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ENERGY FUTURES GROUP

Pathways Analysis: Modeling Results

Presentation to Vermont Climate Council

November 2, 2021

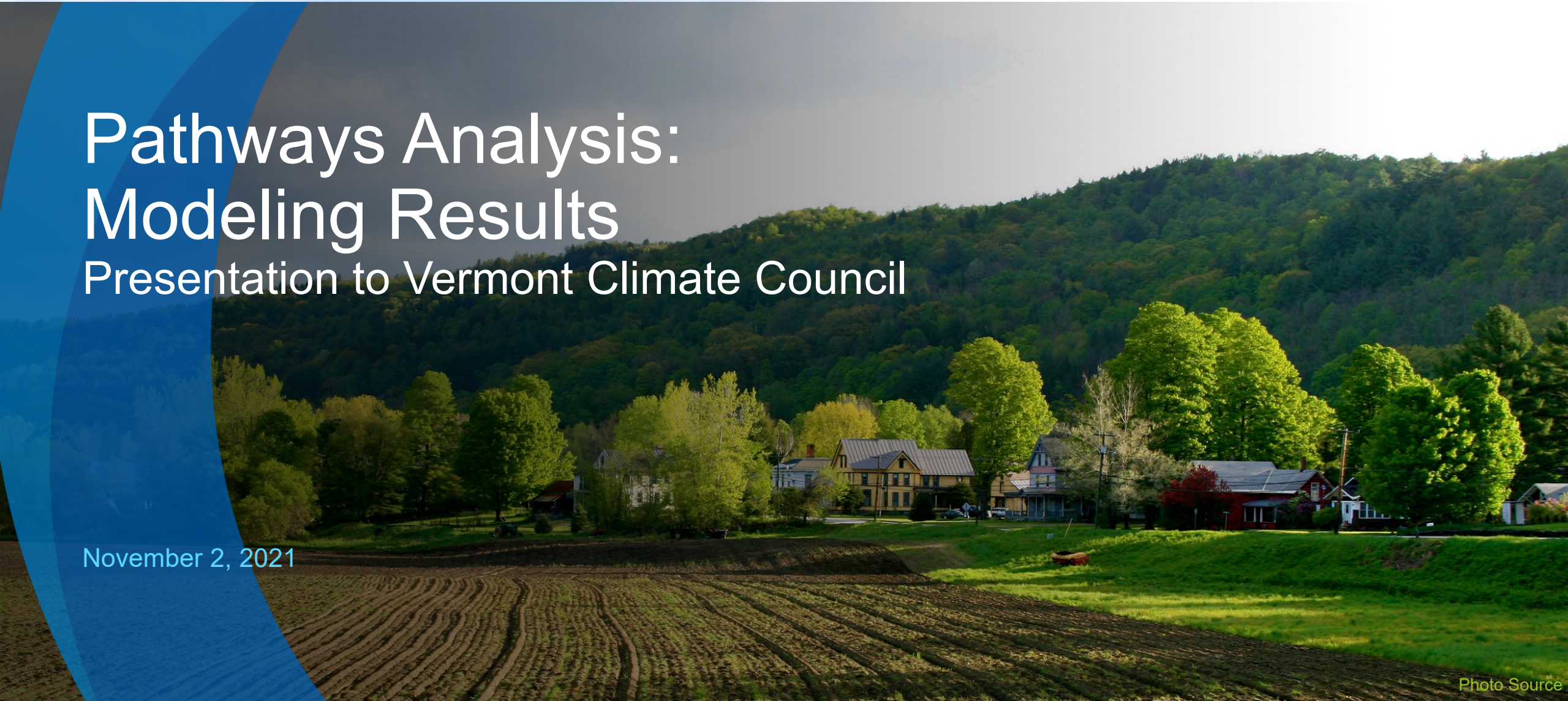

Photo Source

Agenda

Modeling Overview

Sector-Specific Results

- Transportation
- Buildings
- Non-Energy
- Electricity

Conclusions

Modeling Overview

Scope of Modeling Task

- Integrate Cross-Sector Mitigation (CSM) priorities into the Low Emissions Analysis Platform (LEAP) model, initially developed by the Stockholm Environment Institute for Vermont's Comprehensive Energy Plan
- Report initial and final results on GHG reduction pathways and associated costs to inform CSM and Vermont Climate Council deliberations about final CAP recommendations
- Summarize key insights to inform future policy development

Key Considerations

- The LEAP model is not predictive
  - It is an accounting tool that enables decision-makers to compare options for meeting requirements and visualize scope of the transition required
  - Results illustrate the level of activity by sector necessary to meet the GWSA requirements utilizing the approaches recommended by CSM and its stakeholders
- Emissions reductions are generated by the adoption and delivery of technologies that are present in the market today, but at a significantly accelerated pace and scale relative to today

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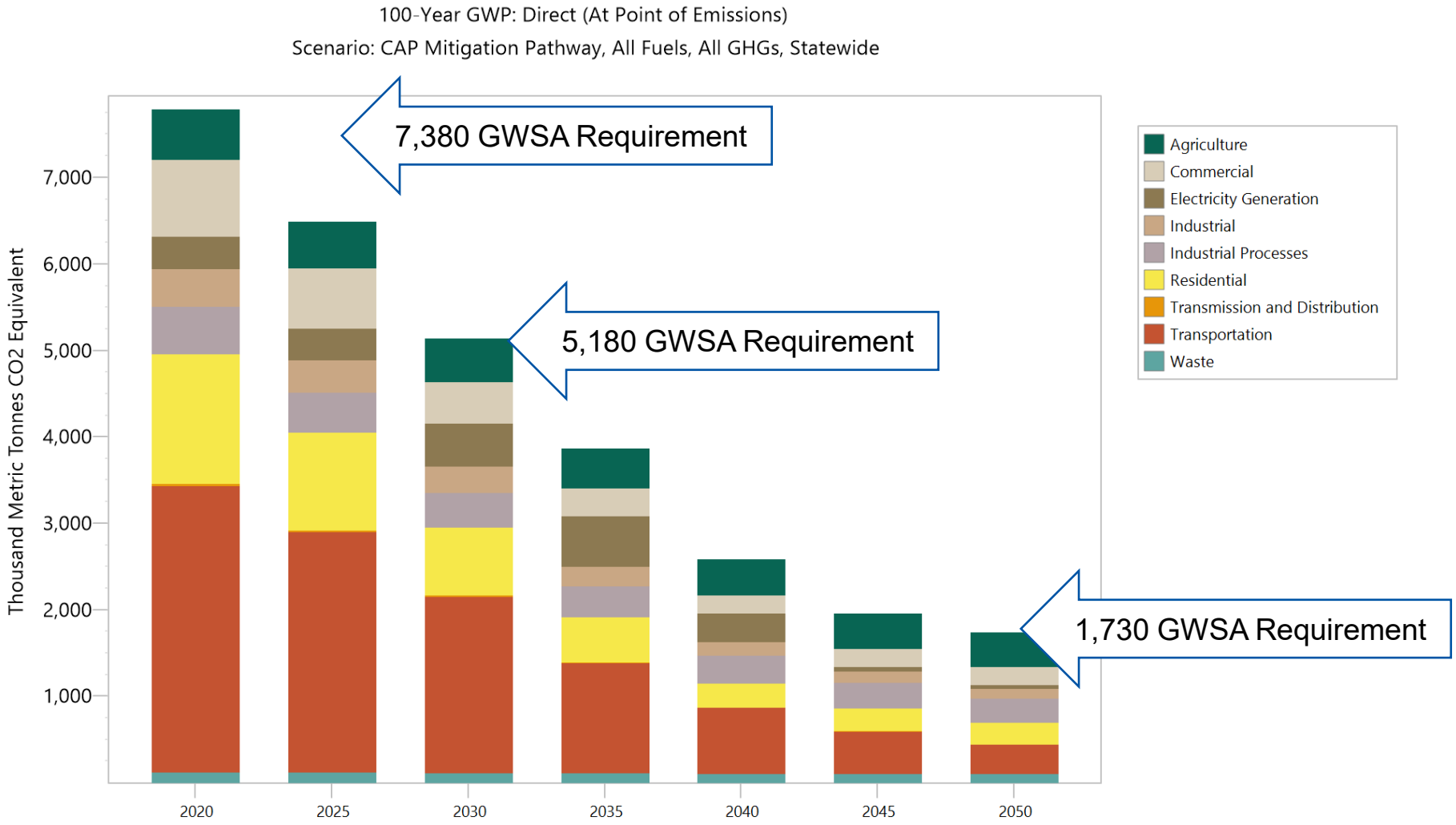
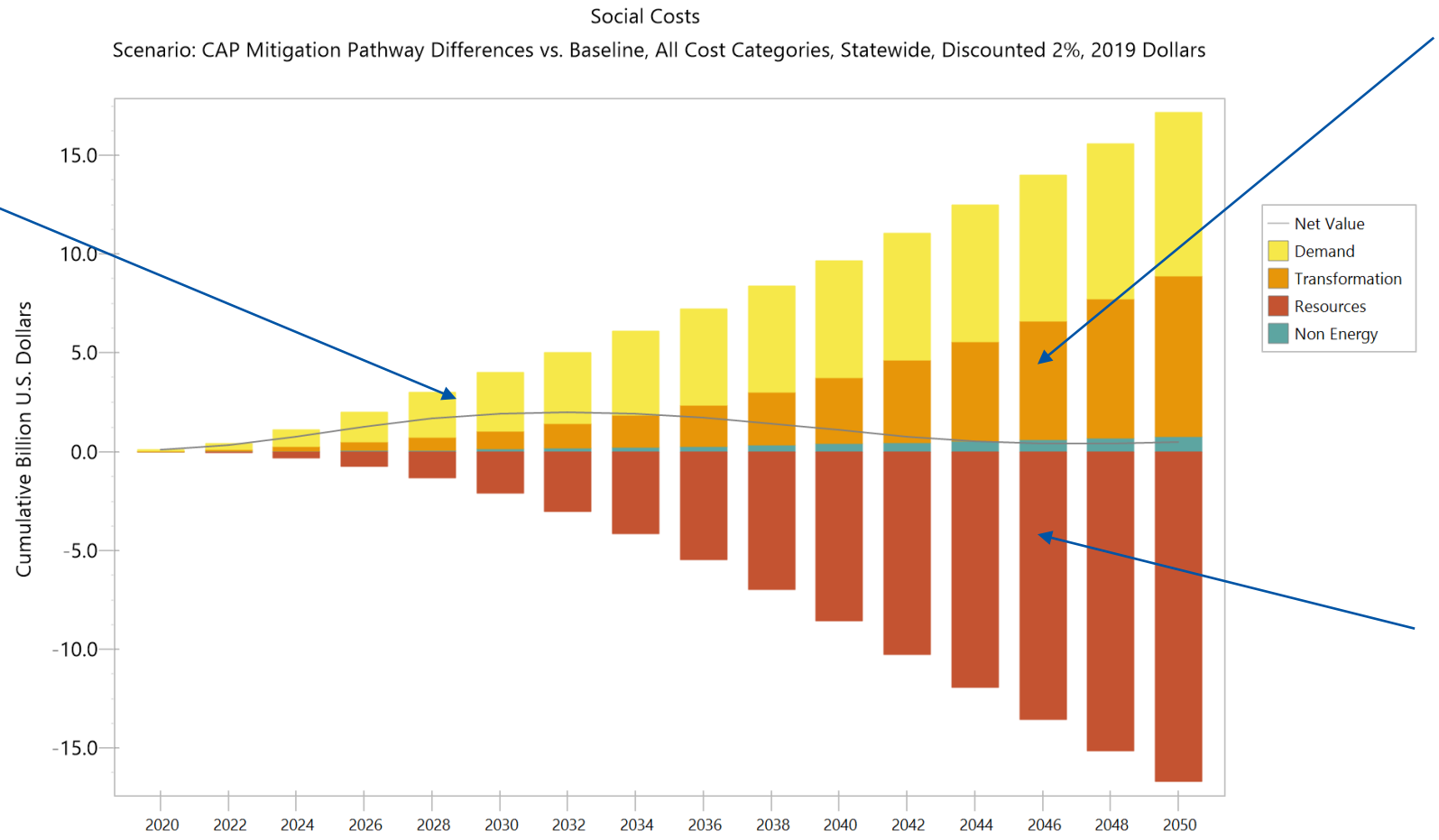
Economy-Wide Results



Transition Investments and Savings

Near-term investments in transportation and buildings…,



…followed by increasing investments in electric generation in later years...

…are offset by fossil fuel savings in medium- to long-term

Transportation

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Strategies and Inputs

CSM Strategies

- Increased vehicle efficiency
- Reduction in carbon intensity of fuels
- Mode shift, increased use of transit, walking, biking
- Increased use of biofuels

LEAP Inputs

- Efficiency of vehicles by class
- Share of vehicle types stock and sales
- Reduced Vehicle Miles Travelled
- Biofuels in Non - Road

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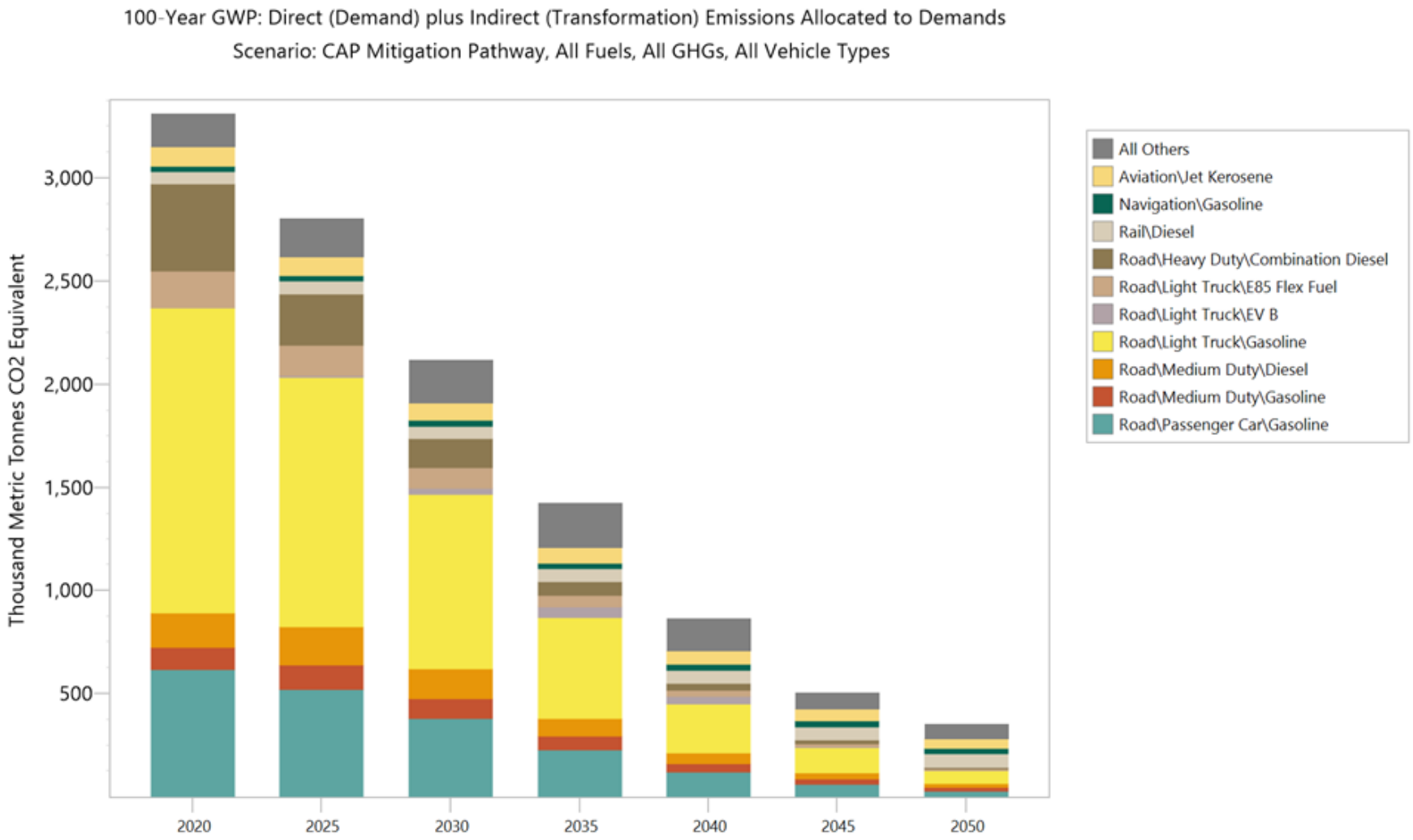
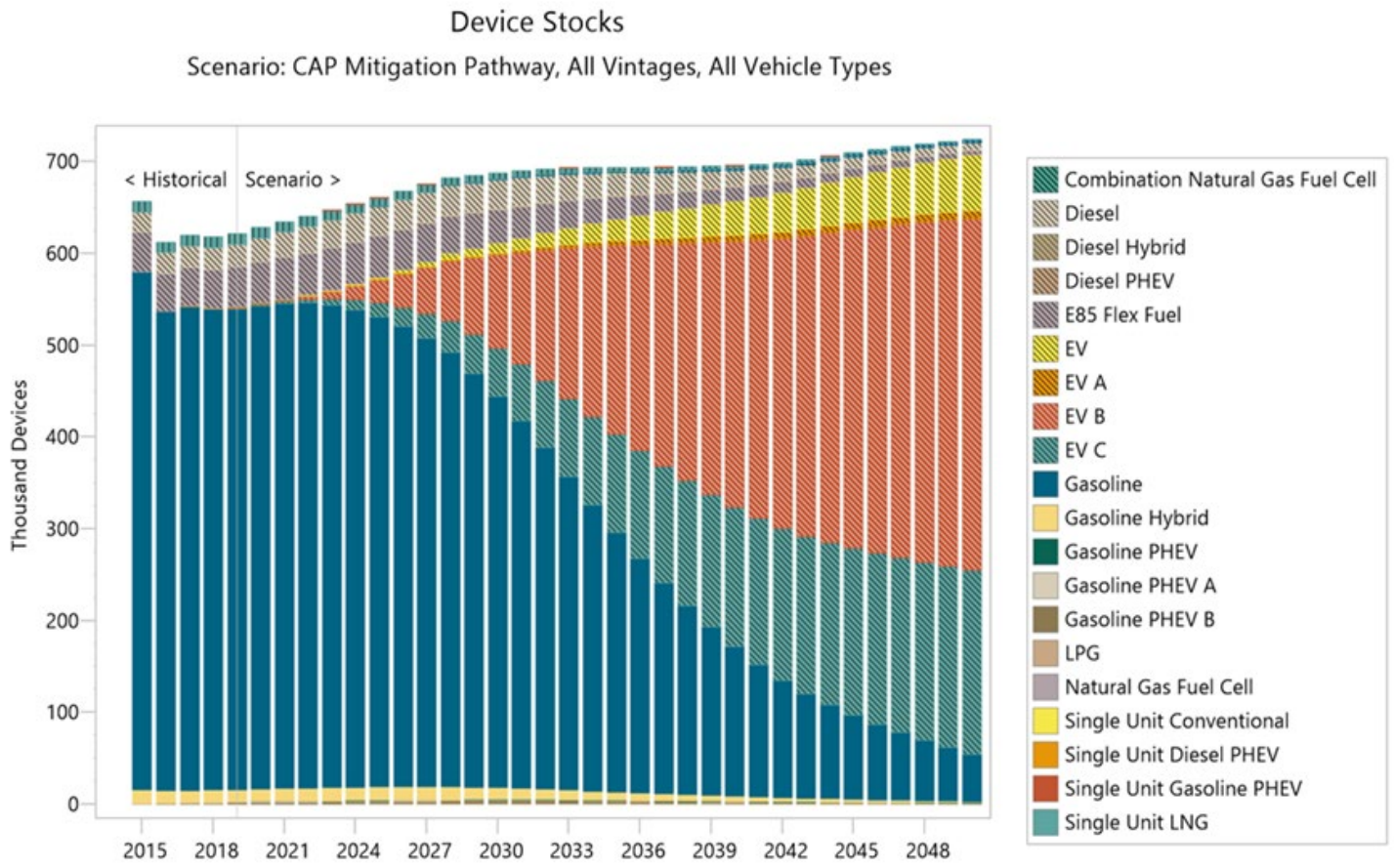
Transportation Sector Transition

