residues and Waste”) was screened out in 2030, and its loss could be compensated for with clean fuels from other pathways.

2.3.4 Step 4: Act 18 (Program Achievable) Optimized Scenario

This step involved optimizing the Maximum Achievable potential, described above, so that the total reduction meets (but does not exceed) the GWSA targets in the most cost-effective way, accounting for additional Act 18 requirements relating to low- and moderate-income and the carbon intensity of clean fuels. The incremental annual adoption rates for many measures in the Maximum Achievable scenario ramp up early in the analysis period before plateauing. Acknowledging that following this aggressive ramp would considerably front-load achievement, exacerbating workforce constraints and leading to highly variable program budgets over the analysis period, we first converted the Maximum Achievable adoption rates to constant annual values by dividing the cumulative adoption by the number of years in the analysis period. Next, we constrained these incremental annual adoption values such that they did not exceed the Maximum Achievable adoption values for the corresponding year during the “slow growth” phase of the S-curves (see the discussion of adoption curves in Section 2.3.3.2). Next, to optimize for costs, we ranked each measure in the order of cost per ton of lifetime *lifecycle* GHG emissions reduced and zeroed out adoption of the most expensive measures until the total emissions reductions matched the 2050 GWSA targets.

There are a few additional nuances to this methodology:

Low- and Moderate-Income

Act 18 requires that 16% of each obligated party’s clean heat credits benefit low-income households, and that another 16% benefit low- or moderate-income households. Of those credits, at least half of these credits need to be generated by measures that involve capital investment in the household, have measure lives of at least 10 years, and are estimated to lower annual energy bills.[33] While the analysis did not explicitly assess the bill impacts of each measure, to accommodate this requirement, we did not remove any energy efficiency or equipment-based fuel switching measures in the low- and moderate- income sectors, regardless of how expensive they were.

GWSA Annual Target Matching

Finally, to further minimize costs, adoption values for clean fuels were adjusted downward in each year, starting with the most expensive resource, until the resulting emissions reductions just meet interpolated annual emissions reductions targets. The required annual emissions reductions for 2026-2029 were linearly interpolated between the 2023 historical emissions and the 2030 target. Likewise, required annual reductions for 2030-2049 were linearly interpolated between the 2030 target and the 2050 target. While this approach does not select the least expensive resources in each year, it ensures that enough non-fuel resources are in the total portfolio to meet the 2050 GWSA target and introduces those resources at a reasonable pace.

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[33] https://legislature.vermont.gov/Documents/2024/Docs/ACTS/ACT018/ACT018%20As%20Enacted.pdf

2.3.5 Economic Potential and Cost Effectiveness

Although the above scenarios did not screen out measures that are not cost-effective, we did examine what portion of the potential passes Vermont's Societal Cost Test (SCT). Each applicable Clean Heat measure was subjected to the Vermont Societal Cost Test using the most recent PUC approved 2021 New England Avoided Energy Supply Costs ("AESC") values as the avoided cost inputs.[34] These avoided costs represent the latest VT PUC approved avoided cost vintage which were used in the most recent January 2023 Vermont Public Service Department Vermont Energy Efficiency Market Potential Study. One caveat to the 2021 avoided costs is that we used updated Social Cost of Carbon (SCC) values consistent with the 2% discount rate scenario from the EPA's 2023 "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances" ($190/metric ton in 2020 in 2020$) which are pending adoption by the VT Climate Council.[35] To estimate the benefits associated with the SCC, this study applies *lifecycle* emissions factors to the energy impacts. Emissions factors for both GWSA accounting and lifecycle are presented by fuel and year in Appendix F. The cost effectiveness analysis performed a full measure life analysis of costs and benefits for all possible measure permutations including technology, sector, building type, and market. Final cost effectiveness results can be found in Appendix E.

2.3.6 Emissions Reductions

Emissions Reductions - Annual and Cumulative Lifecycle

Pursuant to Clean Heat Standard section § 8124 (a)(1):

"The Commission shall establish the number of clean heat credits that each obligated party is required to retire each calendar year. The size of the annual requirement shall be set at a pace sufficient for Vermont's thermal sector to achieve lifecycle carbon dioxide equivalent (CO2e) emission reductions consistent with the requirements of 10 V.S.A. § 578(a)(2) and (3) expressed as lifecycle greenhouse gas emissions pursuant to subsection 8127(g) of this title."

NV5 modeled emissions reduction targets incorporating the most recent RCI emissions values for 1990 as a baseline, and for 2023 as a current starting point (2.26 MMT in 1990 and 2.30 MMT in 2023). The model also incorporated emissions reduction targets reflecting sectoral proportionality based on 2018 (0.69 MMT by 2030 and 1.76 MMT by 2050).

On July 19, 2024, the Vermont Agency of Natural Resources ("ANR") published the Vermont Greenhouse Gas Emissions Inventory and Forecast (1990 - 2021) ("2021 Inventory").[36] The methodology of the 2021 Inventory reflects the retroactive removal of "non-road" emissions previously included in the residential, commercial, and industrial fuel use sector ("RCI"), or "thermal sector", for inventory years 1990-2021.[37] Specifically, emissions from the use of "non-road" or "other dyed

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[34] https://www.synapse-energy.com/avoided-energy-supply-costs-new-england-aesc

[35] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf. Table 4.1.1.

[36] Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990 – 2021, https://climatechange.vermont.gov/climateactionoffice/greenhouse-gas-inventory.

[37] Vermont Greenhouse Gas Emissions Inventory and Forecast Methodologies, 7-11, https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/1990-2021_GHG_Inventory_Uploads/_Methodology_Vermont_Greenhouse_Gas_Emissions_Inventory_1990-2021_Final.pdf

diesel" are now reflected in the Transportation/Mobile Sources sector. This change resulted in lower RCI emissions values than previous reports, particularly relevant for inventory years 1990, 2018, 2020.[38]

On July 26, 2024, ANR provided the Department with estimated RCI emissions for inventory years 2022 and 2023. This data reflects the most current and accurate accounting of Vermont's emissions presently available and was determined appropriate data to be reflected in the Clean Heat potential study. See Table 4 below:

RCI emissions (MMT)	1990	2005	2018	2020	2021	2022*	2023*
1990-2020	2.54	3.06	2.94	2.87	-	-	-
1990-2023	2.26	2.79	2.74	2.59	2.57	2.47	2.3

*Estimated

Table 4: 1990-2020 vs 1990-2021 and 2023 and 2023 RCI emissions values

In producing Vermont's Climate Action Plan the Climate Council ("VTCC") adopted 2018 as the most recent emissions inventory data available at the time for determining proportional emissions reduction obligations pursuant to emission reduction targets of the Global Warming Solutions Act (2020) ("GWSA").[39]

Upon reviewing the VTCC position on sectoral proportionality the Department agreed that 2018 is an appropriate year for determining proportional shares of emissions reductions required of each sector to satisfy GWSA targets unless and until circumstances change that warrant further adjustment to these relative targets. Circumstances warranting adjustments could include a finding of harmful outcomes or inefficiency in maintaining a static proportionality requirement.[40] Note that Act 18 includes provisions for adjusting the emissions reduction requirement of the RCI sector adequate to meet GWSA targets.[41]

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[38] Vermont Greenhouse Gas Emissions Inventory Update 1990-2020 Final, 13 https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/_Vermont_Greenhouse_Gas_Emissions_Inventory_Update_1990-2020_Final.pdf.

[39] 10 V.S.A. § 578(a)(2-3); DRAFT Memo re: Establishing the Reference Year for Proportional Emissions Reduction by Sector and Interpreting 10 V.S.A. § 592 (d), 2-3, https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/Sectoral%20Proportionality%20Memo_DRAFT%2010182021_Final.pdf; Vermont Climate Council October 26, 2021 –Minutes, 2-3, https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/10-26-21%20Minutes%20-%20Vermont%20Climate%20Council.pdf;

[40] Sectoral Proportionality Memo; 10 V.S.A. § 592(d).

[41] 30 V.S.A. § 8124(a)(3) (emissions pacing updates every three years); 30 V.S.A. § 8121 & 8124(a) (setting RCI emissions reductions sufficient to meet GWSA targets by 2030 and 2050).

Emissions reduction targets used in initial drafts of the potential study exclusively focused on emissions from RCI.[42] While this methodology was an effective means of ensuring sufficient thermal sector emissions reductions such that the thermal sector does not exceed its GWSA target allotment for target years, it did not consider the relative shift in the source profile of Vermont's emissions and would reflect emissions reduction targets disconnected from the present. Since 1990, the relative portion of RCI emissions has increased from roughly 26% to 31% of emissions. Setting the RCI emissions target based on the historic RCI emissions proportion (26%, 2.26 MMT) would effectively increase the scale of the sector's emission reduction target and if not updated would have allocated a portion of emissions reductions attributable to other sectors to RCI. While the State emissions profile has changed since 2018, the 2021 Inventory shows RCI emissions as roughly 31% of emissions.

See Table 5 below:

CHS emissions targets by	2020 RCI (1990 proportionality)	2023 RCI (1990 proportionality)	2023 RCI (2018 proportionality)
2030	1.52	1.35	1.61
2050	0.51	0.45	0.54

CHS reductions required by	2020 RCI (1990 proportionality)	2023 RCI (1990 proportionality)	2023 RCI (2018 proportionality)
2030	1.35	0.95	0.69
2050	2.36	1.85	1.76

Table 5: Differences in RCI targets and emissions reduction requirements

Emerging Fuels Emissions

Life-cycle emission factors are primarily used to characterize each pathway. Because the results of life-cycle emission modeling depend heavily on project location, feedstock type, counterfactual or baseline practices, and renewable fuel end use and sector, NV5 used archetypes to capture a range of fuel pathway emissions. NV5 primarily used data from existing projects when available. When such data was unavailable, NV5 used data produced for the state of Vermont.

Oil-based RD, advanced RD, most RNG, and hydrogen pathways will be sourced from the list of currently certified projects for CARB's LCFS program. This database typically contains GREET-estimated emission factors for a wide range of project types, so it can serve as source for a reasonable range of emission factors for biofuel pathways. NV5 estimated the emission factor by finding the median value for active projects located in all US states east of the Mississippi River.[43] When there are fewer than fifteen said projects, NV5 used the full list of US projects. In the rare case where there are no active projects, NV5 used retired projects as well.

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[42] 2024.07.24 CHS Final Draft Results, https://puc.vermont.gov/document/tag-meeting-materials/072524.

[43] Initial draft results of this study assumed the 75th percentile of active projects.

Woody biomass and BD pathway emissions will be based on the Vermont Agency of Natural Resources Draft Vermont Energy Sector Life Cycle Assessment report. In the case of BD, this report has estimated Vermont-specific emission factors for fuel produced primarily out-of-state. Unlike emission factors for renewable natural gas from landfills or animal waste within the same report, those for BD include all possible sources and sinks of emissions within the GREET model. Upstream woody biomass emission factors are similarly Vermont-specific but lack the effects of biomass regrowth and decomposition associated with the types of forests from which wood is obtained in Vermont. To capture this effect, we used a GWPbio factor of 0.30, which estimated climate change impacts of these growth and decomposition cycles when multiplied by woody biomass biogenic emissions. This factor is derived from the state's Greenhouse Gas Emissions Inventory and Forecast and is based on modeling of the carbon cycles mid-to-long rotation temperate forests like those in Vermont.

Finally, the emission factor for RNG based on the gasification of residues and wastes was sourced from Systems Analysis on Biomass Gasification to Carbon-Negative Hydrogen, using the catalyst pathway as a central emission estimate. Since this emission factor does not include transmission, a small transportation emission factor was added to this value, derived from a review of RNG transportation emission factors in R&D GREET.

A summary of sources for all fuel pathway potentials and emissions are included below:

Fuel	Feedstock	Potential	Emissions
Wood Pellets	Wood	VT Inventory; Billion-Ton Report	VT Inventory
Firewood, Commercial	Wood	VT Inventory; Billion-Ton Report	VT Inventory
Firewood, Non-Commercial	Wood	VT Inventory; Billion-Ton Report	VT Inventory
Wood Chips	Wood	VT Inventory Billion-Ton Report	VT Inventory
Biomethane	Animal Manure	Billion-Ton Report; VT RNG Potential Study; AGF Study	CARB LCFS-Registered Projects
Biomethane	Landfill Gas	Billion-Ton Report; VT RNG Potential Study; AGF Study	CARB LCFS-Registered Projects
Biomethane	Residues and Waste	Billion-Ton Report	NETL Gasification Analysis; R&D GREET
Biomethane	Wastewater	Billion-Ton Report; VT RNG Potential Study; AGF Study	CARB LCFS-Registered Projects
Renewable Diesel	Residues and Waste	Billion-Ton Report	CARB LCFS-Registered Projects
Renewable Diesel	Purpose-grown Oil Crops and Waste Oils	EIA SEDS	CARB LCFS-Registered Projects
Biodiesel	Purpose-grown Oil Crops and Waste Oils	EIA SEDS	CARB LCFS-Registered Projects
Hydrogen	Dedicated Renewables	N/A	CARB LCFS-Registered Projects

Table 6: Sources for Fuel Pathway Potentials and Emissions

Based on our interpretation of the Clean Heat Standard, emissions from measure end use materials (e.g. heat pumps or weatherization) are outside of the scope of this potential study.

