Volume 3: Mitigation Modeling
Consolidated Energy Sectors Modeling Results

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Overview

- This presentation contains the consolidated results for the greenhouse gas (GHG) mitigation modeling performed in support of the Maine Climate Council's climate planning project.
- Results are presented for each of the three energy sectors modeled: transportation, buildings, and electric.
- Modeling was performed for a sustained policy scenario and alternative scenarios for each of the three energy sectors.
- The sustained policy scenarios for each sector were based on existing policies and represent the baseline or business as usual scenario.
- Transportation sector alternative scenarios included varying degrees of electrification of the vehicle fleet, reductions in vehicle miles traveled, light duty vehicle fuel economy improvements, and displacement of gasoline and diesel fuels with low-carbon fuels.

Overview

- Building sector alternative scenarios included varying degrees of electrification of heating systems, building efficiency gains, and displacement of heating oil and natural gas with low-carbon fuels.
- The electric sector alternative scenario termed the decarbonization policy scenario assumes deep electrification of the transportation and buildings sectors and baseline efficiency gains.
- The decarbonization policy scenario assumes Maine adopts a 100% by 2050 renewable energy portfolio standard and baseline efficiency gains.

Transportation Sector

Transportation Sector: Results Overview

- These transportation scenario results have been modeled to help inform strategies for meeting Maine's emissions reduction targets
- The results of the transportation sector modeling were used to develop the electric load forecast for the electric sector modeling
- Results for the baseline scenario and four decarbonization scenarios (T1, T2, T3, and T4) are included in this slide deck

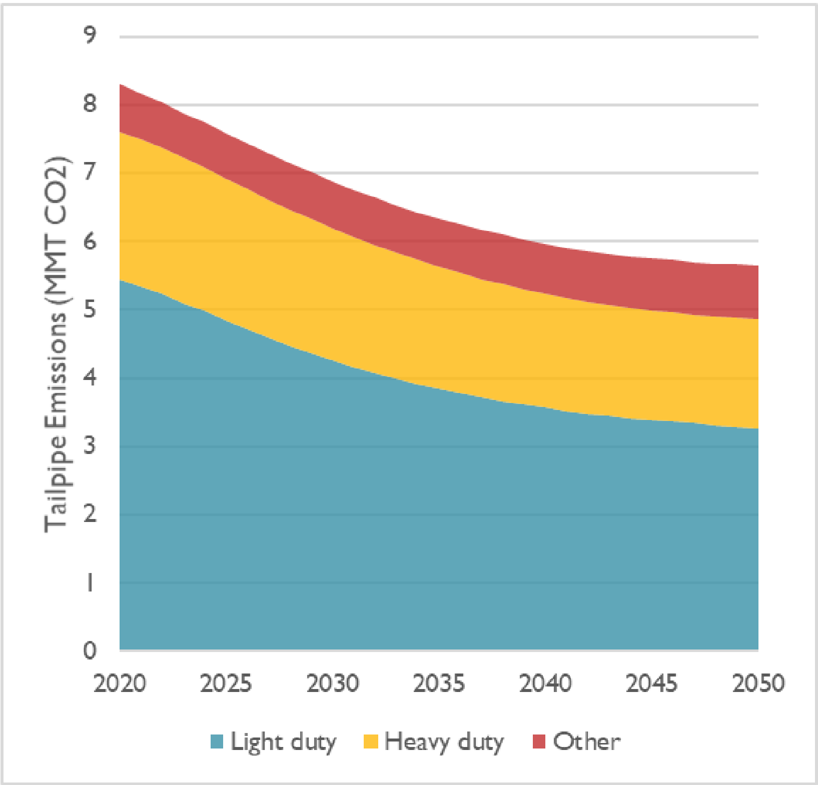
Notes about the Transportation Sector Scenarios

- Synapse has not evaluated the feasibility or cost-effectiveness of the decarbonization scenarios presented
- In all scenarios, non-motor vehicle emissions (aviation, rail, and marine) were assumed to grow slowly over time
  - We did not consider emissions reductions within these subsectors
  - This assumption requires greater emissions reductions from motor vehicles
- Future fuel efficiency improvements are included in all scenarios, despite the Trump administration rollback of CAFE standards
  - Maine follows California's fuel efficiency standards rather than the national standards
  - There is legal uncertainty regarding California's ability to continue to set standards different from the national standards
  - Including the CAFE rollback in our modeling would significantly increase baseline emissions

Transportation Sector Scenarios Analyzed

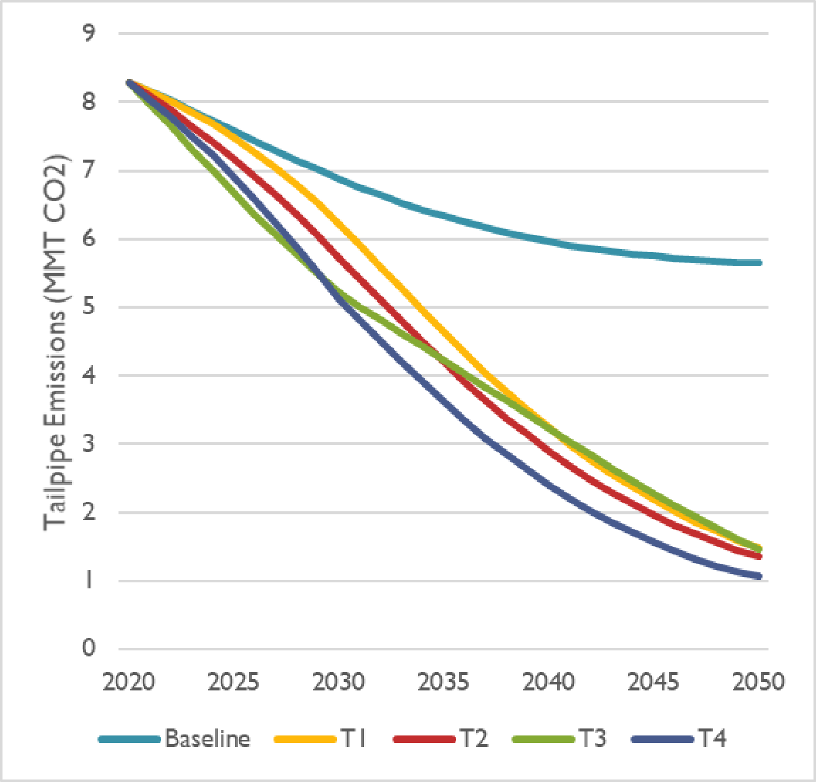
Baseline	T1	T2	T3	T4
Worst case electrification—CAFE standards remain	**Electrification—baseline efficiency**	**Electrification—aggressive efficiency**	**Reduced electrification—extreme efficiency and low carbon fuels**	**All strategies to meet 2030 emissions target**
• 11% of LDVs are electric by 2050 • 0% of HDVs are electric by 2050 • VMT per LDV remains constant through 2050 • VMT per HDV remains constant • Fuel efficiency reaches 42 MPG for new cars and 30 MPG for new light trucks by 2050	• 90% of LDVs are electric by 2050 • 80% of HDVs are electric by 2050 • VMT per LDV remains constant through 2050 • VMT per HDV remains constant • Fuel efficiency reaches 42 MPG for new cars and 30 MPG for new light trucks by 2050 • Managed EV charging	• 90% of LDVs are electric by 2050 • 80% of HDVs are electric by 2050 • VMT per LDV declines 12.1% by 2030 and 27.2% by 2050 • VMT per HDV declines 2.1% by 2030 and 4.2% by 2050 • Fuel efficiency reaches 45 MPG for new cars and 33 MPG for new light trucks by 2050 • Managed EV charging	• 65% of LDVs are electric by 2050 • 55% of HDVs are electric by 2050 • VMT per LDV declines 25% by 2030 and 40% by 2050 • VMT per HDV declines 2.1% by 2030 and 4.2% by 2050 • Fuel efficiency reaches 45 MPG for new cars and 33 MPG for new light trucks by 2050 • Managed EV charging • 20% of LDVs and HDVs use low carbon fuels	• 85% of new LDV sales are electric by 2030 • 55% of new HDV sales are zero emissions by 2030 • VMT per LDV declines 20% by 2030 • VMT per HDV declines 4% by 2030 • Fuel efficiency reaches 42 MPG for new cars and 30 MPG for new light trucks by 2050 • Managed EV charging

