CLEAN HEAT STANDARD POTENTIAL STUDY

FINAL DRAFT RESULTS

July 25, 2024

NV5

****DRAFT RESULTS – NOT FOR DISTRIBUTION OR ATTRIBUTION****

AGENDA

- Introductions
- Project Summary
- Modeling Methodology
  - Scenario definitions
  - Modeling process
  - Assumptions
- Technical Potential Results: Top Measures by Emissions Reduction
- Maximum Achievable and Draft Act 18 Optimized Results
  - Emissions reductions, RCI emission totals and Relative RCI emissions reductions
  - Benefits and costs
  - Program costs
  - Cumulative emissions by measure and sector
  - Cumulative emissions for fuel switching measures
  - Cumulative emissions by measure cost effectiveness (SCT)
  - Top measures by emissions reduction
- Clean Fuels Carbon Intensity Limits
- Low/Moderate Income Potential
- Next Steps

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.

METHODOLOGY

MODELING ASSUMPTIONS

Draft Results Caveats

- Draft results are preliminary and will be updated through continued QC and stakeholder input.
- 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.
- Final results will incorporate updated VT GHG emissions inventory data.
  - The current version of the model shows a larger required emissions reduction from 2020 (2.87 MMT) to reach targets relative to 1990 (2.54 MMT) than the recently released version (2.26 MMT in 1990) using projected 2023 values (2.3 MMT).
  - Reduced emissions reduction requirements will result in reduced costs for the scenarios designed to meet these targets.

METHODOLOGY

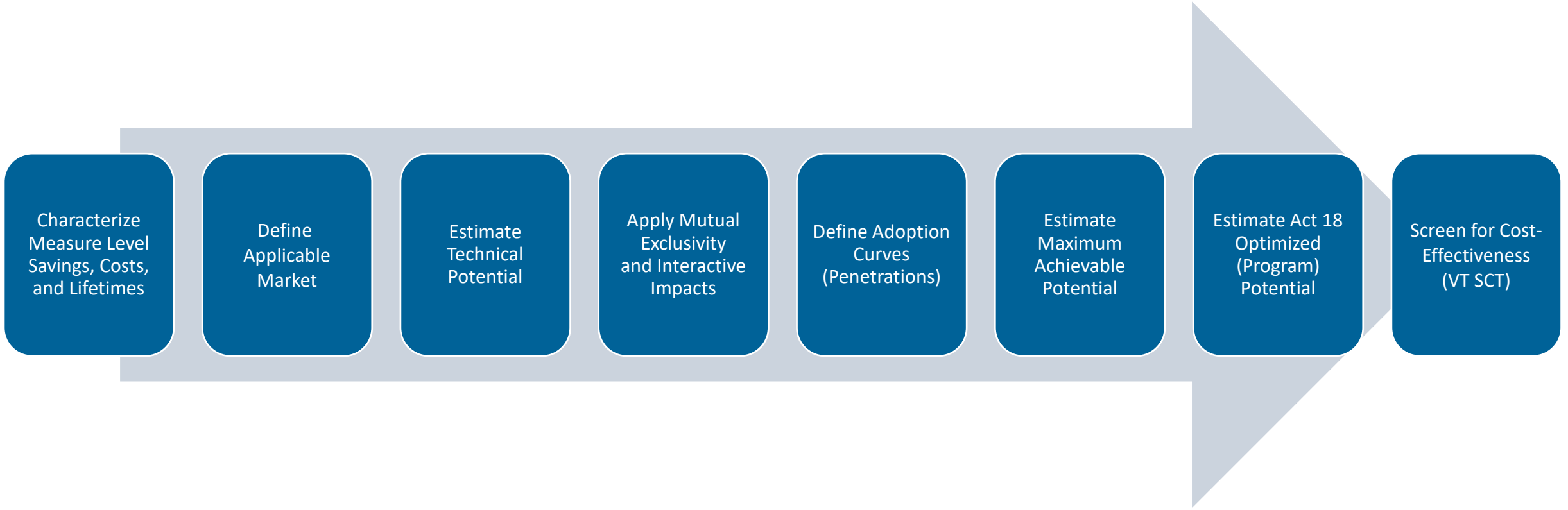
POTENTIAL SCENARIOS

Application of Industry Standard Scenarios to the 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

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

METHODOLOGY

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.

METHODOLOGY

MODELING ASSUMPTIONS

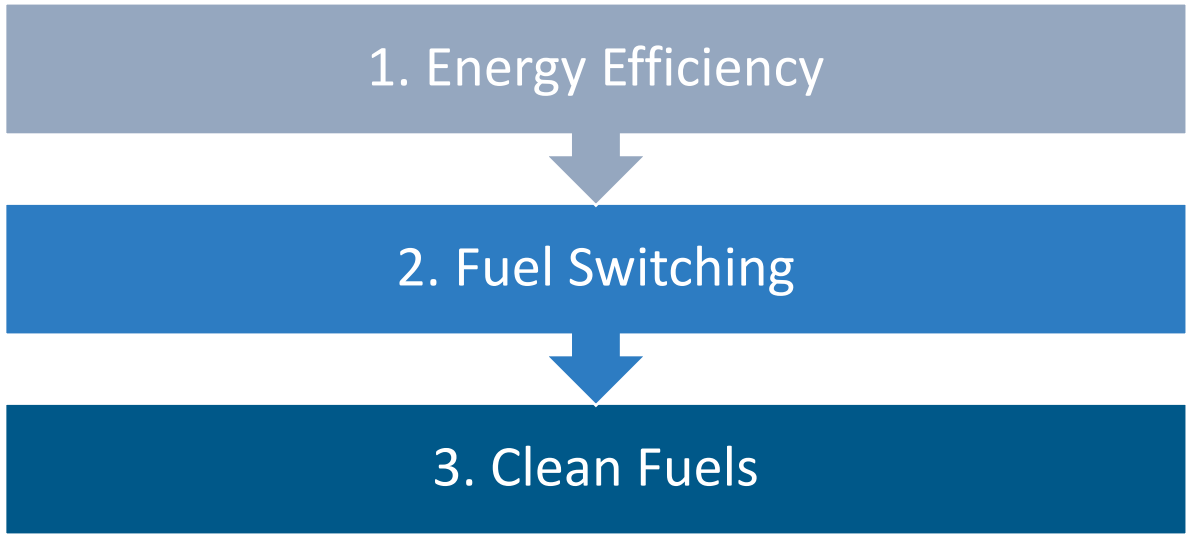
Maximum Achievable Potential Assumptions

- 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



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

MODELING ASSUMPTIONS

Act 18 Optimized Potential Assumptions

- Traditional potential studies typically limit modeled incentives to 100% of incremental measure cost in "achievable" scenarios.
  - To reach 2030 GWSA emissions reduction targets, that limitation in not observed in the Act 18 Optimized scenario.
  - Therefore, the Act 18 Optimized potential is not a subset of the Maximum Achievable Potential.
- Increased incentives (125% of installed costs) and adoption rates for fuel switching measures in the low-income sector.
- Faster adoption for manufactured housing rebuilds.
- Clean Fuels are disqualified if and when they exceed carbon intensity requirements of Act 18.
- **Note:** draft Act 18 Optimized potential results currently reach the GWSA 2050 emissions reductions targets early and exceed them in 2050.
  - Final results will lower adoption of most expensive measures (via reduced incentives) in the later years so that total reductions do not exceed 80% of 1990 RCI emissions levels.

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.
- Draft results assume 2022 EPA projections of Social Cost of Carbon (SCC) under 2% discount rate
  - Value of $190/metric ton in 2020 in 2020$
  - This is pending VT Climate Council adoption of EPA's 2022 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.

