CLEAN HEAT STANDARD POTENTIAL STUDY

FINAL RESULTS

September 5, 2024

AGENDA

- Introductions
- Project Summary
- Major Changes from Final Draft Results
- Modeling Methodology
  - Scenario definitions
  - Modeling process
  - Act 18 Optimized scenario assumptions
- Maximum Achievable Results
  - RCI emission totals
  - Societal costs and benefits
- Act 18 Optimized Results
  - RCI emission totals
  - Societal costs and benefits
  - Cumulative emissions by measure type and sector
  - Cumulative emissions by measure cost-effectiveness
  - Top measures by emissions reductions
  - Low/moderate-income potential
- Workforce
- Other Sources of Funding

INTRODUCTIONS

PROJECT TEAM AND STAFF

- Project Team
  - NV5: Overall potential study project manager
  - Energy and Environmental Economics, Inc. (E3): Emerging fuels subject matter experts
- Staff Intros
  - NV5
    - Ben Cartwright, Project Manager
    - Matthew Socks, Senior Technical Director
    - Cliff McDonald, Senior Consultant
    - Griff Keating, Consultant
  - E3
    - Dr. Bill Wheatle, Emerging Fuels Technical Lead

PROJECT SUMMARY

CLEAN HEAT STANDARD

- To support the goals of the Global Warming Solutions Act (GWSA), The Clean Heat Standard is intended to reduce greenhouse gas emissions in Vermont's thermal sector through clean heat credits representing reduced emissions from clean heat measures.

PROJECT OBJECTIVE

- The potential study will quantify the technically achievable and maximum achievable and thermal resources, including economic potential for Vermont thermal sector resources which will *inform* the price and amount of clean heat measures.
- The study will also quantity an Act 18 optimized (program) achievable scenario to meet the requirements of Act 18.

CAVEATS

- The model simplifies significant variation in project costs, savings, and scope. There are large uncertainties around adoption rates, future technologies and costs, availability of renewable/biofuels, and how the market price will respond to the above factors.
- Modeled potential scenarios do not reflect an implementation plan. Modeled costs are an upper boundary intended to *inform* the ultimate cost of the Clean Heat Standard. Significant uncertainty remains around how an implementation program will function, who will be the primary implementers, and what the market will respond to.

MAJOR CHANGES FROM FINAL DRAFT RESULTS

SUMMARY OF MAJOR CHANGES

- Updates to 2021 Vermont Greenhouse Gas Inventory and Forecast (“VT GHGI”) methods and results:
  - Retroactive removal of “non-road” emissions previously included in the residential, commercial, and industrial fuel use sector (“RCI”), or “thermal sector”
  - This change resulted in lower RCI emissions values than previous reports
- New RCI GWSA reduction targets:
  - Model incorporated emissions reduction targets reflecting sectoral proportionality based on 2018 (0.7 MMT by 2030 and 1.7 MMT by 2050 relative to 1990).
- Clean fuels (CF) assumptions updates:
  - Consistent with historical treatment of renewable natural gas in VG GHGI, emissions factors for biofuels and renewable fuels set to zero for GWSA accounting.
  - CF emissions factors for certain pathways based on median values for active projects CARB’s LCFS project database.
  - Doubled assumed availability of certain CFs in early years (relative to previous population-weighted approach) which transitions to the population-weighted values over time to reflect more competition for the resource.

METHODOLOGY

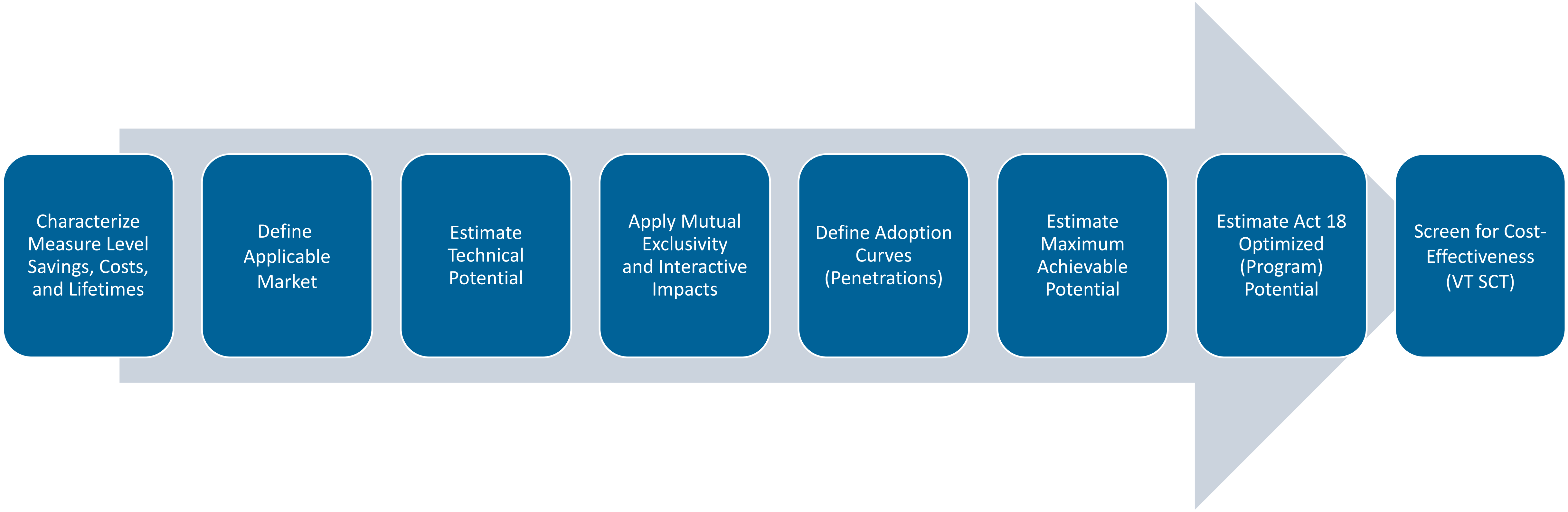
POTENTIAL SCENARIOS

Scenarios for Clean Heat Standard Potential Analysis

- Technical Potential
  - Full technical potential of each measure without competition.
- Maximum Achievable Potential
  - Maximum adoption through idealized program design and incentives covering 100% of installed costs.
- Act 18 Optimization
  - Maximum achievable potential adjusted and optimized to meet Act 18 policy requirements.
- Economic Potential
  - Subset of Maximum Achievable and Act 18 Optimized potential that passes the VT Societal Cost Test. For reporting purposes only (i.e., opportunities are not removed from the analysis based on societal cost-effectiveness).