Transportation Sector Baseline GHG Emissions



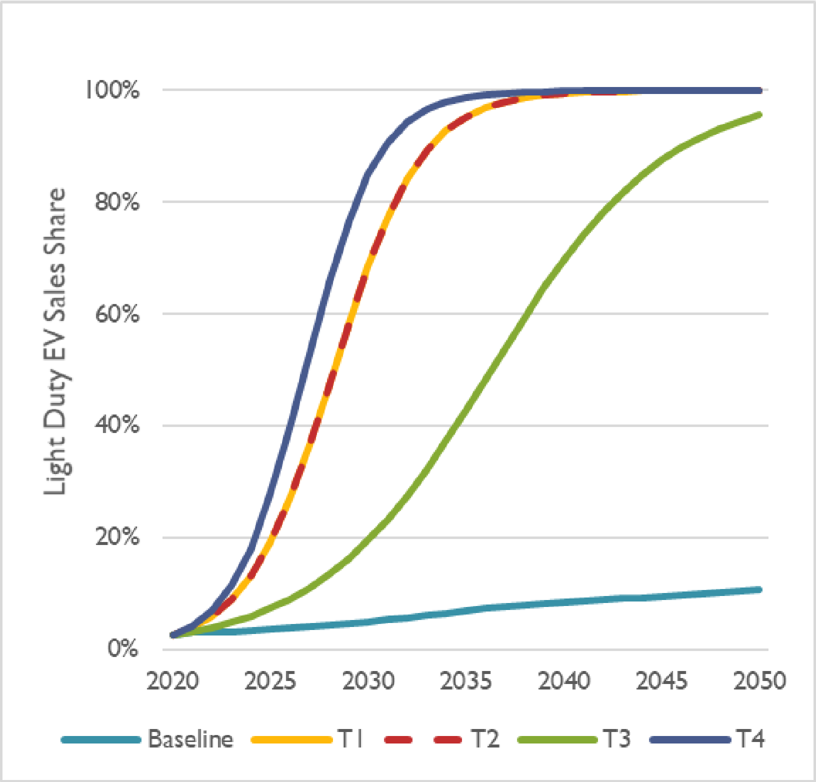
- Motor vehicles (light duty and heavy duty) account for most transportation sector emissions
  - Light duty vehicles are the largest category of emissions
- "Other" includes aviation, rail, and marine emissions
- Baseline emissions are projected to decline due to improvements in fuel efficiency required by CAFE standards
  - The recent rollback of the standards could slow emissions reductions

Transportation Sector Scenarios GHG Emissions



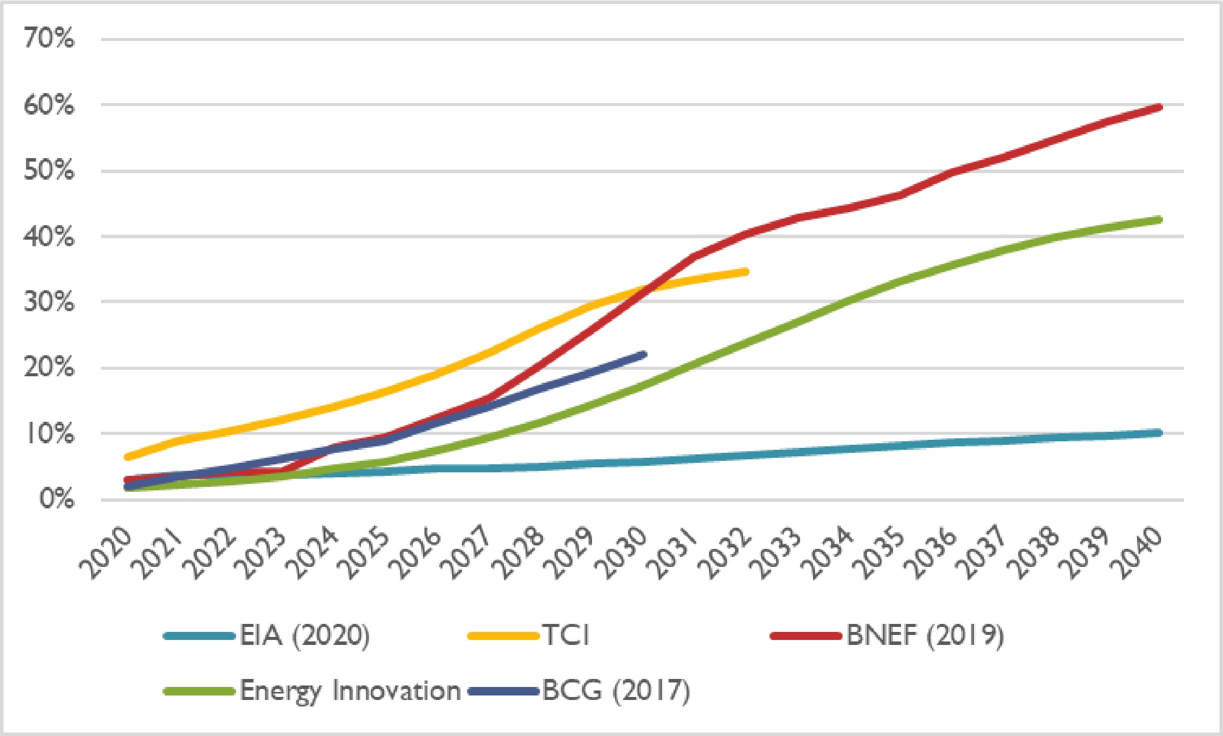
- The T1, T2, T3, and T4 scenarios result in emissions reductions between 2020 and 2050 of 82%, 84%, 82%, and 87%, respectively
- The impacts of reduced VMT and increased fuel efficiency in the T2 scenario have a larger impact in the earlier years when fewer EVs are on the road
  - By 2050, the impact is smaller because most vehicles are electric
- T3 and T4 result in greater emissions reductions through 2030 due to near term VMT reduction