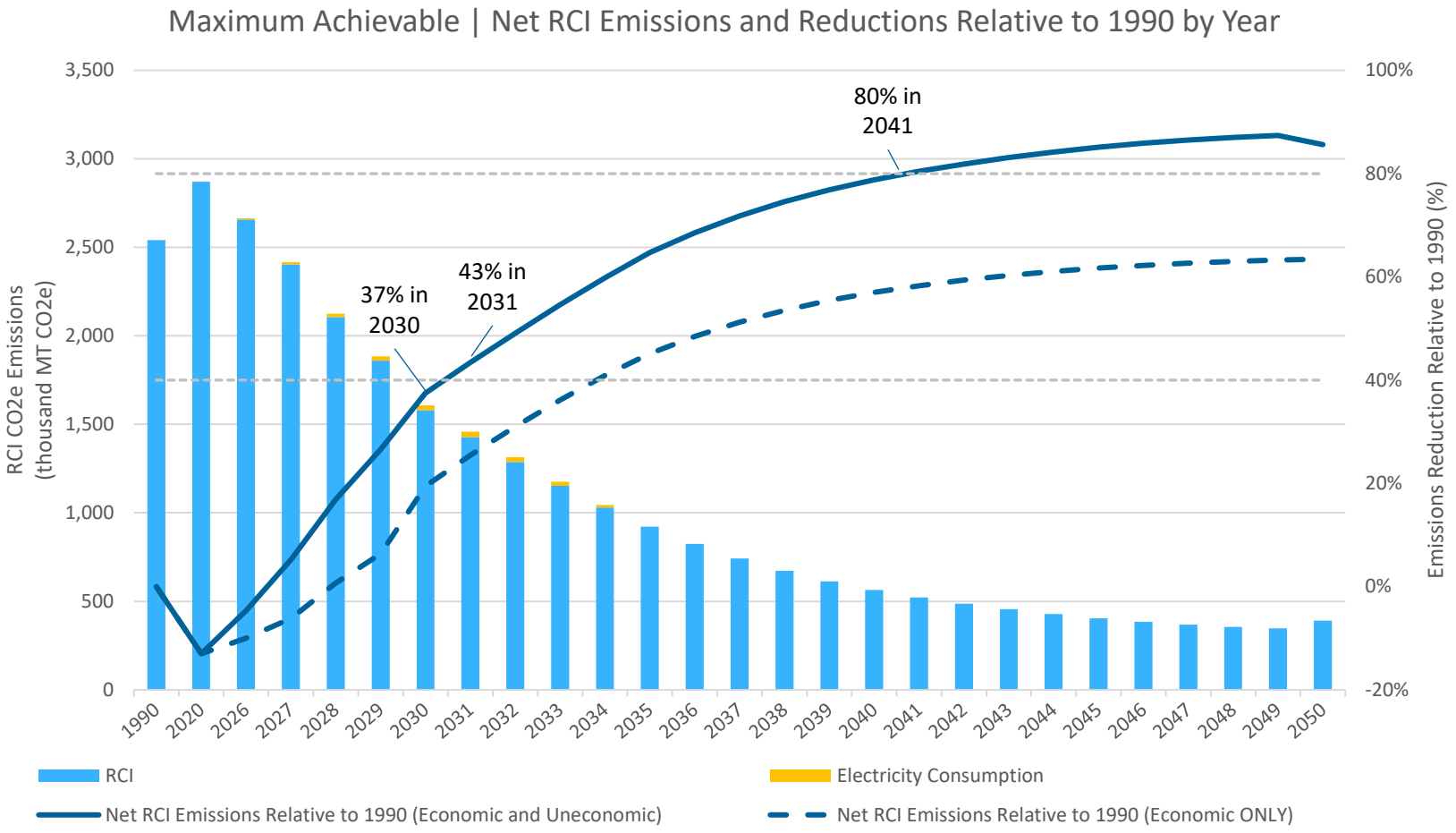
TECHNICAL POTENTIAL

TOP 10 MEASURES BY CONTRIBUTION TO REQUIRED 2050 RCI EMISSIONS REDUCTIONS

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2050	PV Net Societal Benefits (Million 2024$), 2026
Ground Source Heat Pump - Full Replacement	Residential	FS	42.6%	$818
Fossil Fuel to Wood Heating	Residential	FS	27.5%	$1,012
Ductless Heat Pump - Full Replacement	Residential	FS	27.0%	$3,496
Out-of-State | All | Renewable Diesel | Purpose-Grown Oil Crops & Waste Fats and Oils	Sector Neutral	CF	17.6%	($1,520)
Central Heat Pump - Full Replacement	Residential	FS	15.6%	$1,814
Ground Source Heat Pump - Full Replacement	Commercial	FS	15.0%	($810)
Ductless Heat Pump - Partial Displacement	Residential	FS	10.8%	$1,153
Out-of-State | All | Advanced Renewable Diesel | Residues and Waste	Sector Neutral	CF	10.3%	$404
Variable Refrigerant Flow (VRF) Heat Pump - Full Replacement	Commercial	FS	9.7%	($10)
Heat Pump Water Heater	Residential	FS	9.5%	$1,023

FS = Fuel Switching; CF = Clean Fuels

MAXIMUM ACHIEVABLE POTENTIAL



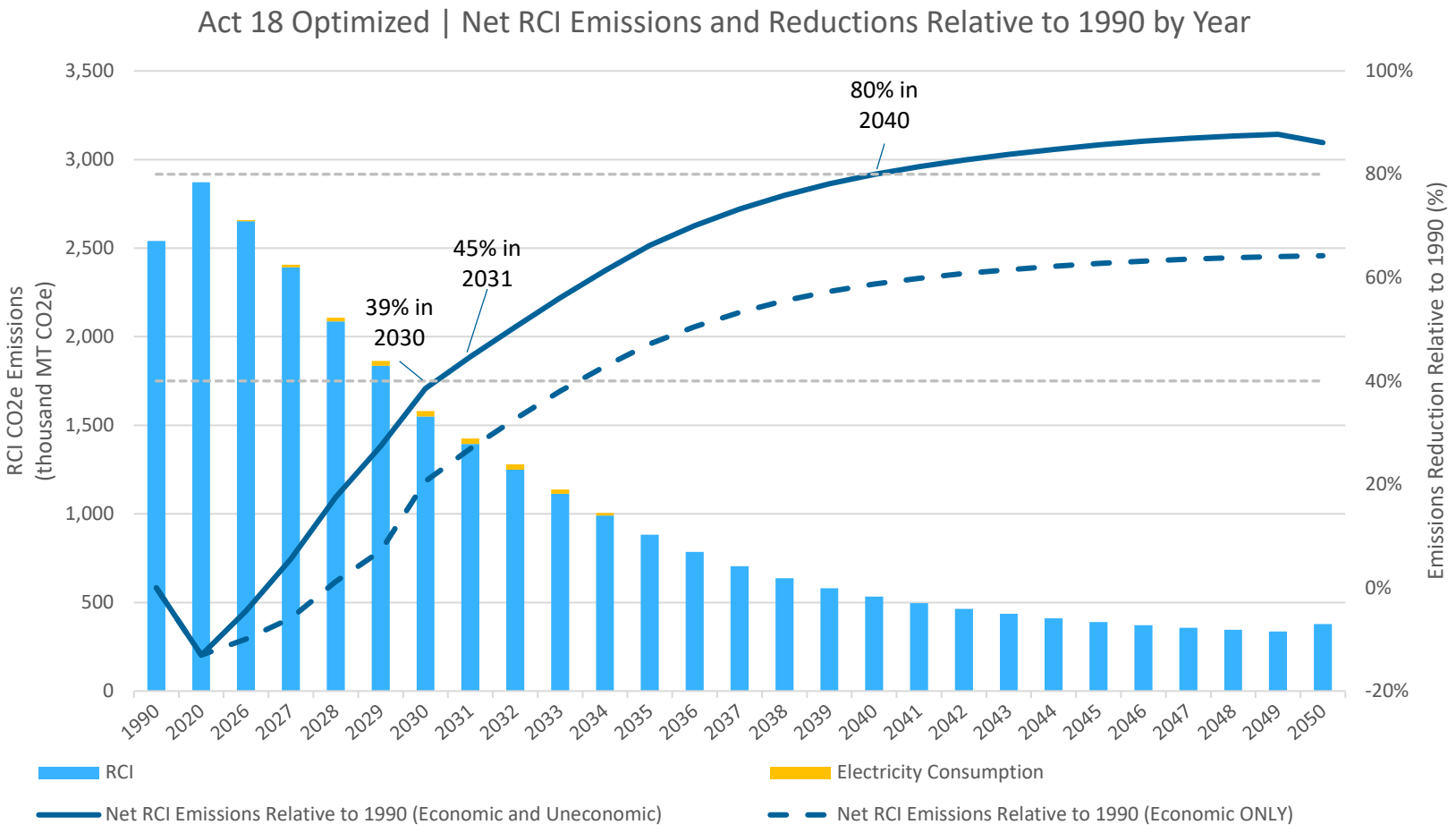
- Maximum Achievable scenario achieves a reduction in net RCI emissions relative to a 1990 baseline of **37% in 2030** and **86% in 2050**.
- "Net RCI Emissions" denotes the inclusion of increased Electricity Consumption sector emissions but impacts barely discernable due to slow ramp of fuel switching measure adoption and plummeting electric emissions rates.
- Increased emissions from 1990 to 2020 undercut achievement toward 2030 GWSA target, but forthcoming updates to the VT GHG emissions inventory may reduce the required reduction.