METHODOLOGY

OVERVIEW OF MODELING PROCESS



METHODOLOGY

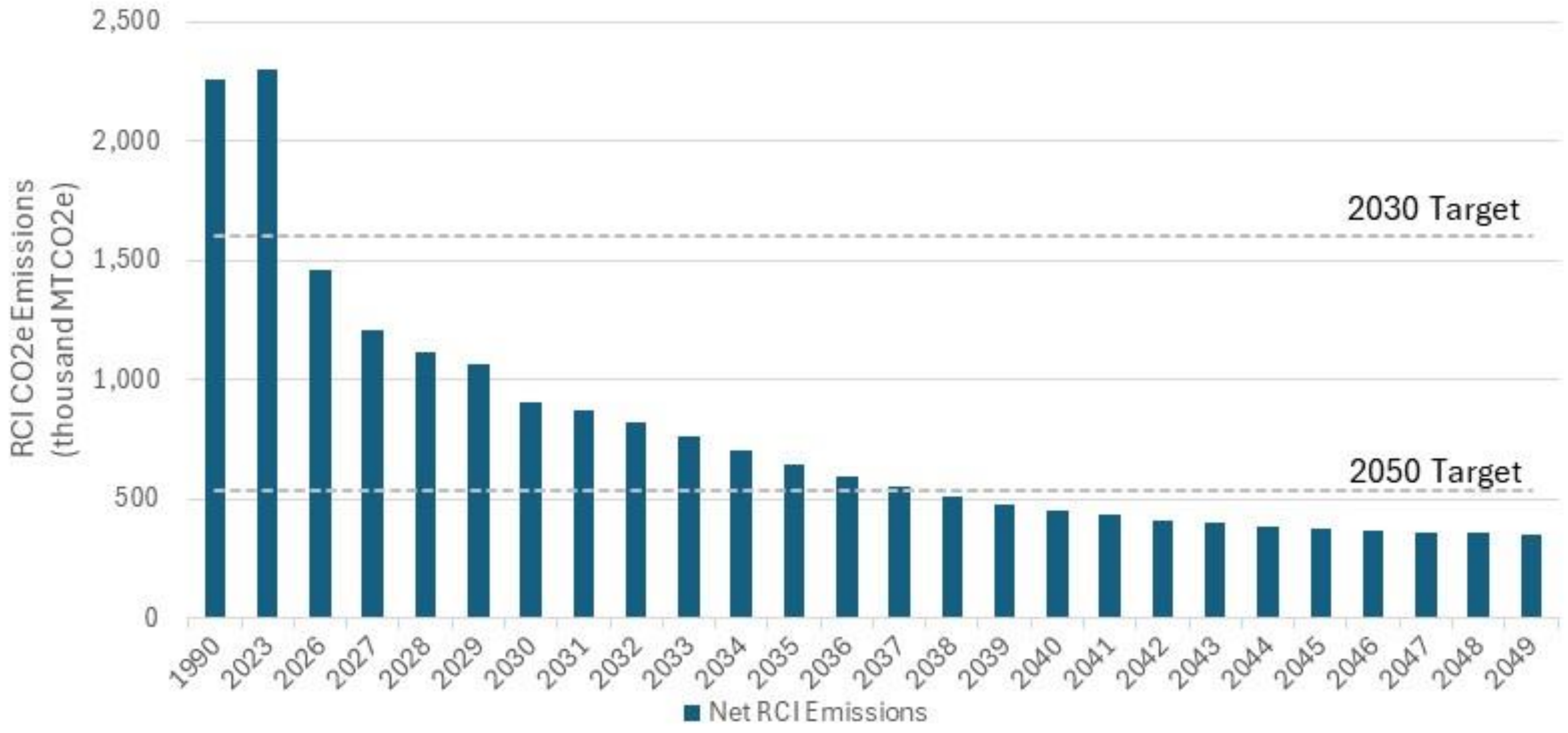
MODELING ASSUMPTIONS

Act 18 Optimized Potential Assumptions

- Aggressive ramp in Maximum Achievable scenario would considerably front-load achievement, exacerbating workforce constraints and leading to highly variable program budgets over the analysis period.
- Converted the Maximum Achievable adoption rates to constant annual values by diving the cumulative adoption by the number of years in the analysis period (limiting incremental annual adoption values such that they did not exceed the Maximum Achievable adoption values for the corresponding year in early years).
- Per Act 18 requirements to prioritize low-income and moderate-income, assumed all LMI energy efficiency and fuel switching measures are adopted.
- Ranked each measure in the order of cost per ton of lifetime *lifecycle* GHG emissions reductions and removed the most expensive measures from the portfolio until the total emissions reductions matched the 2050 GWSA targets in 2049.
- The maximum allowable emissions for 2026-2029 were linearly interpolated between the 2023 historical emissions and the 2030 GWSA target. Likewise, the maximum allowable emissions for 2030-2049 were linearly interpolated between the 2030 target and the 2050 target.
- Adoption values for clean fuels were adjusted downward in each year, starting with the most expensive pathway, until the resulting emissions just meet the interpolated goals in each year.

MAXIMUM ACHIEVABLE POTENTIAL

Maximum Achievable Net RCI Emissions and GWSA Targets



- Maximum Achievable scenario achieves a reduction in net RCI emissions relative to a 1990 baseline of **1.2MMT CO2e in 2029** and **1.9MMT in 2049.**
- "Net RCI Emissions" denotes the inclusion of increased Electricity Consumption sector emissions but impacts minimal due to slow ramp of fuel switching measure adoption and plummeting electric emissions rates.
- Increased emissions from 1990 to 2023 slightly undercut achievement toward 2030 GWSA target

MAXIMUM ACHIEVABLE POTENTIAL

TOTAL MODELED SOCIETAL NET BENEFITS

- The **total societal net benefits** (per the VT SCT) associated with the Maximum Achievable potential are **$1.0B** (2024$).
  - “Net” societal benefits reflect total societal benefits less total societal costs.
  - **Benefits** include avoided energy/fuel, capacity, and T&D costs; additional resource savings; externalities, and non-energy benefits
  - **Costs** include measure costs (less *deferred equipment replacement costs*) and increased electric and/or fuel consumption