Emissions factors by fuel pathway and year are presented in Appendix F.

3.0 WORKFORCE

Overview and Summary of Thermal Sector Trades

This report also includes an analysis of Vermont's workforce's capability to deliver clean heat measures, and any gap between current capacity and the capacity needed to meet the GWSA targets. In 2023, Vermont's clean energy economy employed 18,156 workers, representing 6% of all jobs in the state. Of the total clean energy workforce, nearly 45% of workers were in the installation, maintenance and repair field, with trades and distribution services representing 21% of total workers and engineering and professional services representing 14% of workers.[44]

Within the energy efficiency industry, the majority of the workforce was distributed between traditional HVAC goods and services, Energy Star HVAC equipment, Energy Star lighting and appliances, miscellaneous services (e.g. motors, design, audits, and leak detection) and insulation. See Table 7 for Energy Efficiency employment by subsector.

Energy Efficiency Sector	2023 Employed
Traditional HVAC Goods and Services	2,147
ENERGY STAR/ High AFUE HVAC	1,856
ENERGY STAR Appliances & Efficient Lighting	1,824
Other Energy Efficiency Technologies	1,631
Advanced Building Materials/ Insulation	1,571
Microgrid	441
Storage	444
Smart Grid	54
Total	**9,968**

Table 7: Energy Efficiency Employment by Subsector (2023) [45]

The COVID-19 pandemic had a significant impact on these employment trends. According to the 2023 Vermont Clean Energy Industry report, nearly all employers surveyed expressed having difficulty hiring within the clean energy workforce between 2020 and 2023 with hiring becoming more difficult each year after 2020. See Table 8 for reported difficulty in hiring between 2020 and 2023.

Year	% Reporting Very Difficult in Hiring
2020	34%
2021	46%
2022	52%
2023	67%

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[44] 2023 Vermont Clean Energy Industry Report. https://publicservice.vermont.gov/sites/dps/files/documents/2023%20VCEIR_Final.pdf

[45] Ibid.

Table 8: Employer Reported Hiring Difficulty from 2020 - 2023[46]

About 50% of employers indicated that difficulty in hiring was a result of strong competition with other industries with nearly 35% indicating difficulties resulting from a lack of experience, training, or skills from applicants. Technical positions accounted for a majority of the workforce where employers reported having trouble hiring. Mechanical, electrical, engineering and installation positions accounted for 90% of all clean energy positions that were deemed most difficult to hire.

Current Number of Firms and Workers

Most of the Energy Efficiency Sector workforce listed in Table 7 above will contribute to supporting the Clean Heat Standard measures identified in the Clean Heat Standard Potential study. Relevant positions generally include, but are not limited to, HVAC contractors, weatherization contractors, plumbers and electricians.

As of May 2023, there were 1,160 licensed HVAC contractors in the state of VT representing about 296 HVAC companies. In addition to licensed HVAC contractors, there were approximately 1,695 licensed plumbers and 2,460 licensed electricians in Vermont.[47] A mix of HVAC contractors and licensed plumbers and electricians are qualified to install many Clean Heat Standard measures and can perform cross-trade tasks depending on the type of measure being installed. For example, some electricians install heat pumps, and some plumbers install heat pump water heaters; both measures involve cross-trade work where heat pumps involve HVAC and electrical components, and heat pump water heaters involve plumbing and electric components.

To further segment HVAC contractors into companies that specialize in specific clean heat measure installations, Table 9 below represents a list of Efficiency Vermont Efficiency Excellence Network ("EEN") contractors. These contractors represent a segment of trade professionals that are pre-qualified by Efficiency Vermont and who are trained to deliver high-quality equipment installations.

Equipment Service Type	Number of Firms
Ducted and Ductless Heat Pumps	180
Air-to-Water Heat Pumps	47
Geothermal Heat Pumps	23
Heat Pump Water Heaters	80
Weatherization - Insulation and Air Sealing	43
Wood Pellets	20

Table 9: Efficiency Vermont EEN Professionals[48]

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[46] Ibid.

[47] May 2023 State Occupational Employment and Wage Estimates. Vermont.
https://www.bls.gov/oes/current/oes_vt.htm.
DPS Division of Fire Safety. Trade Licensing and Certifications. https://firesafety.vermont.gov/licensing.
Ibid.

[48] https://www.efficiencyvermont.com/find-contractor-retailer#/

Secondary/Post Secondary Trade School Feeder Capacity

There are several trade schools and continuing educational opportunities in Vermont that feed into the clean energy trade industry. Most notably, Vermont Technical College's Continuing Education and Workforce Development program offers clean energy industry-related trainings such as Building Performance Institute ("BPI") training and certifications, as well as HVAC electrical, plumbing, manufacturing, and business training programs.

In addition to Vermont Technical College, there are several other smaller trade schools that offer HVAC training programs summarized in Table 10.

List of trade schools that feed into the HVAC industry
Burlington Technical Center
Central Vermont Career Center
Cold Hollow Career Center
Essex Center for Technology Education
Green Mountain Technical and Career Center
Hartford Career and Technical Center
Lyndon Institute
North County Career Center
Northwest Technical Center
Patricia Hannaford Career Center
Randolph Technical Career Center
River Bend Career and Tech Center
River Valley Technical Center
St. Johnsbury Academy
Stafford Technical Center
Southwest VT Career Development Center
Windham Regional Career Center

Table 10: HVAC Trade Schools in Vermont

In addition to trade schools, Vermont has several organizations that support continuing education and licensing opportunities in the HVAC industry, summarized in Table 11.

Name of Organization	Description
Heating & Cooling Contractors of Vermont (HCCV)	Training includes a Propane Certified Employee Training Program (CETP) Series, National Oilheat Research Alliance (NORA) Bronze Basic Oilheat Technician Training Program, and Vermont Propane/Natural Gas Renewal.
Vermont Fuel Dealers Association (VFDA)	Training includes Propane CETP Series, NORA Bronze Basic Oil heat Technician Training Program, and Vermont Propane/Natural Gas Renewal.

Name of Organization	Description
Vermont Adult Learning	Through their Energy Works program, Vermont Adult Learning offers free training for weatherization and heat pump installation.
ReSOURCE	ReSOURCE is a nonprofit training organization that assists those who have barriers to employment. ReSOURCE focuses on two categories of workforce training: work experience training and workforce development. Work experience training is intended for those who have never worked due to age, disability, public assistance, or other reasons and prepares students to be ready for further skills building.
Vermont Works for Women	The mission of Vermont Works for Women is to help women find career paths and develop skills.
Vermont Adult Career & Technical Education Center Association	This training center supports weatherization and other construction trades in recruiting, training, and placing workers in careers.
Advance Vermont	Advance Vermont focuses on policy, data/research, facilitation, and changing the narrative around career and technical education to ensure that individuals in Vermont have the necessary access to education and training.
Career & Technical Education Centers VT (CTE)	Career and Technical Education (CTE) helps individuals gain the skills, technical knowledge, academic foundation and real-world experience needed to prepare for high skill, high demand, high wage careers.
Community College of Vermont (CCV)	CCV provides students opportunities for academic and professional growth through flexible, innovative programs and exemplary support services. CCV cultivates a rich network of partners through collaboration and workforce development to create vibrant and economically thriving Vermont communities.

Table 11: Clean Energy Trade Education Organizations

Professional Certifications and Training

The State of Vermont Division of Fire Safety oversees the electrical licensing process for HVAC and HVAC/R technicians which includes administering the Vermont Refrigeration or Air Conditioning electrical exam for Vermont licensed Type-S Journeyman electricians to perform specialty electrical installations. HVAC installers in Vermont must also have EPA Section 608 Certification which is a federal requirement for handling refrigerants. There are several organizations in Vermont, like ReSOURCE listed above, that offer training to prepare for the certification exam.

Business as Usual and Act 18 Optimized Workforce Forecasts

To support the Clean Heat Standard potential study's Act 18 Optimized results, thermal sector workforce forecasts were developed relative to the high-impact measures and the workforce needed to support those measures to meet the GWSA targets. The first step in this forecast was the development of a current-state and business-as-usual forecast.

To estimate current-state workforce, 2023 Efficiency Vermont measure-level results were used in combination with estimated hours of labor to install those measures to develop a total number of full-time equivalent positions needed to support the current state volume of measures. For example, there were 8,991 ductless heat pumps rebated in Efficiency Vermont territory in 2023[49]. With an estimated 11 hours of labor to install a residential ductless heat pump and a total of 1,372.8 hours available per year per worker, there are approximately 70 full time equivalent workers needed to support current-state volume[50,51]. This analysis was then done for the other high impact measures where existing unit volume data was available.

Next, a business-as-usual forecast was developed using the current-state full time equivalent workers as a baseline to forecast how many workers would be needed to support a business-as-usual efficiency program over the duration of the potential study analysis period. For this analysis, business-as-usual was assumed to be the existing Efficiency Vermont market intervention program with annual growth rates from the 25-year "Program Achievable" potential forecast from the 2023 Vermont Energy Efficiency Potential Study. This forecast was used to align a business-as-usual scenario with the most recent energy efficiency potential study results in Vermont.

Finally, an Act 18 Optimized workforce forecast was developed using measure-level results from the current-state analysis (number of units per year per full-time equivalent worker) with the optimized unit results (optimized units per year to meet GWSA targets) to establish the number of full-time equivalent workers needed to support measure volumes to meet GWSA targets.

Table 12 below shows the results of the Current State, Business-As-Usual and Act 18 Optimized workforce. Note that the potential study model focuses heavily on fuels because of the $/lifecycle emissions avoidance and implementation may include other priorities, likely resulting in higher than forecast need for workers providing installed measures. Business-As-Usual and Act 18 Optimized results are shown for workforce in 2035, 2040 and 2049. Additional measure assumptions can be found in the accompanying file *Workforce Analysis File_Final Appendix Version Results_V2.xls*. Results below are shown in total number of full-time-equivalent workers.

Measure	Number of Current Workers (2023)	BAU Workers in 2030	Optimized Workers in 2030	BAU Workers in 2035	Optimized Workers in 2035	BAU Workers in 2040	Optimized Workers in 2040	BAU Workers in 2049	Optimized Workers in 2049
Residential Heat Pumps (Ductless)	70	82	24	91	26	102	28	125	30
Commercial Heat Pumps (Ductless)	10	11	11	12	12	13	12	16	13

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[49] 2023 EVT per-unit program results.

[50] RSMeans HVAC labor hours used for equivalent measures.

[51] Total hours per worker sourced from "Workforce Development in Vermont's Thermal Sector. Challenges and Opportunities for Meeting Vermont's 2030 Climate Goals. Raquel Smith. August 2021" report.

Residential Heat Pumps (Ducted)	15	17	27	19	29	22	31	27	34
Commercial Heat Pumps (Ducted)	3	4	12	4	13	4	14	5	15
Heat Pumps (Ground Source)	1	1	4	1	4	1	4	1	4
Weatherization Single-family	140	113	435	100	435	85	435	65	435
Weatherization Multifamily	4	3	14	3	14	2	14	2	14
Weatherization Mfg. Home	20	16	19	11	19	10	19	7	19
Residential Heat Pump Water Heater	3	3	18	3	21	3	21	4	21
Residential Induction Stovetop	0.4	1	3	1	7	1	7	1	7
Advanced Wood Heating (Pellet Stoves)	0.3	0.3	8	0	8	0	8	0	8
VRF	0.1	0.1	3	0	3	0	3	0	3

Table 12: Current State, Business-As-Usual and Act 18 Optimized Workforce Results

Workforce needed to support Act 18 Optimized results varies by measure. For example, in the optimized scenario, residential ductless heat pumps are projected to have a lower impact than existing programs therefore the workforce needed to support that specific measure is less than current state and business as usual. However, there is an increase in workforce needed to support residential and commercial ducted heat pumps based on optimized results. Because both ductless and ducted heat pumps would typically be supported by HVAC contractors, these results would represent a shift within the existing HVAC contractor workforce to focus on ducted installations. Similarly, Act 18 Optimized results are showing a higher adoption for residential heat pump water heaters above current state installations and would indicate a shift within the HVAC trades to increase support for that technology as well.