MAXIMUM ACHIEVABLE POTENTIAL

TOTAL MODELED INCENTIVE BUDGETS AND SOCIETAL BENEFITS

- Modeled present value **program incentive costs** for the Maximum Achievable are **$17.0B** (2024$).
  - Analysis assumes incentives cover 100% of the total installed costs.
  - Any additional participant costs such as electric panel upgrades and pre-weatherization barrier costs are not considered in total installed costs.
  - Any non-incentive program costs are not included.
  - Note: From a societal perspective, incentives are a transfer cost in that they are collected from and returned to VT ratepayers.
- The **total net societal benefits** (per the VT SCT) associated with the Maximum Achievable potential are **$3.6B** (2024$).
  - "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



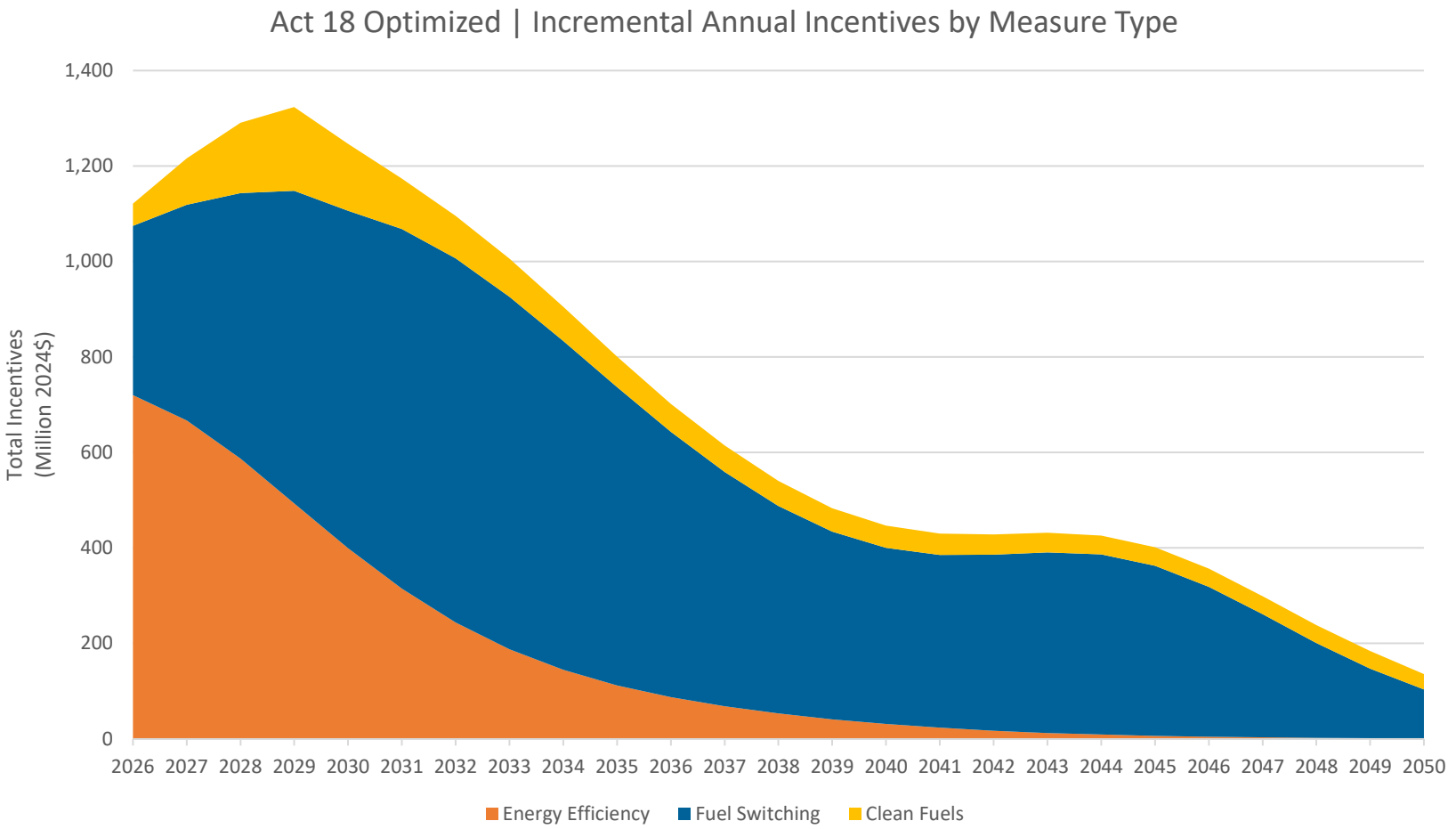
- Act 18 Optimized scenario achieves a reduction in net RCI emissions relative to a 1990 baseline of **39% in 2030** and **86% in 2050**.
- "Net RCI Emissions" denotes the inclusion of increased Electricity Consumption sector emissions but impacts barely discernable due to slow ramp of fuel switching measure adoption and plummeting electric emissions rates.
- Forthcoming revisions to this scenario will eliminate achievement in excess of 2050 GWSA requirements thereby reducing costs.
- Increased emissions from 1990 to 2020 undercut achievement toward 2030 GWSA target, but forthcoming updates to the VT GHG emissions inventory may reduce the required reduction.

ACT 18 OPTIMIZED POTENTIAL

TOTAL MODELED INCENTIVE BUDGETS AND SOCIETAL BENEFITS

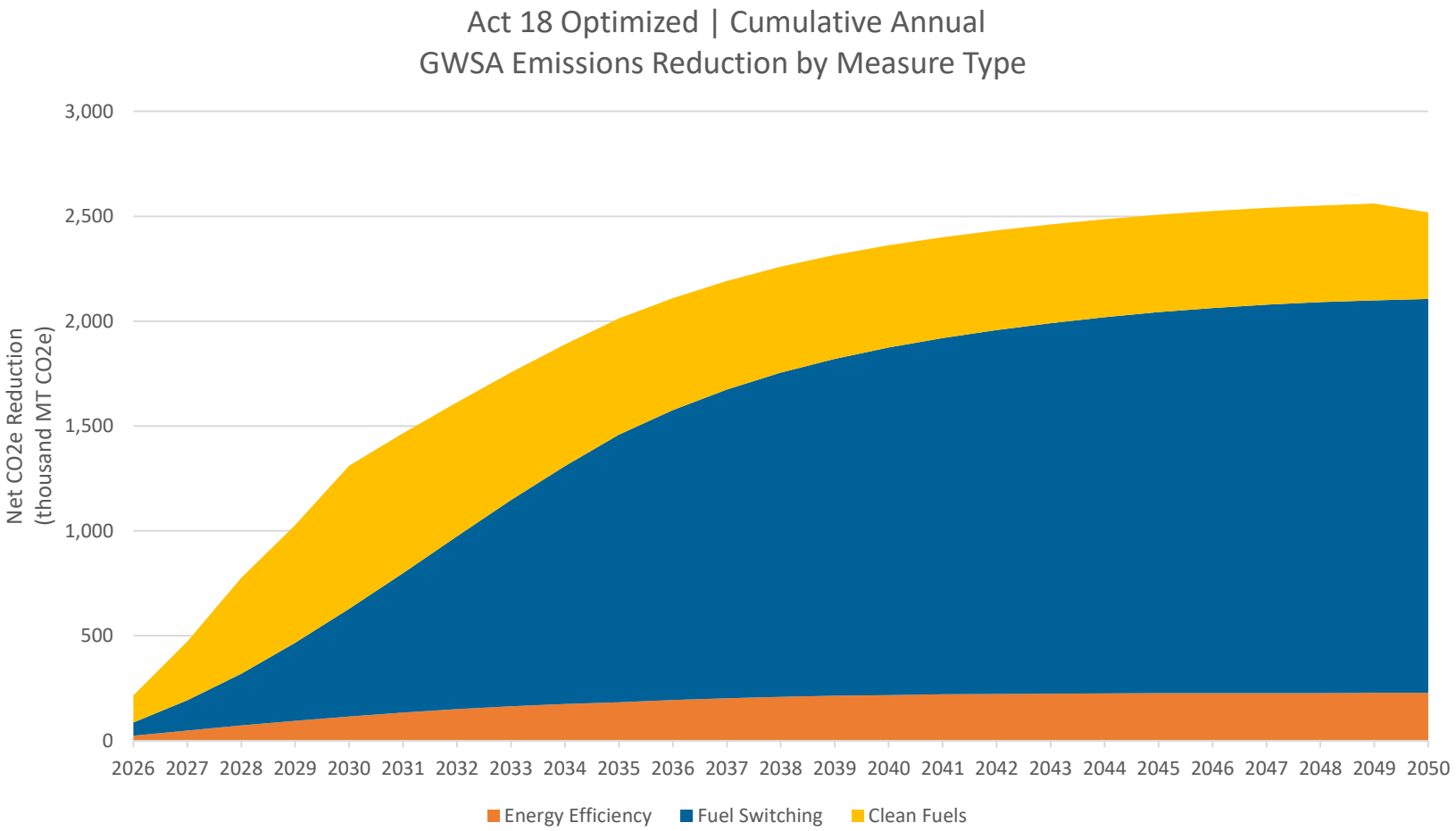
- Modeled present value **program incentive costs** for the Act 18 Optimized potential are **$17.3B** (2024$).
  - Analysis assumes incentives cover 100% of the total installed costs or 125% of total installed costs for fuel switching measures in low-income households.
  - Any additional participant costs such as electric panel upgrades and pre-weatherization barriers costs are not considered in total installed costs.
  - Any non-incentive program costs are not included.
  - Note: From a societal perspective, incentives are a transfer cost in that they are collected from and returned to VT ratepayers.
- The **total net societal benefits** (per the VT SCT) associated with the Act 18 Optimized potential are **$3.6B** (2024$).
  - "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