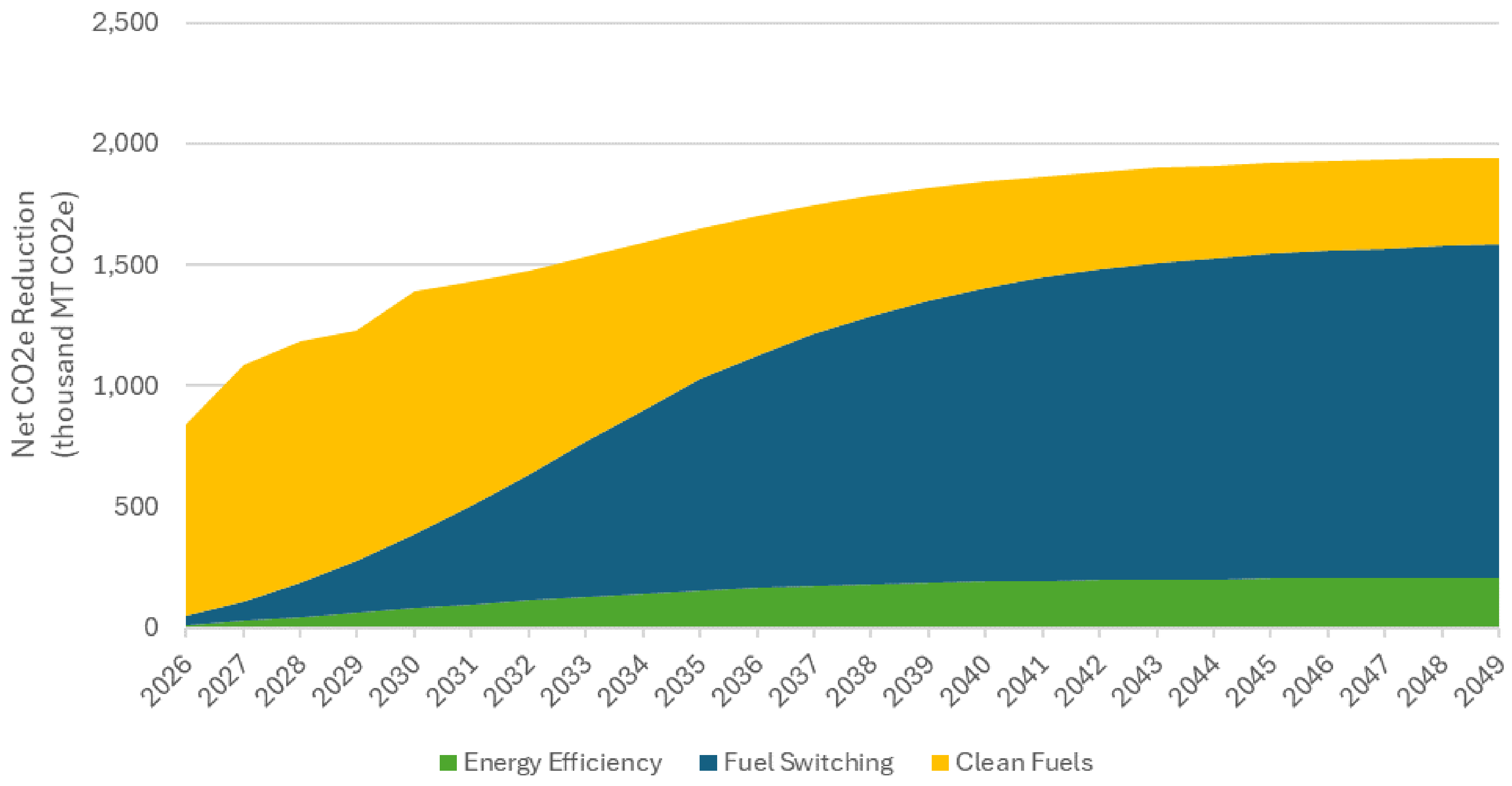
MAXIMUM ACHIEVABLE POTENTIAL

SOCIETAL COSTS AND BENEFITS

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
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

MAXIMUM ACHIEVABLE POTENTIAL

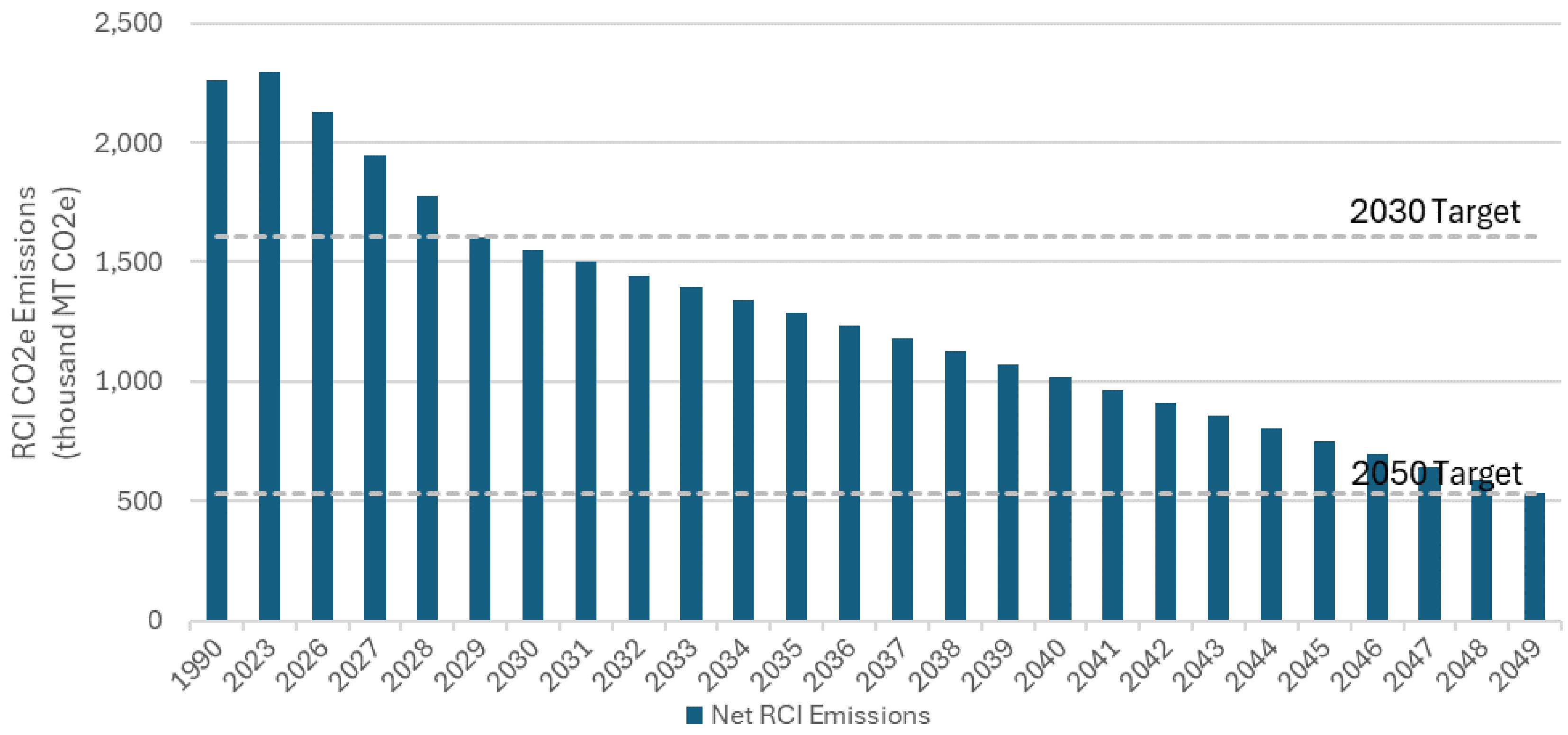
Maximum Achievable Cumulative Annual GWSA Emissions Reduction by Measure



- Due to lower barriers biofuels/renewable fuels represent the majority of the potential in early years.
- As fuel switching and energy efficiency measures increase in adoption, clean fuels potential is partially displaced.
- By 2049, fuel switching measures represent 71% of the cumulative emissions reduction potential.