The largest need for additional workforce, based on Act 18 Optimized results, is for single and multifamily weatherization measures and based on these results would require a significant increase in weatherization workforce over existing workforce capacity. Based on interviews with VT workforce agencies who implement training programs for HVAC-related jobs, including weatherization, there has been increased demand in students looking for training in these areas since 2020. However, due to program funding constraints and difficulty in conducting training in rural areas throughout VT, the supply of training programs hasn't met the demand of both trainee interest and market needs. Furthermore, HVAC organizations are using workforce agency training as a path to vetting high-quality labor as students who go through workforce training programs are often more prepared with the skillsets needed for the job than those candidates without prior training. This further emphasizes the importance of workforce training programs to support future HVAC trade employment, including the need for increased weatherization workforce capacity.

The Inflation Reduction Act may provide some solutions to help fund HVAC trade workforce development. For example, a recent report by the University of Massachusetts Amherst suggests that for the State of Pennsylvania, IRA funding could support the creation of 122,540 clean energy jobs over the next 10 years.[52] Another potential funding path could be provided through the DOE Weatherization Assistance Program Innovation Grants program which awards funding specifically for weatherization-based workforce development.[53] In 2023, grants totaling $5.5M were awarded to communities in ME, MD and PA to help fund weatherization workforce development over the next three years.[54] Finally, a further discussion on the importance of leveraging the Weatherization Assistance Program to meet the large gap in weatherization workforce needed for VT can be found in the Efficiency Vermont Weatherization Workplan report from 2021.[55] Similar to the Optimized Workforce results above, this report also emphasized the need to grow VT's weatherization workforce by 4-5 times over a 5-year period.

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[52] https://peri.umass.edu/images/InflationReductionBill-PA-10-11-22.pdf

[53] https://www.energy.gov/scep/wap/weatherization-innovation

[54] https://www.energy.gov/scep/wap/weatherization-assistance-program-innovation-programs-selections

[55] https://www.efficiencyvermont.com/Media/Default/docs/white-papers/Weatherization-Workforce-Plan.pdf

4.0 RESULTS

4.1 TECHNICAL POTENTIAL

As noted previously, the Technical Potential was assessed at the measure-level without any consideration of competing measures (i.e., mutual exclusivity) and measure interactions. While these results are foundational to conducting the Maximum Achievable and Act 18 Optimized scenarios, they are not particularly meaningful by themselves. Full measure-level Technical Potential results can be viewed in Appendices C1, D1, and E1.

4.2 MAXIMUM ACHIEVABLE POTENTIAL

4.2.1 Summary of Emissions Reduction Potential

Figure 4 below presents the Maximum Achievable net RCI emissions by year. The emissions presented for 1990 represent historical values from the Vermont Greenhouse Gas Emissions Inventory and Forecast: 1990-2021[56] and the 2023 value reflects preliminary estimates provided by ANR. Note that because the 2030 and 2050 targets must be achieved by January 1 in the respective years, for the purposes of this analysis they are treated as 2029 and 2049 targets. The Maximum Achievable scenario surpasses the 2030 target in 2026 and surpasses the 2050 target in 2036. "Net RCI Emissions" denotes that these values include Electricity Consumption sector emissions impacts (positive or negative), but these impacts are small due to the slow ramp of fuel switching measure adoption and low electric emissions rates.

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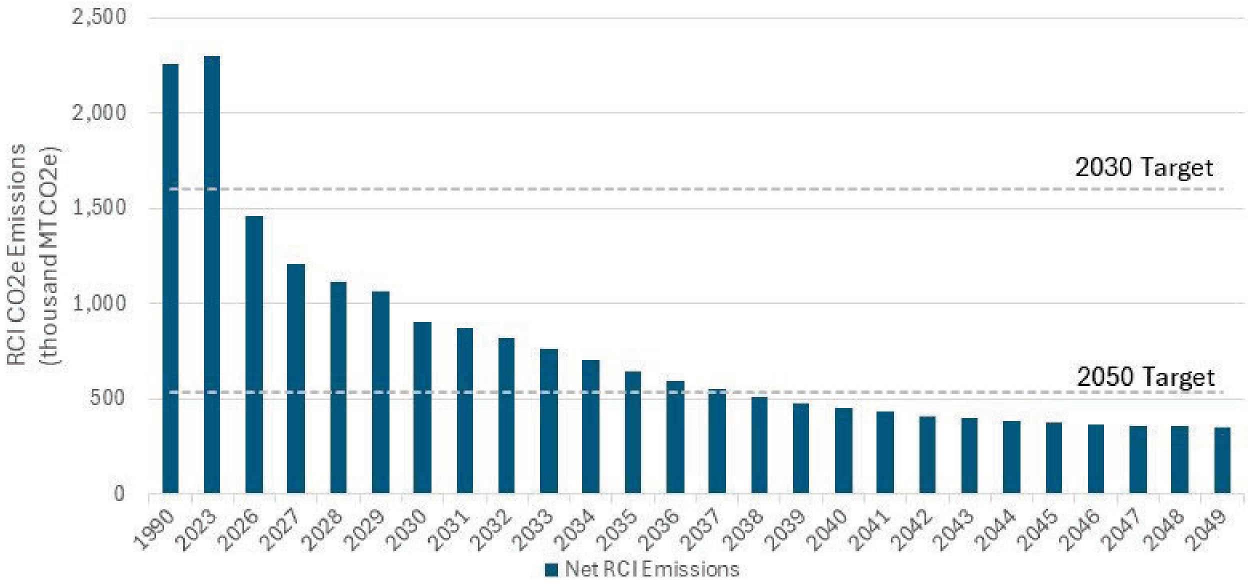
[56] https://outside.vermont.gov/agency/anr/climatecouncil/Shared%20Documents/1990-2021_GHG_Inventory_Uploads/_Vermont_Greenhouse_Gas_Emissions_Inventory_Update_1990-2021_Final.pdf

Figure 4: Maximum Achievable Net RCI Emissions and GWSA Targets



While the increased emissions from 1990 to 2023 undercut achievement toward the 2030 GWSA target, the Maximum Achievable potential comfortably achieves all statutory targets.

Figure 5 presents the Maximum Achievable cumulative annual GWSA emissions reduction by measure type. The “Energy Efficiency” measure type includes opportunities such as weatherization and faucet aerators, “Fuel Switching” includes fuel-switching measures enabled by new equipment such as heat pumps, and “Clean Fuels” includes biofuels and renewable fuels. Clean Fuels dominate the potential in the early years as they have high initial availability and ramp quickly through 2030 up to available resource and/or blending limits. Fuel Switching potential ramps more slowly but represents 71% of the reduction potential by the end of 2049 as it partially displaces the need for Clean Fuels.

Figure 5: Maximum Achievable Cumulative Annual GWSA Emissions Reduction by Measure Type

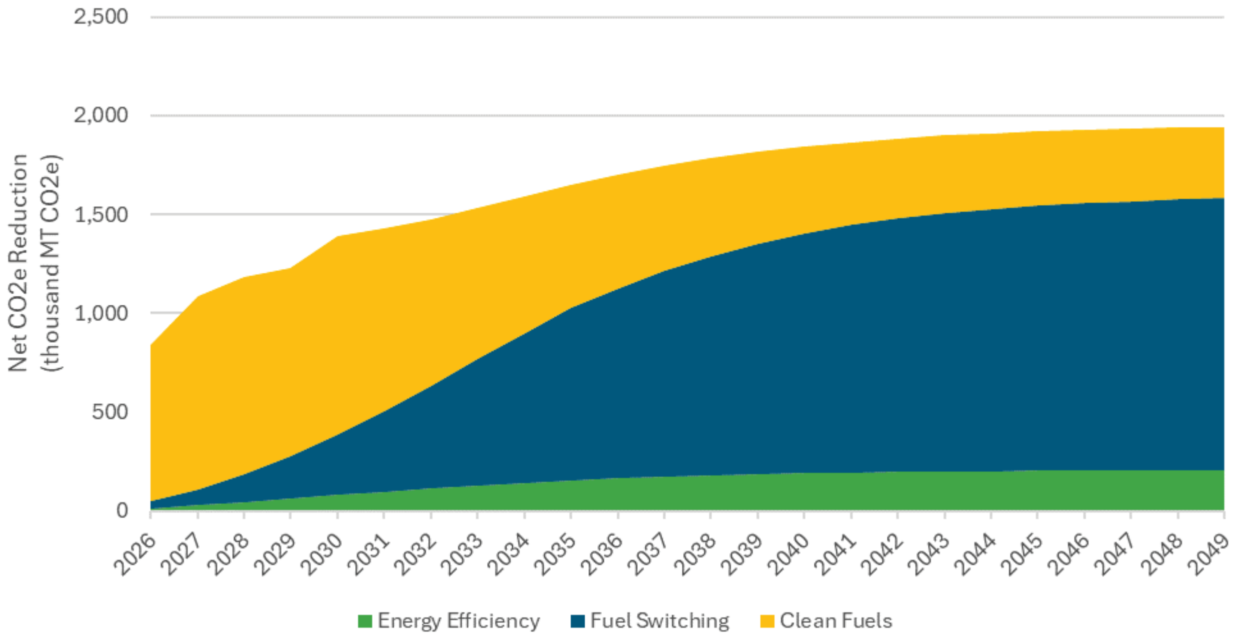
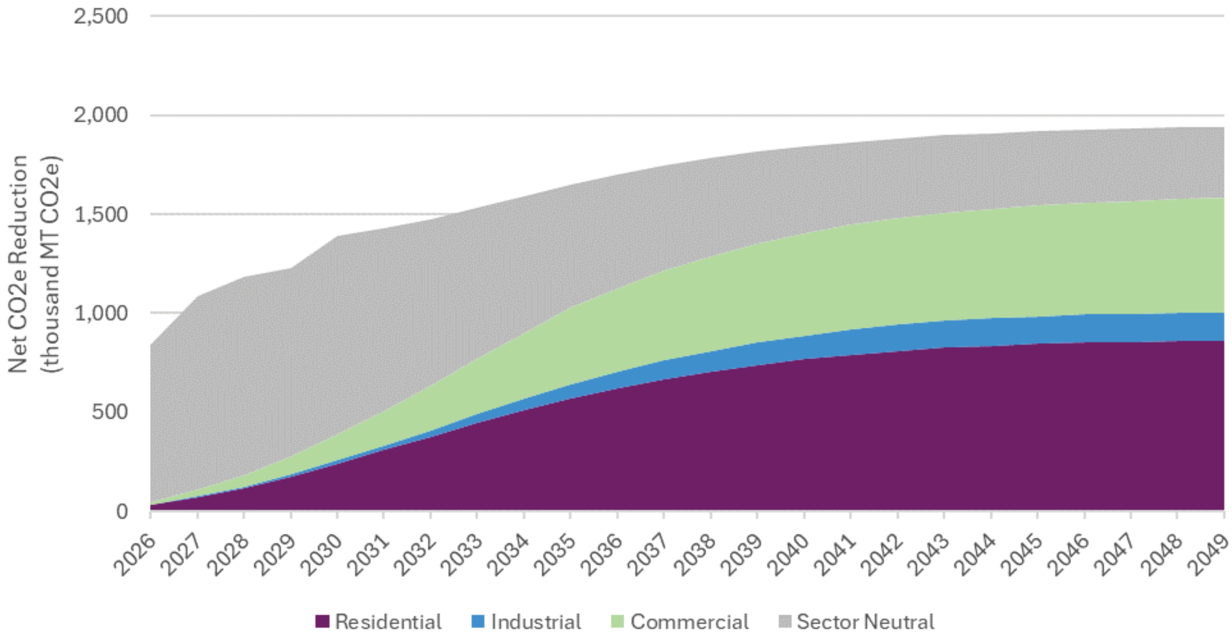


Figure 6 below shows the Maximum Achievable cumulative annual GWSA emissions reductions by sector from 2026 through 2049. Mirroring the emissions inventory, residential has the highest long term emissions reduction potential, followed by commercial then industrial. “Sector Neutral” potential is served entirely by clean fuels. Given the difficulty of electrifying certain industrial end-uses, much of the clean fuels potential is likely to serve the industrial sector in later years.