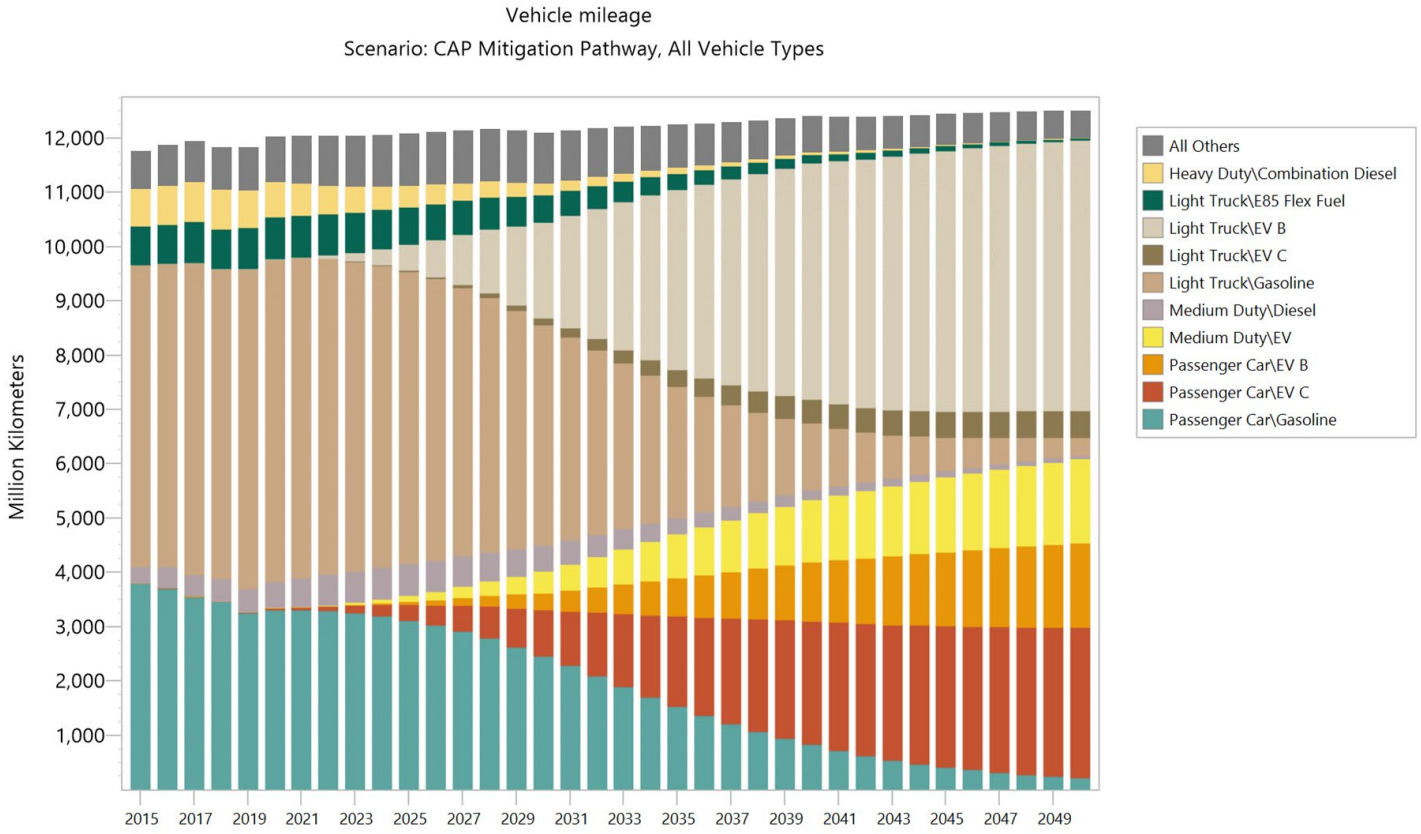


Transportation Sector Key Indicators



Key LEAP Outputs	2025	2030
EVs	43,000	166,000
EV share of sales	40%	>80%
VMT Reduction from Baseline	1.9%	3.5%
EV share of VMTs	8%	29%
EV Managed Charging	27%	50%

Transportation Sector Key Indicators



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Transportation Sector Insights

- As Vermont's largest source of emissions, required **pace of change in the transportation sector is significant, but essential** for meeting the GWSA requirements
- Fortunately, **national and regional initiatives are already creating major impacts** in the market that Vermont can and should leverage
- Modeling indicates that **these solutions alone are not enough** to drive the pace of change needed; Vermont will likely need to invest in additional strategies, such as
  - Incentives for more fuel efficient and electric vehicles
  - Public messaging and promotion to support rapid adoption
  - Charging infrastructure deployment
- The Transportation Climate Initiative, in addition to helping reduce emissions, can create an important **source of revenue** for these additional approaches
- **To not over-burden the electric grid, managed charging is needed**
- **Attention to equity and reducing transportation energy burden** for Vermonters

Buildings

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Strategies and Inputs

CSM Strategies

- Increased shell efficiency
- Increased equipment efficiency
- Decrease in carbon intensity of fuels
- Coordinated loads
- Role of biofuels in future requirements

LEAP Inputs

- Reduce building energy use intensity
- High efficiency equipment replacement (i.e., heat pumps)
- Electricity replacing combustion fuels
- Alter proportion of biofuels utilized

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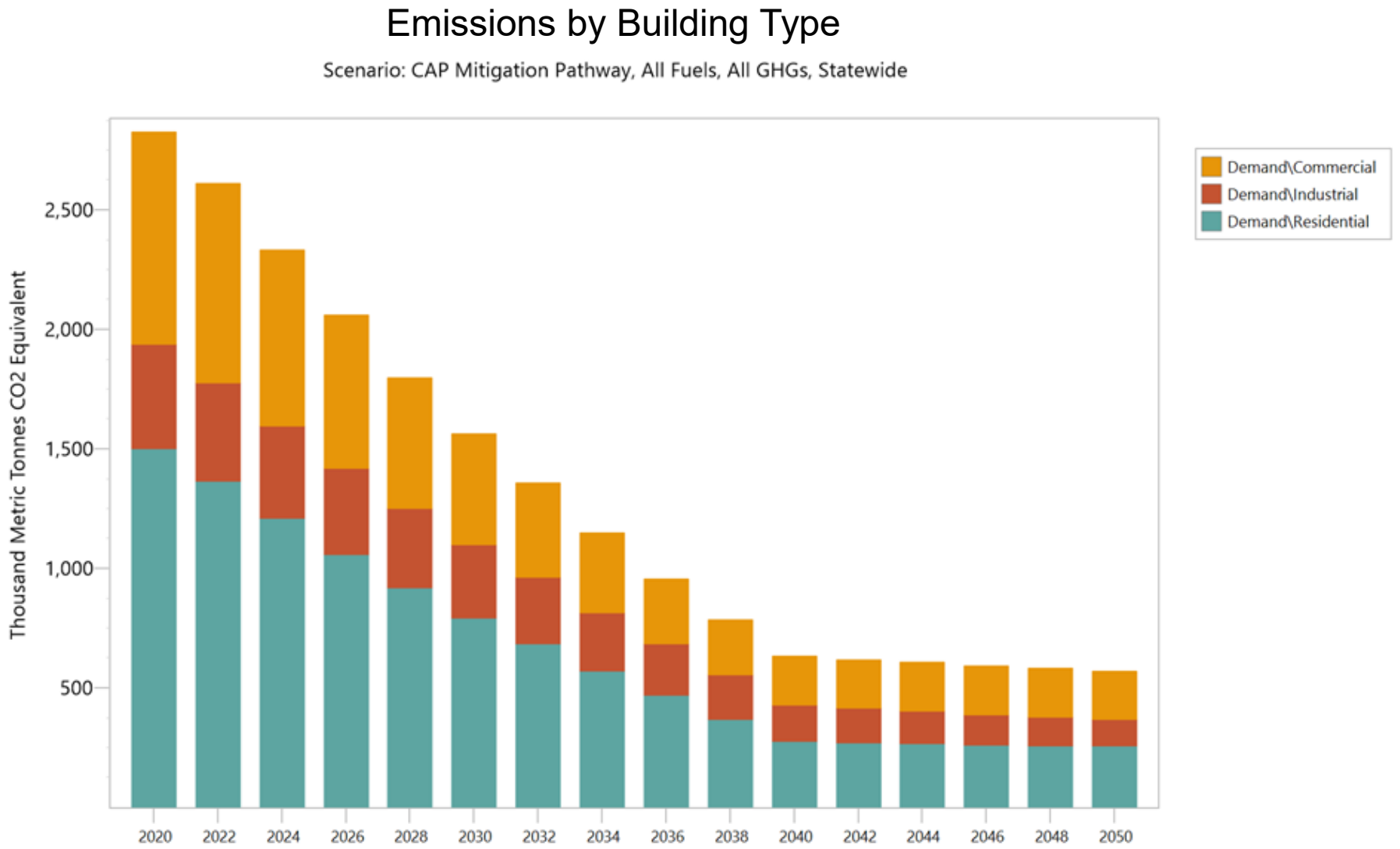
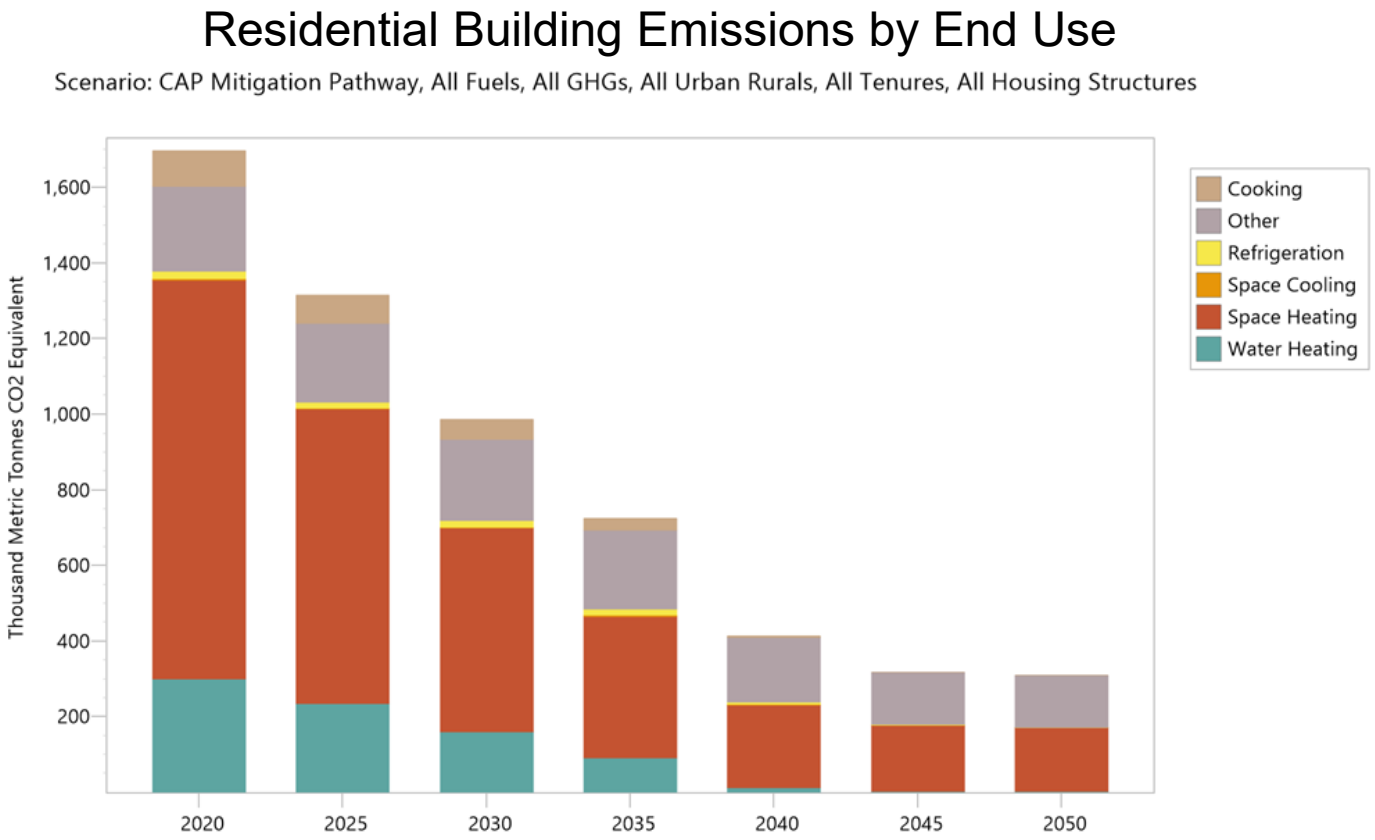
Building Sector Transition



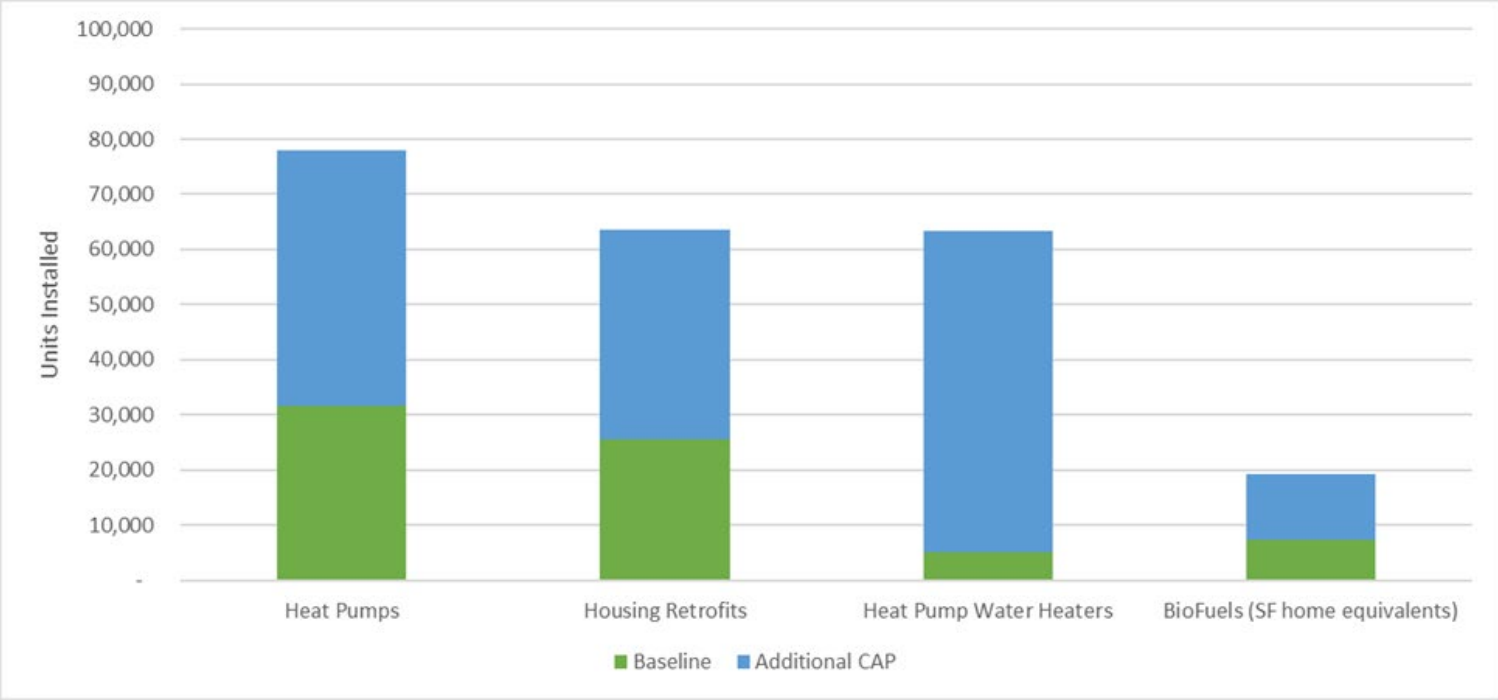
Building Sector Key Indicators



Key LEAP Output - Residential	2025	2030
Homes Weatherized	63,599	108,160
Heat Pumps Installed	78,041	142,851
Heat Pump Water Heaters Installed	63,247	136,558
Homes with Biofuels	19,324	29,823

Building Sector Key Indicators

Equipment Installations by 2025



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Homes with Biofuels	19,324	29,823

Building Sector Insights

- Model utilizes **commercially available and proven technologies,** meaning delivery mechanisms and organizations are already in place but must scale rapidly.
- The **pace of change in the modeling is greater than the natural level of market turnover**, meaning new interventions are necessary to accelerate adoption.
- The scale of installations is significant, making **work force development and training essential**.
- Incentives and extensive public messaging and promotion to support rapid adoption.
- **Weatherization reduces impacts** on the electric system, reducing household and system-wide costs.
- Particular attention to equity and reducing energy burden is required. Supporting **navigation and financing assistance** for customers, as well as strategies and assistance to **help consumers "bundle" building performance upgrades** should be encouraged

Non-Energy

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Strategies and Inputs

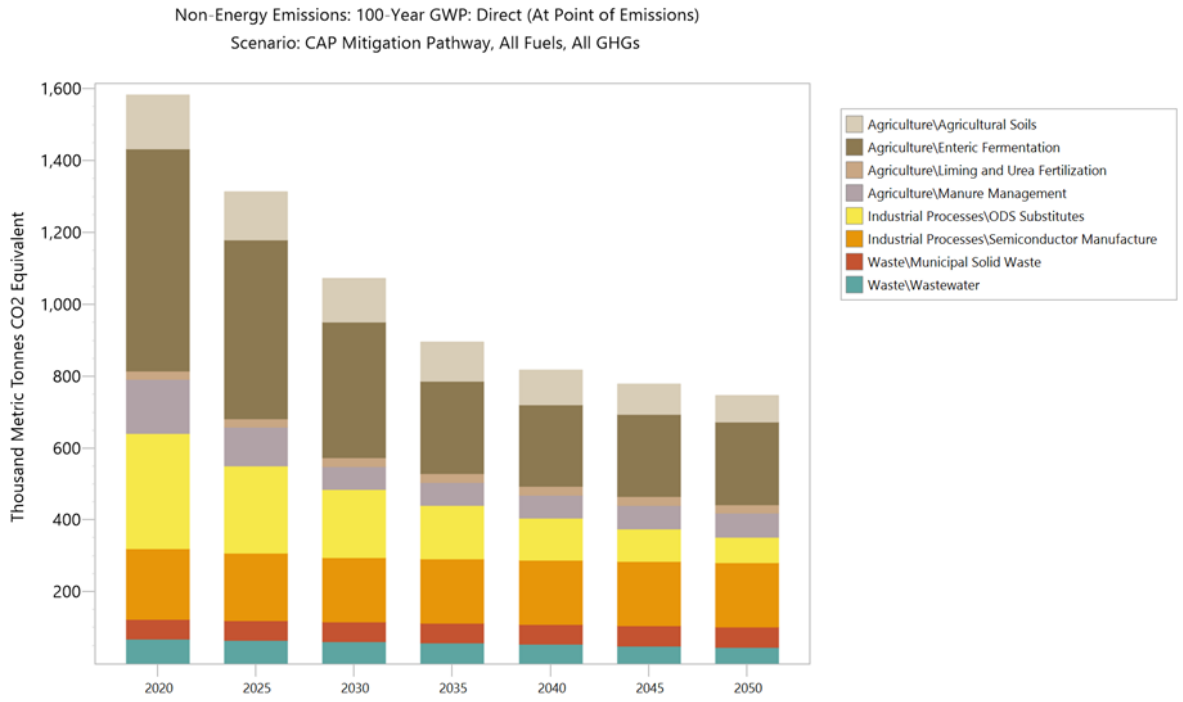
CSM Strategies

- Reduce direct agriculture emissions
- Increase agriculture sequestration
- Reduce direct emissions from refrigerants
- Address direct industrial direct emissions