ACT 18 OPTIMIZED POTENTIAL

Act 18 Optimized Net RCI Emissions and GWSA Targets



- Act 18 Optimized scenario achieves a reduction in net RCI emissions relative to a 1990 baseline of **0.7MMT CO2e in 2029** and **1.7MMT in 2049**.
- "Net RCI Emissions" denotes the inclusion of increased Electricity Consumption sector emissions but impacts minimal due to slow ramp of fuel switching measure adoption and plummeting electric emissions rates.
- Increased emissions from 1990 to 2023 slightly undercut achievement toward 2030 GWSA target.

ACT 18 OPTIMIZED POTENTIAL

TOTAL MODELED SOCIETAL NET BENEFITS

- The **total societal net benefits** (per the VT SCT) associated with the Act 18 Optimized potential are **$3.0B** (2024$).
  - "Net" societal benefits reflect total societal benefits less total societal costs.
  - **Benefits** include avoided energy/fuel, capacity, and T&D costs; additional resource savings; externalities, and non-energy benefits
  - **Costs** include measure costs (less *deferred equipment replacement costs*) and increased electric and/or fuel consumption

ACT 18 OPTIMIZED POTENTIAL

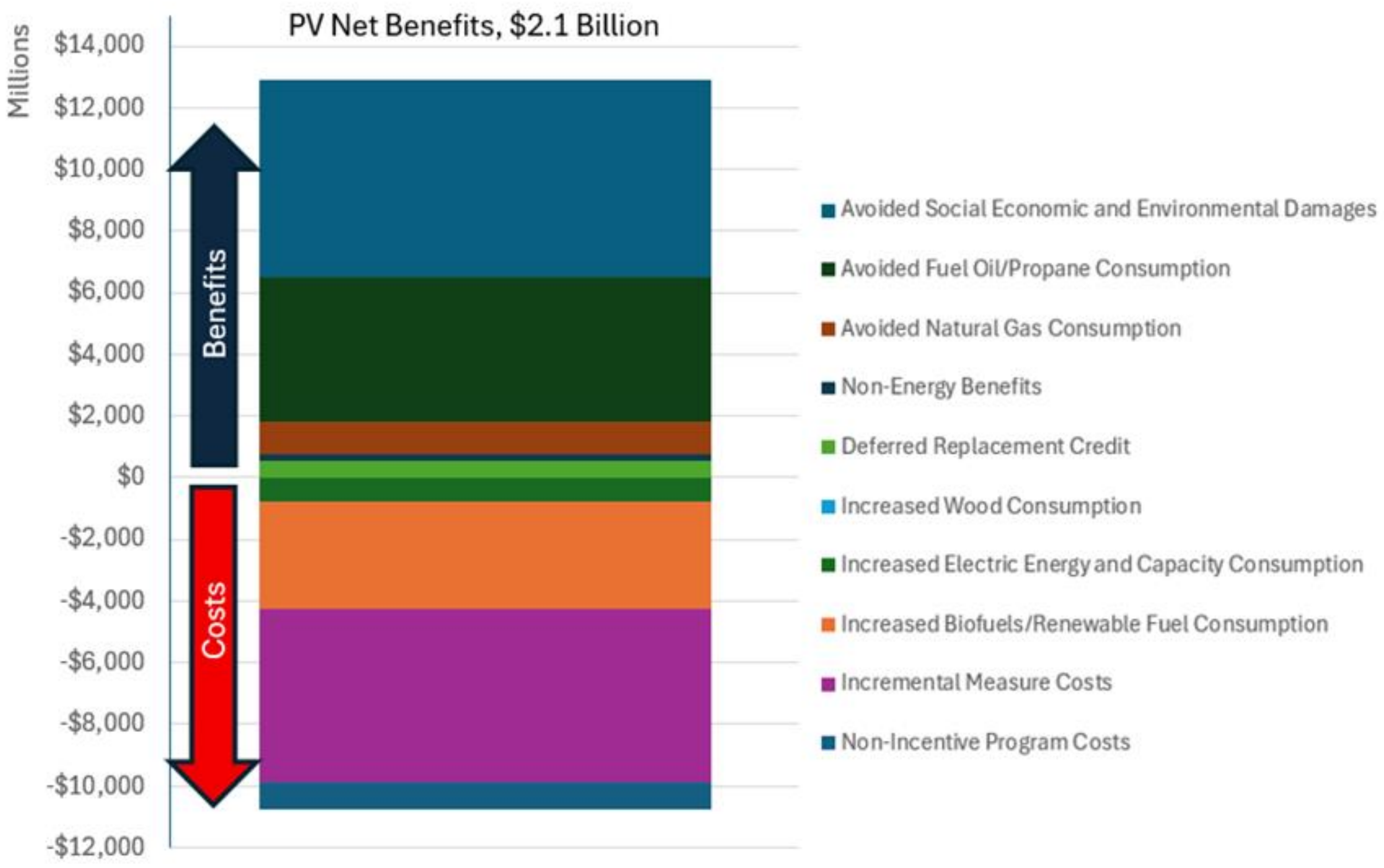
NV5

SOCIETAL COSTS AND BENEFITS

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
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
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**