Figure 6: Maximum Achievable Cumulative Annual GWSA Emissions Reductions by Sector



4.2.2 Summary of Costs, Benefits, and Cost-Effectiveness Summary

Table 13 below presents the present value societal benefits, costs, net benefits, and portfolio VT SCT BCR for the Maximum Achievable scenario both with and without estimated program non-incentive costs (e.g., program administrative costs; marketing; evaluation, measurement and verification) through 2029 and 2049. While the residential and sector-neutral opportunities are cost-effective in aggregate, the commercial and industrial sectors are not cost-effective. However, the entirety of the Maximum Achievable portfolio through 2049 is cost-effective without consideration of non-incentive program costs and would generate $1.03 billion in net societal benefits. A discussion of non-incentive program costs can be found in Section 5. Note from Table 1 that societal costs include installed costs (less deferred replacement credits) and any increased non-electric fuel costs and any associated externalities (e.g., SCC, NO2).

	Cumulative Through 2029 (Million 2024$)				Cumulative Through 2049 (Million 2024$)			
Sector	PV Societal Benefits	PV Societal Costs	PV Societal Net Benefits	VT SCT BCR	PV Societal Benefits	PV Societal Costs	PV Societal Net Benefits	VT SCT BCR
Residential	1,470	1,453	17	1.01	5,289	4,601	689	1.15
Commercial	544	919	(375)	0.59	2,550	4,036	(1,486)	0.63
Industrial	27	84	(58)	0.32	254	811	(558)	0.31
Sector Neutral	2,216	2,048	168	1.08	7,972	5,590	2,381	1.43
Total w/o Non-Incentive Costs	**4,256**	**4,504**	**(248)**	**0.95**	**16,065**	**15,038**	**1,027**	**1.07**
Total w/ Non-Incentive Costs	**4,256**	**4,899**	**(642)**	**0.87**	**16,065**	**16,568**	**(503)**	**0.97**

Table 13: Maximum Achievable Societal Benefits and Costs

Figure 7 below presents the incremental annual program incentive spending associated with the Maximum Achievable scenario by measure type. High incentive spending in early years reflects high incremental annual participation. As cumulative adoption of Energy Efficiency and Fuel Switching measure increases over time, incremental annual participation (and associated incentive spending) drop as emissions reductions from these measure types are assumed to persist through the full analysis period. In assessing the relative magnitude of incentive spending between Clean Fuels and the other measure types it important to note that the Clean Fuels incentives only “buy” emissions reductions for a single year whereas the other measure types typically generate benefits for 15-20 years. Present value incentive costs over the analysis period total $11.1 billion.

Figure 7: Maximum Achievable Incremental Annual Incentives by Measure Type

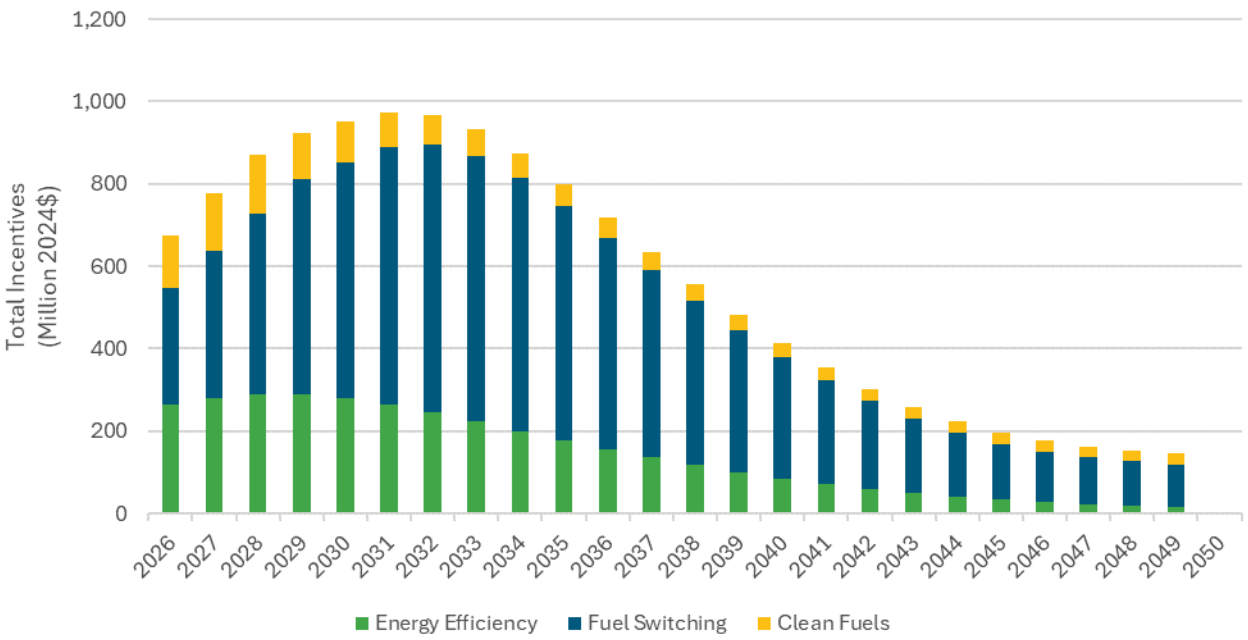
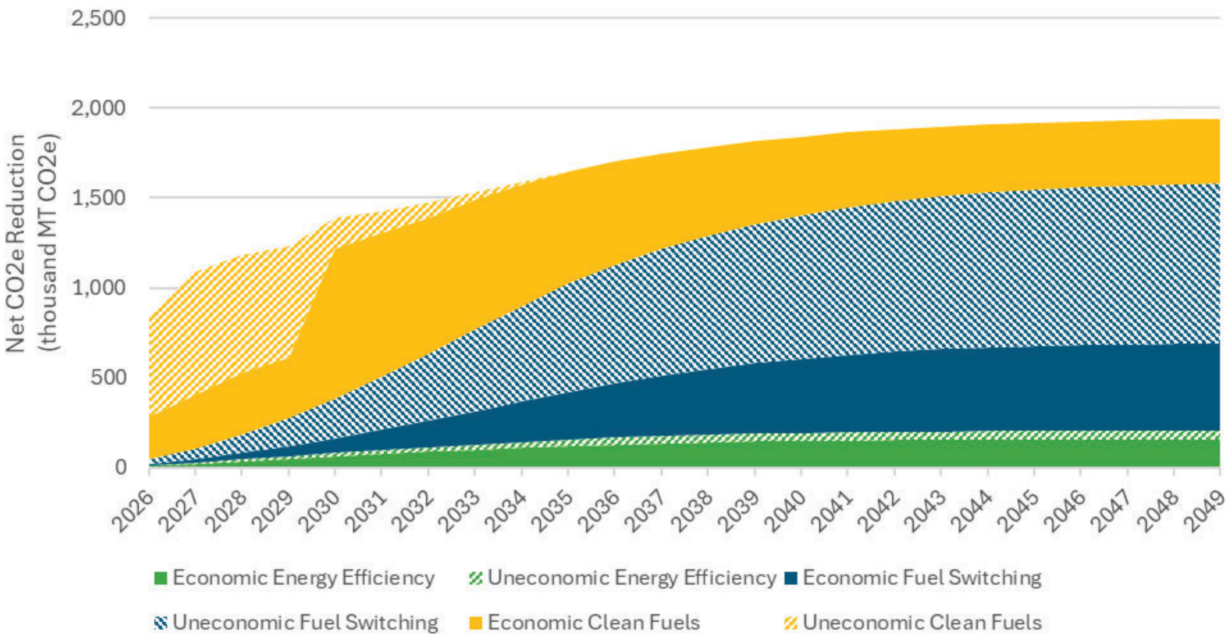


Figure 8 below shows the Maximum Achievable cumulative annual GWSA emissions reduction by measure type and cost-effectiveness according to the Vermont Societal Cost Test ("VT SCT"). While the majority of Energy Efficiency and Clean Fuels potential is cost-effective, the majority of the Fuel Switching potential is not cost-effective. The results demonstrate that in 2049, 52% of the identified Maximum Achievable potential emissions reductions are cost-effective.

Figure 8: Maximum Achievable Cumulative Annual GWSA Emissions Reduction by Measure Type and Cost Effectiveness



4.2.3 Summary of Key Measure Impacts

The following tables show the top 10 measures by sector ranked by their contribution to required 2050 RCI emissions reductions. The tables also show these same measures' contribution to required 2030 reductions targets, eight out of the top ten measures are Fuel Switching measures and two are Energy Efficiency measures. The measure with the highest contribution to 2050 targets is "Heat Pump Water Heater," and heat pump technologies make up seven of the ten opportunities.

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2030 (GWSA), 2029	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2049	PV Net Societal Benefits (Million 2024$), 2026
Heat Pump Water Heater	Res	FS	2.1%	12.2%	$881
Ductless Heat Pump - Full Replacement	Res	FS	8.4%	11.8%	($328)
Central Heat Pump - Full Replacement	Res	FS	4.9%	6.8%	($238)
Advanced Thermostat	Res	EE	1.1%	2.5%	$260
Ductless Heat Pump - Part-to-Full	Res	FS	0.0%	2.2%	($23)
Ductless Heat Pump - Partial Displacement	Res	FS	1.3%	1.8%	($85)
Ground Source Heat Pump	Res	FS	1.1%	1.6%	($125)
Central Heat Pump - Part-to-Full	Res	FS	0.0%	1.5%	($29)
FF to Wood Heat	Res	FS	1.1%	1.3%	$9
Air Sealing	Res	EE	1.9%	1.3%	$22

Table 14: Maximum Achievable Top 10 Residential Measures by Contribution to Required 2050 RCI Emissions Reductions

Table 15 below shows the top 10 commercial and industrial measures by contribution to required 2050 RCI emissions reductions. Eight out of the ten measures are Fuel Switching measures and two are Energy Efficiency measures. The commercial measure with the highest contribution to 2050 targets is Variable Refrigerant Flow (VRF) Heat Pumps – Full Replacement

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2030 (GWSA), 2029	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2049	PV Net Societal Benefits (Million 2024$), 2026
Variable Refrigerant Flow (VRF) Heat Pump - Full Replacement	Com	FS	3.2%	7.7%	$(403)
Ductless Heat Pump - Full Replacement	Com	FS	1.4%	4.4%	$(43)
Heat Pump Rooftop Unit (RTU)	Com	FS	1.4%	3.2%	$128
Heat Pump Water Heater	Com	FS	1.5%	3.0%	$(17)
Electric Furnace - Process Heat	Ind	FS	0.3%	2.6%	$(154)
Industrial Indirect Boiler to Electric Boiler	Ind	FS	0.3%	2.5%	$(246)
Central Heat Pump - Full Replacement	Com	FS	0.7%	2.1%	$(18)
Networked Geothermal Heat Pump	Com	FS	0.1%	1.9%	$(202)
Advanced Thermostats	Com	EE	2.0%	1.8%	$199
Envelope Improvements	Com	EE	1.2%	1.6%	$(1,205)

Table 15: Maximum Achievable Top 10 C&I Measures by Contribution to Required 2050 RCI Emissions Reductions

Table 16 below shows the top 10 sector neutral measures by contribution to required 2050 RCI emissions reductions.

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2030 (GWSA), 2029	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2049	PV Net Societal Benefits (Million 2024$), 2026
Out-of-State | Advanced Renewable Diesel | Residues and Waste	All	CF	0.0%	14.4%	$891
Out-of-State | Biomethane | Landfill Gas	All	CF	10.0%	2.0%	$42
In-State | Biomethane | Animal Manure	All	CF	3.3%	1.3%	$768
In-State | Biomethane | Landfill Gas	All	CF	3.0%	1.2%	$22
Out-of-State | Biomethane | Animal Manure	All	CF	2.3%	0.6%	$408
In-State | Hydrogen | Dedicated Renewables	All	CF	3.8%	0.5%	$66
Out-of-State | Biomethane | Wastewater	All	CF	1.0%	0.2%	$9
Out-of-State | Biomethane | Residues and Waste	All	CF	0.0%	0.2%	$65
In-State | Biomethane | Wastewater	All	CF	0.0%	0.0%	$0
In-State | Biomethane | Residues and Waste	All	CF	0.0%	0.0%	$0

Table 16: Maximum Achievable Top 10 Sector Neutral Measures by Contribution to Required 2050 RCI Emissions

Full measure-level Maximum Achievable potential results can be viewed in Appendices C2, D2, and E2.

4.3 ACT 18 OPTIMIZED POTENTIAL

4.3.1 Summary of Emissions Reduction Potential

Figure 9 below presents the Act 18 Optimized net RCI emissions by year. As discussed above, this scenario has been calibrated to meet the 2030 target in 2029 and the 2050 target in 2049. Required annual reductions for 2026-2029 have been linearly interpolated between the 2023 historical emissions and the 2030 target. Likewise, required annual reductions for 2030-2049 have been linearly interpolated between the 2030 target and the 2050 target.