LEAP Inputs

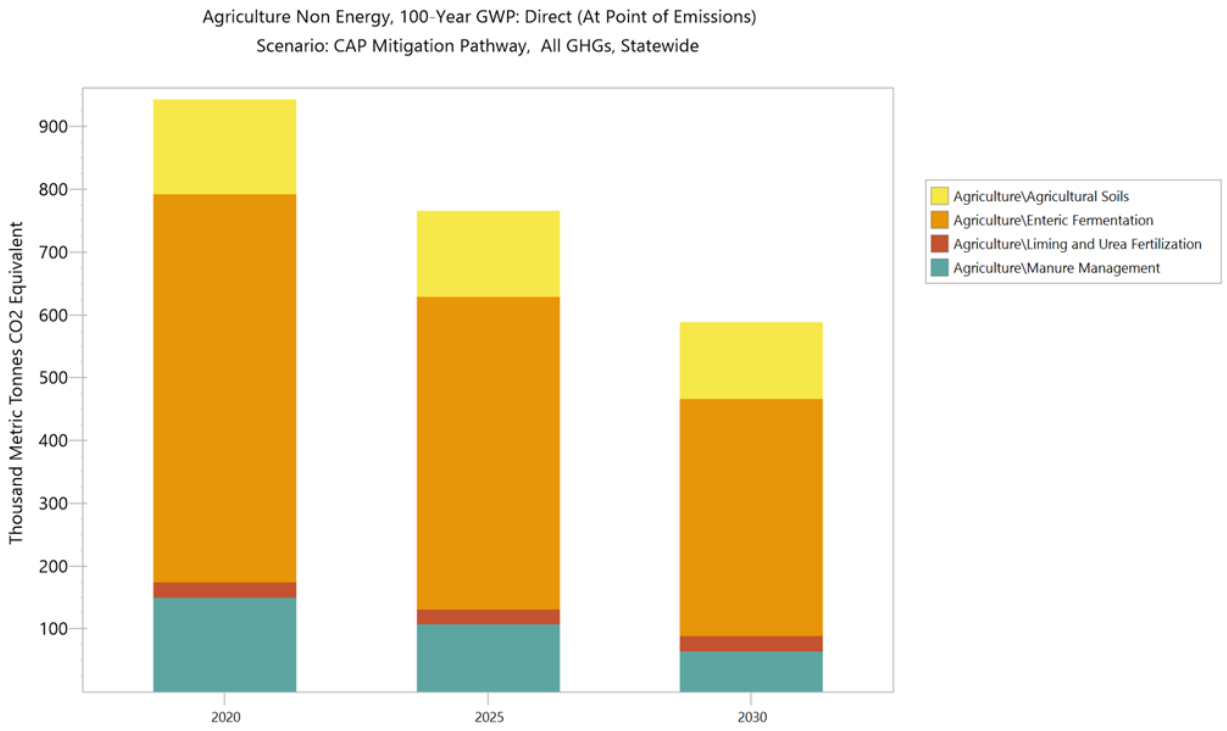
- Reduce enteric fermentation
- Increase manure management
- Increase soil carbon sequestration
- Align ODS substitutes with HFC Rule and refrigerant management plans.
- Reduce semi-conductor manufacturing emissions

Non-Energy Sector Transition



Emissions Reductions Relative to 2020	2025	2030
ODS Substitutes	25%	41%
Semi-Conductor Manufacturing	4%	8%

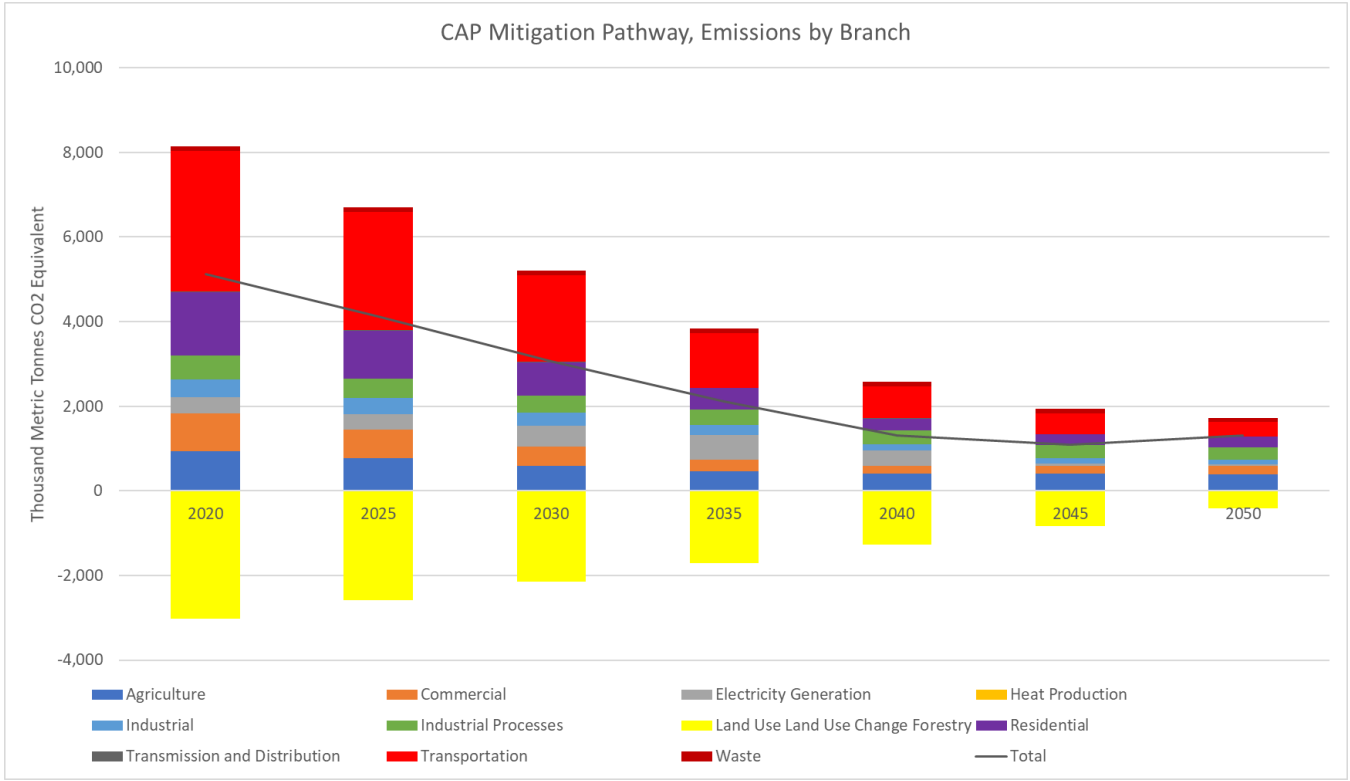
Non-Energy Sector Key Indicators



Emissions Reductions Relative to 2020	2025	2030
Enteric Fermentation	20%	39%
Manure Management	29%	57%
Agricultural Soils	9%	19%

Non-Energy Sector Insights

- Steady linear decline in sequestration based on historic trends means **interventions are necessary to attain net zero target**
    - Strategies will need to reduce loss and maintain at or above projected 2035 levels.
- **More data is needed** to determine the scale of emissions reductions possible from the agriculture sector.
- Reduction in emissions from ODS substitutes in line with **Vermont's Hydrofluorocarbons (HFC) Rule**.
- Process for setting **semi-conductor manufacturing** energy targets, should also include non-energy emissions.



Electricity

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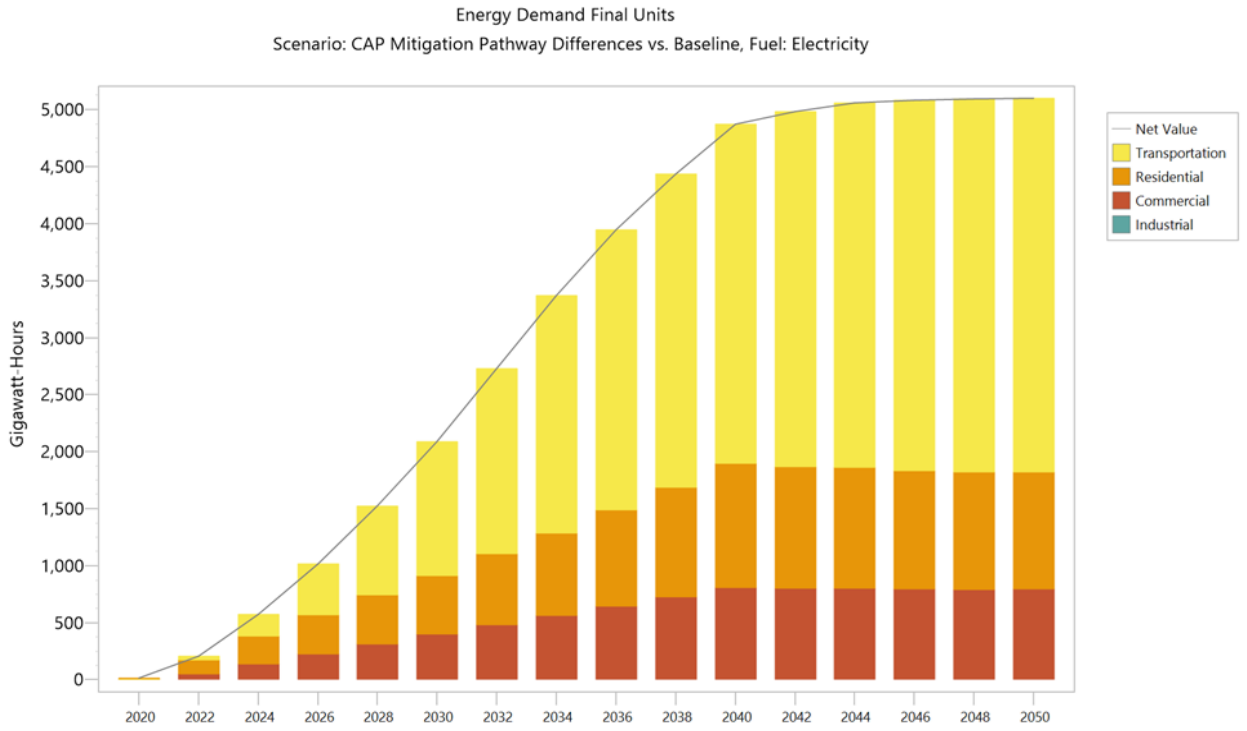
Key Modeling Considerations

- LEAP is a “demand-driven” model, meaning:
  - Outputs are a response to the inputs from the other sectors
  - The LEAP model optimizes the electric generation technologies and resources available to meet the new demand in each time period.
- LEAP cannot and should not replace the more granular modeling and planning work that Vermont’s transmission and distribution utilities undertake
- Detailed analyses will be essential for coordinating load management and ensuring that technology advances (for example, battery performance and cost) are captured to reduce costs



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Strategies and Inputs

CSM Strategies

- Meet Increasing Electric Demand from Transport and Buildings
- Increase Renewable Generation
- Flexible Load Management
- Storage
- Electrification for All

LEAP Inputs

- Electricity demands from demand module by time period
- Costs and Performance for Electric Generation Systems
- Regional Electric Grid energy mix

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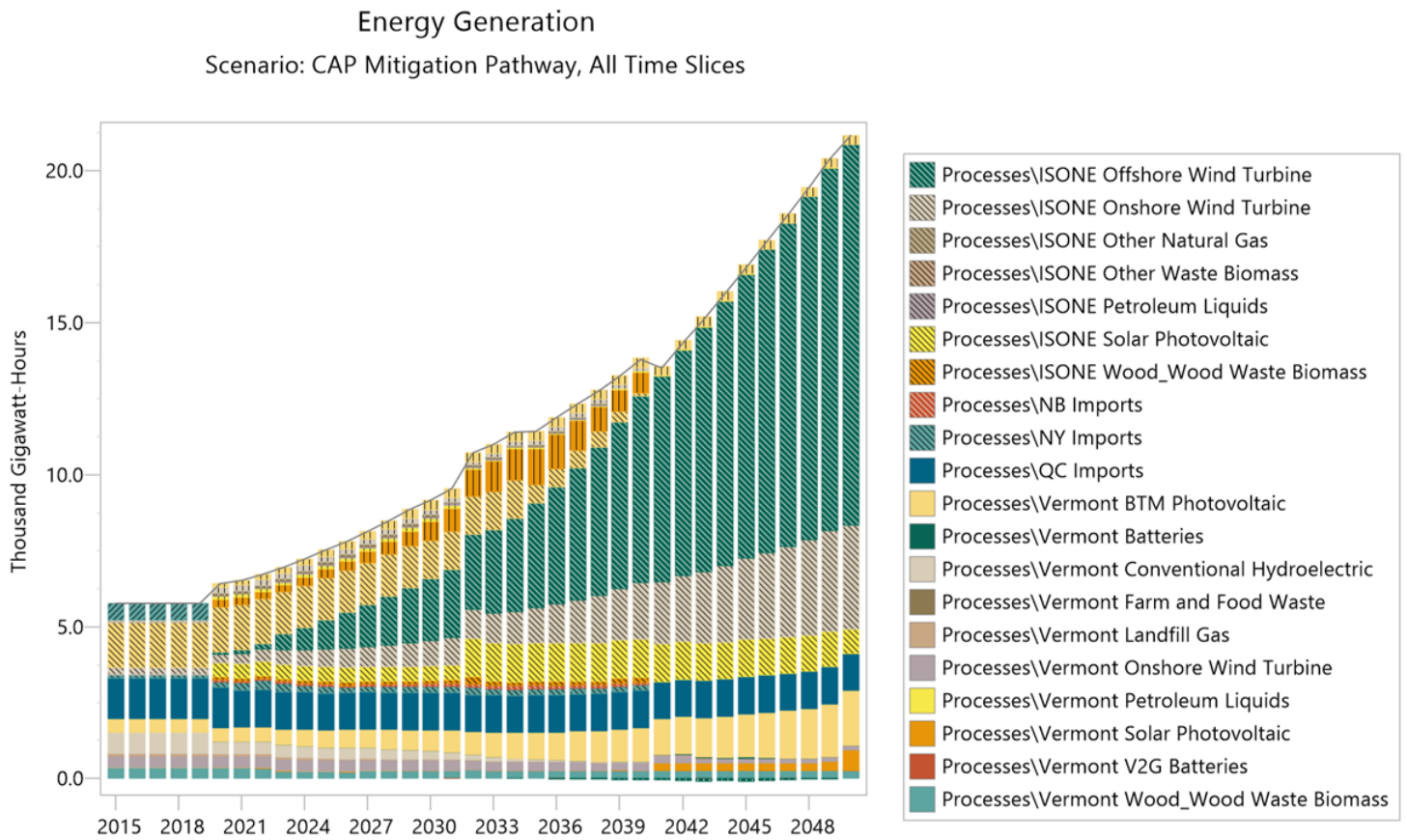
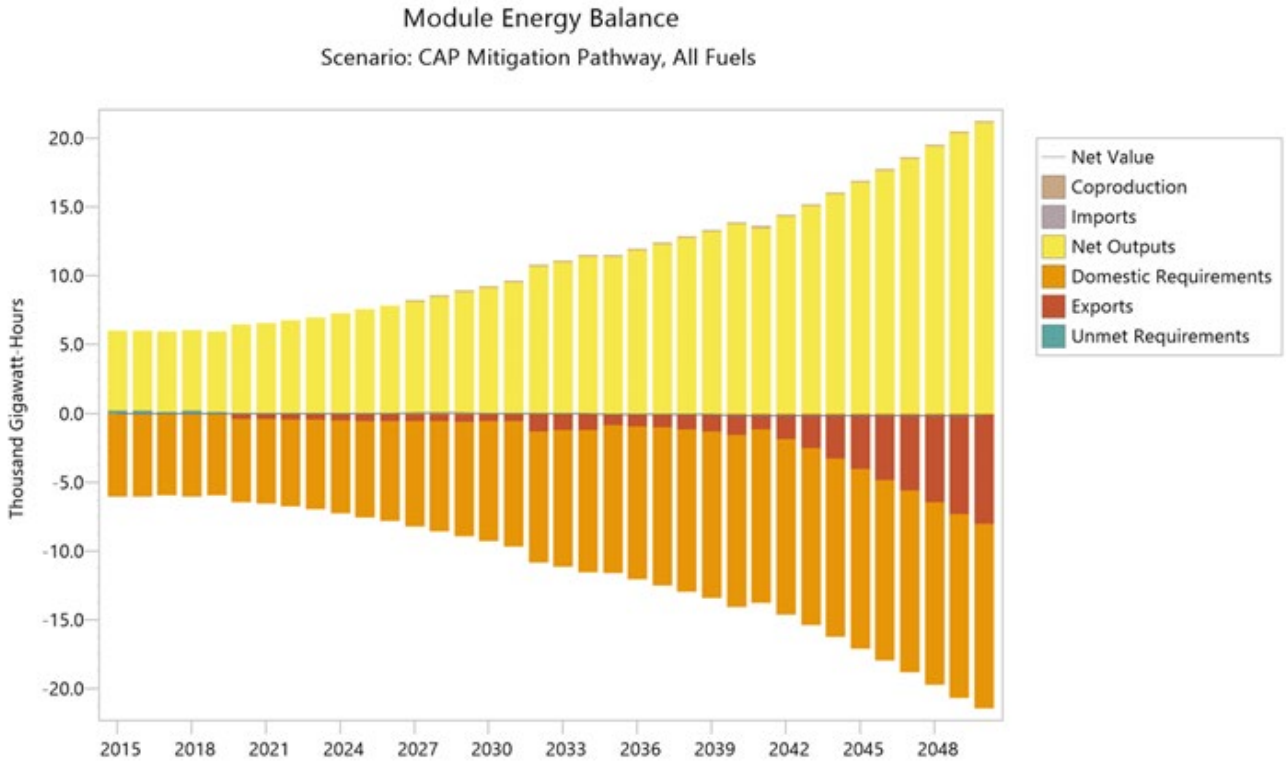
Electricity Key Indicators



Key LEAP Output	2025	2030
Electricity as Share of Total Energy	20%	30%
Total Demand (GWh)	6,416	7,911
Peak Demand (MW)	1,441	1,777
Share of EV Managed Charging	27.3%	50%

Electric Sector Insights

- The emphasis on electrification in the transportation and building sectors requires that Vermont plans for and seeks to actively manage increasing electric demands
  - This will require flexible load management and coordination of multiple loads at multiple sites and active planning to address transmission and distribution system needs
  - This is particularly important to address system costs
- Vermont is fortunate to have one of the cleanest electric supplies in the county, but will need to expand renewable resources



Conclusions

Policy Implications

- LEAP modeling results are consistent with the CSM recommendations and provide insights on scale, scope, and pace of the transitions that should be considered during implementation of CAP pathways, strategies, and actions
- The transitions are significant, particularly in the near-term, but necessary to achieve the requirements set forth in the GWSA and required by the science of climate change
- While the scale of technology and market changes may feel daunting:
  - The modeling utilizes existing technology, meaning implementation can begin immediately
  - Disruptive technology is often not linear
  - Policy can drive market innovation
- It will be important to address workforce needs and equity impacts to ensure the benefits of this transition are available to all Vermonters
  - CSM has already begun this important work with the support in development of CAP strategies
  - It will need to be carried on through the next phases of implementation by other actors

Questions and Discussion

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Thank You!