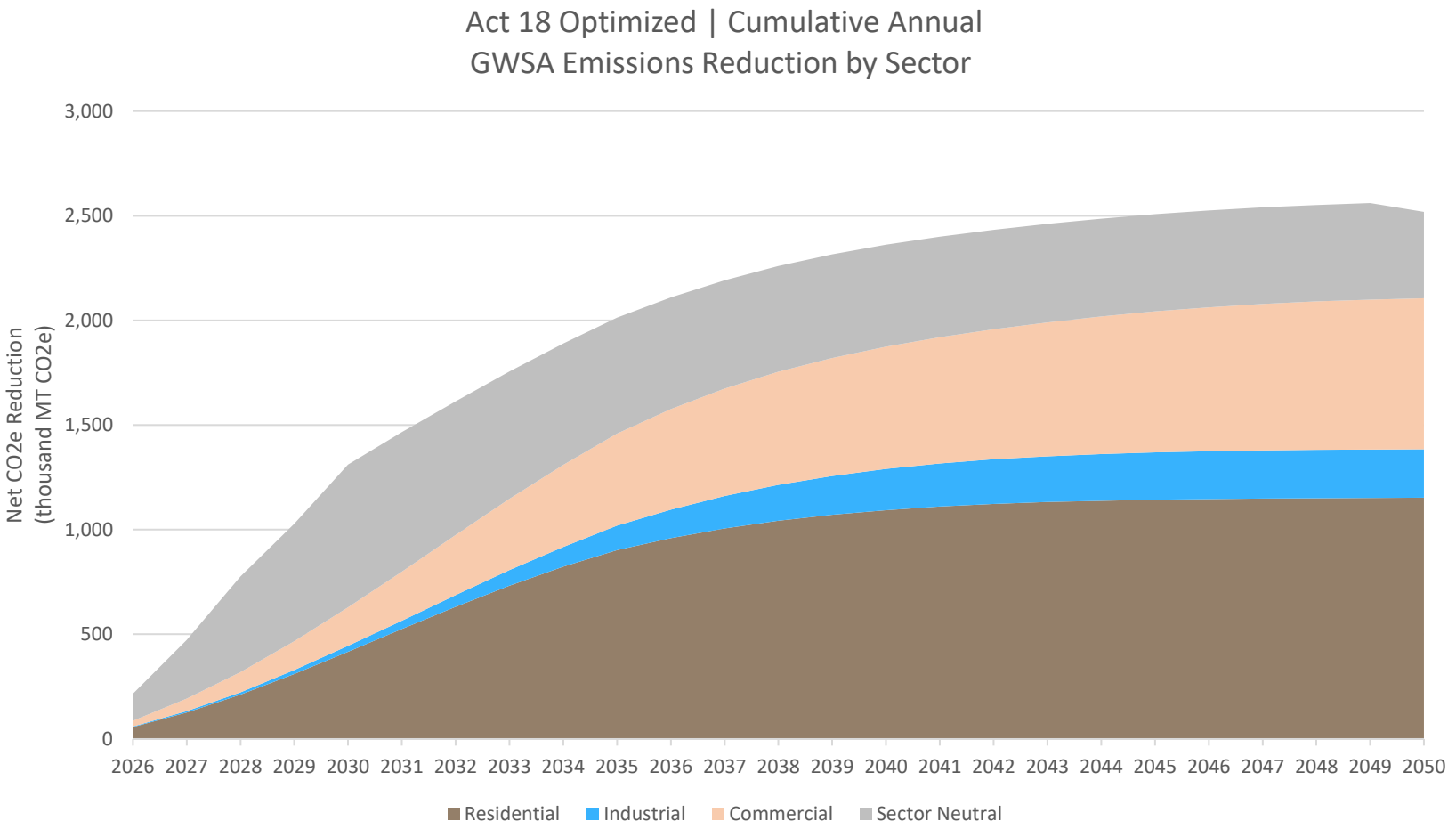
- Figure presents program incentive spending only as optimized to achieve GWSA targets.
- High incentive spending in early years reflects high incremental annual participation.
- As cumulative adoption of EE and FS measure increases over time, incremental annual participation (and associated incentive spending) drop.

ACT 18 OPTIMIZED POTENTIAL



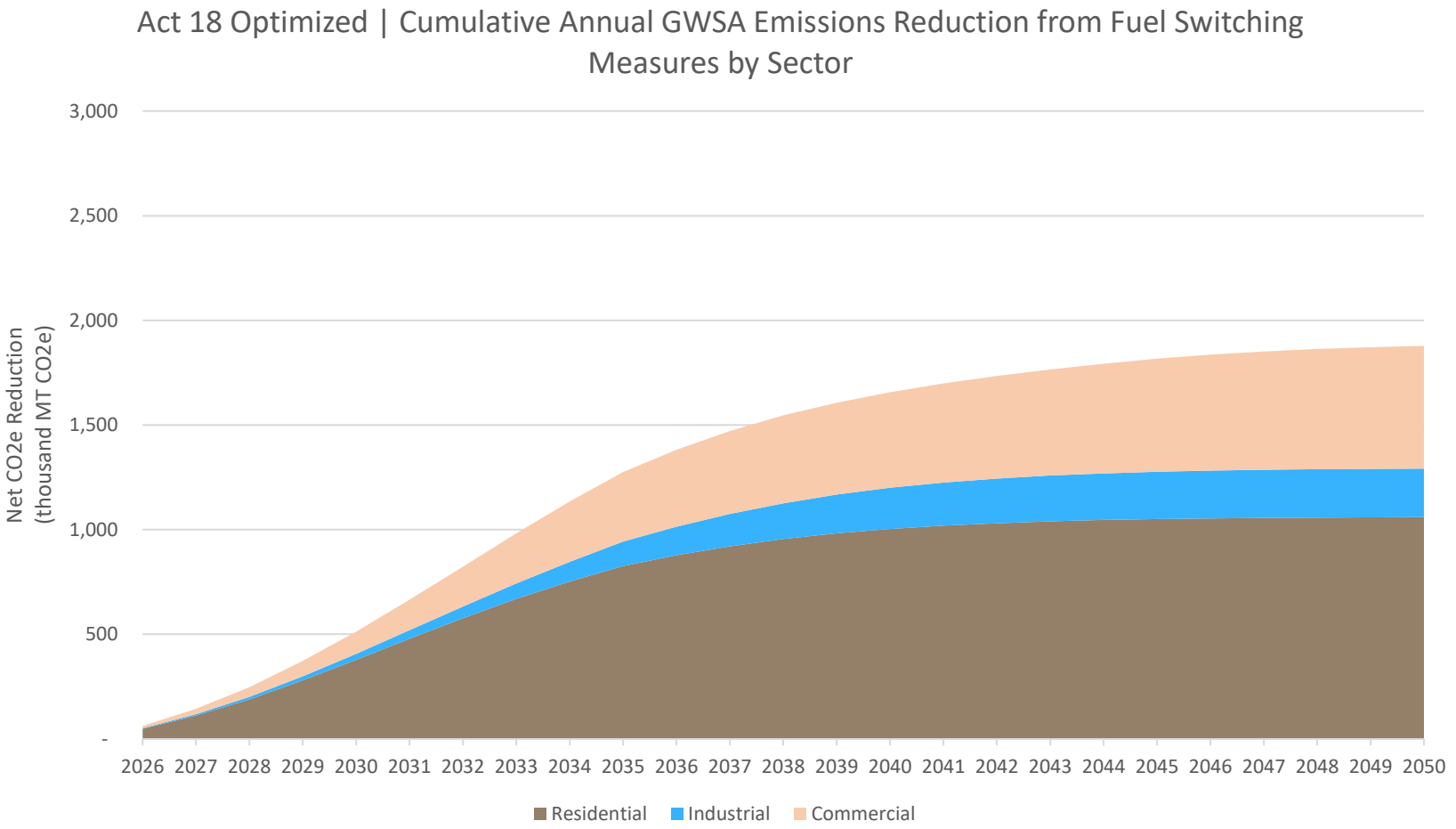
- Relative to the Maximum Achievable scenario, FS potential ramps earlier in analysis period.
- Biofuels/renewable fuels ramp quickly through 2030, then plateau at available resource and/or blending limits.
- Clean fuels potential observably drops in 2050 due to phase out based on CHS carbon intensity limits.