ACT 18 OPTIMIZED POTENTIAL

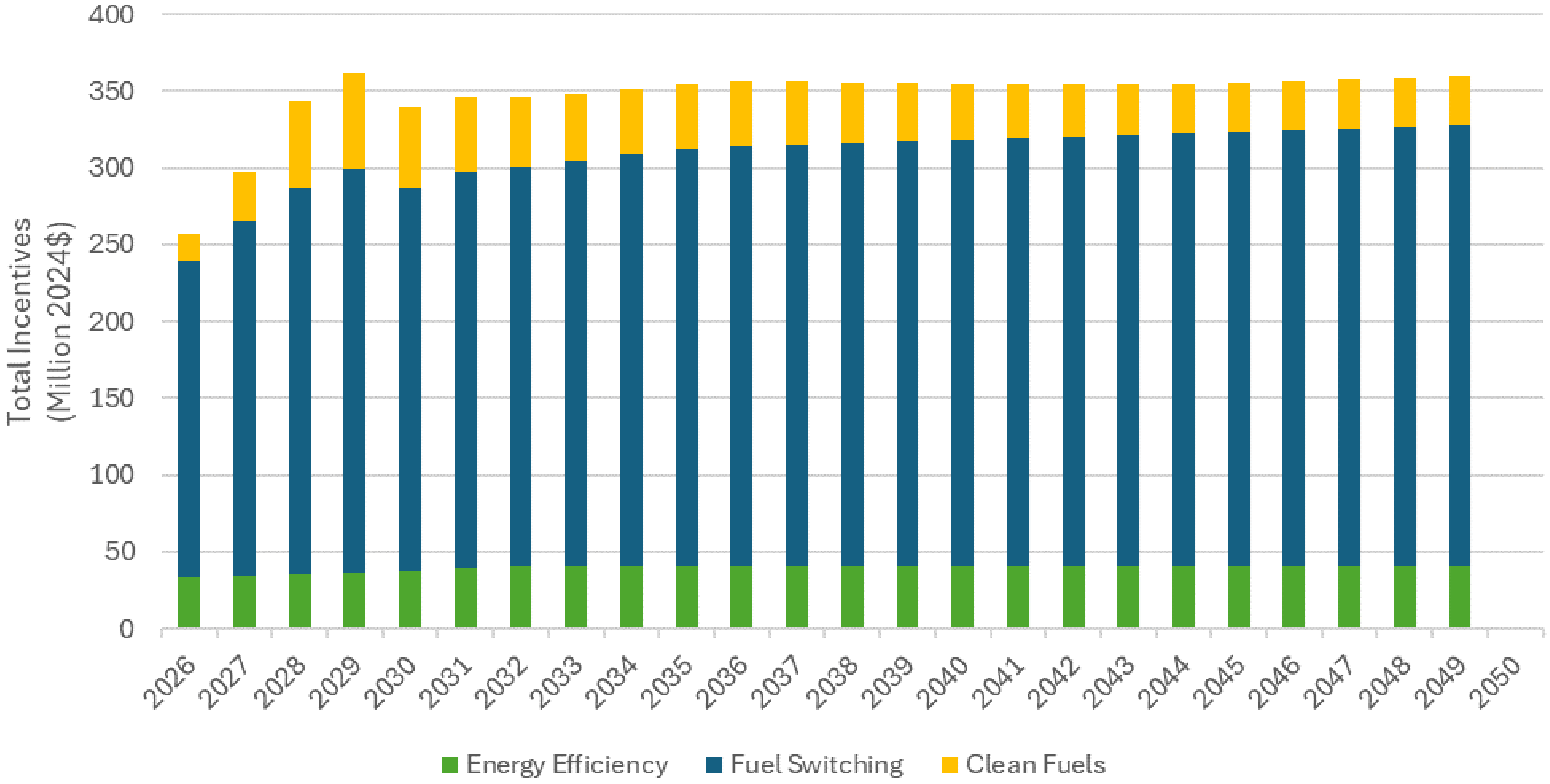
SOCIETAL COSTS AND BENEFITS



- The majority of the net benefits are generated by avoided social economic and environmental damages and avoided fuel oil and propane consumption.
- The majority of the costs are due to incremental measure costs and increased biofuels and renewable fuels consumption.
- Note certain SCT cost categories that contribute to both costs and benefits have been combined into “net” column elements.

ACT 18 OPTIMIZED POTENTIAL

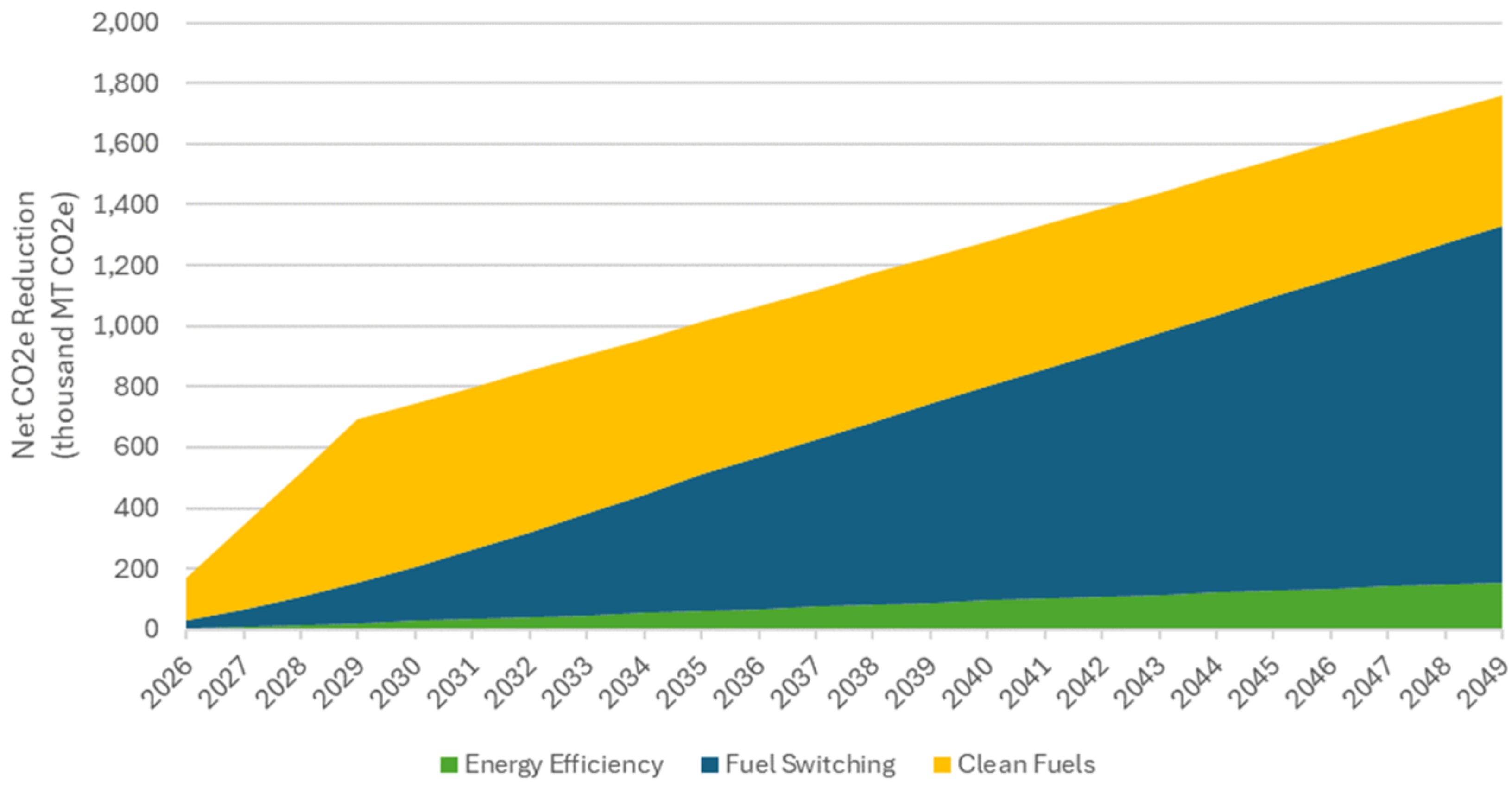
Act 18 Optimized Incremental Annual Incentives by Measure Type



- Figure presents <u>program incentive spending only as</u> optimized to achieve GWSA targets.
- Incentive spending relatively flat over analysis period due to calibration to interpolated annual GWSA targets.
- Important to note that spending on CF yields one year of emissions reductions whereas spending on EE/FS measures can yield 15-20 years of reductions.