Figure 9: Act 18 Optimized Net RCI Emissions and GWSA Targets

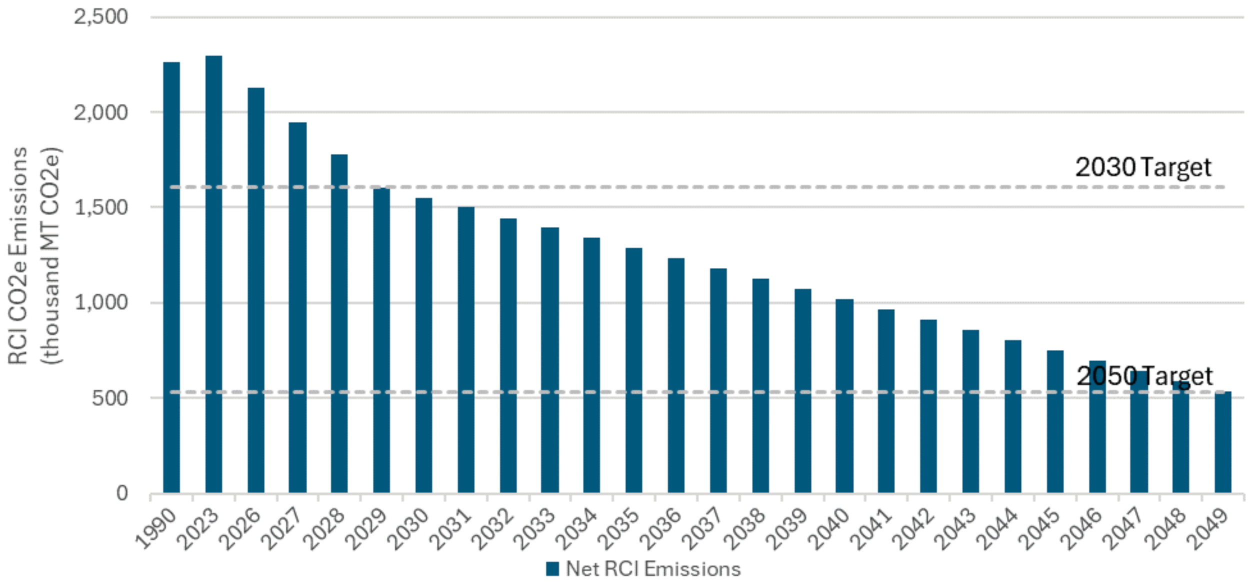


Figure 10 presents the Act 18 Optimized cumulative annual GWSA emissions reduction by measure type. Cost-optimization and higher near-term availability leads to Clean Fuels dominating the potential in the early years; however, Clean Fuels alone cannot meet the entirety of the 2050 GWSA targets. Therefore, Fuel Switching measures are gradually ramped such that combined contribution of all measure types meet statutory requirements in 2049. Similar to the Maximum Achievable scenario, Fuel Switching measures represent 67% of the reduction potential by the end of 2049.

Figure 10: Act 18 Optimized Cumulative Annual GWSA Emissions Reduction by Measure Type

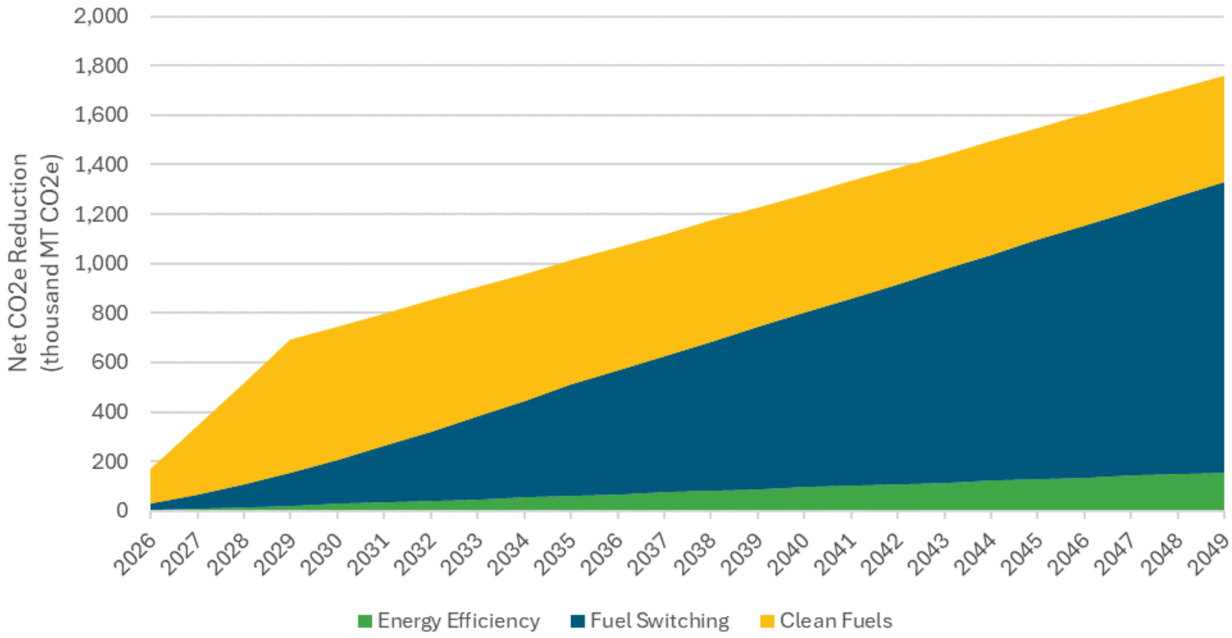
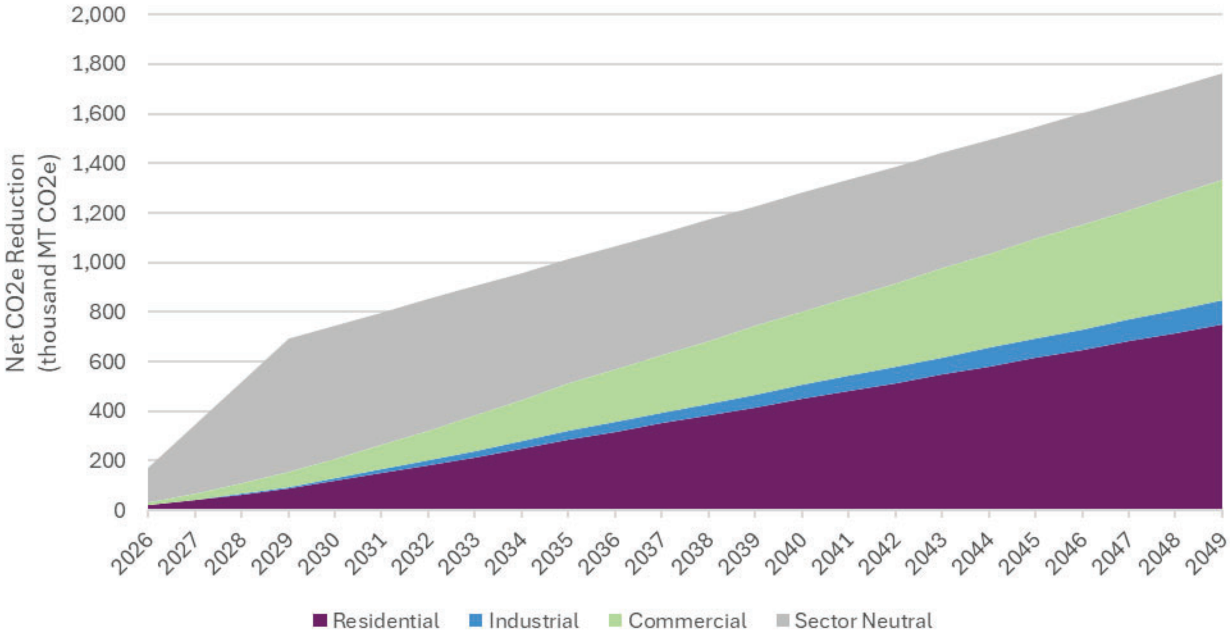


Figure 11 below shows the Act 18 optimized cumulative annual GWSA emissions reductions by sector from 2026 through 2049. Consistent with the Maximum Achievable potential, residential has the highest long term emissions reduction potential, followed by commercial then industrial.

Figure 11: Act 18 Optimized Cumulative Annual GWSA Emissions Reductions by Sector



4.3.2 Summary of Costs, Benefits, and Cost-Effectiveness Summary

Table 17 below presents the present value societal benefits, costs, net benefits, and portfolio VT SCT BCR for the Act 18 Optimized scenario both with and without estimated non-incentive program costs through both 2029 and 2049. Even though the industrial sector, taken as a whole, is not cost-effective, all other sectors and the entirety of the Act 18 Optimized scenario is cost-effective and would generate $282 million and $3.0 billion in net societal benefits by 2029 and 2049, respectively, without consideration of potential program non-incentive costs. When the impacts of program non-incentive costs are included, the scenario would generate $124 million and $2.1 billion in net societal benefits by 2029 and 2049, respectively.

	Cumulative Through 2029 (Million 2024$)				Cumulative Through 2049 (Million 2024$)			
Sector	PV Societal Benefits	PV Societal Costs	PV Societal Net Benefits	VT SCT BCR	PV Societal Benefits	PV Societal Costs	PV Societal Net Benefits	VT SCT BCR
Residential	744	643	101	1.16	4,293	3,401	892	1.26
Commercial	282	268	14	1.05	1,505	1,469	36	1.02

Sector	Cumulative Through 2029 (Million 2024$)				Cumulative Through 2049 (Million 2024$)			
	PV Societal Benefits	PV Societal Costs	PV Societal Net Benefits	VT SCT BCR	PV Societal Benefits	PV Societal Costs	PV Societal Net Benefits	VT SCT BCR
Industrial	20	56	(35)	0.36	177	467	(290)	0.38
Sector Neutral	751	550	201	1.37	5,762	3,414	2,348	1.69
Total w/o Non-Incentive Costs	**1,798**	**1,517**	**282**	**1.19**	**11,737**	**8,751**	**2,986**	**1.34**
Total w/ Non-Incentive Costs	**1,798**	**1,674**	**124**	**1.07**	**11,737**	**9,623**	**2,114**	**1.22**

Table 17: Act 18 Optimized Societal Benefits and Costs

Figure 12 below illustrates the present value of cumulative societal costs and benefits by category in 2049. The majority of the benefits are generated by avoided social economic and environmental damages and avoided fuel oil and propane consumption while the majority of the costs are due to incremental measure costs and increased consumption of biofuels and renewable fuels. Note that to simplify the presentation of Figure 12, certain categories that contribute to both costs and benefits have been combined into “net” column elements (e.g., costs from increased social economic and environmental damages due to the combustion of renewable fuels and benefits from decreased damages due to avoided fossil fuel consumption). Therefore, the total societal costs and benefits presented in Figure 12 do not equal those presented in Table 17 above, but the societal net benefits are consistent.

Figure 12: PV Cumulative Societal Costs and Benefits by Category, 2049

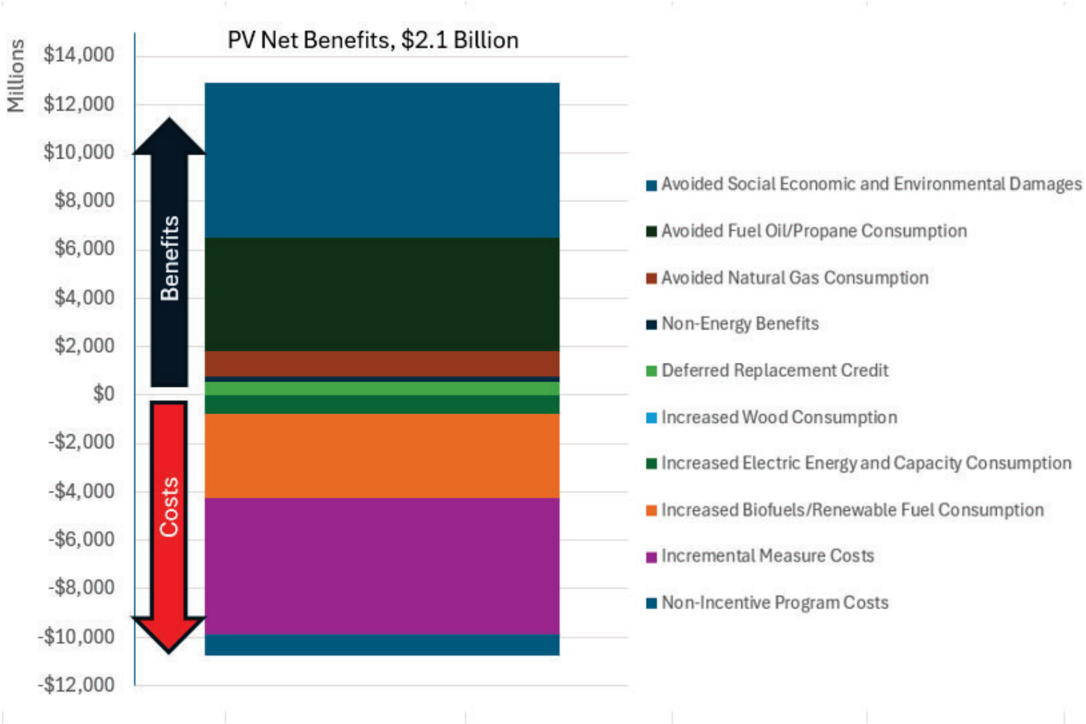


Figure 13 presents the incremental annual program incentive spending, which again assumes incentives cover the full incremental costs of all measures associated with the Act 18 Optimized scenario by measure type. After a modest ramp in incentive spending between 2026-2029, incremental annual incentives spending levels off for the remainder of the analysis period. Annual spending is dominated by Fuel Switching measures with comparable spending between Clean Fuels and Energy Efficiency. Present value incentive costs over the analysis period total $6.4 billion.