Light Duty EV Sales Share



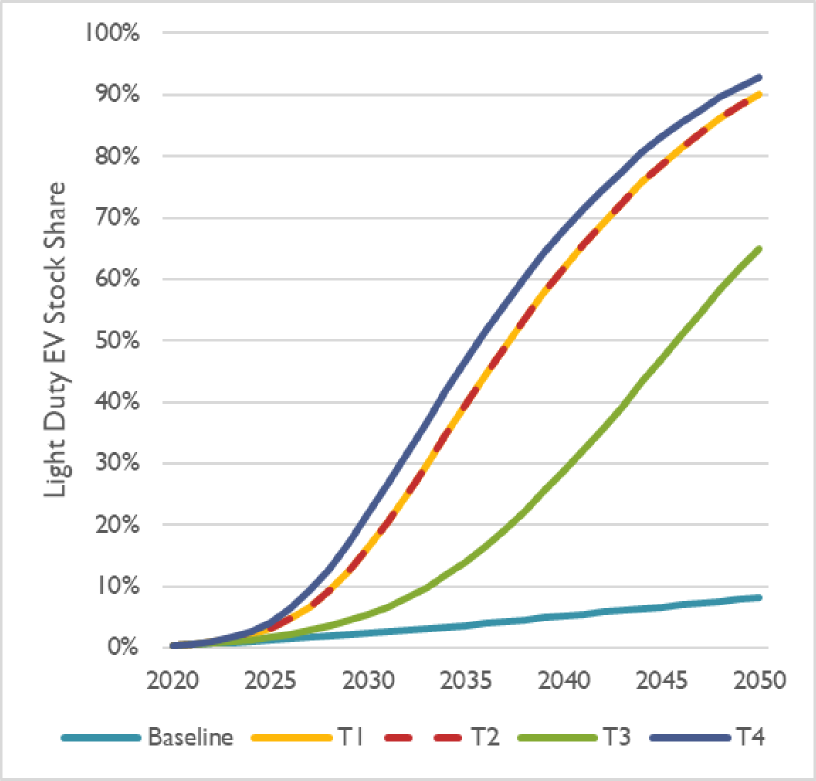
- The T1 and T2 scenarios include identical EV adoption trajectories
- EV sales increase to 19% in 2025, 69% in 2030, and 100% in 2050 in the T1 and T2 scenarios
- The T3 scenario includes less electrification than T1 and T2
  - EV sales increase to 7% in 2025, 19% in 2030, and 96% in 2050
- In T4, EV sales accelerate to 85% of new light-duty vehicles by 2030

Business as Usual EV Adoption Forecasts for the US



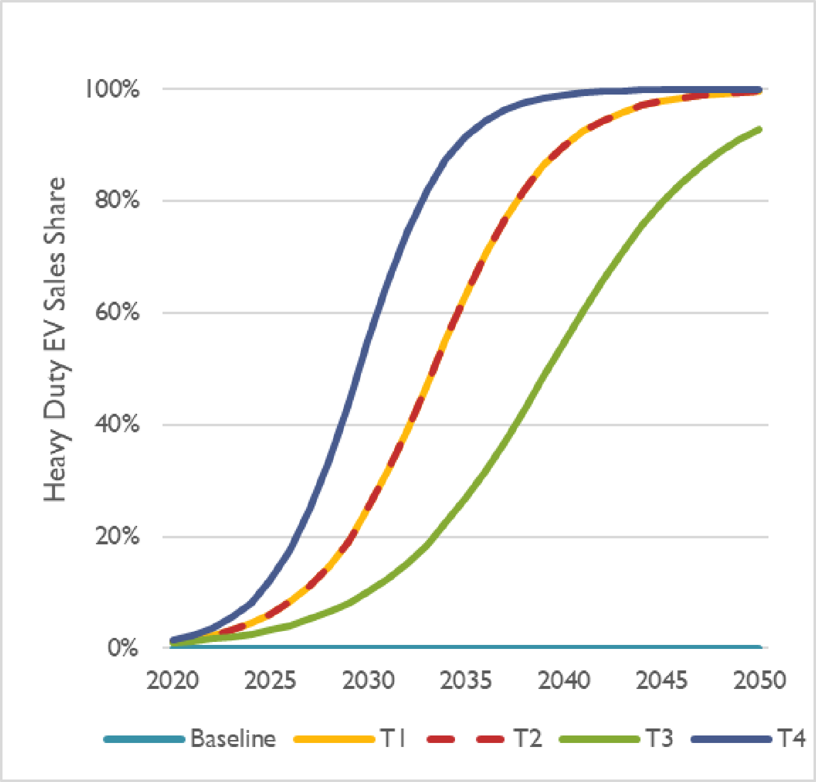
- EIA's forecast, used to inform the baseline scenario, is the most conservative
- The T1, T2, and T4 scenarios are more aggressive than any of these projections

Light Duty EV Stock Share



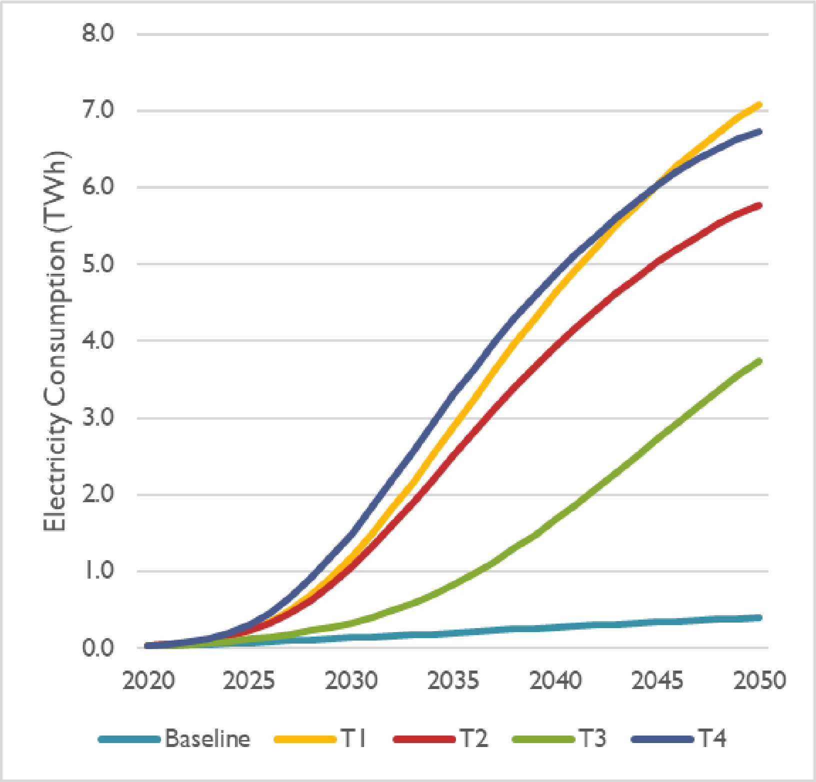
- EV stock is the same in the T1 and T2 scenarios
- EV stock share reaches only 5% by 2030 in the T3 scenario before rising to 65% in 2050
- EV stock growth lags EV sales due to the slow turnover of the vehicle fleet
  - The average light duty vehicle remains on the road for more than 15 years