ACT 18 OPTIMIZED POTENTIAL

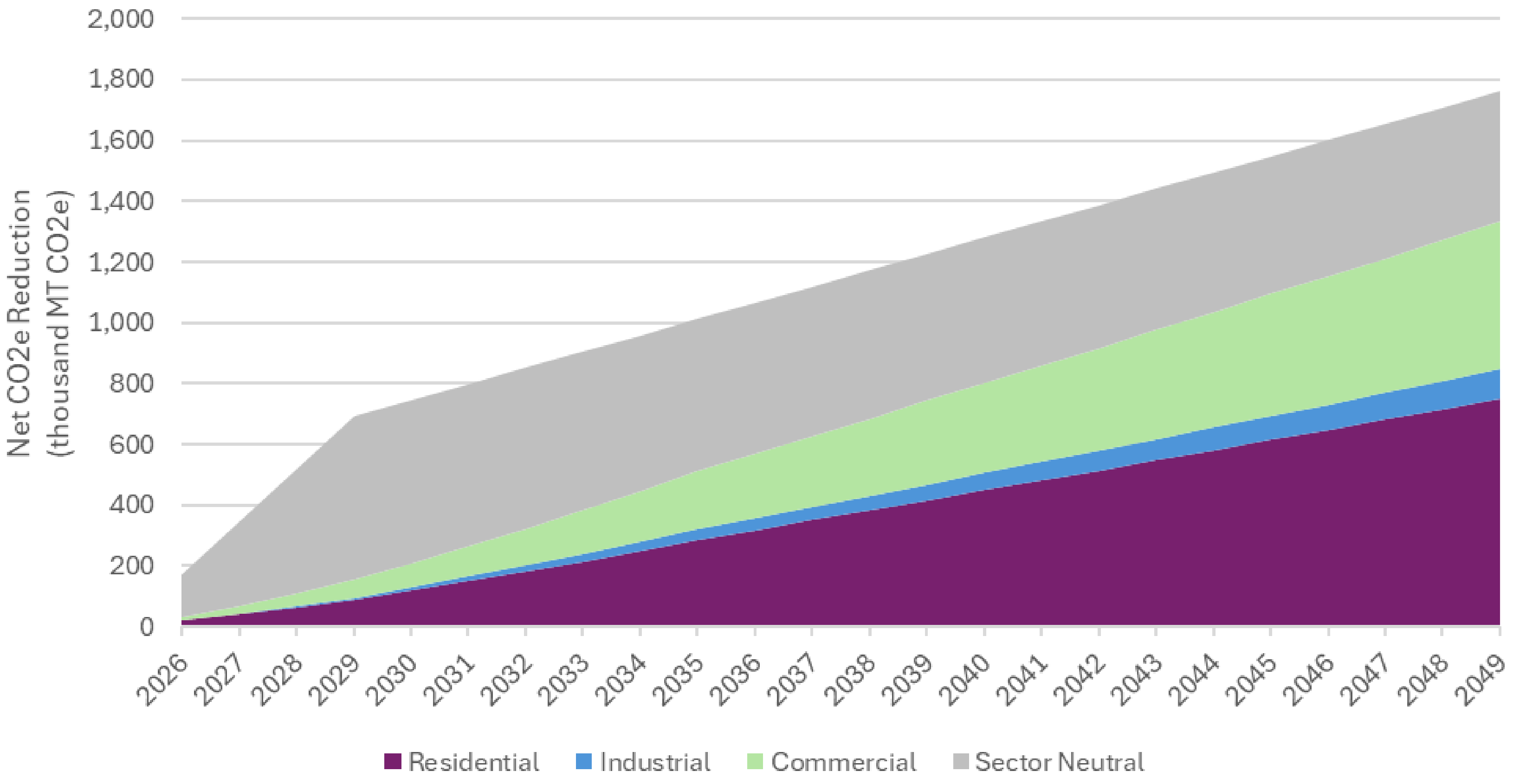
Act 18 Optimized Cumulative Annual GWSA Emissions Reduction by Measure Type



- Relative to the Maximum Achievable scenario, Act 18 Optimized potential increases gradually to match interpolated GWSA targets.
- Biofuels/renewable fuels represent the majority of the cumulative emissions reduction potential through 2035, then overtaken by fuel switching measures.

ACT 18 OPTIMIZED POTENTIAL

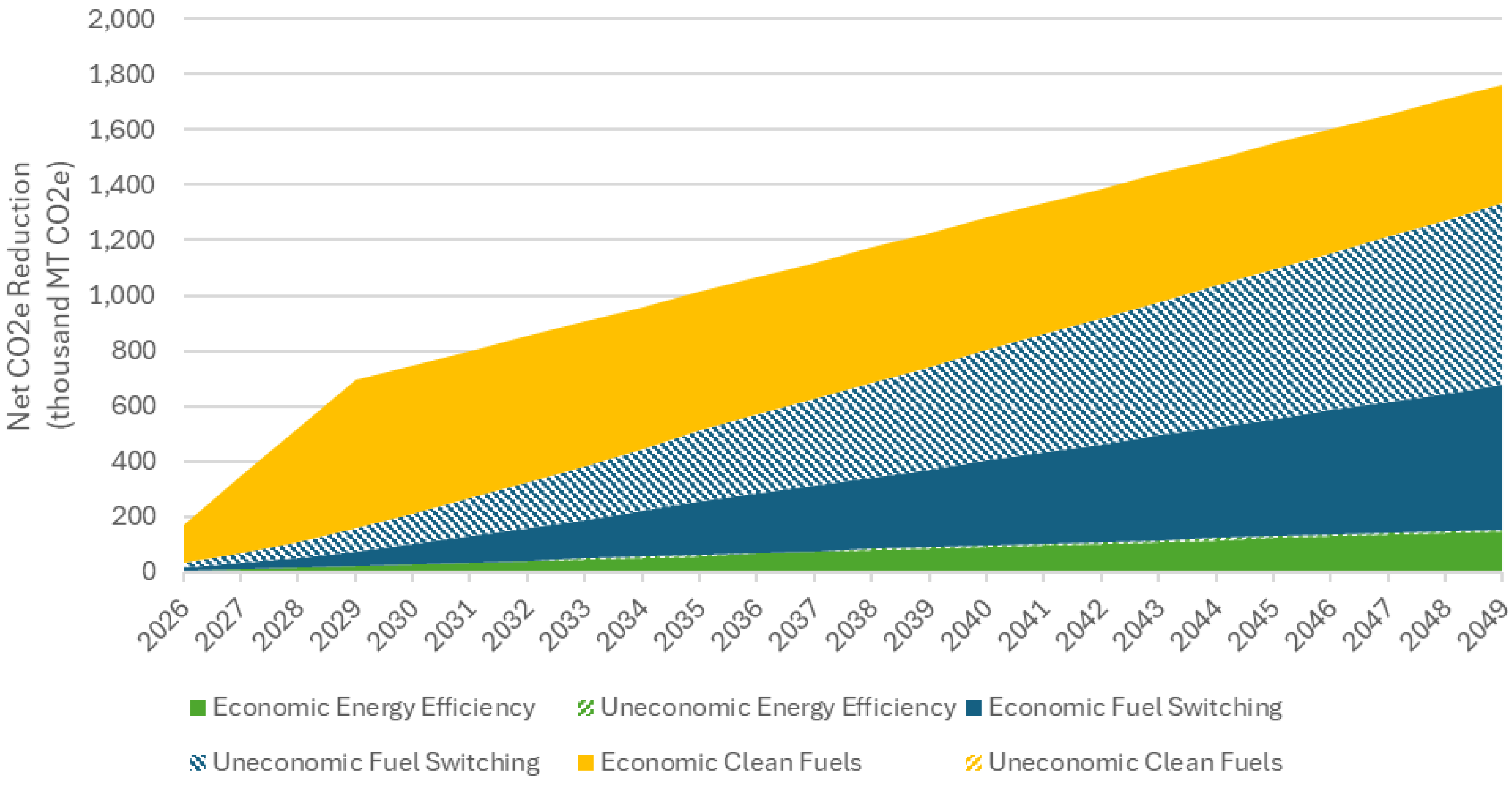
Act 18 Optimized Cumulative Annual GWSA Emissions Reductions by Sector