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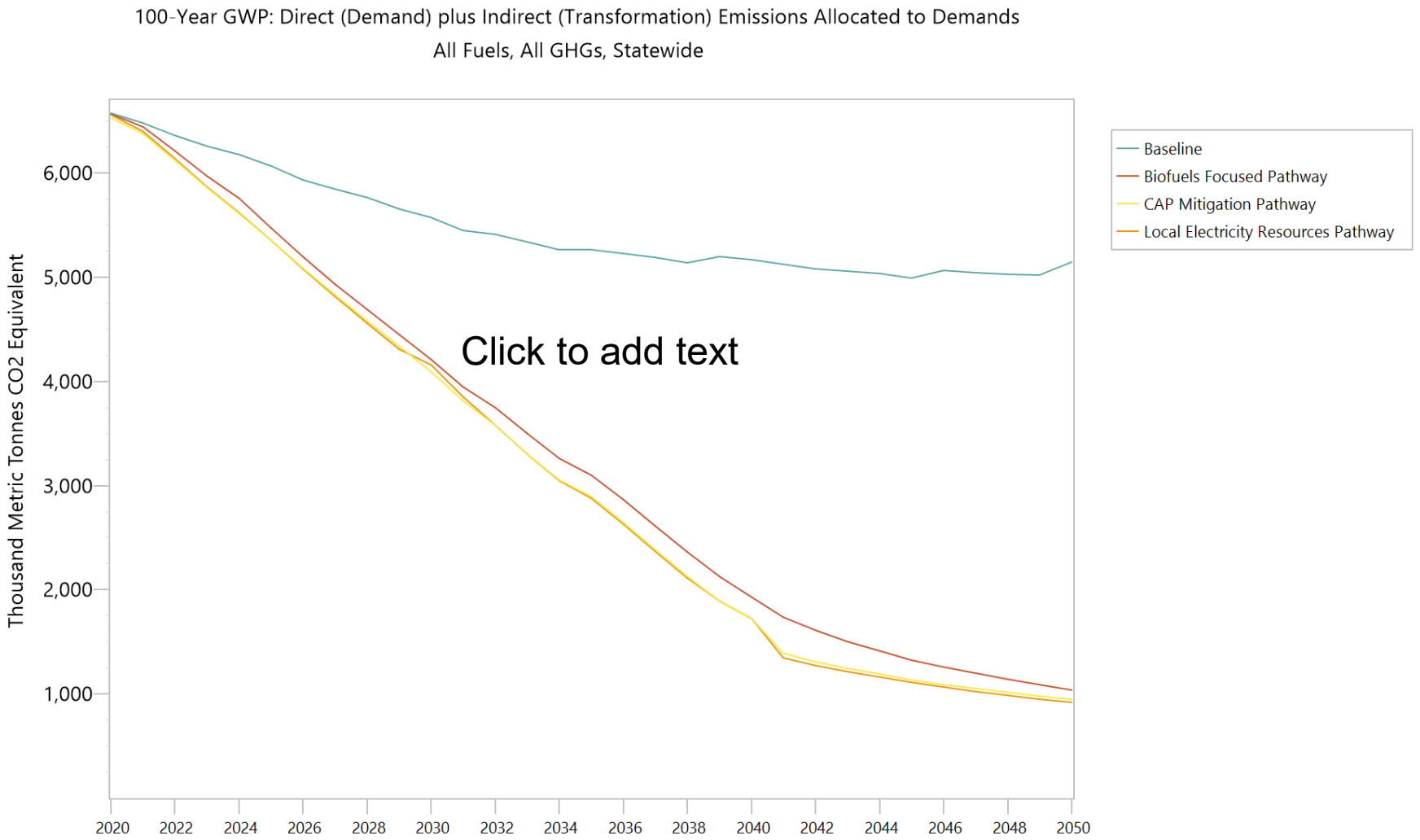
Appendix:
Full Modeling Details

All Pathways Reflect Deep Multi-Sectoral Action

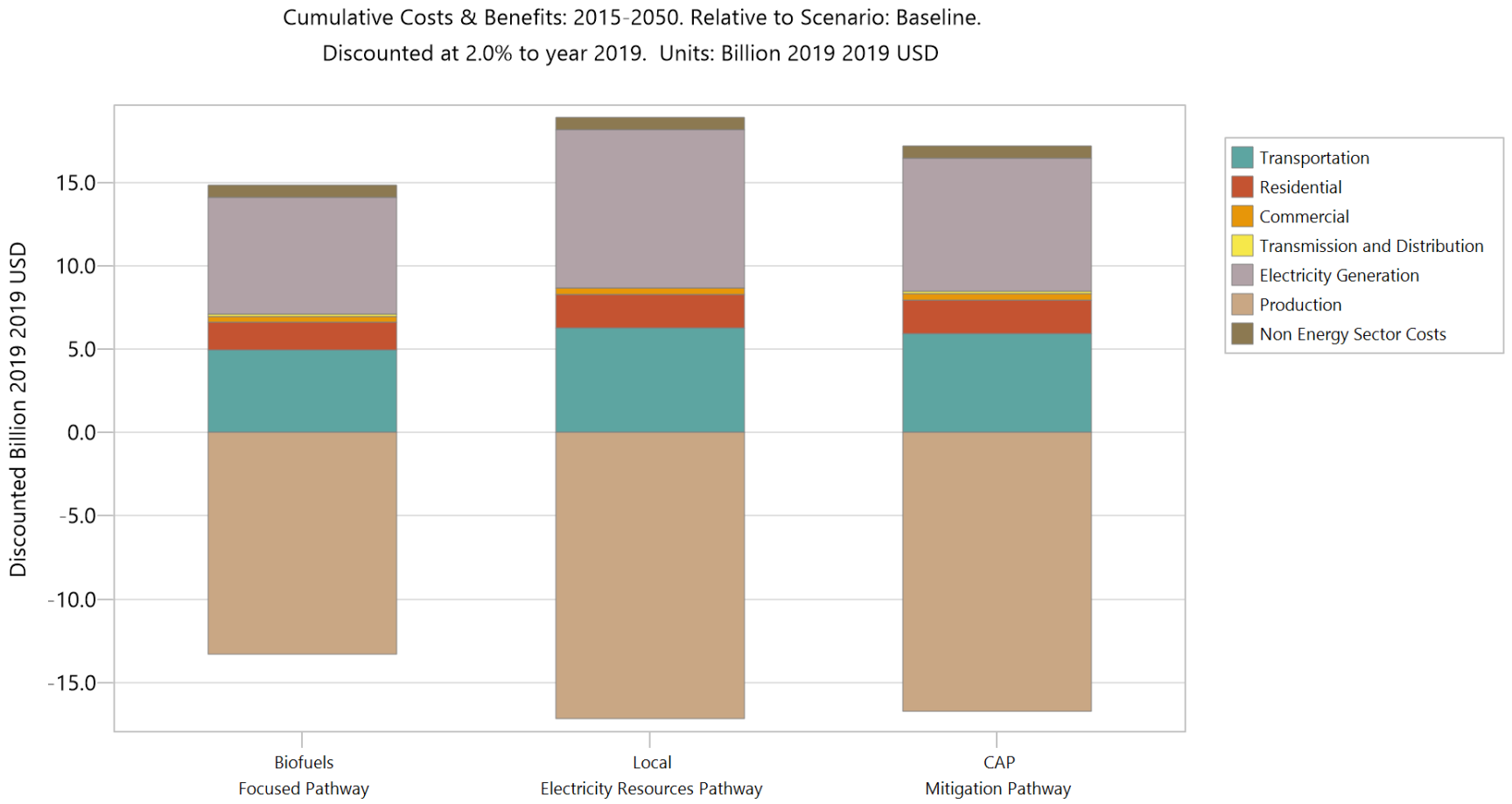


Economic: Net costs of $22 to $6/tonne CO2e

Economic Summary: Cumulative Costs-Benefits 2015-2050, Relative to Baseline
Discounted 2% to year 2019, Units Billion 2019 US Dollars

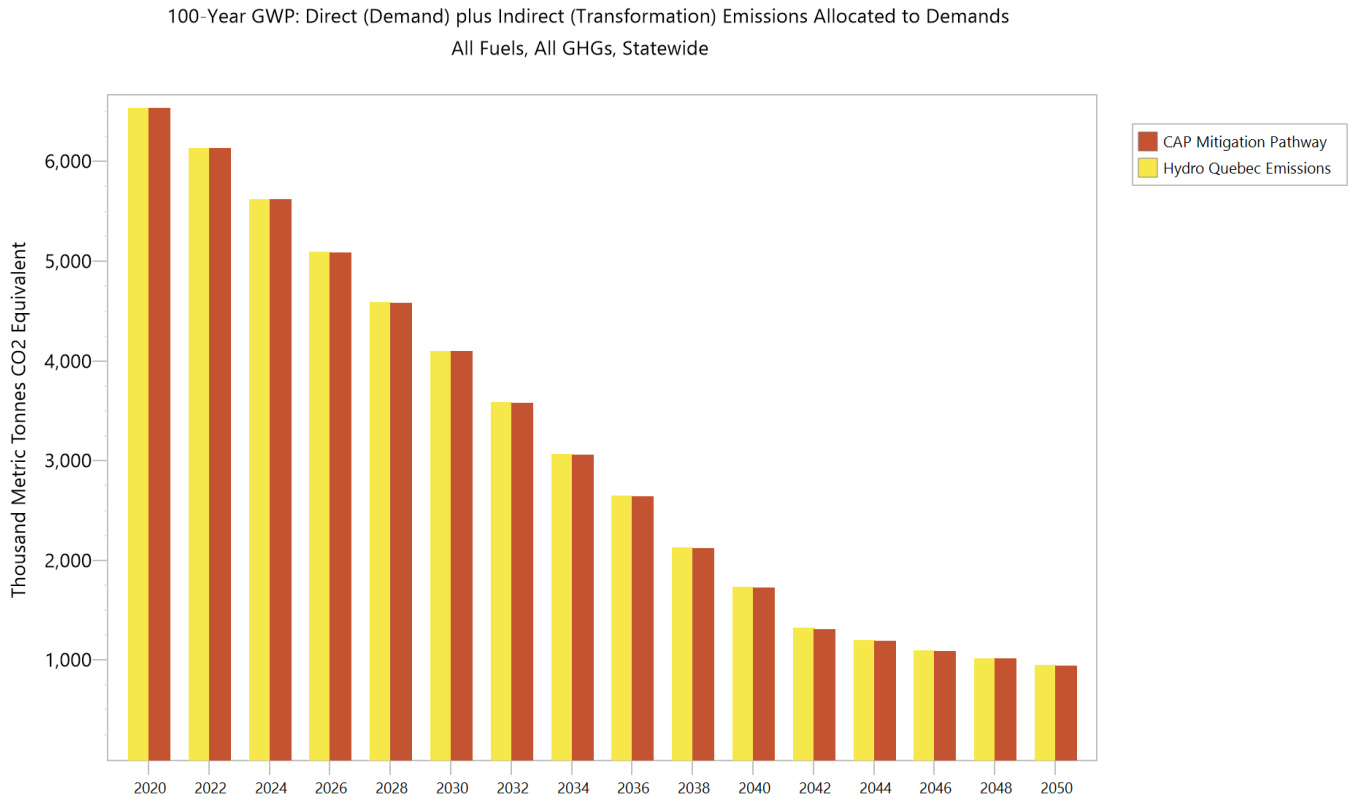
Sector	Biofuels Focused Pathway	Local Electricity Resources Pathway	CAP Mitigation Pathway
Demand	7.0	8.7	8.3
Transportation	5.0	6.3	5.9
Residential	1.6	2.0	2.0
Commercial	0.4	0.4	0.4
Industrial	-	-	-
Transformation	7.1	9.5	8.1
Distributed Gas Blending	-	-	-
Transmission and Distribution	0.2	-	0.2
Electricity Generation	7.0	9.5	8.0
Heating Oil Blending	-	-	-
Heat Production	-	-	-
Resources	-	-	-
Production	-13.3	-17.2	-16.7
Imports	-	-	-
Exports	-	-	-
Other Costs			
Unmet Requirements	-	-	-
Environmental Externalities	-	-	-
Non Energy Sector Costs	0.7	0.7	0.7
Total Net Present Value	1.6	1.7	0.5
GHG Savings (Mill Tonnes CO2e)	75.1	79.5	79.7
Cost of Avoided GHGs (2019 USD/Tonne CO2e)	20.8	21.8	5.9

Economic: All Pathways Strong Net Economic Benefits including Social Cost of Greenhouse Gases



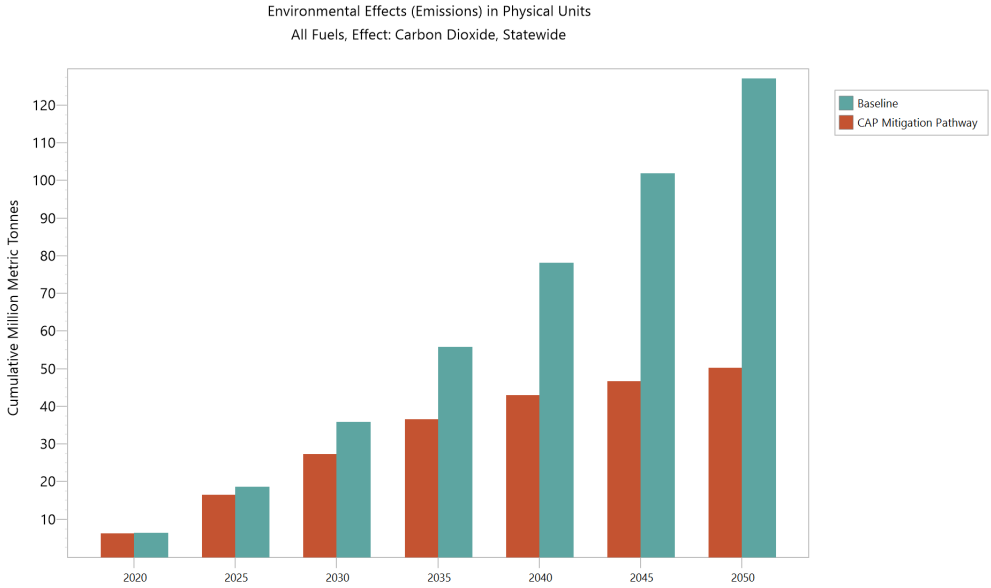
Sensitivities: Hydro Quebec Emissions

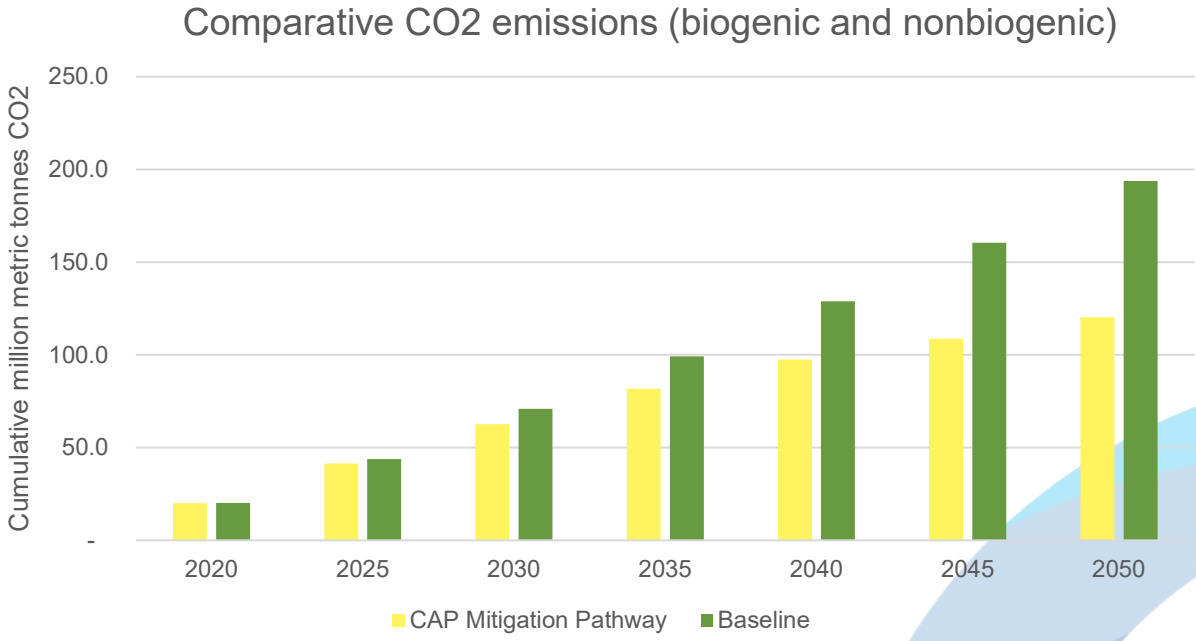
- Based on Science and Data Subcommittee recommendation and citation from a literature reference by A. Levasseur.
- Net biogenic emissions values of 16.5 gCO2/kWh, and 0.29gCH4/kWh included in a sensitivity for Large Hydro emissions
- Cumulative difference of 250,000 metric tonnes CO2e by 2050.



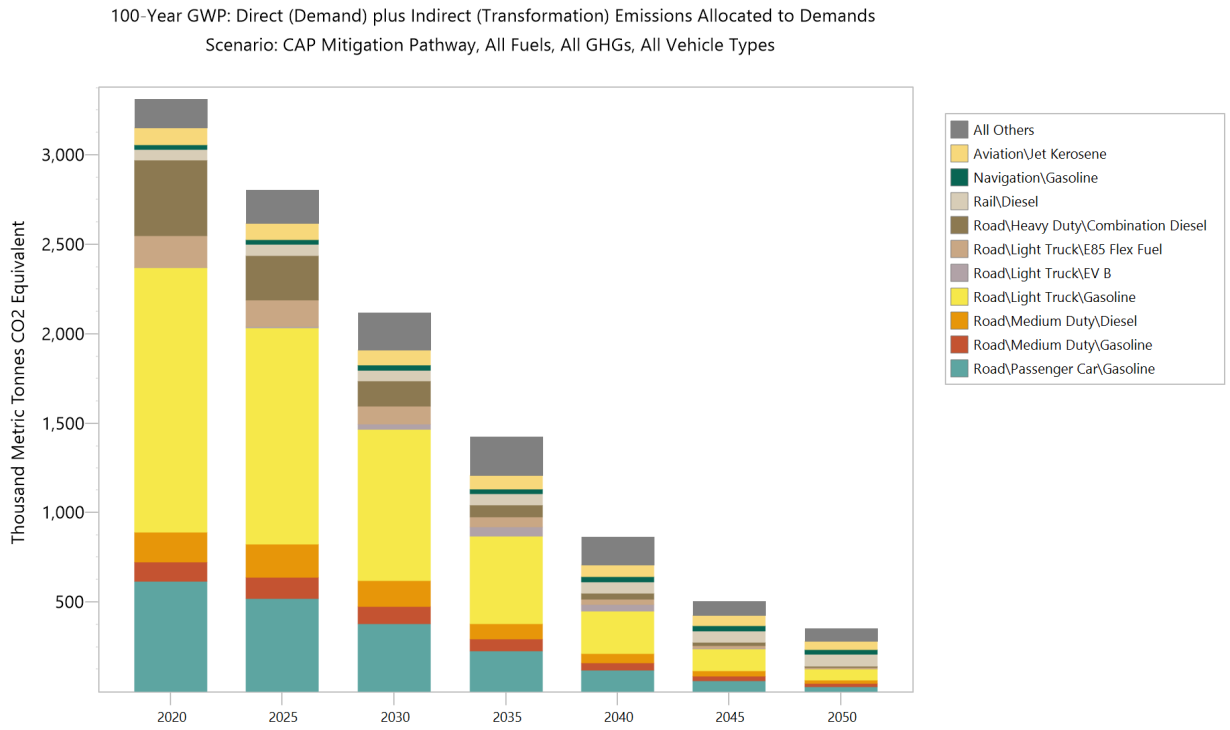
Sensitivities: Biogenic CO2

- Based on Science and Data Subcommittee recommendation report on Biogenic C02 for CAP mitigation Pathway.
- Net cumulative reductions decrease from 77 million tonnes if biogenic is not counted (top graph) to 74 million metric tonnes if it is included (bottom graph).