ACT 18 OPTIMIZED POTENTIAL



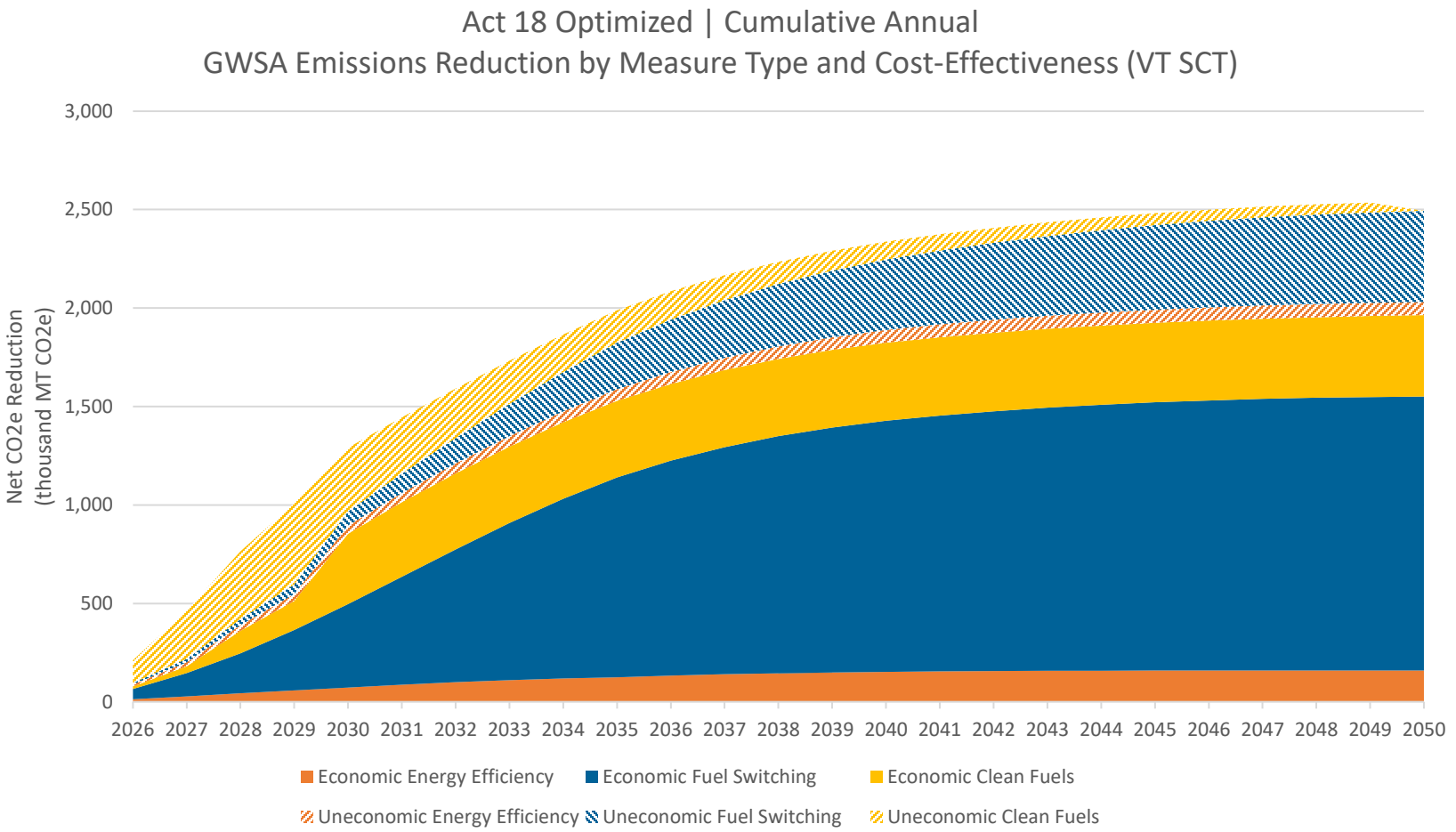
- Mirroring the emissions inventory, residential has the highest long term emissions reduction potential, followed by commercial then industrial.
- "Sector Neutral" potential served entirely by clean fuels. Given difficulty to electrify certain industrial end-uses, much of the clean fuels potential is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

ACT 18 OPTIMIZED POTENTIAL



- "Fuel Switching" (FS) as used here includes equipment-based fuel switching only (e.g., heat pumps) and excludes biofuels/renewable fuels.
- Distribution of FS measure potential by sector follows same general trend as overall potential.
- Relatively lower opportunities in industrial facilities due to hard to electrify end-uses.
- In contrast to biofuels/renewable fuels potential, FS measures exhibit slower growth trajectories.

ACT 18 OPTIMIZED POTENTIAL



- Measure cost-effectiveness determined by the Vermont Societal Cost Test (VT SCT)
- While the majority of EE, FS, and CF potential is cost-effective, much of the CF potential is not cost-effective in early years while the share of FS potential that is not cost-effective grows over time.
- In 2050, 78% 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 2050 (GWSA), 2050	PV Net Societal Benefits (Million 2024$), 2026
Ductless Heat Pump - Full Replacement	Residential	FS	13.1%	$1,631
Heat Pump Water Heater	Residential	FS	8.4%	$861
Central Heat Pump - Full Replacement	Residential	FS	7.5%	$854
Pool Heat Pump Water Heater	Residential	FS	3.7%	$248
Advanced Thermostat	Residential	EE	2.8%	$346
Ductless Heat Pump - Part-to-Full	Residential	FS	2.2%	$235
Ductless Heat Pump - Partial Displacement	Residential	FS	2.2%	$227
Ground Source Heat Pump	Residential	FS	1.7%	$46
Central Heat Pump - Part-to-Full	Residential	FS	1.5%	$175
Central Heat Pump - Partial Displacement	Residential	FS	1.5%	$151

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

ACT 18 OPTIMIZED POTENTIAL

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 2050 (GWSA), 2050	PV Net Societal Benefits (Million 2024$), 2026
Variable Refrigerant Flow (VRF) Heat Pump - Full Replacement	Commercial	FS	6.3%	$46
Networked Geothermal	Commercial	FS	5.1%	($415)
Ductless Heat Pump - Full Replacement	Commercial	FS	3.6%	$134
Electric Furnace - Process Heat	Industrial	FS	3.3%	($111)
Heat Pump Rooftop Unit (RTU)	Commercial	FS	2.6%	$239
Industrial Indirect Boiler to Electric Boiler	Industrial	FS	2.5%	($227)
Envelope Improvements	Commercial	EE	2.1%	($2,276)
Advanced Thermostats	Commercial	EE	1.9%	$435
Central Heat Pump - Full Replacement	Commercial	FS	1.7%	$67
Heat Pump Water Heater	Commercial	FS	1.7%	$116

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

ACT 18 OPTIMIZED POTENTIAL

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 2050 (GWSA), 2050	PV Net Societal Benefits (Million 2024$), 2026
Out-of-State | All | Advanced Renewable Diesel | Residues and Waste	All	CF	10.3%	$405
In-State | All | Biomethane | Animal Manure	All	CF	4.7%	$382
Out-of-State | All | Biomethane | Animal Manure	All	CF	2.2%	$155
In-State | All | Hydrogen | Dedicated Renewables	All	CF	0.2%	$135
Out-of-State | All | Biomethane | Residues and Waste	All	CF	0.1%	$63
In-State | All | Advanced Renewable Diesel | Residues and Waste	All	CF	0.02%	$0.8

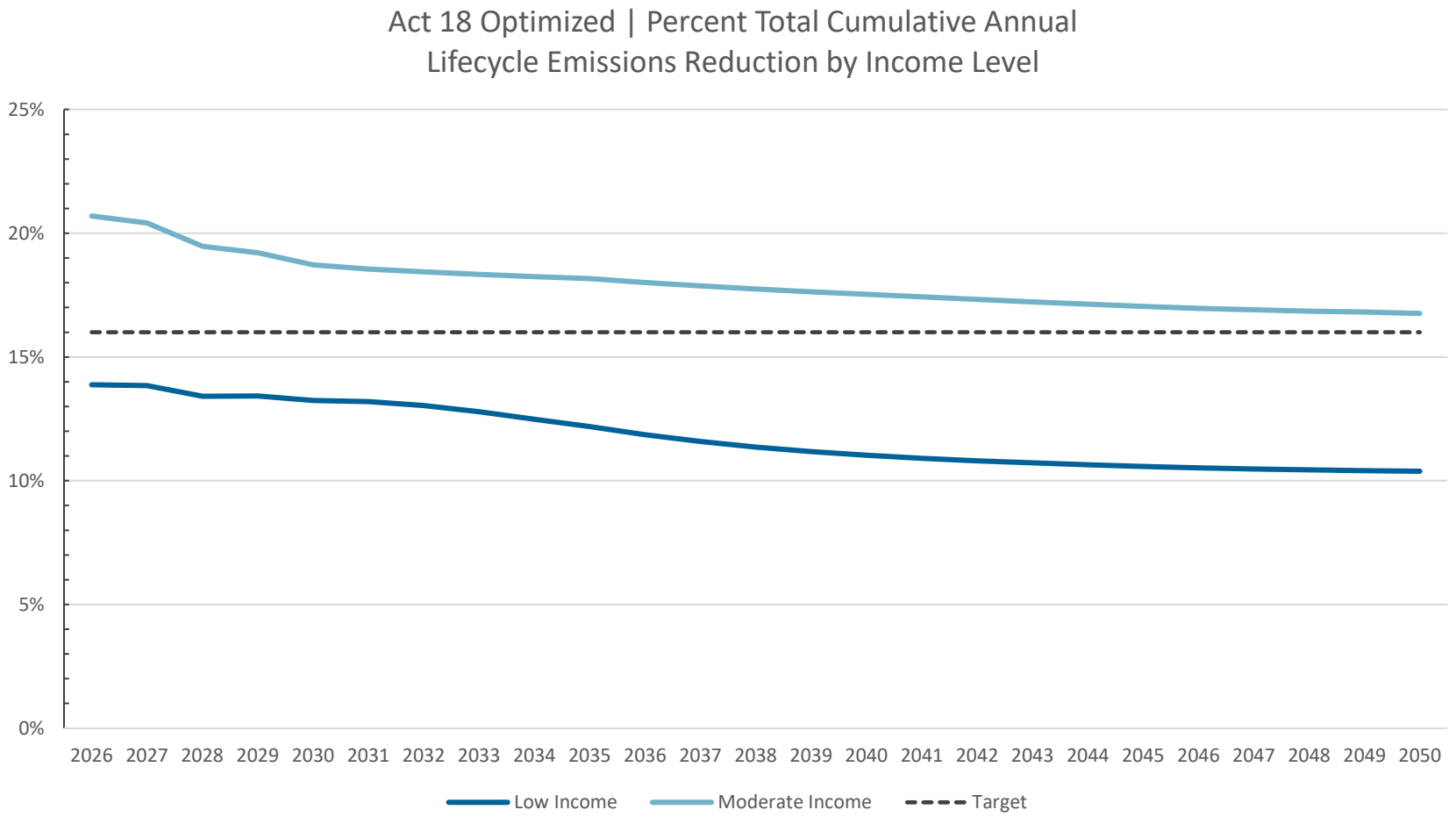
FS = Fuel Switching; CF = Clean Fuels; EE = Energy Efficiency