Heavy Duty EV Sales Share



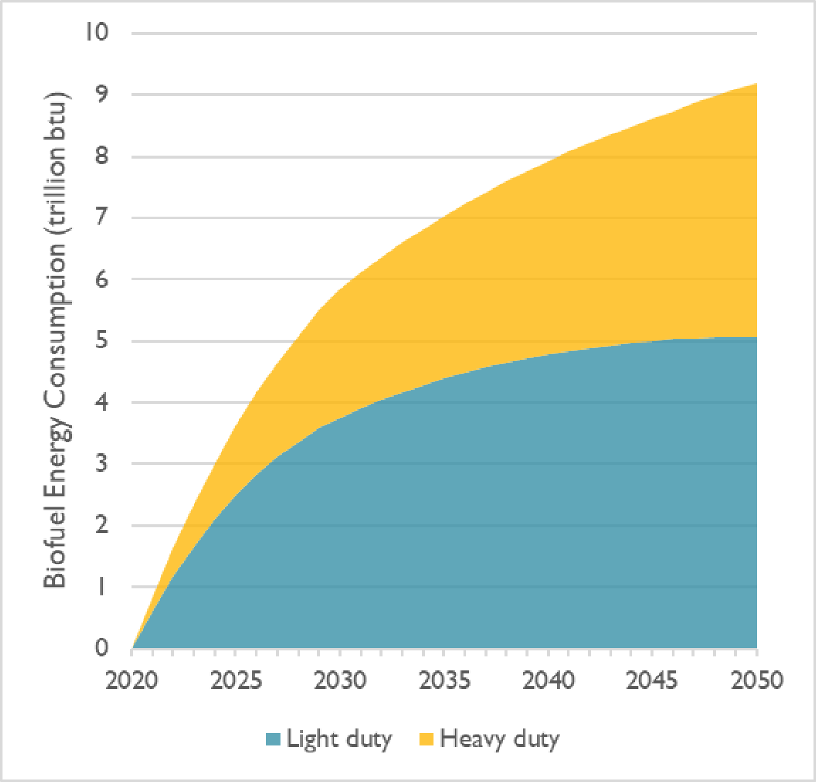
- The T1 and T2 scenarios include identical EV adoption trajectories
- Heavy-duty EV sales increase to 6% in 2025 and 25% in 2030 in the T1 and T2 scenarios
- The T3 scenario includes less electrification than T1 and T2
  - EV sales increase to 3% in 2025 and 10% in 2030
- The T4 scenario includes faster heavy-duty electrification and other zero emissions technologies, reaching 55% market share in 2030

Transportation Electrification Electricity Consumption



- Electricity consumption for charging light and heavy duty EVs grows to 7.1 TWh by 2050 in the T1 scenario and 6.85 TWh in the T4 scenario
  - In 2017 Maine's total electricity consumption was 11.2 TWh
- In 2030, T4 is 0.32 TWh above T1 due to accelerated EV adoption to meet GHG goal
  - By 2050, most vehicles are EVs
  - At that point VMT effects electricity consumption more than gasoline consumption

Biofuel Energy Consumption in Scenario T3



- Biofuel consumption in the T3 scenario ramps up to provide energy for 8% of light and heavy-duty vehicles on the road by 2030
  - By 2050, biofuels provide energy for 20% of all vehicles
- In this analysis, we assume that the biofuels utilized produce no net greenhouse gas emissions

Buildings Sector

Buildings Sector: Results Overview

- These thermal scenario results have been modeled to help inform strategies for meeting Maine’s emissions reduction targets
- The results of the thermal sector modeling were used to develop the electric load forecast for the electric sector modeling
- Results for the baseline scenario and four decarbonization scenarios (H1, H2, H3, and H4) are included in this slide deck

Buildings Sector: Scenarios Analyzed

Baseline	H1	H2	H3	H4
Continued efforts to install residential retrofit heat pumps—baseline efficiency	**Full Electrification—baseline efficiency**	**Electrification—aggressive efficiency**	**Electrification—baseline efficiency and low carbon fuels**	**All strategies to meet 2030 emissions target**
• 2.2% cumulative residential space heat energy reduction by 2050 through weatherization • 41% of households have heat pumps or legacy resistance heating by 2050	• 2.2% cumulative residential space heat energy reduction by 2050 through weatherization • 90% of households have heat pumps and 90% of commercial heating load is electrified by 2050	• 20% cumulative residential space heat energy reduction by 2050 through weatherization • 90% of households have heat pumps and 90% of commercial heating load is electrified by 2050	• 2.2% cumulative residential space heat energy reduction by 2050 through weatherization • 67% of households have heat pumps and 60% of commercial heating load is electrified by 2050 • Remaining load in 2050 is primarily supplied with biodiesel and fuel oil blends and renewable natural gas	• 2.9% cumulative residential space heat energy reduction by 2050 through weatherization (1.5% by 2030) • 90% of all residential and commercial heating systems that burn out are replaced with heat pumps by 2030

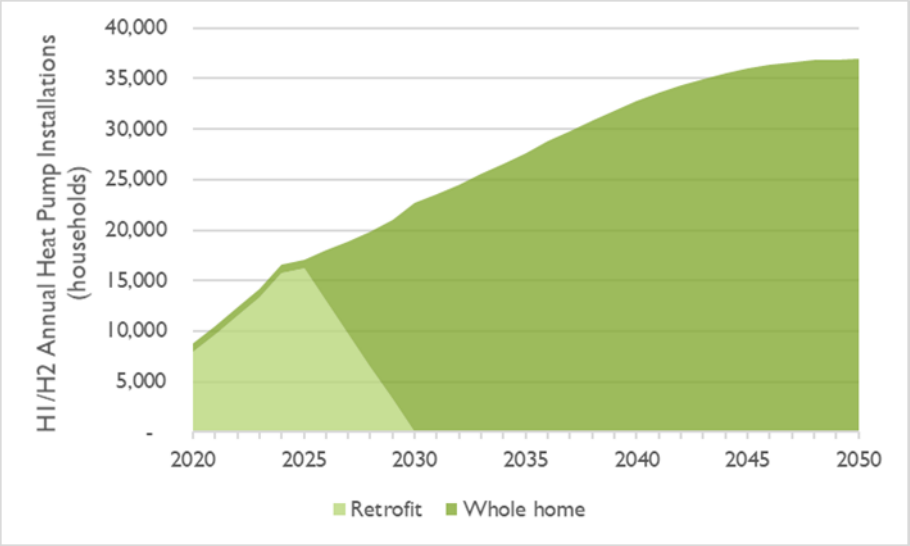
Heat Pump Adoption Modeling

- There are two types of heat pump adoption modeled for residential space heating: heat pump retrofits and whole home heat pumps
  - Heat pump retrofits displace fuel oil consumption in households that choose to maintain their legacy heating system
    - These heat pump installations are specified as a number of households each year
    - The fraction of total heating load provided by heat pumps increases from 39% in 2020 to 57% in 2030
  - Whole home heat pumps replace legacy heating systems upon burnout
    - These heat pump installations are specified as a percentage of all new heating systems installed to replace retiring legacy heating systems
- In the commercial sector, only heat pumps replacing the entire legacy heating system upon burnout are considered