Transport Sector – CAP Mitigation Pathway



By 2025:

- 43,400 EVs, increase of more than 39,000 over today.
- By 2025 EVs are almost 40% share of light duty vehicle sales.

- All major automakers have invested in EV technology and are expected to release additional EV models in the next three years, including new electric pickup trucks and sports utility vehicles, which are currently under-represented in the vehicle market.

- Precedes California Advanced Clean Cars II – which would require manufacturers to deliver increasing share of Light Duty Evs in 2026, ramping up to 100% in 2035.

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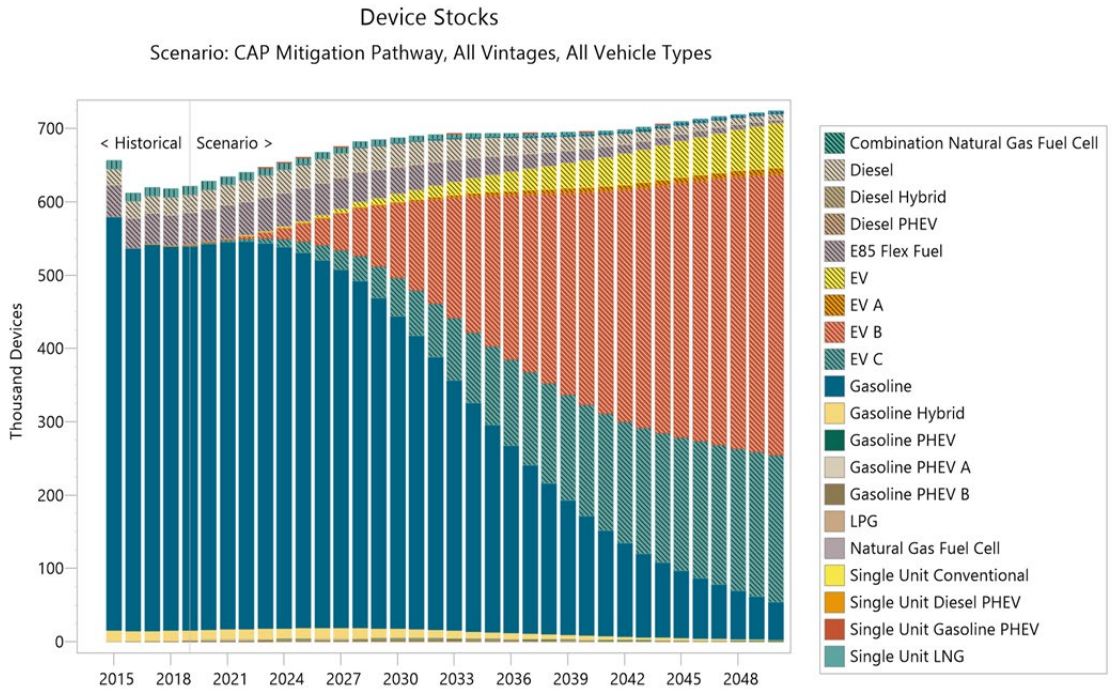
Transport Sector – CAP Mitigation Pathway



By 2030:

- 166,000 EVs, almost 4x greater than baseline projection of 43,000.
- By 2030 EVs account for 29% of vehicle miles travelled.
- Vehicle mile demand management initiatives result in 3.5% reduction in vehicle miles travelled compared to baseline.
- 50% of EV charging is managed to reduce peak impacts.
- Sales of new ICE vehicles phased out by 2033.

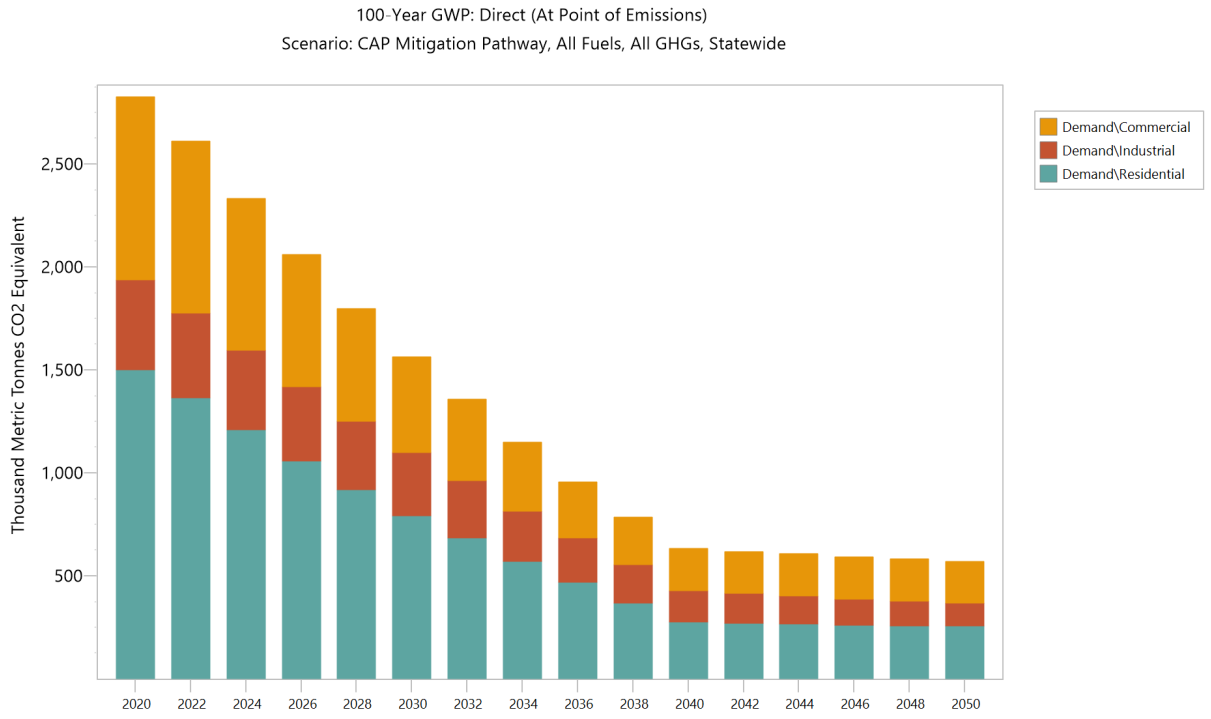
CSM Recommendations

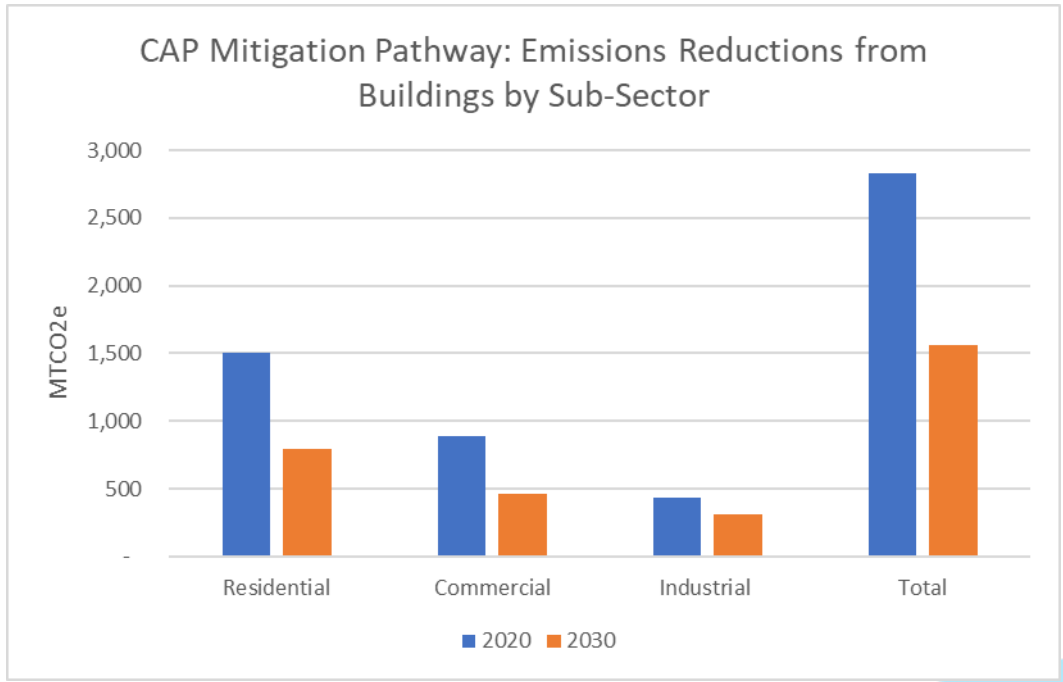
To meet GWSA Requirements for Transportation:

- Transportation Climate Initiative
- Replace your Ride
- Transit
- Smart growth and other Transportation Demand Management, and
- Feebates
- Managed Charging

Source TCI-P updates program webinar, March 2021

Buildings Sector – CAP Mitigation Pathway

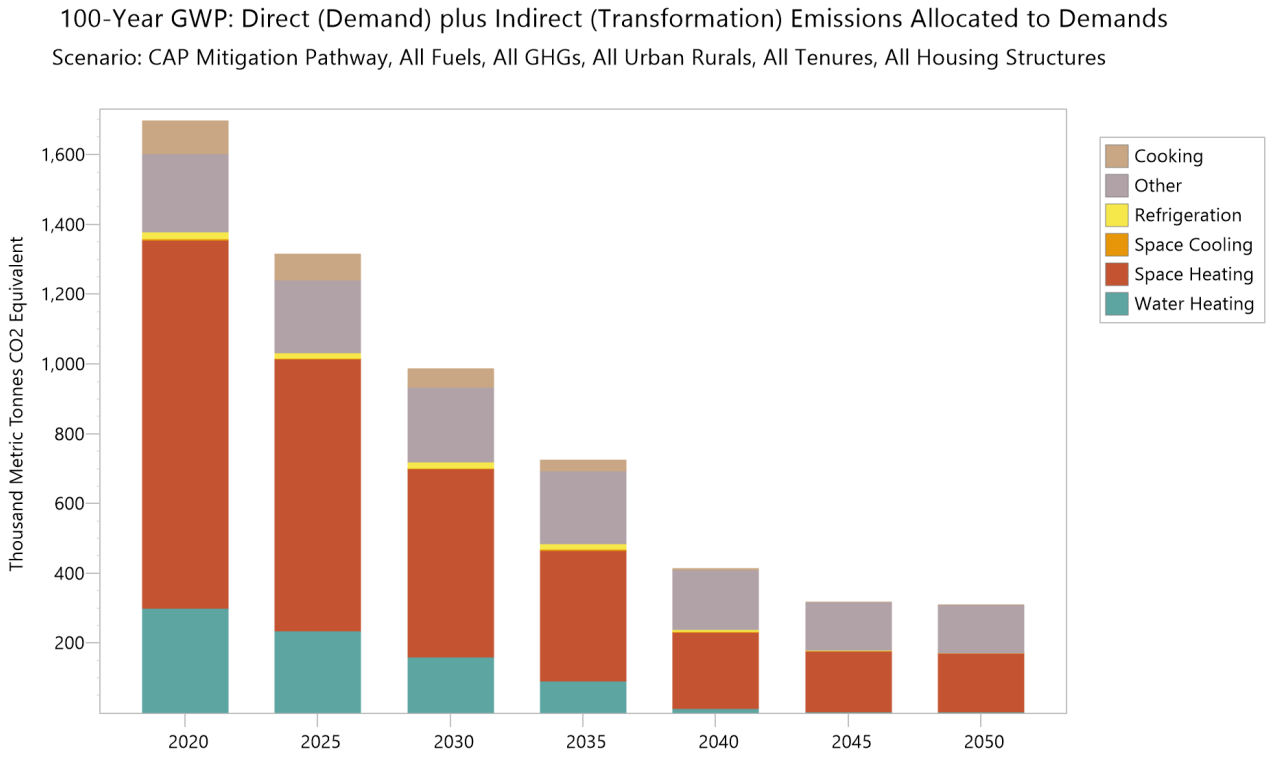


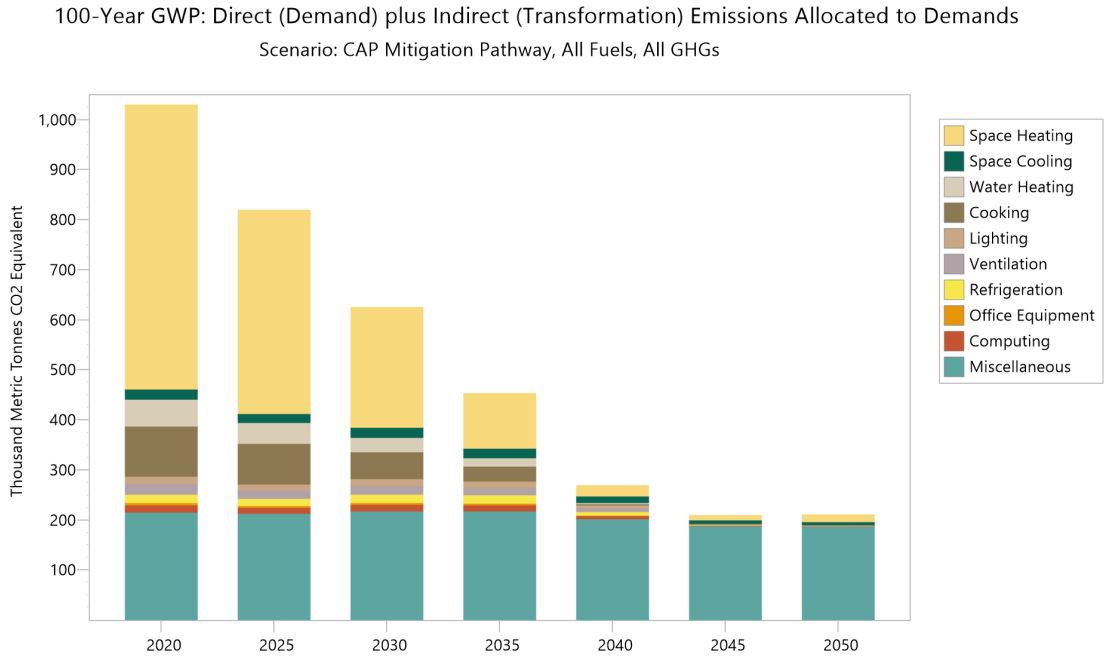


Emissions reductions from 2020 to 2030 45%, and by 2050 80%.

~55% from residential, 33% Commercial, 12% Industrial

Buildings Sector – CAP Mitigation Pathway





Residential, primarily space heating

Heat pumps, shell efficiency.

Phase out of fossil cooking and water heating

Blended heating oil and increased RNG blending

Commercial, primarily space heating

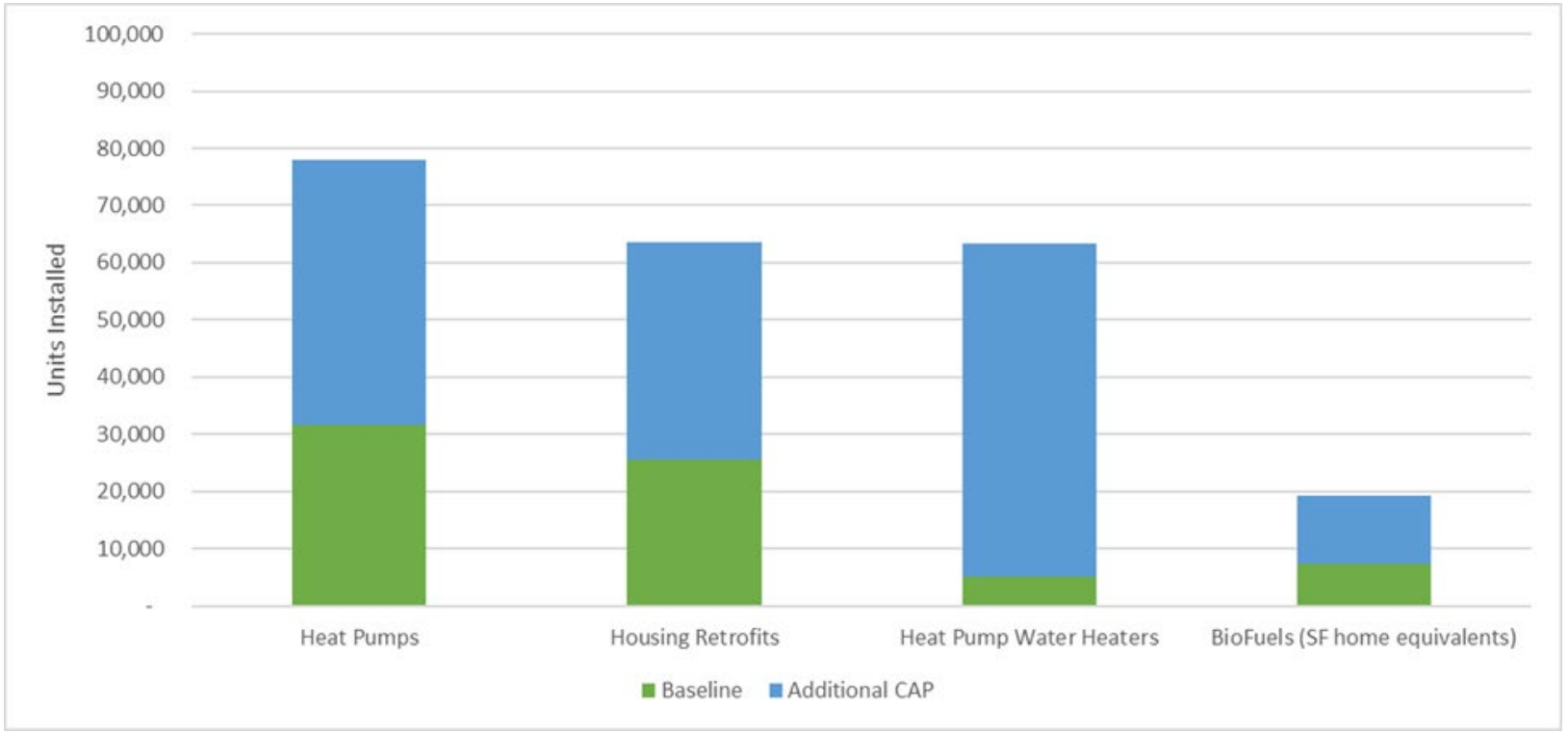
Heat pumps, phase out of water and cooking fossil

Blended heating oil and increased RNG blending

Residential Buildings CAP Mitigation Pathway

By 2025:

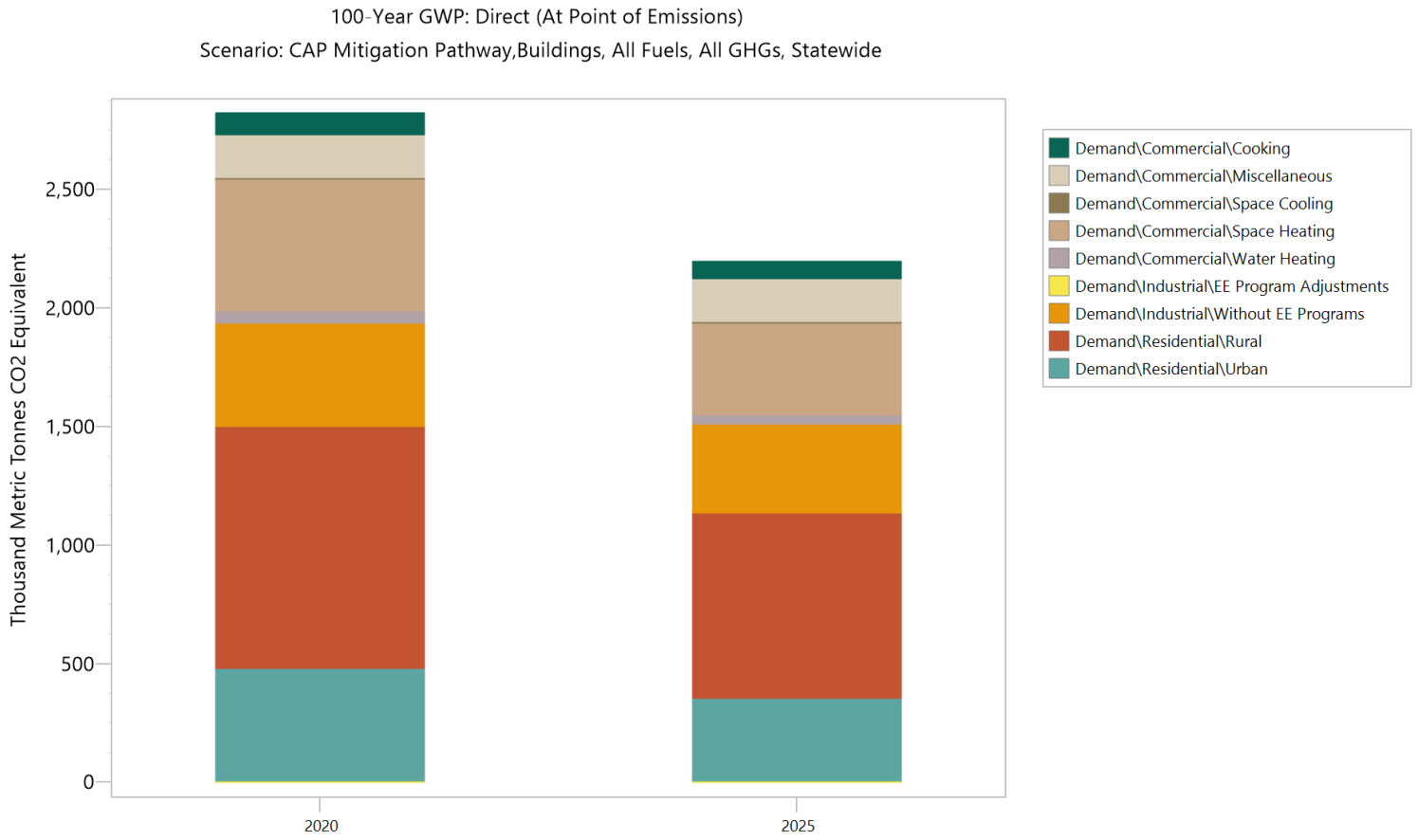
- Nearly 80,000 heat pumps, almost 50,000 above baseline.
- More than 60,000 heat pump water heaters.
- More than 60,000 Weatherized units - more than 2x baseline.
- 1.9 Trillion Btu's of biofuels, equivalent to meeting the needs of almost 20,000 average single-family units.