Figure 13: Act 18 Optimized Incremental Annual Incentives by Measure Type

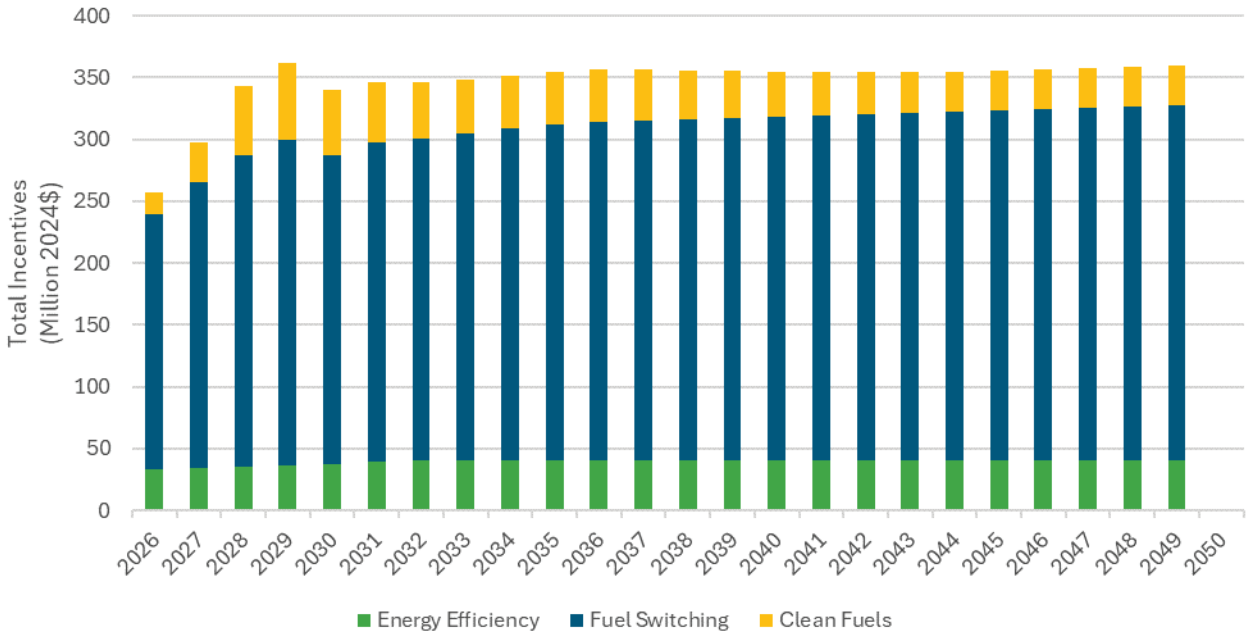
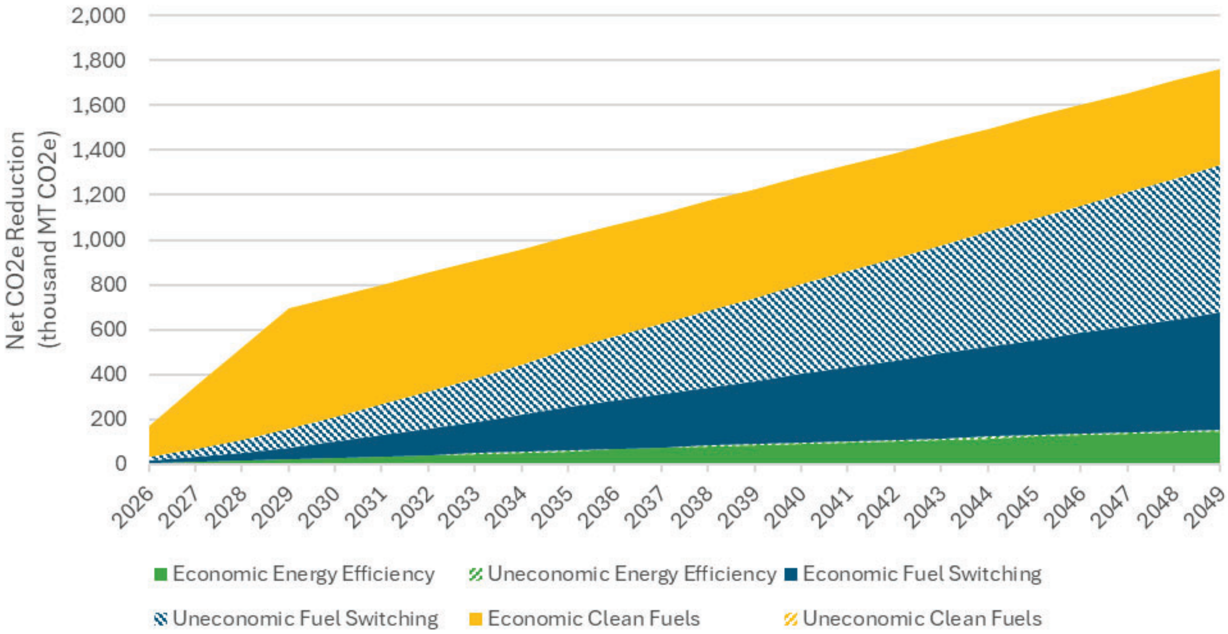


Figure 14 below shows the Act 18 Optimized cumulative annual GWSA emissions reduction by measure type and cost-effectiveness according to the Vermont Societal Cost Test ("VT SCT"). Similar to the Maximum Achievable scenario, the vast majority of Energy Efficiency and Clean Fuels potential is cost-effective. A significant portion of the Fuel Switching potential—56% in 2049—is not cost effective driven in part by assuming all low- and moderate-income opportunities are adopted in this scenario Overall, the results demonstrate that in 2049, 62% of the identified Act 18 Optimized emissions reductions are cost-effective.

Figure 14: Act 18 Optimized Cumulative Annual GWSA Emissions Reduction by Measure Type and Cost Effectiveness



4.3.3 Summary of Key Measure Impacts

The following tables show the top 10 measures by sector ranked by their contribution to required 2050 RCI emissions reductions. The tables also show these same measures' contribution to required 2030 reductions targets,

Table 18 below shows the top 10 residential measures by contribution to required 2050 RCI emissions reductions. Eight out of the top ten measures are Fuel Switching measures and the remaining two are Energy Efficiency measures. The measure with the highest contribution to 2050 targets is "Heat Pump Water Heater" and heat pump technologies make up seven of the ten opportunities.

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2030 (GWSA), 2029	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2049	PV Net Societal Benefits (Million 2024$), 2026
Heat Pump Water Heater	Res	FS	2.1%	11.0%	$773
Ductless Heat Pump - Full Replacement	Res	FS	4.1%	10.9%	($192)
Central Heat Pump - Full Replacement	Res	FS	2.4%	6.3%	($148)
Advanced Thermostat	Res	EE	0.9%	2.5%	$242
Ductless Heat Pump - Partial Displacement	Res	FS	0.6%	1.7%	($57)
Fossil Fuel to Wood Heat	Res	FS	0.6%	1.3%	$11
Ground Source Heat Pump	Res	FS	0.5%	1.3%	($82)
Central Heat Pump - Partial Displacement	Res	FS	0.4%	1.2%	($42)
Ductless Heat Pump - Part-to-Full	Res	FS	0.0%	1.1%	($5)
Air Sealing	Res	EE	0.4%	1.1%	$30

Table 18: Act 18 Optimized Top 10 Residential Measures by Contribution to Required 2050 RCI Emissions Reductions

Table 19 below shows the top 10 commercial and industrial measures by contribution to required 2050 RCI emissions reductions. Eight out of the ten measures are Fuel Switching measures and two are Energy Efficiency measures. The C&I measure with the highest contribution to 2050 targets is “Variable Refrigerant Flow (VRF) Heat Pumps – Full Replacement.”

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2030 (GWSA), 2029	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2049	PV Net Societal Benefits (Million 2024$), 2026
Variable Refrigerant Flow (VRF) Heat Pump - Full Replacement	Com	FS	2.6%	7.5%	$(347)
Ductless Heat Pump - Full Replacement	Com	FS	1.3%	4.3%	$(34)
Heat Pump Rooftop Unit (RTU)	Com	FS	1.2%	3.2%	$121
Heat Pump Water Heater	Com	FS	1.1%	3.0%	$(13)
Industrial Indirect Boiler to Electric Boiler	Ind	FS	0.3%	2.3%	$(215)
Central Heat Pump - Full Replacement	Com	FS	0.6%	2.0%	$(14)
Advanced Thermostats	Com	EE	0.8%	1.8%	$186
Electric Furnace - Process Heat	Ind	FS	0.2%	1.5%	$(56)
Energy Recovery Ventilator	Com	EE	0.1%	1.2%	$42
Ductless Heat Pump - Partial Displacement	Com	FS	0.3%	1.1%	$4

Table 19: Act 18 Optimized Top 10 C&I Measures by Contribution to Required 2050 RCI Emissions Reductions

Table 20 below shows the top 10 sector neutral measures by contribution to required 2050 RCI emissions reductions.

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2030 (GWSA), 2029	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2049	PV Net Societal Benefits (Million 2024$), 2026
Out-of-State | Advanced Renewable Diesel | Residues and Waste	All	CF	0.0%	17.3%	$847
Out-of-State | Biomethane | Landfill Gas	All	CF	10.0%	2.0%	$42
In-State | Biomethane | Animal Manure	All	CF	3.3%	1.3%	$768
In-State | Biomethane | Landfill Gas	All	CF	3.0%	1.2%	$22
In-State | Hydrogen | Dedicated Renewables	All	CF	3.8%	1.0%	$94
Out-of-State | Biodiesel | Purpose-Grown Oil Crops & Waste Fats and Oils	All	CF	24.2%	0.6%	$68
Out-of-State | Biomethane | Animal Manure	All	CF	2.3%	0.6%	$408
Out-of-State | Biomethane | Wastewater	All	CF	1.0%	0.2%	$9
Out-of-State | Biomethane | Residues and Waste	All	CF	0.0%	0.2%	$65
In-State | Advanced Renewable Diesel | Residues and Waste	All	CF	0.0%	0.0%	$1

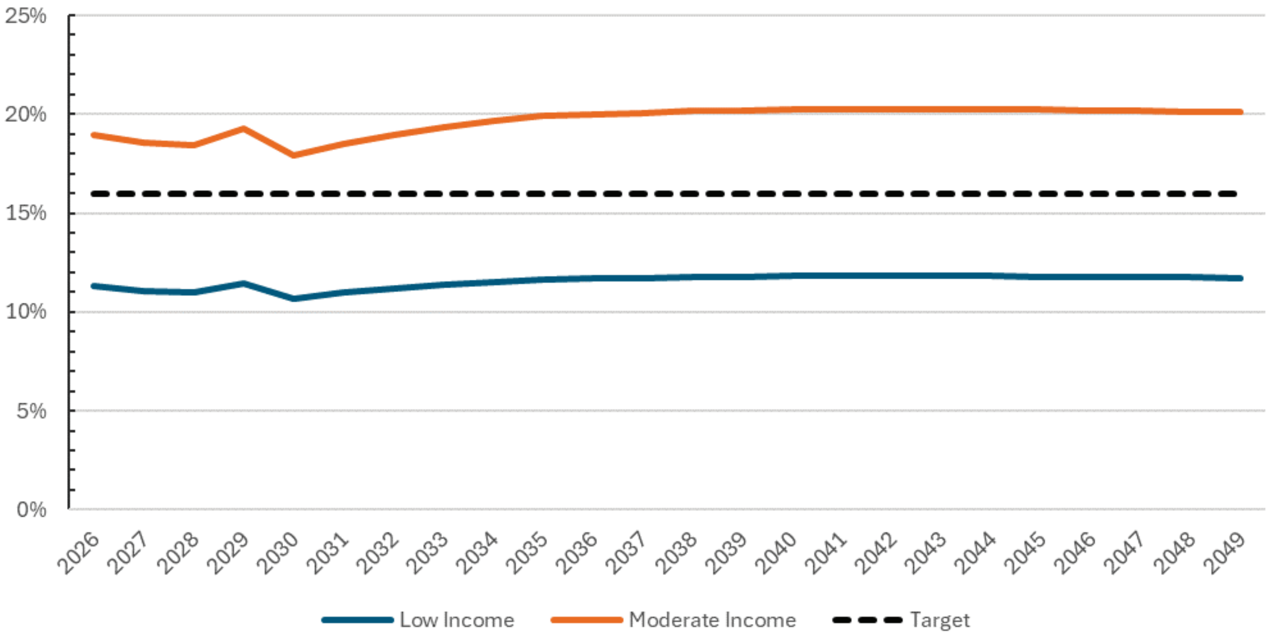
Table 20: Act 18 Optimized Top 10 Sector Neutral Measures by Contribution to Required 2050 RCI Emissions

Full measure-level Act 18 Optimized potential results can be viewed in Appendices C3, D3, and E3.