- Mirroring the emissions inventory, residential has the highest long term emissions reduction potential, followed by commercial then industrial.
- “Sector Neutral” potential served entirely by clean fuels. Given difficulty to electrify certain industrial end-uses, much of the clean fuels potential is likely to serve the industrial sector in later years.

ACT 18 OPTIMIZED POTENTIAL

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



- Measure cost-effectiveness determined by the Vermont Societal Cost Test (VT SCT).
- While the majority of EE and CF potential is cost-effective, much of the FS potential is not cost-effective.
- In 2049, 62% of the identified Act 18 Optimized potential emissions reductions is cost-effective.

ACT 18 OPTIMIZED POTENTIAL

TOP 10 RESIDENTIAL 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
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

FS = Fuel Switching; CF = Clean Fuels; EE = Energy Efficiency

ACT 18 OPTIMIZED POTENTIAL

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TOP 10 C&I 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
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

FS = Fuel Switching; CF = Clean Fuels; EE = Energy Efficiency

ACT 18 OPTIMIZED POTENTIAL

NV5

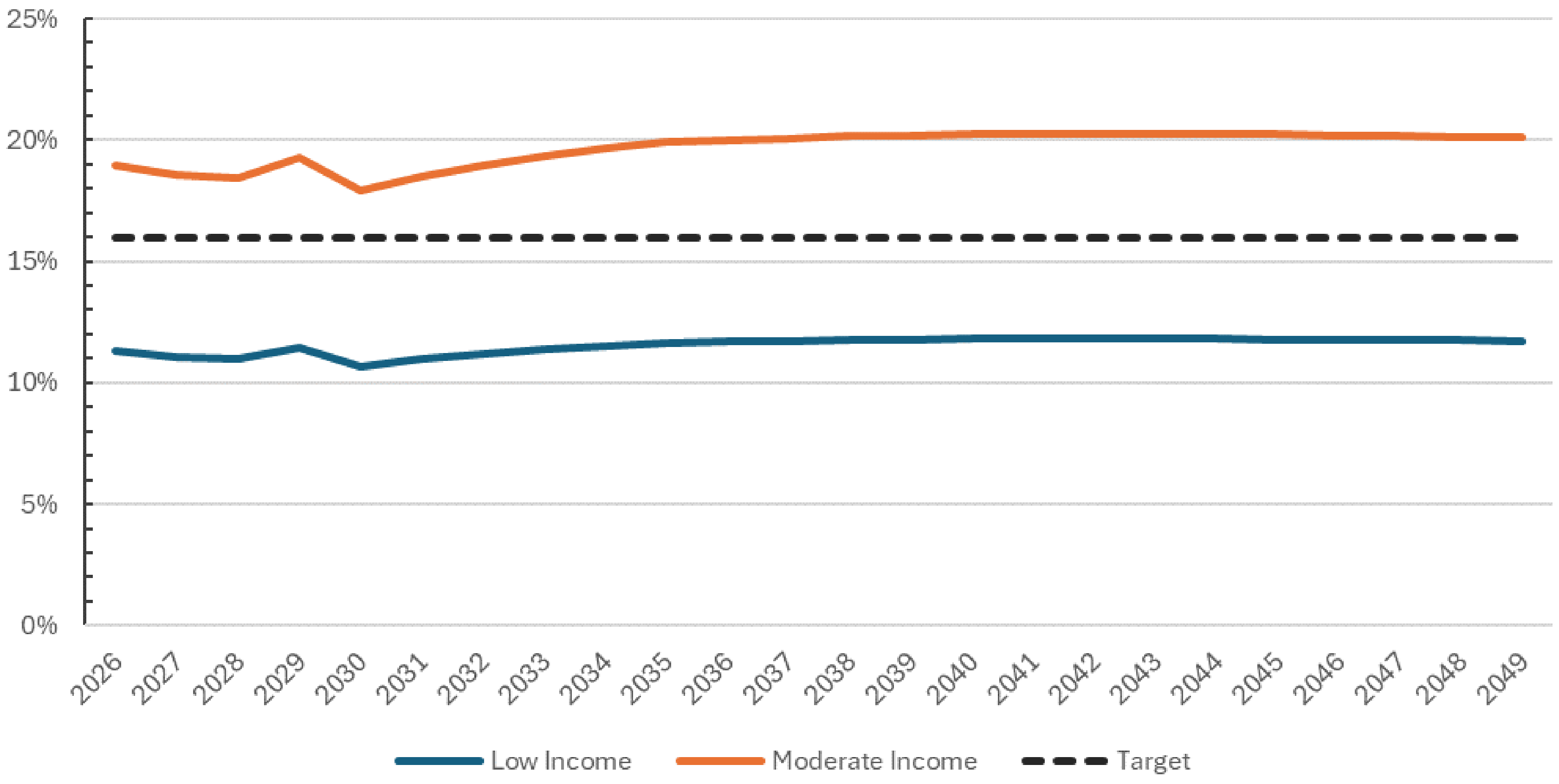
TOP 10 SECTOR NEUTRAL MEASURES BY CONTRIBUTION TO REQUIRED 2050 RCI EMISSIONS REDUCTIONS

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

FS = Fuel Switching; CF = Clean Fuels; EE = Energy Efficiency

ACT 18 OPTIMIZED POTENTIAL

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



- 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."
- Act 18 Optimized scenario exceeds requirement for Moderate Income but falls short for Low Income.
- Analysis assumes clean fuels potential is apportioned to segment and income category based on remaining conventional fuel consumption.