Buildings CAP Mitigation Pathway

By 2025:

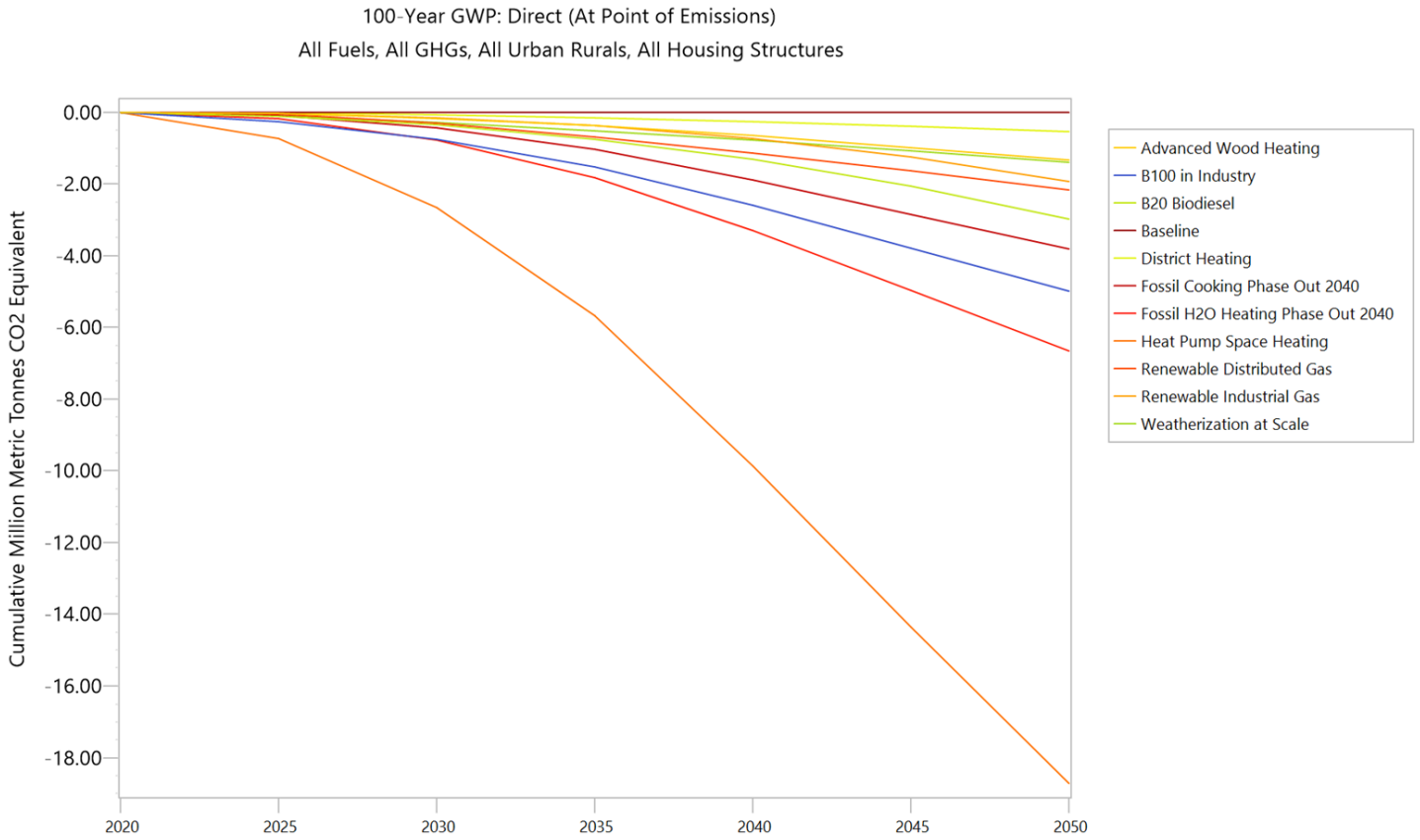
- Support income qualified heat pumps and weatherization.
- Heat pumps gaining rapid market share, more than 11,000 in 2020, but continued rapid adoption required.
- Workforce development essential to scale activity in building sector – wages and training.
- Coaching and financing important supports.



Buildings CAP Mitigation Pathway

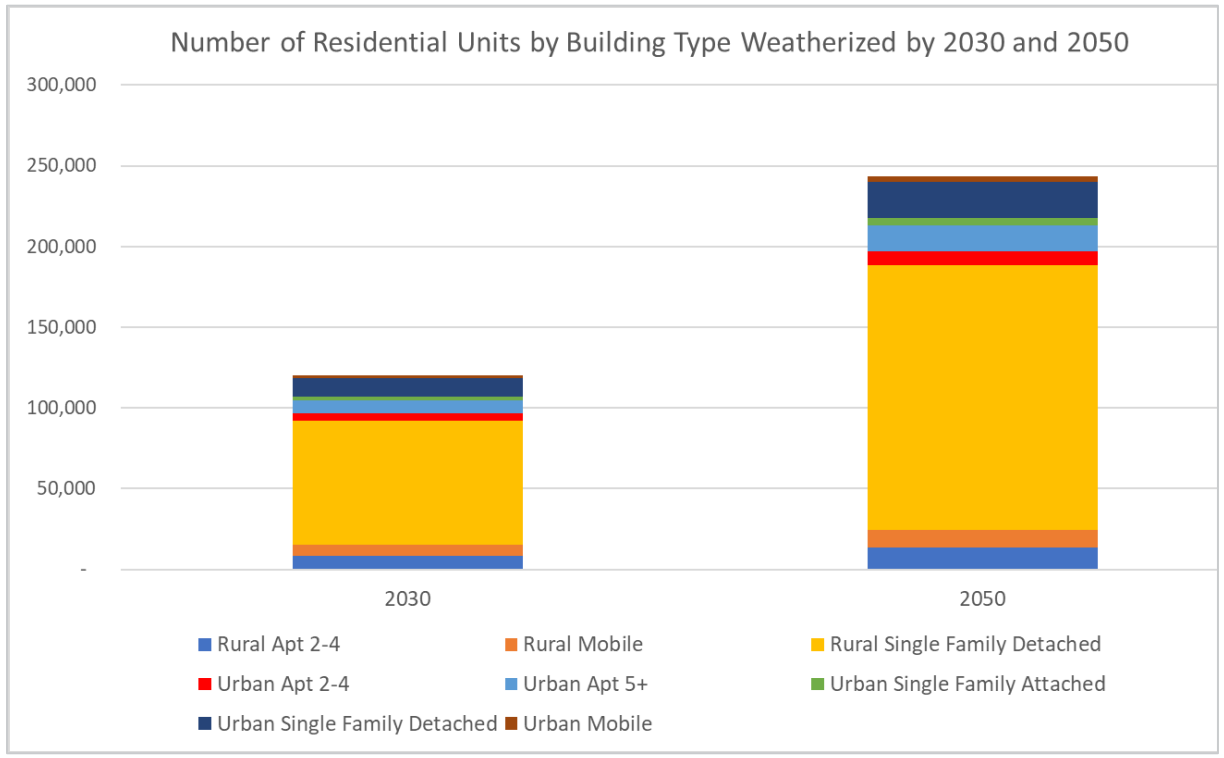
By 2030:

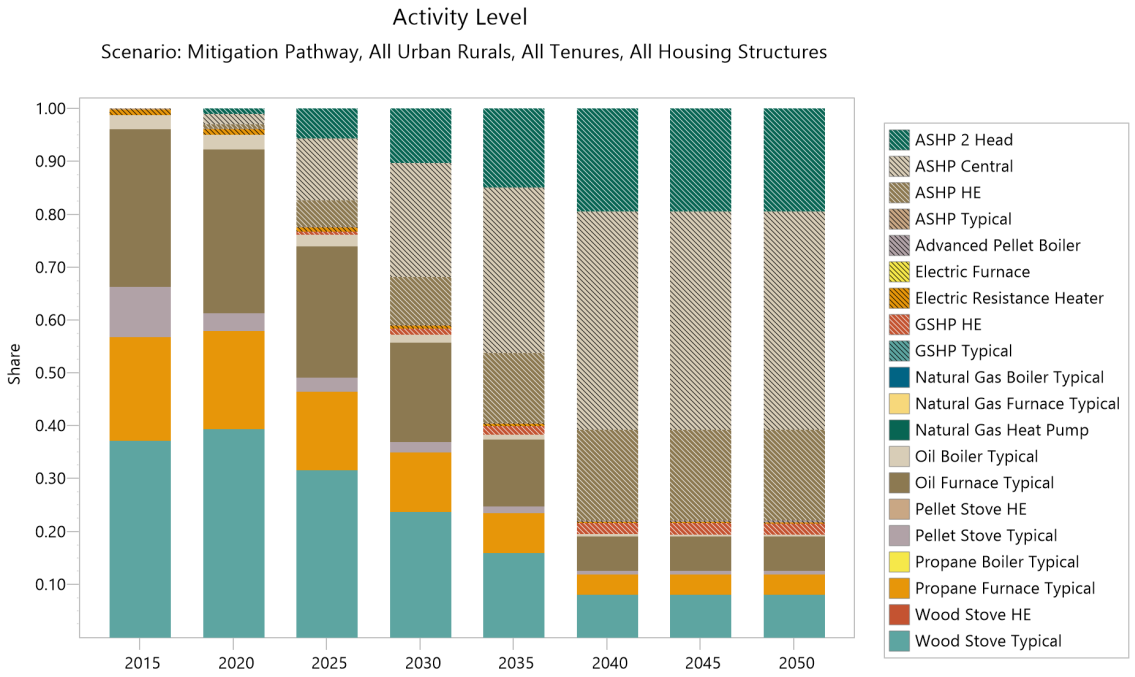
- More than 142,000 residential heat pumps – an increase of 84,000 above baseline.
- Phasing out of water heating and cooking underway.
- Weatherization of 120,000 units.
- Biofuels increasing contribution to reductions.



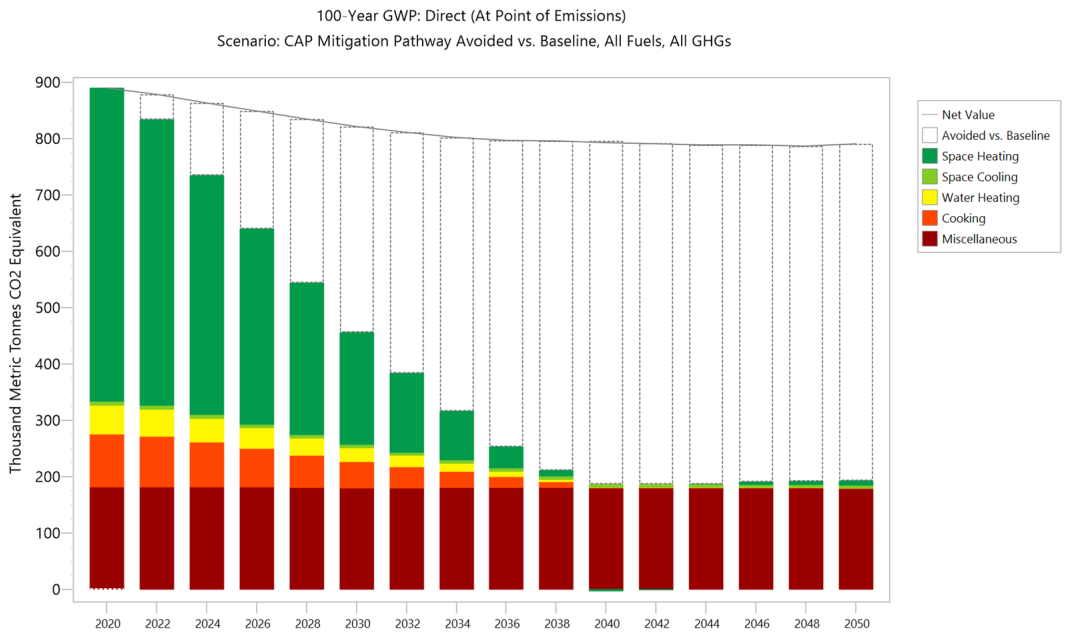
Cumulative Emissions Reduction by Element Compared to Baseline