Act 18 Optimized Percent Total Cumulative Annual Lifecycle Emissions Reduction by Income Level

The figure below shows Act 18 Optimized percent total cumulative annual lifecycle emissions reduction by income level from 2026 through 2050. Act 18 requires "[o]f their annual [clean heat credit] requirement, each obligated party shall retire at least 16 percent from customers with low income and an additional 16 percent from customers with low or moderate income." The Act 18 Optimized scenario exceeds the requirement for Moderate Income but falls short for Low Income which achieves a maximum contribution of just under 12% in 2040 and beyond.

Figure 15: Act 18 Optimized Percent Total Cumulative Annual Lifecycle Emissions Reduction by Income Level



Even when assuming all low- and moderate income measures are adopted in the Act 18 Optimized scenario, the modeled low income requirement is not achieved. It is possible that there is an inconsistency between data used to inform the 16% target and the assumptions made in this study regarding how much of total RCI emissions low-come residential is responsible for. Such sustained, high attainment for low-income households may not be possible. This analysis assumes clean fuels potential is apportioned to sector and income category based on remaining conventional fuel consumption. As the low-income target was not achieved in the model, the bill impact requirement was not considered.

5.0 DISCUSSION

5.1 ASSUMPTIONS AND CAVEATS

This is a highly complex analysis, with many cross-measure interactions, assumptions, projections, and other considerations. This section highlights some of the largest sources of uncertainty in the analysis.

5.1.1 Program Costs

This study primarily focuses on the Max Achievable and Act 18 Optimized potential, with a focus on total installed costs, in order to get insight into the upper bound of potential and give rough estimates on possible societal costs that this would entail. There is a lot of uncertainty about how the clean heat credits would be delivered and how any related programs would be administered, including:

- How may fuel suppliers would deliver credits themselves versus buying them from the default delivery agent or other sources?
- Who the default delivery agent would be and how they would structure the programs?
- What types of measures would the market be most inclined to adopt?
- How much of the delivery costs could be offset by efficiency Vermont funds, federal programs, tax credits, and other sources?

Finally, although the installed cost less deferred replacement per emissions reduction is used for screening, this study focuses on the full installed costs of the measures. In reality, any program is likely to only pay a fraction of this amount, especially in a cost-optimized scenario that is not trying to reach 80%+ of the total applicable market, and especially in the initial years of the program that are reaching early adopters and customers where the economics makes the most sense. If installing a cold climate heat pump to replace a fossil fuel boiler or furnace costs more than $20,000 – obviously a program only paying half of the cost would see significant savings compared to a program paying 100% of incremental cost. In reality, the amount of incentive coverage that is necessary will depend on 1) the eagerness of Vermonters to install the measure 2) the amount of clean heat credits required, and 3) the opportunity cost of getting clean heat credits via other measures. A study can provide order of magnitude estimates on possible societal costs, but much will depend on the details of how a Clean Heat Standard is implemented. Program cost implications, including potential additional funding streams, are discussed in more detail in Section 5.2.

5.1.2 Non-Incentive Program Costs

In both the Maximum Achievable and Act 18 Optimized scenarios, we assume non-incentive program costs of 3% for biofuel measures and 15% for energy efficiency/fuel switching measures of the modeled incentive costs. However, there is particularly large uncertainty in this value, due to the unknowns discussed above regarding how any program to deliver clean heat credits would be structured and delivered. We note that this is very low compared to current EVT and BED spending on non-incentive costs.[57] This difference is due to several factors that seem likely to drive non-incentive costs down relative to measure costs:

- Non-incentive costs for clean fuels are likely to be significantly lower than for efficiency and fuel switching, as it requires less marketing, outreach, and technical assistance; clean fuels are a very large fraction of total potential, particularly in the cost optimized scenario.
- Efficiency programs promote mostly lower cost measures and don't pay the full installed cost. The non-incentive costs needed to provide rebates for $20,000 worth of light bulbs will clearly be higher than the non-incentive costs needed to install and rebate one heat pump.
- To the extent that many fuel suppliers are generating their own clean heat credits, this may be partially rolled up into their general overhead.

5.1.3 Market Effects

As is always the case in potential studies, this study projects costs and savings based on current day prices and energy rates – a forecast that has significant inherent uncertainty. However, this study also considers scenarios with significant adoption of relatively new technologies, at a time when other states in the region are also setting ambitious targets for these same technologies. In this scenario, the market effects from Vermont's Act 18 and similar policies in other states will likely have a significant impact on the prices of the technologies. Some speculative possibilities include:

- This study relies somewhat on the availability of clean fuels from out-of-state sources. If clean heat policies in other states such as California, New York, and Massachusetts significantly increase their demand, prices are likely to rise and/or availability will be lower than forecast.
- This study envisions a significant increase in demand for full replacement cold-climate heat pumps. This could result in short-term price increases due to shortages in trained contractors and the availability of additional incentive money, but medium-to-long-term price declines are likely as additional contractors see the demand/profit and join the market, and as the technology and installation both become cheaper due to learning/economies of scale.
- Unlike efficiency, the desirability of fuel switching is significantly impacted by the relative cost between electricity and natural gas, oil, or propane. Large changes in this differential (as opposed to the absolute cost of any fuel) will be a significant driver of the desirability of heat pumps.

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[57] In 2020, the ratio of non-incentives program costs to incentive costs for Efficiency Vermont was 87% (https://www.efficiencyvermont.com/Media/Default/docs/plans-reports-highlights/2022/efficiency-vermont-annual-report-2022.pdf). In that same year, the ratio Burlington Electric Department for 123% (https://www.burlingtonelectric.com/wp-content/uploads/2022-BED-EEU-Annual-Report.pdf). For programs with similar annual budgets to those modeled in the Act 18 Optimized scenario, this ratio typically ranges from 30-40%, but is highly variable depending on program design. For example, the ratio for Eversource's electric and gas programs in Massachusetts in 2023 were 39% and 29%, respectively (https://ma-eeac.org/wp-content/uploads/D.P.U.-24-65-NSTAR-Electric-Plan-Year-Report-Combined-6-3-24.pdf, https://ma-eeac.org/wp-content/uploads/D.P.U.-24-65-NSTAR-Gas-Plan-Year-Report-Combined-6-3-24.pdf). In that same year, the ratio for National Grid's Massachusetts electric and gas programs were 36% and 32%, respectively (https://ma-eeac.org/wp-content/uploads/National-Grid-Electric-EE-PYR.pdf, https://ma-eeac.org/wp-content/uploads/National-Grid-Gas-EEPYR.pdf). Note that the non-incentive costs for the Massachusetts reference data exclude any performance incentives.

5.1.4 Measure Loading Orders

The Maximum Achievable potential assumes a measure loading order of efficiency first, then fuel switching, then clean fuel to cover the remaining fuel load. This allows for the maximum GHG reductions in a relatively cost-efficient way. However, due to differences in the cost per ton of GHG reduced, the Act 18 Optimized scenario relies significantly, but not entirely, on clean fuels. In practice, in the future this will necessitate efficiency and fuel switching on homes that are already using clean fuels with low (but non-zero) emissions. The clean heat credits for these situations will look more expensive on a cost per ton of carbon reduced basis.

5.2 OTHER PROGRAMS IMPACTING COSTS

There are many different policies and programs active in Vermont that reduce the upfront cost of measures eligible under Act 18. The budget from these programs will be available to offset the total costs of the Clean Heat Standard estimated in Section 3. This is a non-comprehensive overview of these programs and their likely financial contributions, focusing on a few of the major external programs and policies that will significantly impact CHS measure adoption and costs.

5.2.1 Federal Funding & Tax Credits

The Inflation Reduction Act of 2022 (IRA) enhanced and extended tax credits for energy efficiency and decarbonization, while also establishing two energy efficiency rebate programs, the Home-Owner Energy Savings (HOMES) rebate and the High-Efficiency Electric Home Rebate Act (HEEHRA). The table below shows the likely flow of funds to Vermont from the HOMES/HEEHRA programs. It's important to acknowledge that the IRA introduced a variety of funding sources that could potentially reduce CHS costs, including programs targeted at rural towns and Loan Program Office funding. We assume an even distribution of HOMES/HEEHRA funding from 2026 to 2030.

Program	2026	2027	2028	2029
Homes	$4,893,820	$4,893,820	$4,893,820	$4,893,820
HEEHRA	$4,865,360	$4,865,360	$4,865,360	$4,865,360
Total	$9,759,180	$9,759,180	$9,759,180	$9,759,180

Table 21: Federal Funding by Program and Year

IRA also enhanced the 25C tax credit, which provides a capped 30% tax credit for certain electrification, efficiency, and electrification-ready measures, and 25D tax credit, which provides an uncapped tax credit on geothermal heat pumps (and other technologies not eligible for clean heat credits under Act 18). NV5 did not account for the 48E tax credit due to its highly project specific nature.

The tables below show per household impacts from the 25C and 25D tax credits. Note that many households, particularly low- and moderate-income households are likely to not have the necessary tax burden to benefit from the credits. Others may pursue multiple measures and thus not get the full benefit or may choose not to utilize the tax credit for various reasons. Additionally, no assumptions were made about the tax credits being extended beyond the currently prescribed dates.

25C	Single Family	Multifamily	Mobile Home
Air Source Heat Pumps	$2,000	$2,000	$2,000
Wood Stoves	$2,000	$800	$1,700
HPWH	$800	$800	$800
Insulation	$1,200	$1,000	$1,000

Table 22: Impact of 25C Tax Credit

25D	Single Family	Multifamily	Mobile Home
Geothermal Heat Pumps	$12,000	$4,500	$9,900

Table 23: Impact of 25D Tax Credit

5.2.2 Tier 3 Renewable Energy Standard Activity

Vermont’s Renewable Energy Standard (RES), revised in 2024, mandates that electric Distribution Utilities (DUs) obtain a certain percentage of their electricity from renewable sources. A subcomponent of this policy, known as Tier 3, specifically requires implementation of "energy transformation projects" as part of the DU’s obligation. These projects aim to reduce the fossil fuel consumption of DU customers.

The table below shows total likely contribution from the DUs to CHS measure during the analysis period. In 2022, the DUs significantly exceeded minimum tier 3 requirements in the RES. We assume that the DUs will continue exceeding the minimums, holding 2022 spending constant in real terms.

The following table presents the overall spending forecasted from this policy.

Distribution Utility	Spending in $2024
GMP	$11,231,431
BED	$1,102,991
WEC	$274,098
VEC	$766,166
VPPSA	$377,379
Stowe	$166,689
Hyde Park*	$9,167
Total Spending	**$13,927,921**

Table 24: Contribution from DUs to CHS during analysis period

*Hyde Park spending estimated based on average $ per MWh of other DUs. Hyde Park used carryover activity from previous year for 2022.

5.2.3 Pre-Weatherization and Pre-Electrification Barriers

Pre-weatherization and pre-electrification barriers, such as knob-and-tube wiring and the need for electrical panel upgrades, represent potentially significant and uncertain costs in the pursuit of widespread decarbonization. Reliable data on the prevalence of these barriers and the costs to remediate them are scarce, so our cost estimates are limited to the residential sector, where most available data is focused.