Baseline Residential Heat Pump Adoption

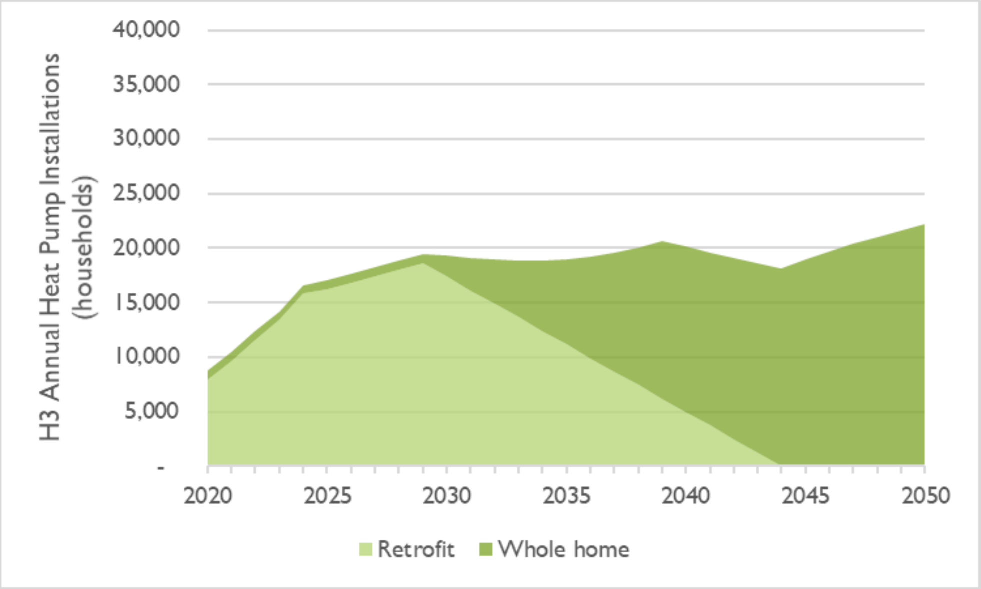
- In the baseline scenario, heat pump retrofits increase in line with Maine's 2025 goal and continue in line with ISO New England projections through 2029
  - After 2029, heat pump installations are phased out to capture existing policies only
  - A small number of whole home heat pumps are installed to replace heat pumps that burn out

H1/H2 and H4 Residential Heat Pump Adoption



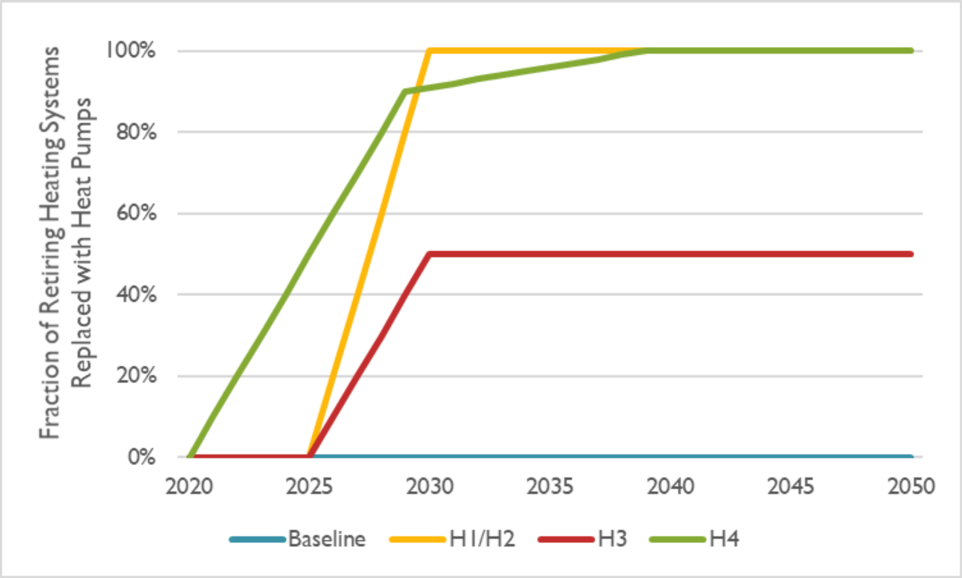
- In the H1 and H2 scenarios, heat pump retrofits are phased out in the late 2020s as whole home heat pump installations increase
  - Whole home heat pumps attain 100% market share when replacing systems that burn out by 2030
- In the H4 scenario, whole home heat pump adoption increases more quickly to replace fossil fuel systems that burn out
  - Wholes home heat pumps attain 90% market share in 2030.

H3 Residential Heat Pump Adoption



- In the H3 scenario, heat pump retrofits continue through 2044
  - Relative to H1 and H2, more heat pump retrofits are completed, but fewer whole home heat pumps are installed
  - Whole home heat pump market share increases between 2029 and 2039 to 50% of households replacing fuel oil and natural gas and 100% of households replacing propane