Residential Buildings Weatherization and Heat Pumps – CAP Mitigation Pathway

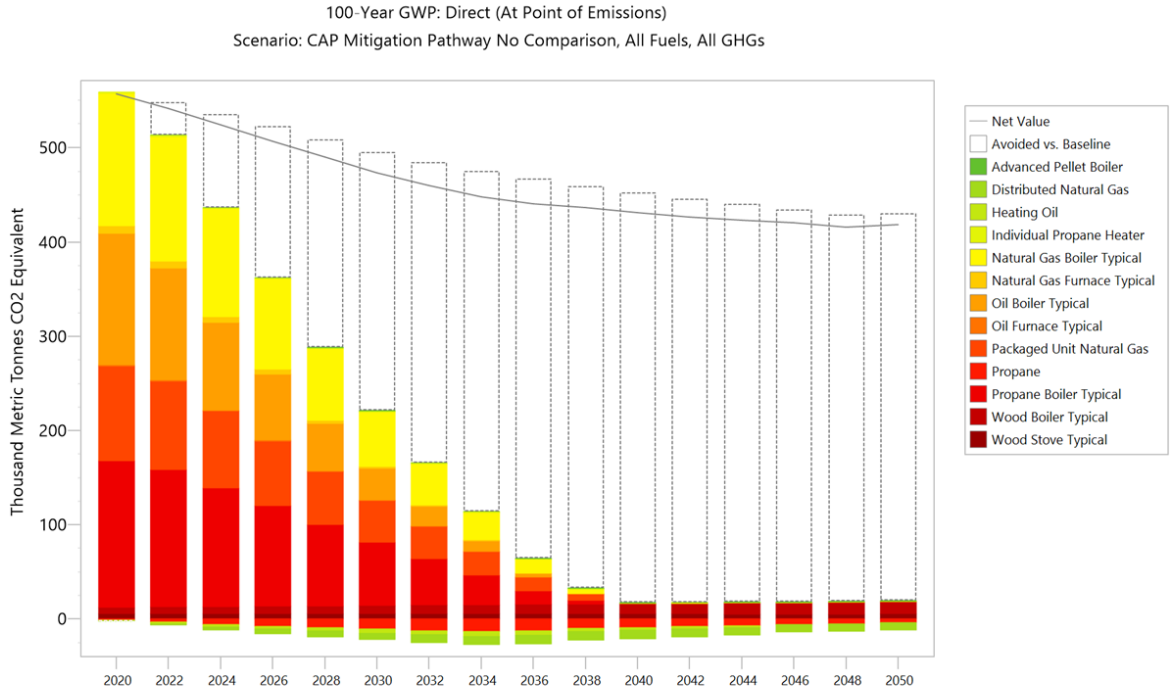




Commercial Buildings CAP Mitigation Pathway

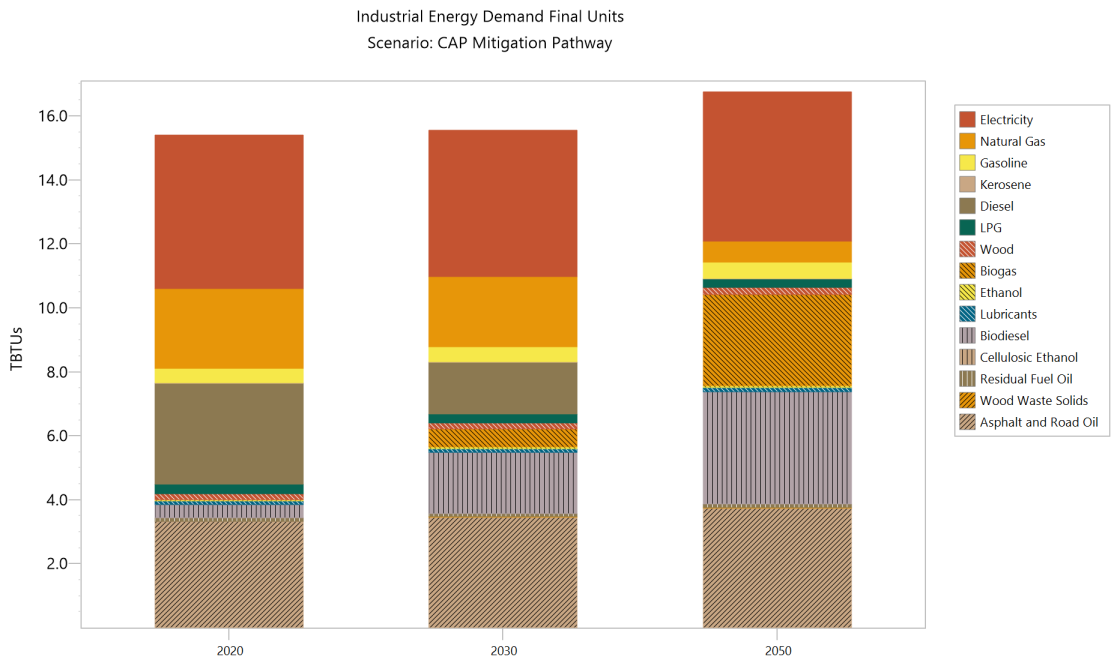


Commercial Emissions by End Use

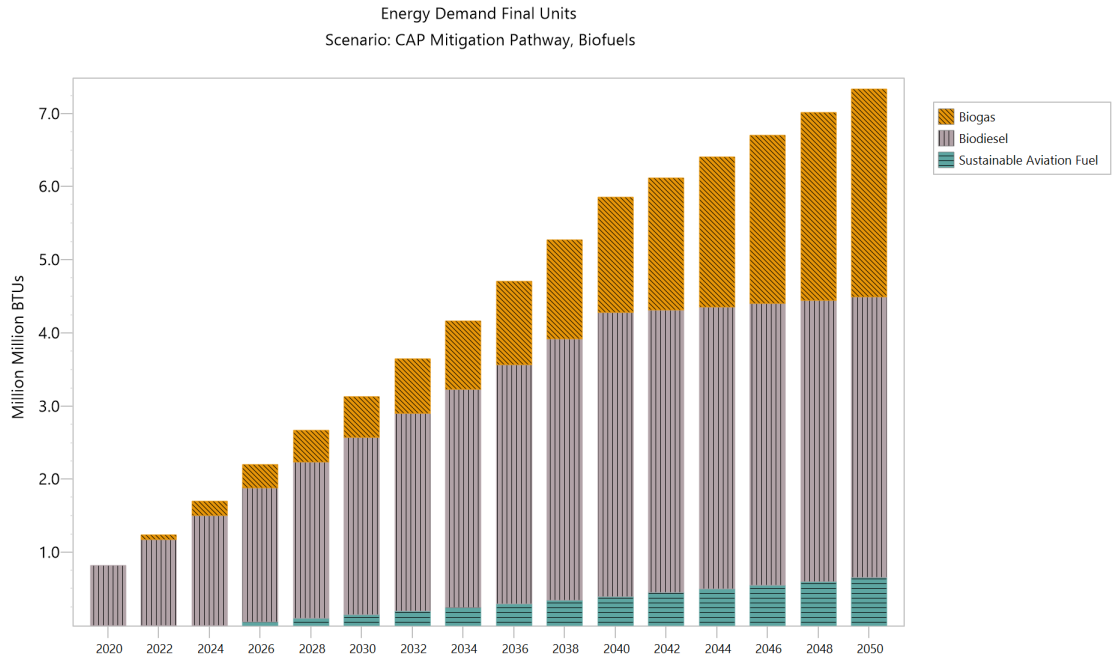


Commercial Emissions by Heating System Type

Industry CAP Mitigation Pathway



Industry Final Energy Demand

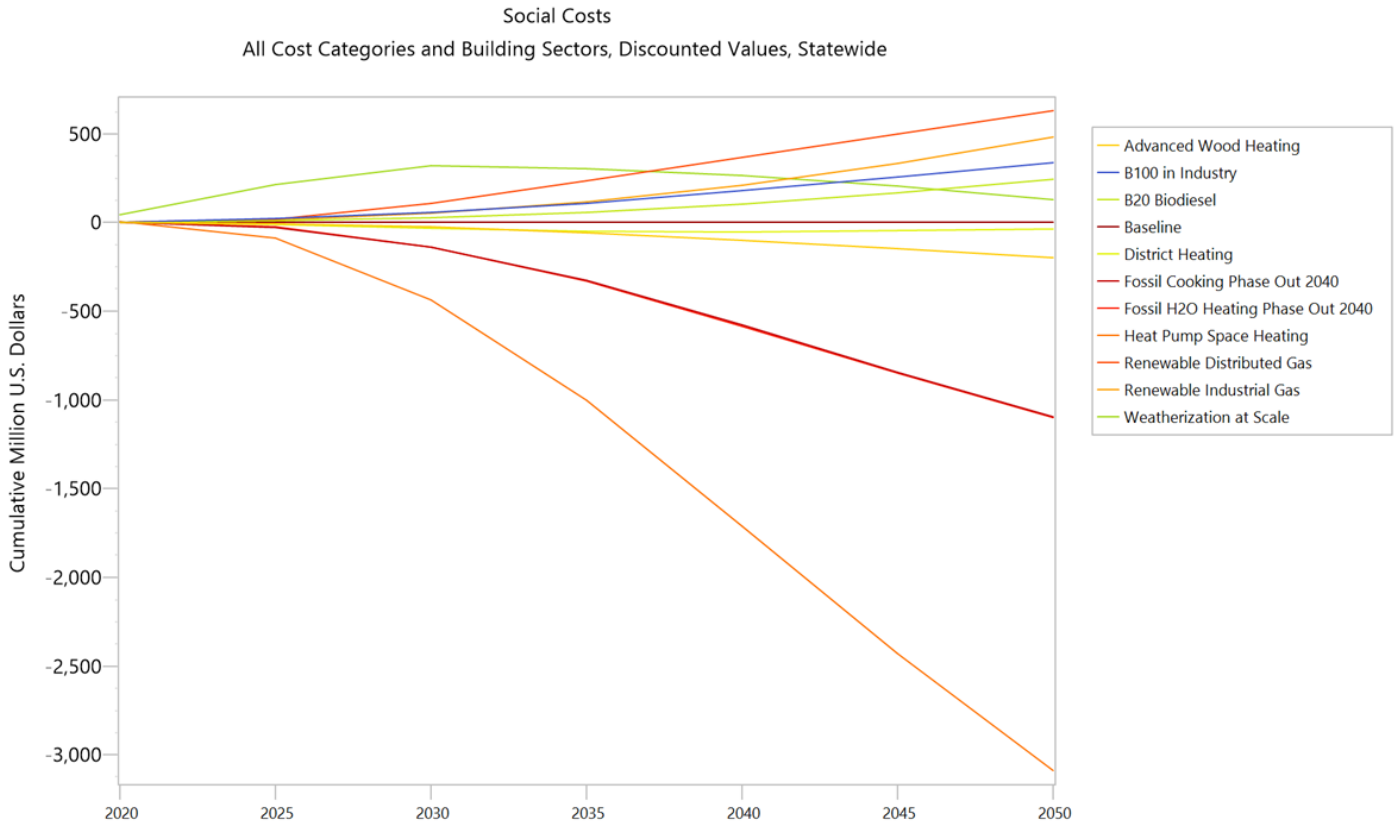


Biogas and Biodiesel All Sectors

Buildings CAP Mitigation Pathway

By 2050:

- Modernized building infrastructure.
- Electrified end uses
- Grid interactive and connected buildings to coordinate multiple loads across multiple sites.
- Storage for resilience.
- Reduced energy burdens for buildings.
- Greater on-site generation.

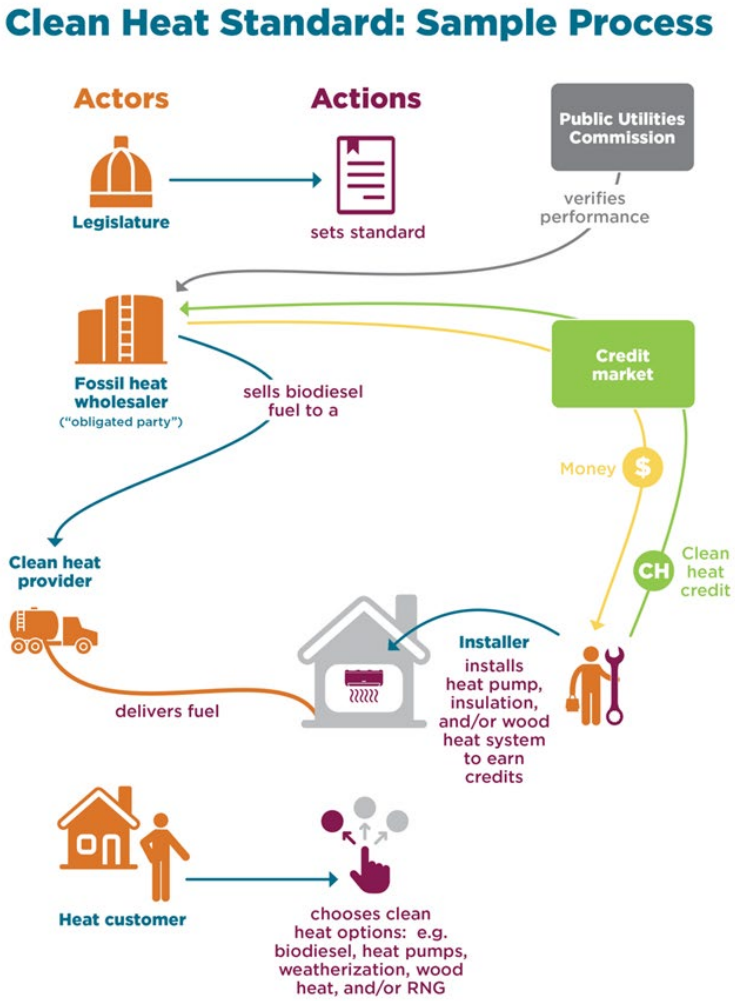


Discounted Social Costs by Element Compared to Baseline

Key Policies, Strategies & Actions

To Meet GWSA Requirements in the Building Sector:

- Clean Heat Standard,
- Rental Efficiency Initiative,
- Weatherization at scale,
- Net zero new construction standards for residential and commercial,
- Increased demand response and coordinated load management



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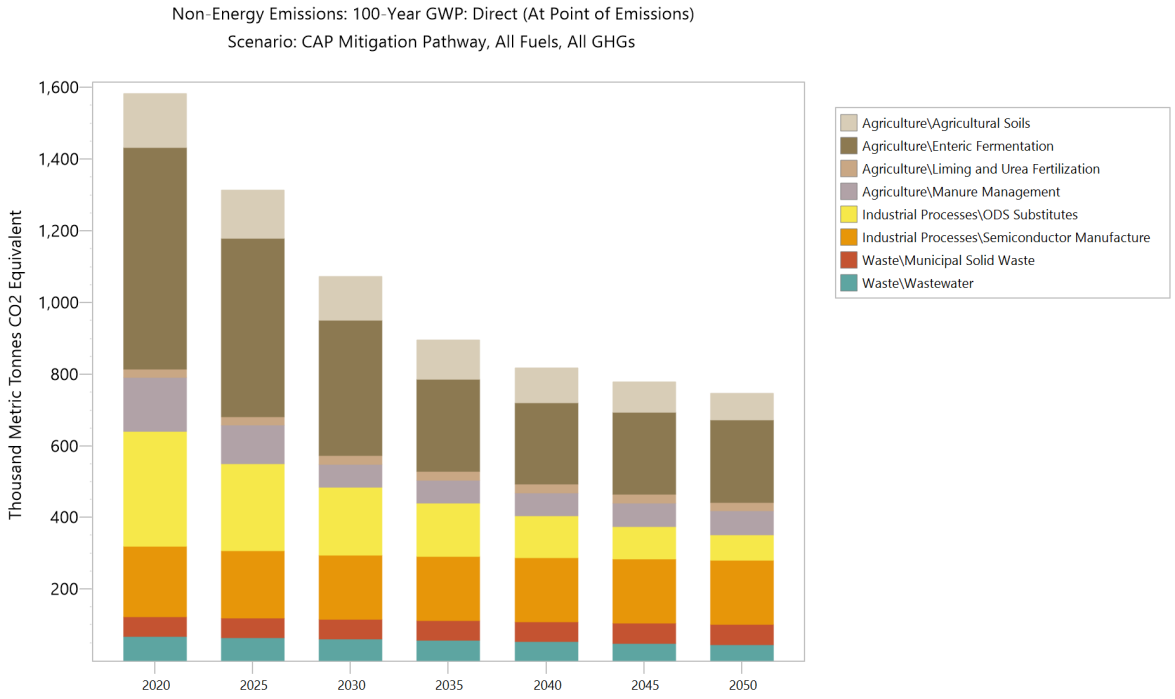
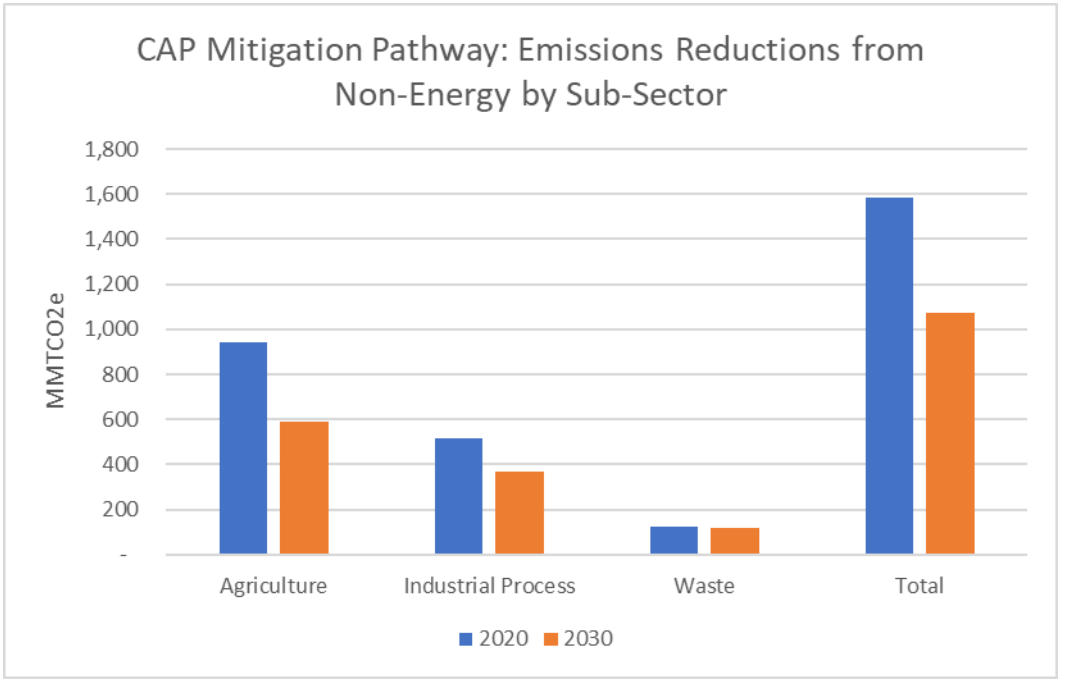
Non-Energy Sector – CAP Mitigation Pathway





Emissions reductions from 2020 to 2030 32%, and by 2050 53%.

~2/3rds of the reductions are from Agriculture, 1/3rd Industrial Processes

CADMUS

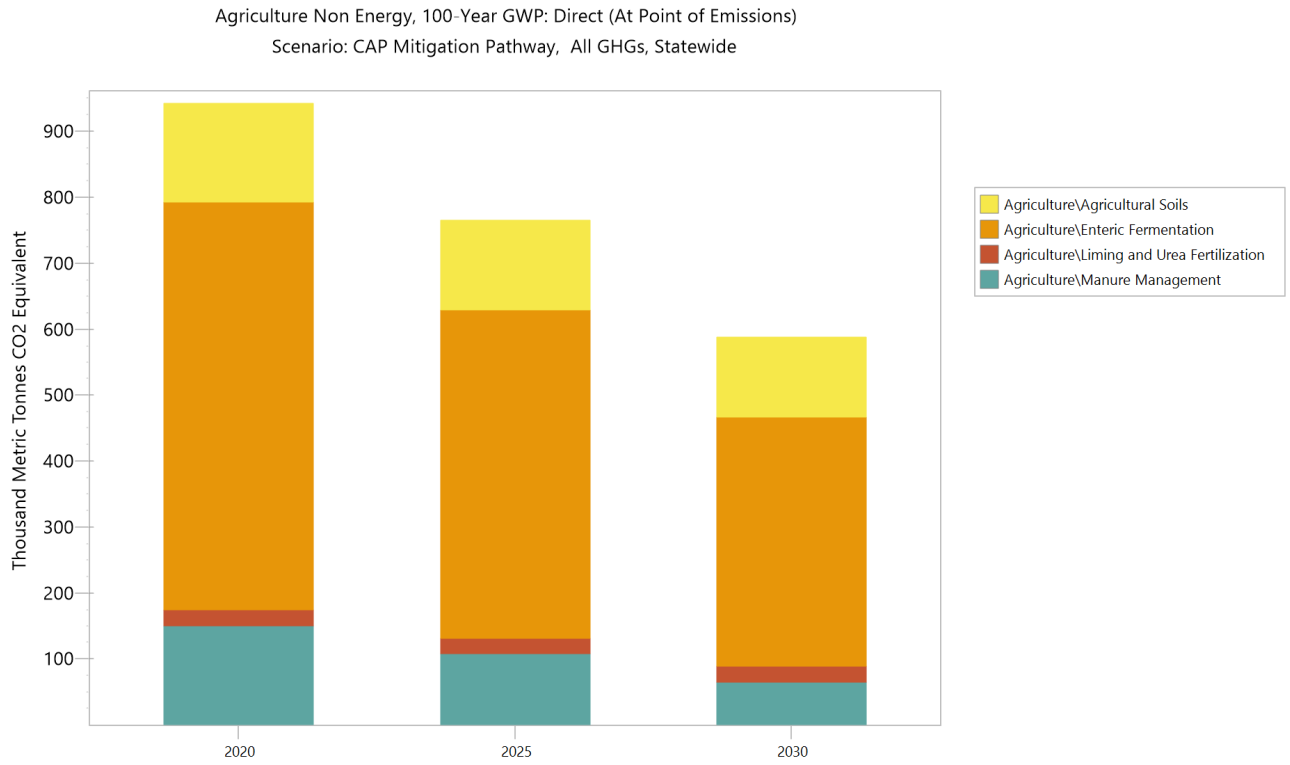
CAP Mitigation Non-Energy Agriculture

By 2030:

- Adoption of alternative feed practices to reduce emissions from enteric fermentation.
- Adoption of manure management practices.
- Increased sequestration by agricultural soils.

- Value of reduced emissions of 350,000 Metric Tonnes CO2e by 2030 has social cost of carbon value of more than $40 million.

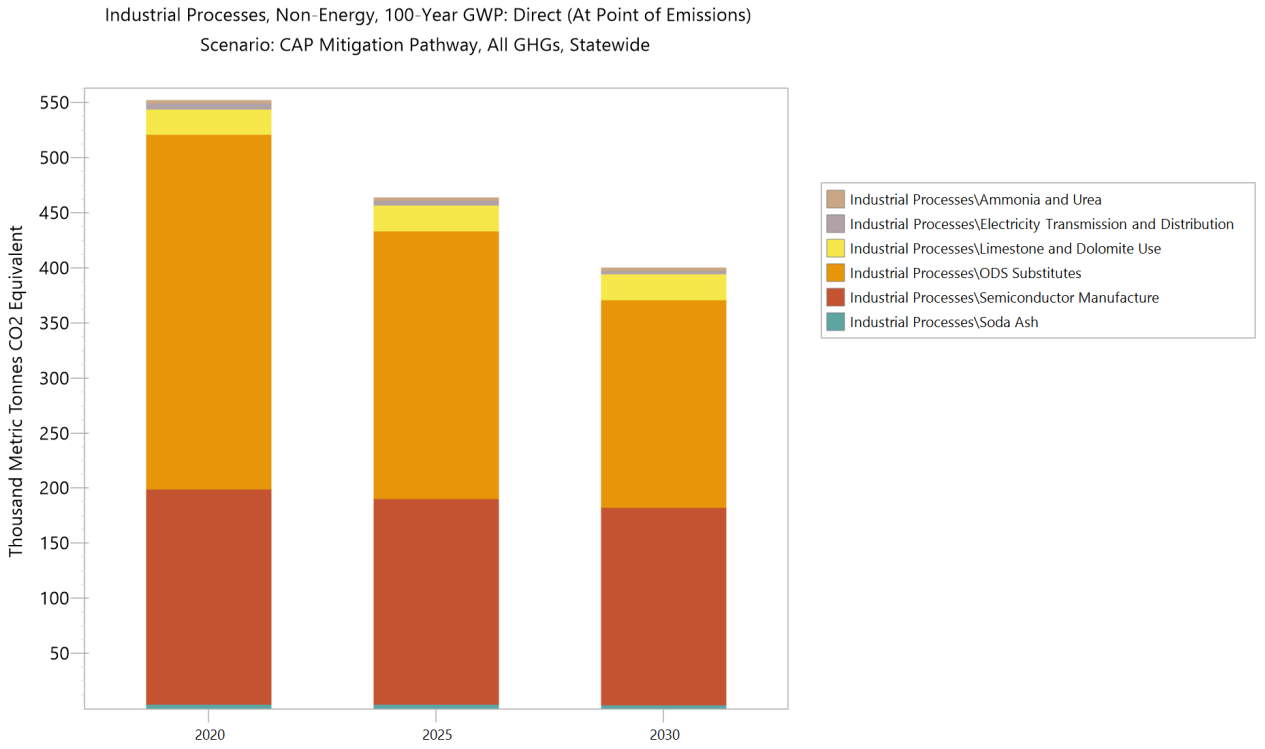
- Increased research on feasibility, adoption and impacts all required.