ACT 18 OPTIMIZED POTENTIAL

IMPLICATIONS OF CLEAN FUELS CARBON INTENSITY LIMITS

- Act 18 imposes carbon intensity (CI) limits for liquid and gaseous fuels that increase in stringency over time
  - CI limit defined relative to No. 2 Fuel Oil (i.e., No. 2 Fuel Oil CI = 100)
  - Act 18 requires below 80 in 2025, below 60 in 2030, and below 20 in 2050
- Impact of the limits on the potential are relatively small
  - In 2030:
    - In-State and Out-of-State resources for biomethane from landfill gas feedstocks become ineligible
  - In 2050:
    - In-State and Out-of-State resources for biomethane from wastewater feedstocks become ineligible
    - Out-of-State resources for biodiesel and renewable diesel from purpose-grown oil crops & waste fats and oils become ineligible

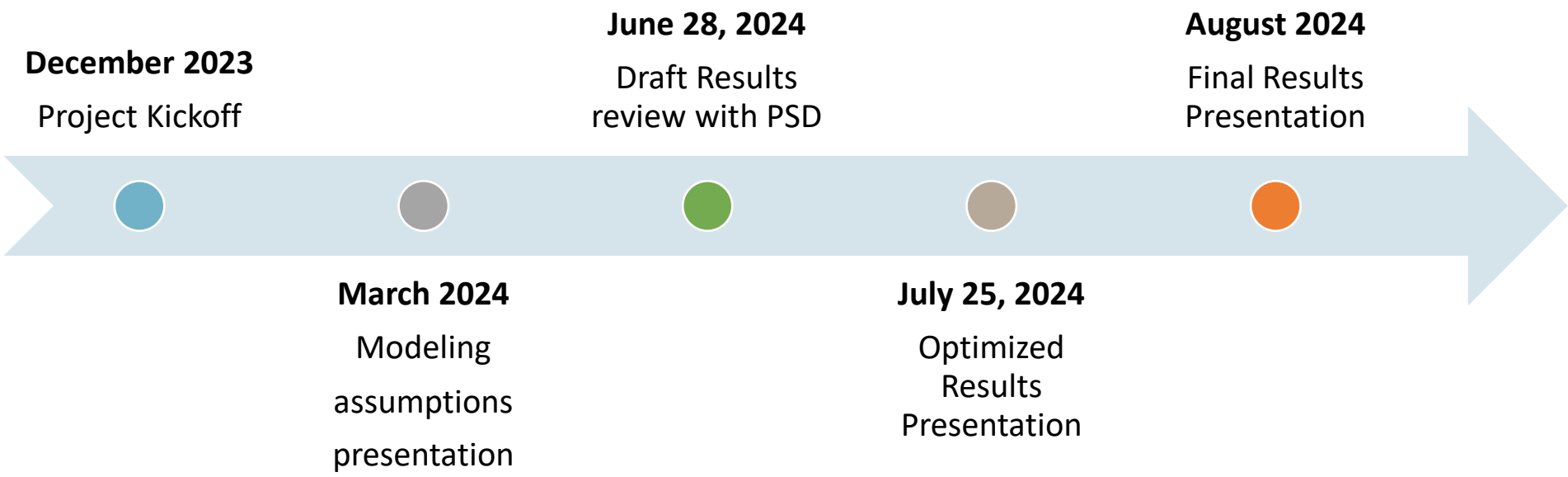
ACT 18 OPTIMIZED POTENTIAL



- 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.

NEXT STEPS

- Finalize Optimized Results
  - Continued QA/QC
  - Address/incorporate stakeholder comments
  - Incorporate updated RCI values
- Project Timeline



Please provide feedback on the potential study to PSD.cleanheat@vermont.gov by July 31, 2024.

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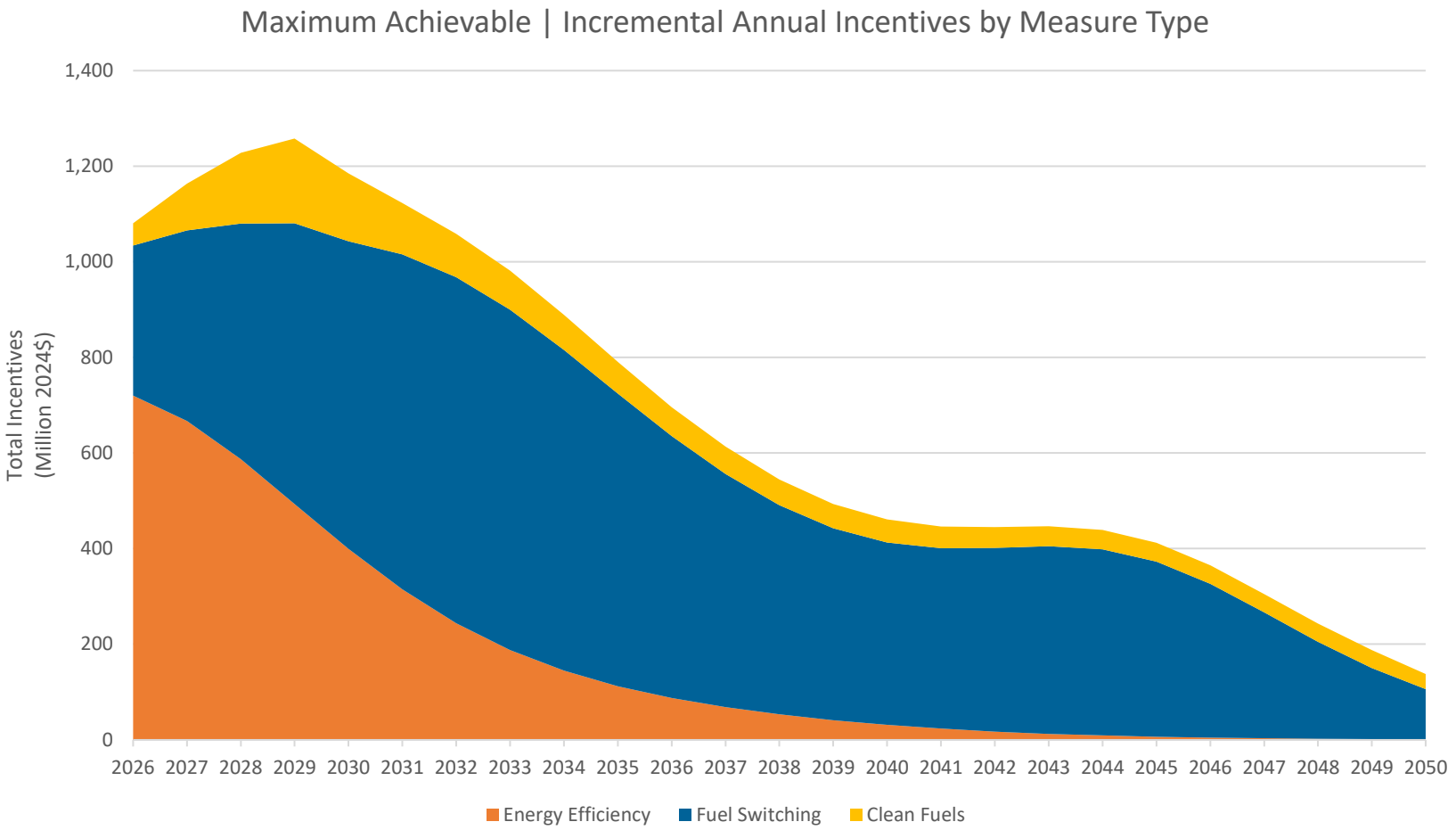
APPENDIX