The table below shows estimated per household costs for pre-weatherization and pre-electrification barriers. The data we used is largely derived from Massachusetts energy efficiency programs, supplemented by personal communication with program administrators regarding the costs and prevalence of these types of projects. However, these estimates should be taken with caution. While the estimates are broken down by income bracket, we were unable to further segment them by housing type due to a lack of detailed information and therefore were not included in overall cost estimates. The following tables present average barrier costs on a per household basis only.

Income	Pre-Weatherization	Pre-Electrification	Comments
Market Rate	$1,000	$1,900	Based on Personal Communications with Eversource Energy & 25C Tax Credit
Moderate Income	$1,600	$3,300	Average of Low-Income & Market Rate Costs Without Tax Credits
Low Income	$2,200	$4,400	Based on MA-EEAC Presentation[58] & Personal Communications with Eversource Energy

Table 25: Average Barrier Costs Per Household Basis

5.2.4 Existing Efficiency Spending by EVT

A significant portion of current Efficiency Vermont spending goes towards measures eligible under Act 18, and thus could offset costs. The table below shows 2023 spending for relevant measures, and how much it would likely contribute during the analysis period. The table gives spending data from the 2023 year-end report, specifically from tables 6.10 and 6.17, and assumes that this spending remains constant to calculate likely impacts on Act 18 spending.

End Use	2023 Spending	2026 to 2050
Hot Water Efficiency	$ 1,642,609	$ 41,065,225
Hot water Fuel Switch	$ -	$ -
Space Heat Efficiency	$ 4,566,594	$ 114,164,850
Space Heat Fuel Switch	$ 2,049,194	$ 51,229,850
Industrial Process	$ 493,890	$ 12,347,250
Other Fuel Switch	$ 72,000	$ 1,800,000
Ventilation	$ 155,102	$ 3,877,550
Total	**$ 8,979,389**	**$ 224,484,725**

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[58] https://ma-eeac.org/wp-content/uploads/C-Team-2025-2027-Draft-Plan-Review-Updates-6.12.24.pdf

Table 26: Spending by End Use

5.3 SUMMARY OF OTHER CONTRIBUTING FUNDING SOURCES

To determine total funding already in place that could be applicable to Clean Heat measures, contributions from local programs and federal tax credits and programs were estimated included:

- EEU Spending
    - Electric EEC spending for EVT and BED (electrification only)
    - Thermal Energy and Process Fuel spending for EVT and BED
    - VGS spending
- Federal IRA funding from HOMES and HEEHRA programs as well as tax credits as discussed in section 5.2.1
- LMI Weatherization spending
- Tier III Renewable Energy Standard spending discussed in section 5.2.2

The total cumulative spending from these programs over the 24-year period is estimated to be $1.47B.

Funding	Total Spending
Total EEU Budget Applicable to CHS	$ 537,711,405
Total IRA Funding (HOMES/HEEHRA)	$ 39,036,720
Total LMI Wx Funding	$ 488,540,028
Total Tier III RES Spending	$ 334,270,104
Federal Tax Credits	$ 72,200,216
Total	**$ 1,471,758,473**

Table 27: Summary of Other Funding Sources

5.4 ESTIMATED RATE IMPACTS

Presumably, the incentive and non-incentive program costs necessary to implement programs that will generate clean heat credits will eventually be passed through to thermal sector fuel customers. To estimate the possible range of impacts on fuel rates, we used the Act 18 Optimized scenario to estimate remaining natural gas, fuel oil, and propane consumption in each year of the analysis period. Next, we developed the following four hypothetical cost scenarios:

1. Act 18 Optimized Incentive and Non-Incentive Costs, As Modeled
2. Act 18 Optimized Incentive and Non-Incentive Costs, As Modeled Less Other Funding
3. Act 18 Optimized Incentive and Non-Incentive Costs, 60% Modeled
4. Act 18 Optimized Incentive and Non-Incentive Costs, 60% Modeled Less Other Funding

In all scenarios, Act 18 Optimized fuel savings were maintained as modeled assuming well implemented programs are able to successfully reduce costs relative to modeled budgets. In the

"60%" scenarios, incentive and non-incentive costs were reduced to 60% of original modeled values.[59] In the "Less Other Funding" scenarios, incentive and non-incentive budgets are reduced by the funding summarized in Section 5.3. In each scenario, program budgets were allocated to each fuel in each year proportional to lifecycle emissions. The average annual impacts on a $/MMBtu basis by scenario and fuel type are presented in Table 28.[60]

Fuel	Scenario	$/MMBtu
Natural Gas	As Modeled	21.4
	As Modeled Less Other Funding	18.1
	60% Modeled	12.9
	60% Modeled Less Other Funding	9.5
Propane	As Modeled	23.2
	As Modeled Less Other Funding	19.6
	60% Modeled	13.9
	60% Modeled Less Other Funding	10.3
Fuel Oil	As Modeled	29.1
	As Modeled Less Other Funding	24.6
	60% Modeled	17.5
	60% Modeled Less Other Funding	12.9

Table 28: Average Annual Fuel Price Impacts by Fuel and Scenario

Over the analysis period, relatively flat incentive budgets are spread over decreasing volumes of remaining baseline fuel sales.

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[59] The original modeled values assumed incentives cover the full incremental costs of all measures. Energy efficiency and fuel switching measures are modeled as time-discretionary retrofits where the incremental costs, and thus the modeled incentives, equal the total installed costs inclusive of equipment and labor costs. For biofuels and renewable fuels, incremental costs were calculated as the difference in cost between the baseline fuel and the clean fuel.

[60] Average 2022 $/MMBtu were 17.03 for natural gas, 36.24 for propane, and 35.41 for fuel oil, https://publicservice.vermont.gov/document/2024-annual-energy-report.

5.5 MCNEIL DISTRICT ENERGY PROJECT

The McNeil District Energy Project, recently approved by the Burlington City Council, represents a significant capital expenditure and decarbonization effort that may contribute to the CHS goals. Although the project is not directly included in the CHS modeling, we conducted an analysis of its scale and scope to estimate its likely impact. We also compared its relative cost and carbon reductions to those of other high-impact CHS measures.

According to materials presented to the Burlington City Council and published carbon intensity analyses, the McNeil District Energy Project is expected to cost approximately $42 million and reduce 220,000 MMBtus of natural gas usage per year. Based on the carbon intensity analysis conducted by First Environment, the project is expected to save 10,214 metric tons of carbon per year, resulting in a reduction of approximately 0.4% of RCI emissions in 2025. Assuming a 25-year measure life, which is typical for Combined Heat and Power (CHP) projects, the district energy project may achieve lifetime lifecycle reductions at a cost of $0.16 per lifetime lifecycle kilogram. Below, we provide comparisons to other high-impact CHS measures.

Category	Value
Total Project Cost	$42,000,000
Annual Natural Gas Reduction (MMBtu)	220,000
Annual Lifecycle Carbon Reduction (Metric Tons)	10,214
Lifetime Lifecycle Carbon Reduction (Metric Tons)	255,357

Table 29: Relative Cost and Carbon Reductions

District Energy Facility	Carbon Intensity (g CO2e/MJ)
Fuel Processing	7.7
Fuel Transport	1.32
Power Generation	6.14
Natural Gas Offset	-11.57
Total	**3.6**

Table 30: District Energy Facility by Carbon Intensity

Measure (Sector)	$ per Lifetime Lifecycle CO2e Reduction
Out-of-State | Advanced Renewable Diesel | Residues and Waste (Sector Neutral)	$0.11
Heat Pump Water Heater (Res)	$0.20
Ductless Heat Pump – Full Replacement (Res)	$0.32
McNeil District Energy System	$0.16

Table 31: Measure by $ per Lifetime Lifecycle CO2e Reduction

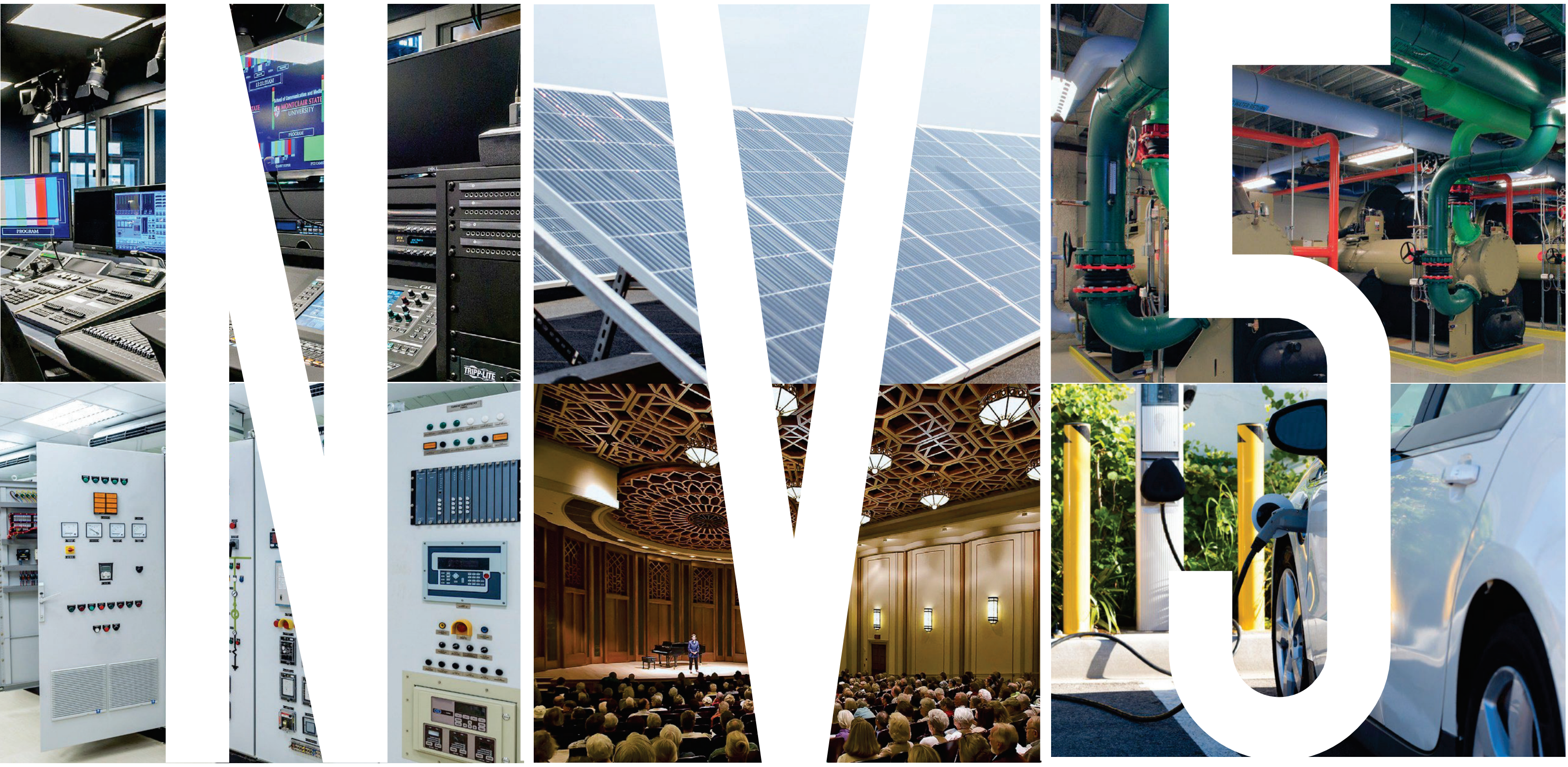
6.0 CONCLUSION

6.1 MAXIMUM ACHIEVABLE

The Maximum Achievable potential for Act 18 requires significant amounts of fuel switching with clean fuels being used to offset the remaining fuel usage. This scenario involves significant expenditures, with societal costs including non-incentive program costs of about $16,568 million and benefits of $16,065 million resulting in -$503 million in total net benefits. However, the Maximum Achievable portfolio is cost-effective without consideration of non-incentive program costs as discussed in section 4.2.2 above.

6.2 ACT 18 OPTIMIZED

The cost optimizations in this scenario lead to clean fuels dominating the potential in the early years with fuel switching measures gradually ramping up throughout the analysis horizon to help meet GWSA requirements in 2049. As a result, costs for this scenario are significantly lower than the Maximum Achievable Scenario with $9,623 million in costs which include non-incentive program costs, compared to $11,737 million in benefits, for a total of $2,114 million in net societal benefits. Note, non-incentive (program costs) for both the Maximum Achievable and Act 18 Optimized scenario represent an upper-bound of program cost assumptions, if lower program costs occur in actual implementation lower savings would result. Furthermore, as described in section 5.3 above, there is an estimated $1,471 million in existing local program spending and tax credits possible throughout the 24-year analysis period that could help offset total CHS costs.



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