CAP Mitigation Non-Energy Industrial Processes

By 2030:

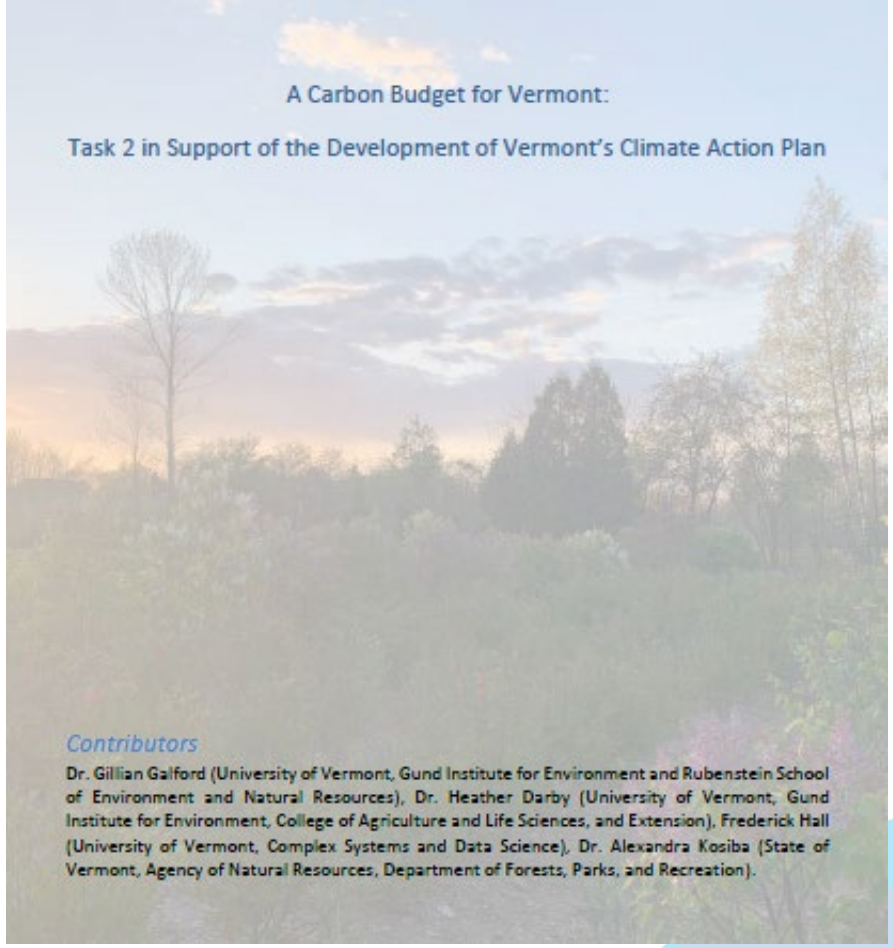
- The reduction in emissions from ODS substitutes are in line with Vermont's Hydrofluorocarbons (HFC) Rule, which mandates a phase down of the use of HFCs to meet the goal of a 40% reduction from the 2013 level of use by 2030.
- Federal initiative to phase down HFC production and consumption by 85% over next 15 years.
- Refrigerant management, leak reduction and alternative refrigerants
- Modest (8% by 2030) reduction for semi-conductor manufacturing based on historic trend.



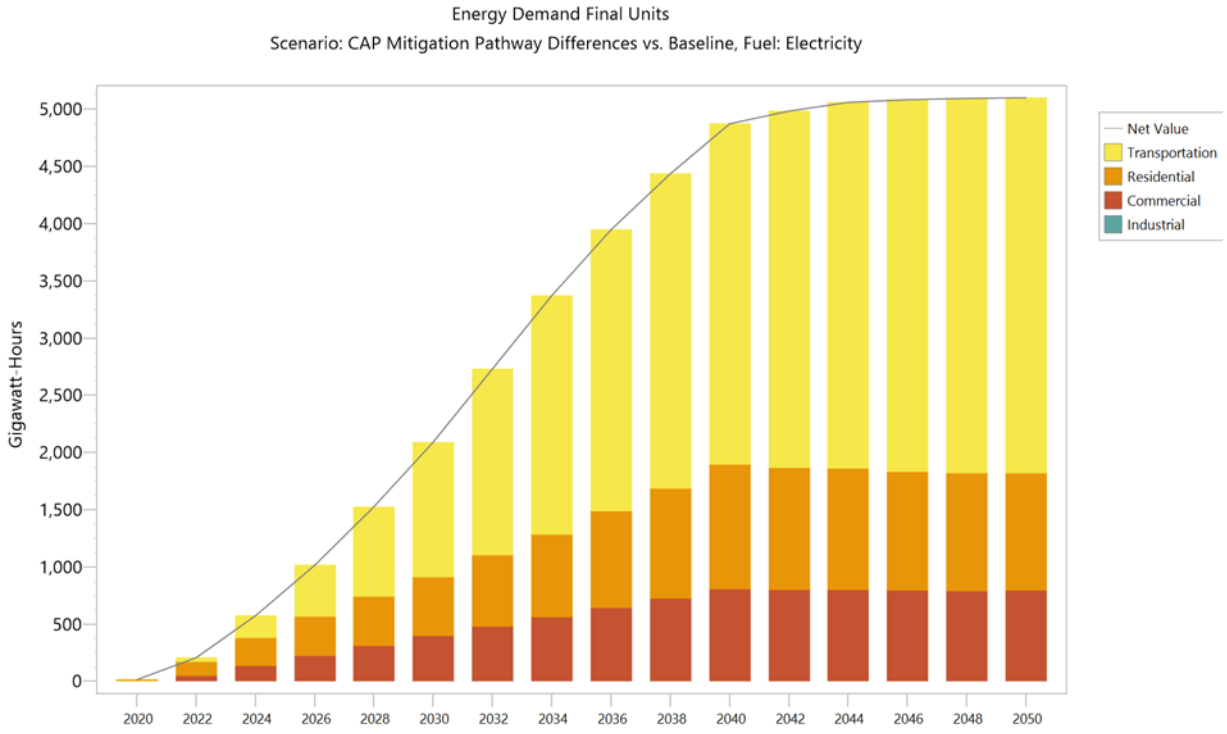
Pathway Key Policies, Strategies & Actions

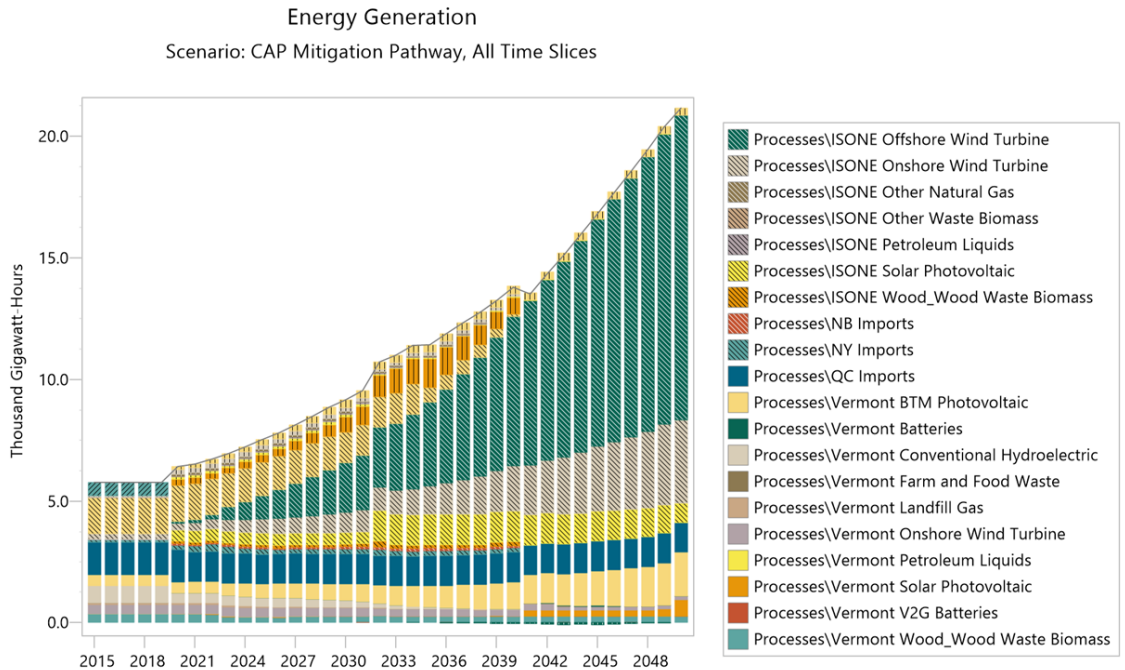
To Meet GWSA Requirements for Non-Energy:

- Increased research and implementation support
- Practices to reduce enteric fermentation emissions,
- Manure management initiative,
- Practices to increase soil carbon sequestration,
- ODS substitutes including refrigerant management,
- Target reductions for semi-conductor manufacturing
- Maintain and enhance sequestration to achieve net zero in 2050.



Electricity Sector – CAP Mitigation Pathway





Significant increase in electricity demand to meet the electrification demands from transportation and buildings.

Electric Generation mix continues trend toward renewables, and 100% Renewable Energy Standard by 2050.

Load management, flexible and coordinated loads and storage all key strategies.

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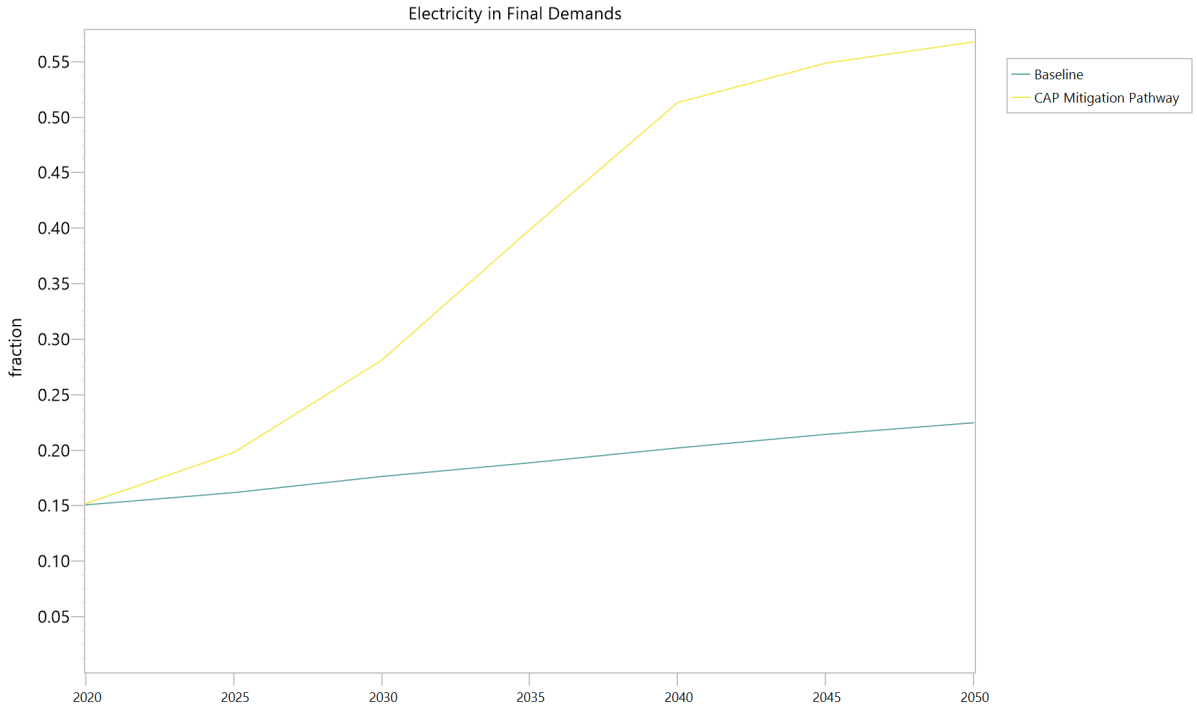
Electricity Sector – CAP Mitigation Pathway

By 2025:

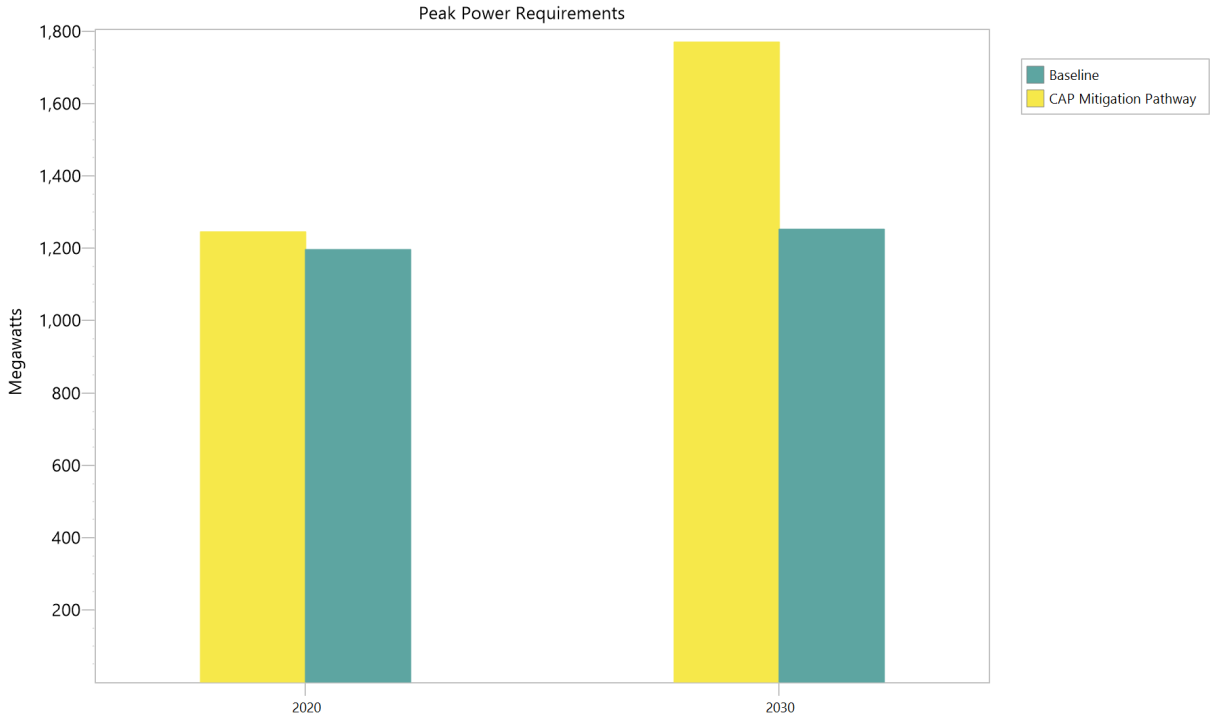
- Increase of electric demand over baseline of 796,000 MWh.
- Electricity meeting 20% of final demands by 2025, reaching more than 55% by 2050
- Potential upgrades to serve close to 80,000 heat pumps, 60,000 heat pump water heaters, and more than 40,000 EVs.
- Equity and access to electrification for all.
- Continued growth of customer sited solar, 600 GWh by 2025.



Electricity CAP Mitigation Pathway

By 2030:

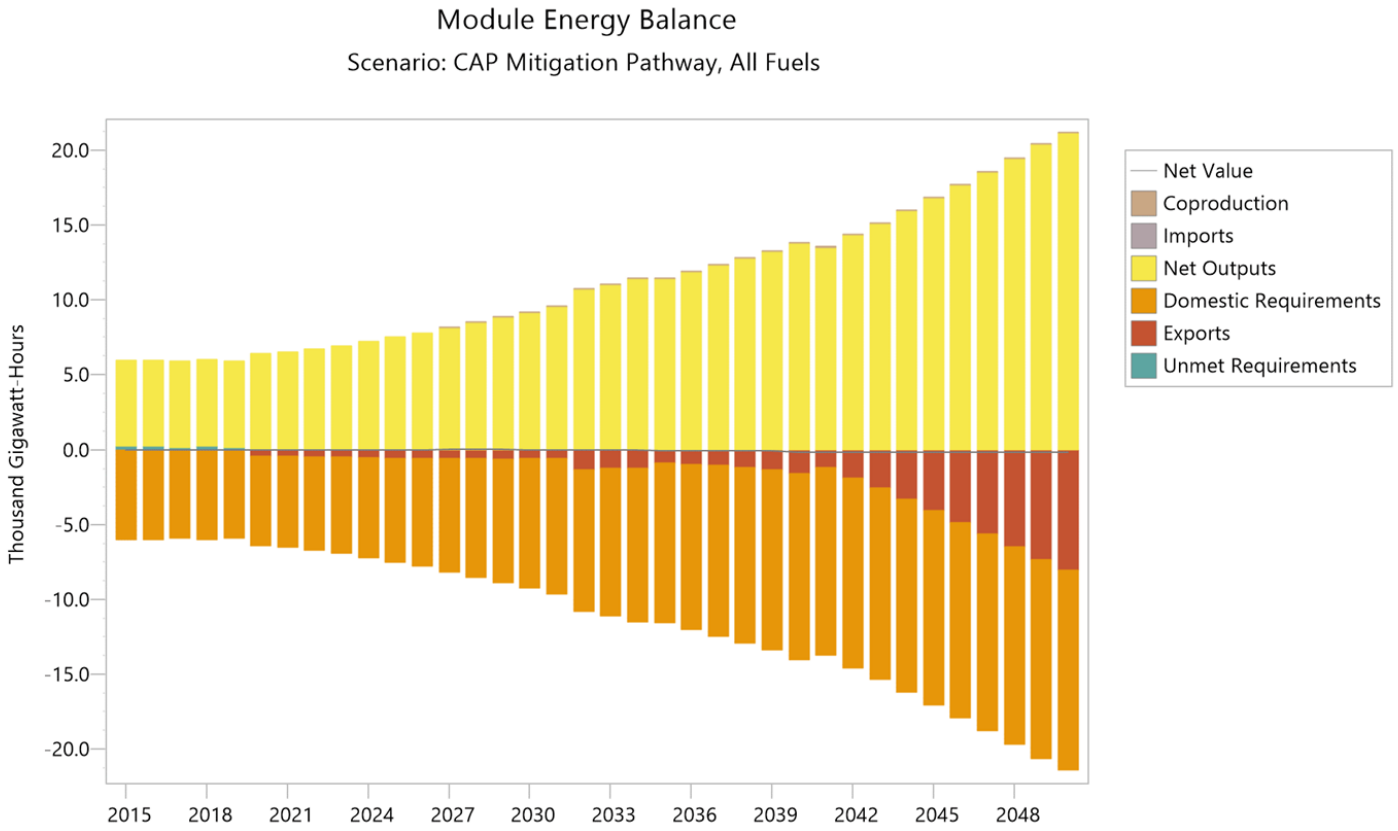
- Peak power requirements increase by more than 40% over baseline.
- Offshore wind providing more than 2,000 GWh, Onshore wind 1,200 GWh.
- 50% of EV charging is managed.



Electricity CAP Mitigation Pathway

By 2050:

- 8,000 GWh of “export” or curtailed power in order to meet demand in all time slices.
- Opportunities for coordinated and flexible load management to reduce the over-generation.
- May also provide strategic electrification for industry.



Key Policies, Strategies & Actions

Meeting the GWSA Requirements for Electricity:

- Expansion of renewable energy standard to reach 100% by 2050
- Participation in regional market and shift to renewables
- Investigation of demand response, flexible load management, and storage to address curtailment
- Potential for additional strategic electrification in industry