Commercial Heat Pump Adoption

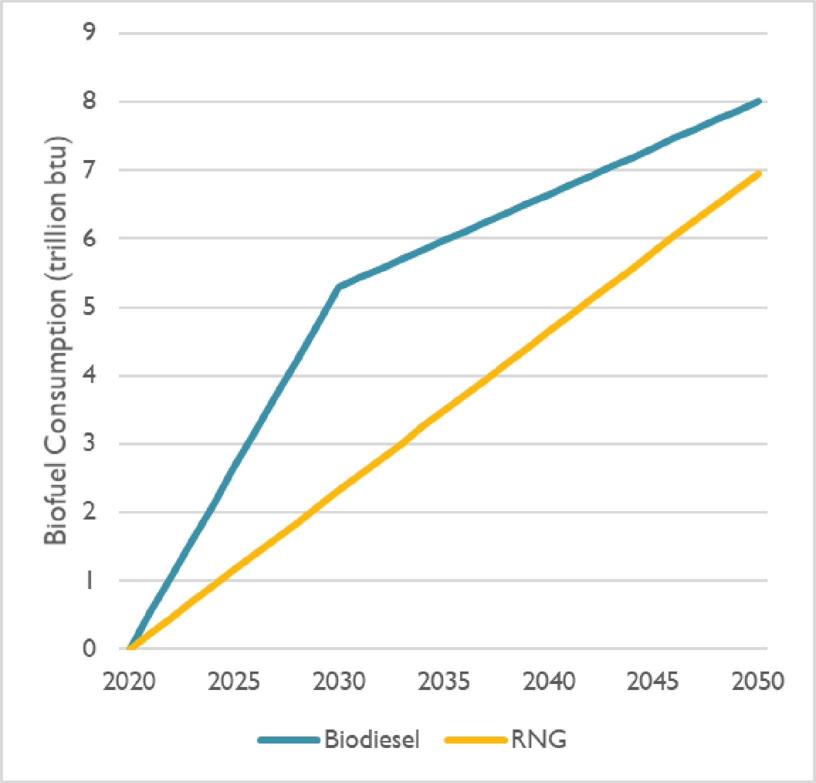


- All commercial heat pump adoption is assumed to occur when the existing heating system burns out or is otherwise retired
- No heat pump adoption is included in the baseline
- In the H1 and H2 scenarios, heat pump adoption increases to 100% market share in 2030
- In H3, market share increases to 50% in 2030
- In H4, adoption begins in the early 2020s, reaching 90% market share by 2030

Biofuel Modeling in Scenario H3

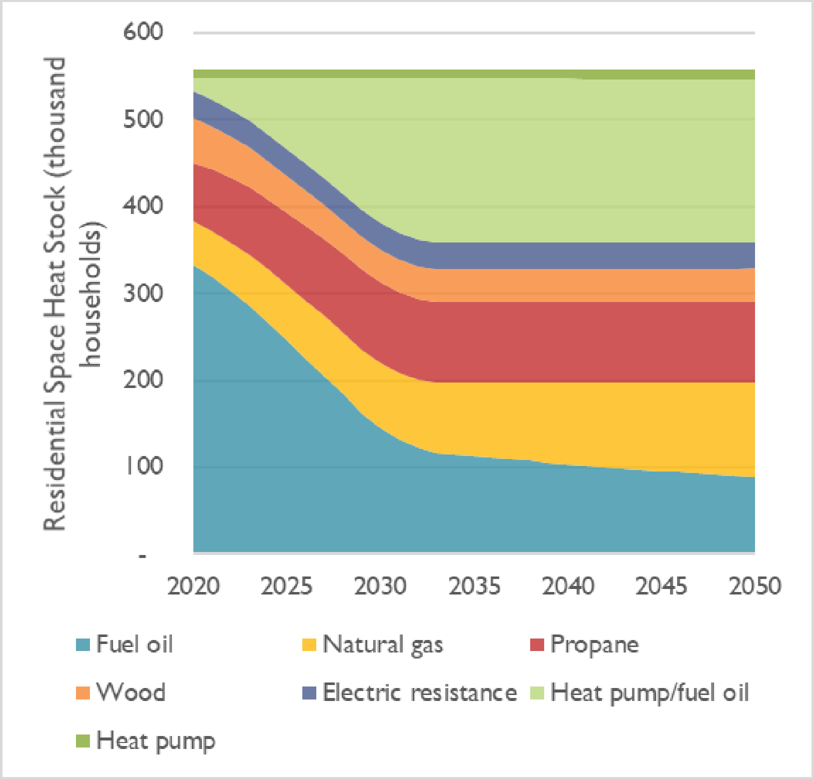
- Wood, biodiesel, and renewable natural gas (RNG) are all included in the H3 scenario
  - Wood is primarily utilized in the residential sector, while biodiesel and RNG displace fuel oil and natural gas in both the residential and commercial sectors
  - Biodiesel and RNG are assumed to be drop-in replacements for fuel oil and natural gas, respectively
    - Today, B20 (a fuel oil blend that includes 20% biodiesel) is more common than B100 (100% biodiesel), but a 2019 report from Brookhaven National Laboratory found no "clear technical barrier which would limit the use of biodiesel in home heating systems"
- Resource availability was not independently evaluated as part of this work
  - We referenced a December 2019 ICF study evaluating the RNG resource potential in determining how much RNG could be produced in Maine
- RNG, biodiesel, and wood are all assumed to be carbon neutral

Biofuel Supply in Scenario H3



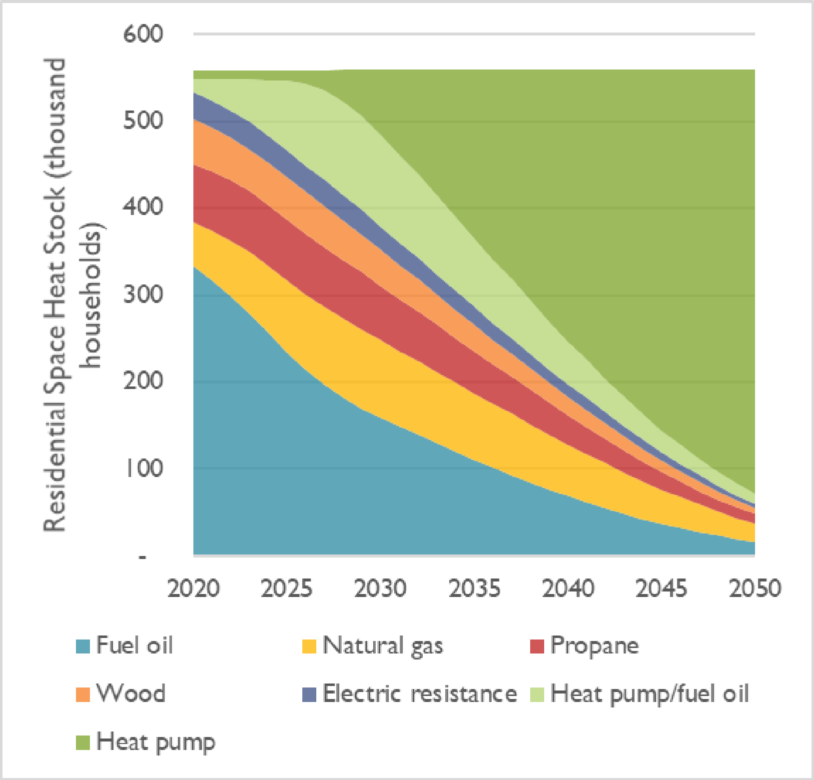
- RNG and biodiesel availability increase over time
- By 2050, we assume that 15 trillion btu of biodiesel and RNG are available
  - RNG is assumed to supply all natural gas demand in 2050