MAXIMUM ACHIEVABLE POTENTIAL



- Figure presents <u>program incentive spending only.</u>
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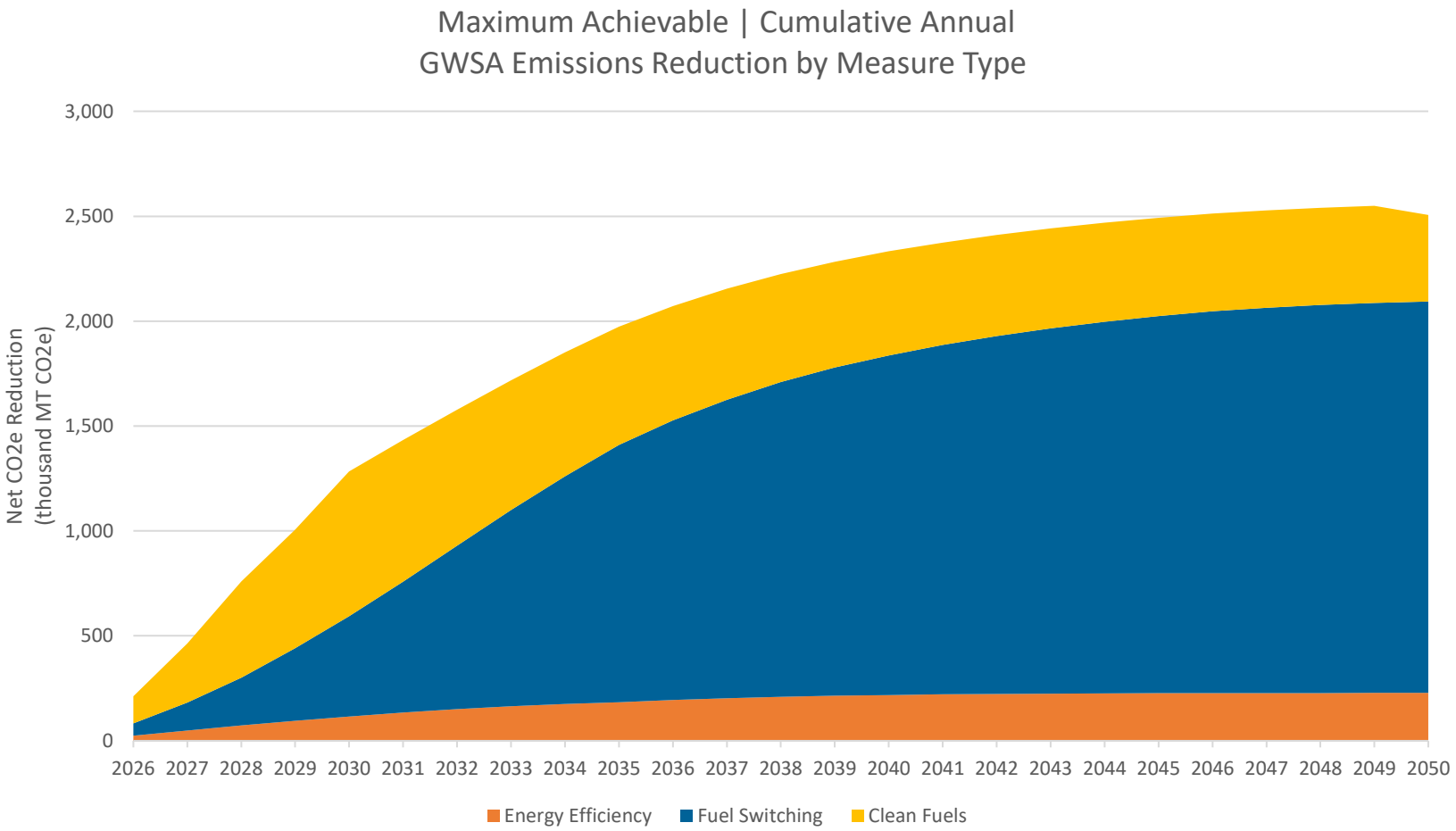
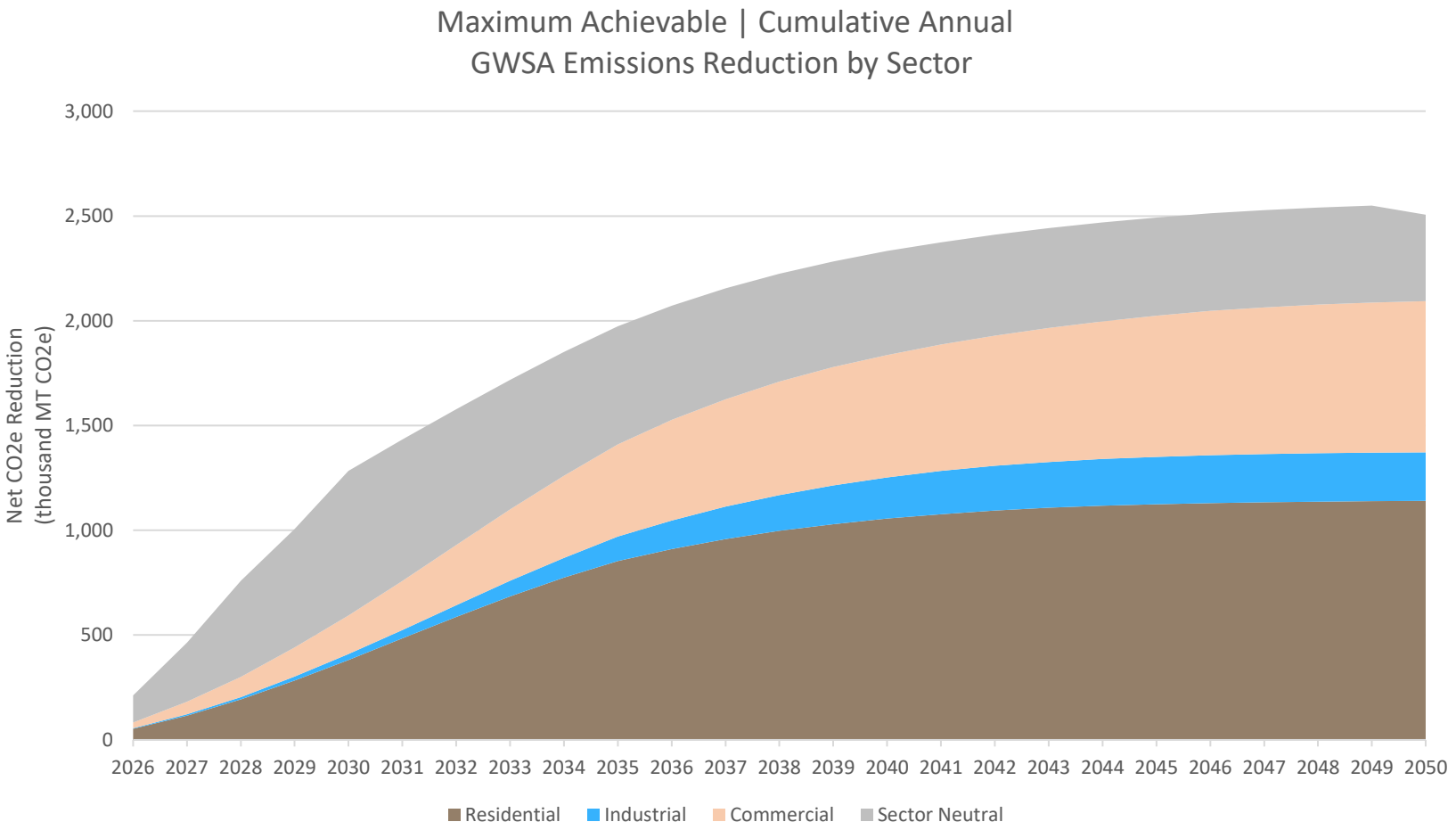
MAXIMUM ACHIEVABLE POTENTIAL