WORKFORCE DEVELOPMENT

SUMMARY OF THERMAL SECTOR TRADES

- VT’s Clean Energy Industry (2023): 18,156 workers, representing 6% of all jobs in the state
- Nearly half of these workers were in the installation, maintenance and repair field
- Difficulty in hiring; mainly due to competition with other industries and lack of experience

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

Source: 2023 Vermont Clean Energy Industry Report

- Mechanical, electrical, engineering and installation represented 90% of positions most difficult to hire

WORKFORCE DEVELOPMENT

WORKFORCE TRAINING ORGANIZATIONS

- Several organizations in VT provide continuing education training for HVAC trade workforce
  - Heating & Cooling Contractors of Vermont (HCCV), Vermont Fuel Dealers Association (VFDA), Vermont Adult Learning, ReSOURCE, etc.
- Training programs include heat pump installation, weatherization and EPA Section 608 Certification (refrigerant handling)
- Interviews with training organizations cite funding as major barrier to increased participation
  - First-year funding can be adequate, but lack of support exists to maintain programs
  - Regional training can be difficult due to lower participation in rural areas
- Employers use training to pre-vet employees
  - High satisfaction from HVAC trade employers with level of student training/skillsets
  - Workforce organizations have relationships with HVAC trades for placement

GAPS IN WORKFORCE – OPTIMIZED RESULTS

Measure	Number of Current Workers (2023)	BAU Workers in 2030	Optimized Workers in 2030	BAU Workers in 2049	Optimized Workers in 2049
Weatherization Single-family	140	113	435	65	435
Residential Heat Pumps (Ductless)	70	82	24	125	30
Weatherization Mfg. Home	20	16	19	7	19
Residential Heat Pumps (Ducted)	15	17	27	27	34
Commercial Heat Pumps (Ductless)	10	11	11	16	13

- Measures selected where existing data aligned with modeling data
- Largest gap is in Weatherization workforce based on Act 18 Optimized results
- Increased funding can help support gaps
  - WAP Innovation Grant Programs
  - IRA funding
- Additional measures in final report

SOURCES OF ADDITIONAL FUNDING

Federal IRA Funding & Tax Credits	Tier 3 Renewable Energy Standard	Existing Efficiency Spending
• Inflation Reduction Act provided for programmatic funding and enhanced tax credits applicable to several clean heat measures • Direct funding for the rebate programs were considered in full, while applicability factors for tax-credit eligible measures were developed • In aggregate accounted for $111M	• Tier 3 of the Renewable Energy Standard requires Distribution Utilities to implement "energy transformation projects" that reduce fossil fuel usage • This spending contributes to CHS requirements • We hold 2022 spending constant over the study period • This accounts for a total of $334M	• Energy Efficiency Utilities spend significant funds on rebates for measures that would be CHS eligible • We took 2023 spending on these measures and held it constant for the study period • This resulted in a total $538M of spending

SOURCES OF ADDITIONAL FUNDING

LMI Weatherization Funding

- Federal funding for low-income weatherization has been a long standing contributor to weatherization activity in VT
- We hold current funding levels constant for the study period
- This accounts for a total of $489M

Total Other Funding Sources

- Adding up the previously mentioned funding sources, we get a supplemental funding of $1.47B

Funding	
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**

Pre-Wx & Pre-Elx 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
- We did not incorporate these costs into the study, but initial data from like jurisdictions reflect a possible cost of up to $5,000 per house on average

FINAL REPORT AND SUPPLEMENTAL DATA

- Detailed appendices with measure-level potential results are available for all scenarios
- Final report, supplemental workbooks, and TAG feedback responses available on Public Service Department website:
  - https://publicservice.vermont.gov/clean-heat-standard/public-service-department-thermal-sector-carbon-reduction-potential-study

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APPENDIX

METHODOLOGY

MODELING ASSUMPTIONS

General Assumptions

- Baseline is the existing condition
  - "Like-for-Like" replacement assumed for when the existing equipment would have failed
- Results represent **gross** savings (i.e., no Net-to-Gross Ratios applied)
- Baseline forecasted energy use assumed to be flat over analysis period
- CHS is envisioned as a tool to meet GWSA targets (consistent with GHG inventory accounting) but credits are quantified in annual *lifecycle* emissions reductions
  - Wood heating uses a GWPbio factor of 0.30 to reflect VT forests
- Renewable/biofuels fuels repurchased every year; however, electrified customers (or more generally, customers who have fuel switched) will not revert to fossil fuel-fired equipment

MODELING ASSUMPTIONS

Technical Potential Assumptions

- Technical Potential assumes all technologically feasible measures could be installed instantaneously
- Assumes measures impacts persist over the entire analysis period
  - Exception: Biofuels and renewables fuels which must be implemented annually
- Results reflect measure-level technical potential without any consideration of competition (i.e., mutual exclusivity) and measure interactions.
- Therefore, the measure-level potential is not additive.
- Technical Potential is useful as a steppingstone to conducting Maximum Achievable and Act 18 Optimized scenarios.

MODELING ASSUMPTIONS

Maximum Achievable Potential Assumptions

- Reflects application of adoption curves considering market barriers.
- Includes impacts of measure competition (i.e., mutual exclusivity) and interactions.
- Maximum Achievable potential assumes incentive costs only and does not include administrative program costs.
- Maximum Achievable analysis assumes program incentives cover 100% of the total installed costs
  - Installed costs are total estimated equipment and labor costs associated a customer would pay for the installation of clean heat measures.
  - Exception: Installed cost for biofuel/renewable fuel measures is calculated as the difference in retail cost between the baseline conventional and clean fuel.
  - Note: Electric panel upgrades and pre-weatherization barriers costs are not considered in total installed costs.
- Clean Fuels are disqualified if and when they exceed carbon intensity requirements of Act 18.

METHODOLOGY

MODELING ASSUMPTIONS – MAXIMUM ACHIEVABLE

Measure Loading Order

1. Energy Efficiency
2. Fuel Switching
3. Clean Fuels

Measure Loading Order Example #1 (Residential – SF Home, Space Heating)

1. Air Sealing
2. Insulation
3. Advanced Thermostats
4. Partial Electrification
5. Clean Fuels
6. Part-to-Full Electrification

Measure Loading Order Example #2 (Industrial – Mfg. Facility, Industrial Process)

1. Clean Fuels

METHODOLOGY

MODELING ASSUMPTIONS

Economic Potential Assumptions

- Uses the Vermont Societal Cost Test (SCT) as the primary test*
- As the Clean Heat Standard does not have explicit cost-effectiveness requirements, the SCT 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.
- Results assume 2023 EPA projections of Social Cost of Carbon (SCC) under 2% discount rate
  - Value of $190/metric ton in 2020 in 2020$
  - Pending VT Climate Council adoption of EPA's 2023 value
- For the purposes of monetizing the impacts of avoided emissions, assumes *lifecycle* emissions factors

*Components of the VT SCT can be found in Section 2.4.2.1 'Vermont Societal Cost Test' in the January 2023 Vermont Energy Efficiency Market Potential Study.