Baseline Residential Space Heating Stock



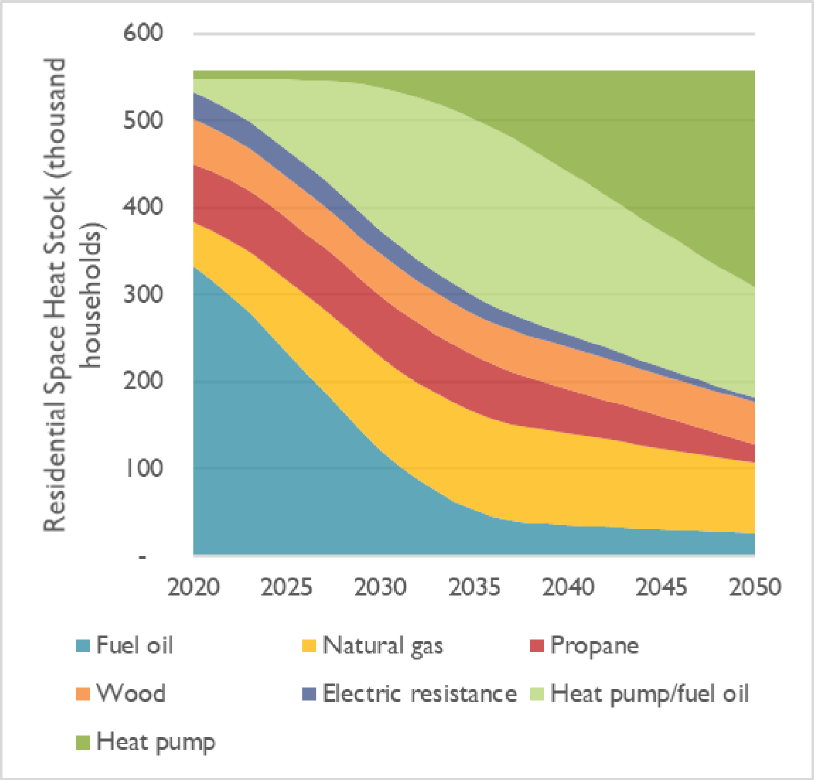
- 166,000 households that heat with oil are retrofitted with heat pumps by 2030
  - These households are labeled “Heat pump/fuel oil” because they maintain their fuel oil heating systems
- Between 2020 and 2050, the number of homes heated by natural gas and propane increases by 85,000

H1 and H2 Residential Space Heating Stock



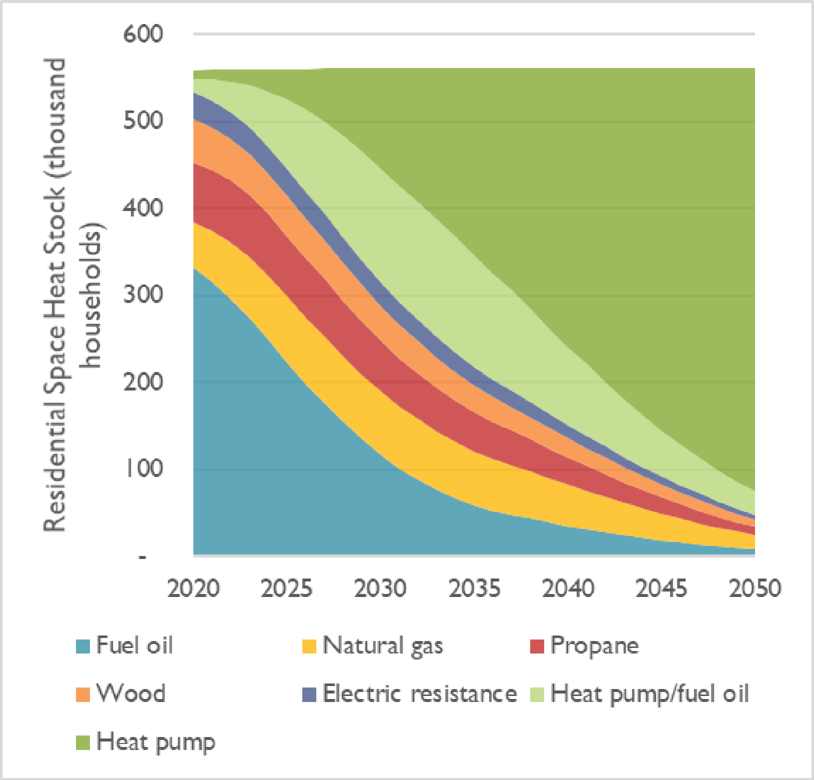
- Between 2020 and 2028, the number of homes heating with natural gas increases by 42,000 and the number of homes heating with both heat pumps and fuel oil increases by 94,000
  - By 2050, most of these homes switch to using heat pumps exclusively
- By 2050, 488,000 homes meet their full heating load using heat pumps

H3 Residential Space Heating Stock



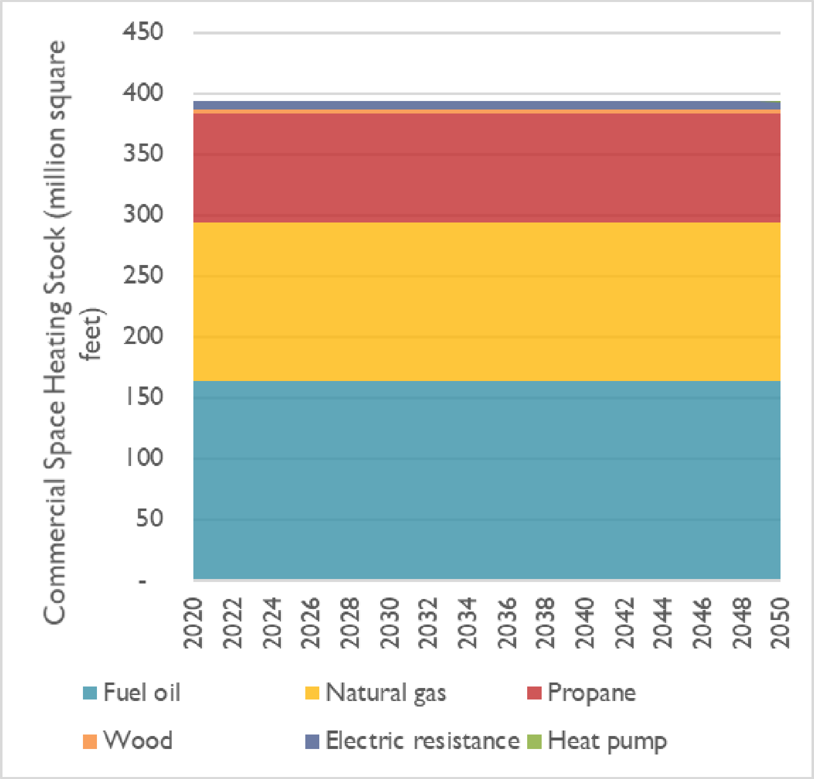
- Relative to the H1 and H2 scenarios, more homes continue to heat with both heat pumps and fuel oil (primarily biodiesel) in 2050
  - More homes also maintain natural gas (supplied by RNG) and wood heating through 2050