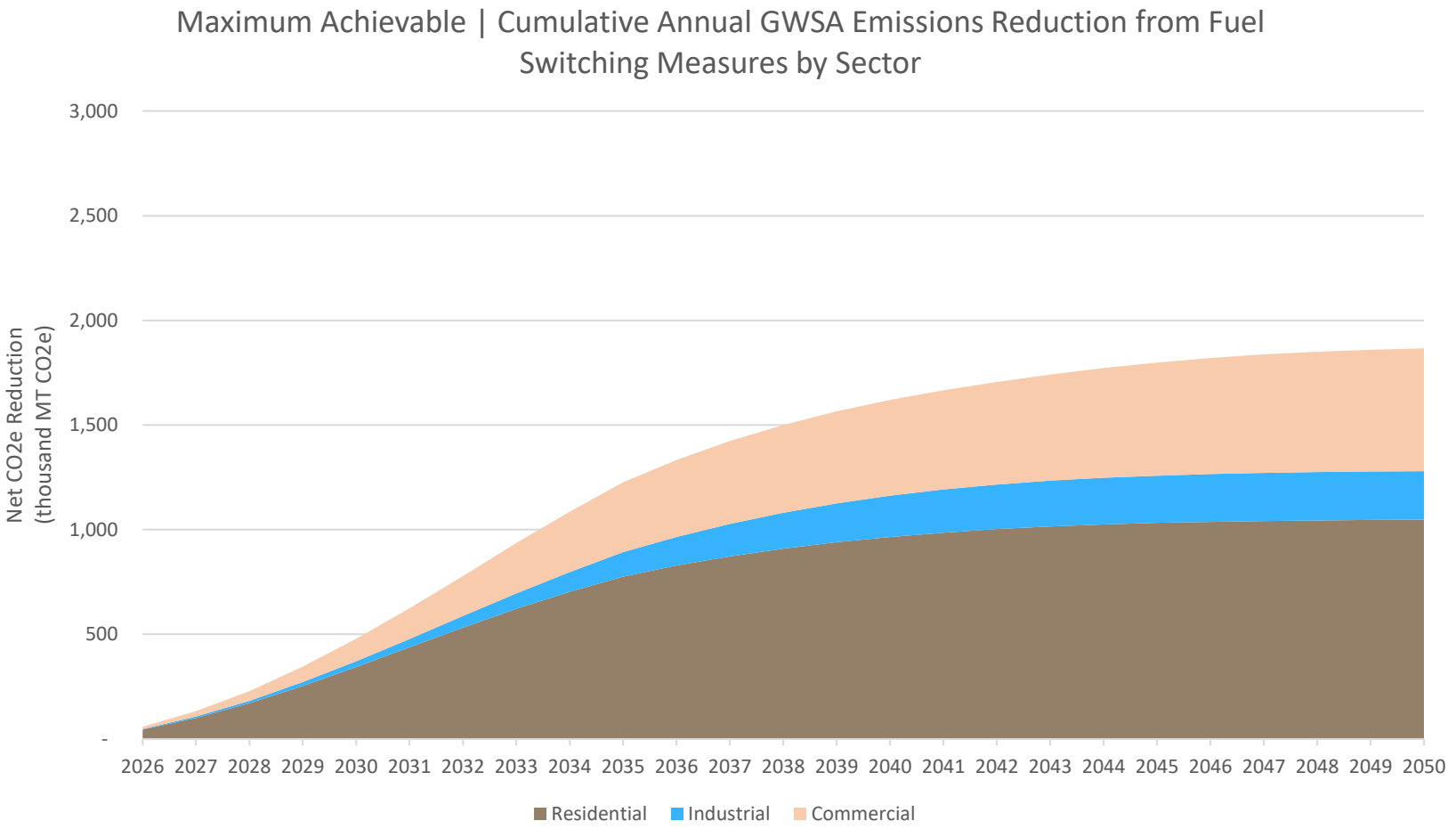
- Biofuels/renewable fuels ramp quickly through 2030, then plateau at available resource and/or blending limits.
- As fuels switching measures begin ramping more quickly after 2030, some clean fuel adoption is displaced.
- Clean fuels potential observably drops in 2050 due to phase out based on CHS carbon intensity limits.

MAXIMUM ACHIEVABLE POTENTIAL



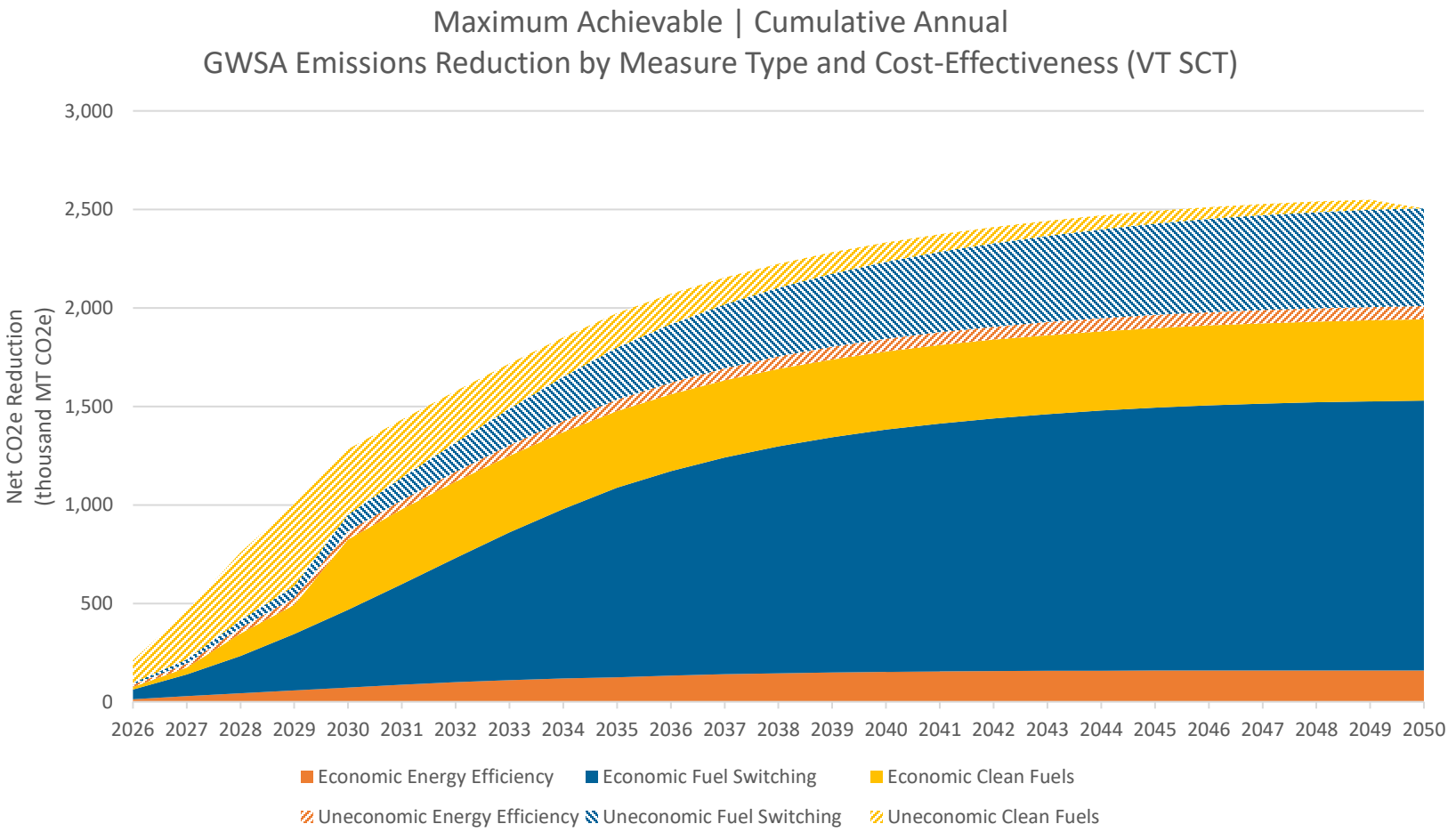
- Mirroring the emissions inventory, residential has the highest long term emissions reduction potential, followed by commercial then industrial.
- "Sector Neutral" potential served entirely by clean fuels. Given difficulty to electrify certain industrial end-uses, much of the clean fuels potential is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

MAXIMUM ACHIEVABLE POTENTIAL



- "Fuel Switching" (FS) as used here includes equipment-based fuel switching only (e.g., heat pumps) and excludes biofuels/renewable fuels.
- Distribution of FS measure potential by sector follows same general trend as overall potential.
- Relatively lower opportunities in industrial facilities due to hard to electrify end-uses.
- In contrast to biofuels/renewable fuels potential, FS measures exhibit slower growth trajectories.

MAXIMUM ACHIEVABLE POTENTIAL



- Measure cost-effectiveness determined by the Vermont Societal Cost Test (VT SCT)
- While the majority of EE, FS, and CF potential is cost-effective, much of the CF potential is not cost-effective in early years while the share of FS potential that is not cost-effective grows over time.
- In 2050, 77% of the identified Maximum Achievable potential emissions reductions is cost-effective.

MAXIMUM ACHIEVABLE POTENTIAL

TOP 10 MEASURES BY CONTRIBUTION TO REQUIRED 2050 RCI EMISSIONS REDUCTIONS

Measure	Sector	Measure Type	Percent of Total RCI Emissions Reductions Required by 2050 (GWSA), 2050	PV Net Societal Benefits (Million 2024$), 2026
Ductless Heat Pump - Full Replacement	Residential	FS	12.8%	$1,593
Out-of-State | All | Advanced Renewable Diesel | Residues and Waste	Sector Neutral	CF	10.3%	$405
Heat Pump Water Heater	Residential	FS	8.3%	$847
Central Heat Pump - Full Replacement	Residential	FS	7.4%	$834
Variable Refrigerant Flow (VRF) Heat Pump - Full Replacement	Commercial	FS	6.3%	$46
Networked Geothermal	Commercial	FS	5.1%	($415)
In-State | All | Biomethane | Animal Manure	Sector Neutral	CF	4.7%	$382
Pool Heat Pump Water Heater	Residential	FS	3.7%	$248
Ductless Heat Pump - Full Replacement	Commercial	FS	3.6%	$134
Electric Furnace - Process Heat	Industrial	FS	3.3%	($111)

FS = Fuel Switching; CF = Clean Fuels