H4 Residential Space Heating Stock



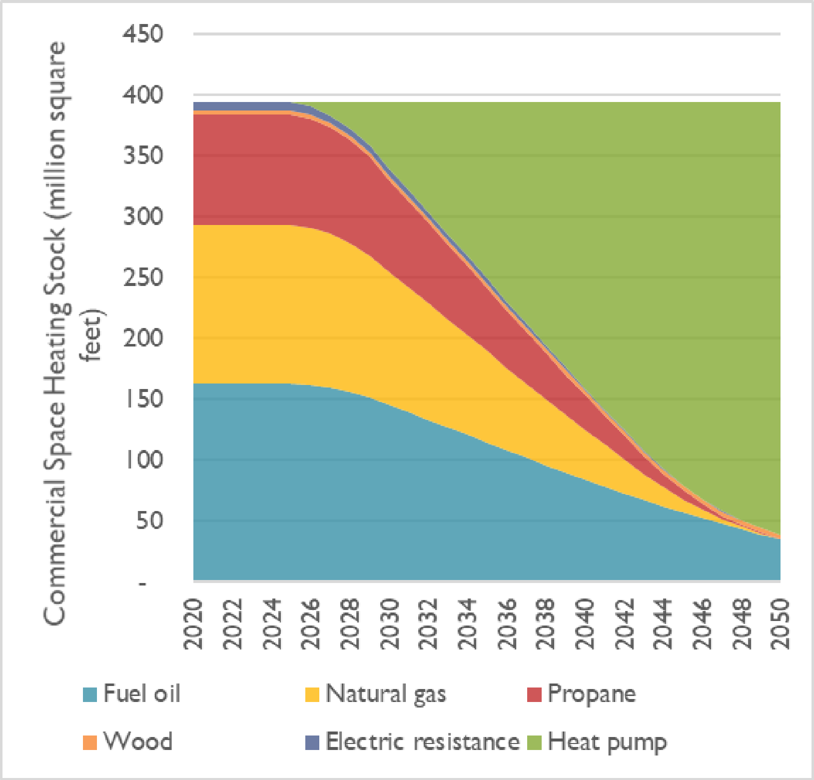
- Heat pump adoption accelerates more quickly than it does in the H1 and H2 scenarios
- By 2030, 44% of households have heat pumps installed (with or without supplemental oil heating)
- By 2050, 487,000 homes meet their full heating load using heat pumps

Baseline Commercial Space Heating Stock



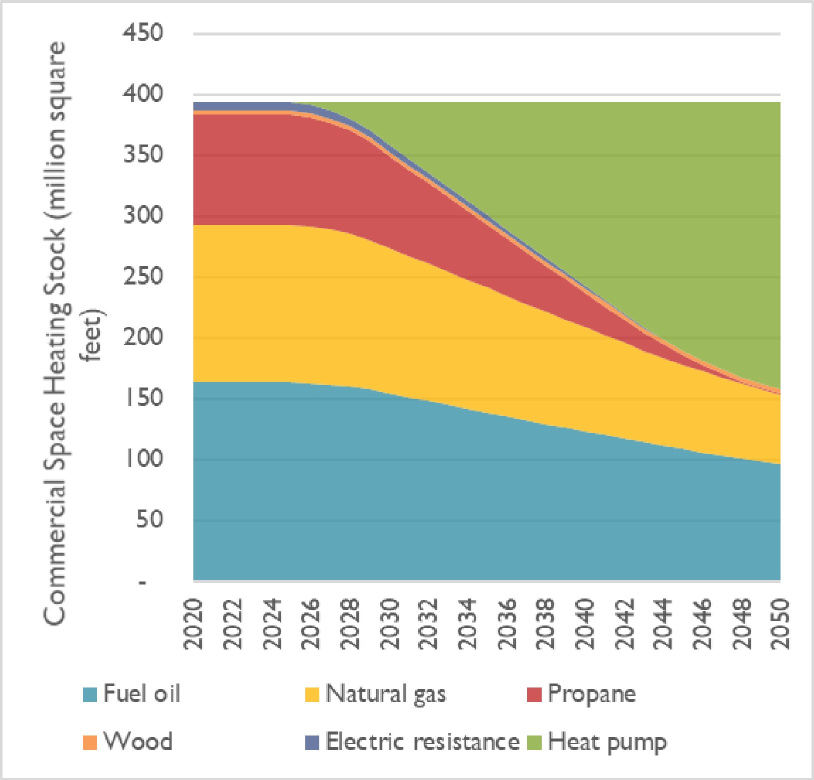
- Commercial space heating stock is assumed to remain unchanged in the baseline

H1 and H2 Commercial Space Heating Stock



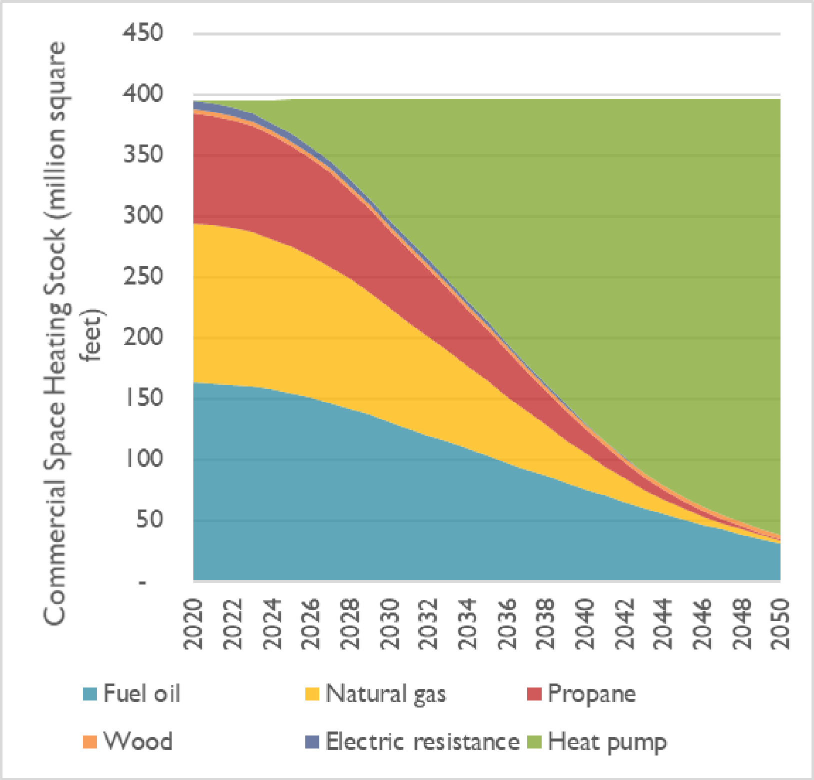
- By 2050, 90% of all commercial building space is heated with heat pumps
- The largest remaining fossil fuel source is fuel oil, due to the longer lifetimes of oil furnaces
  - This assumption is based on equipment-specific lifetime distributions developed for the Department of Energy's appliance standard rulemakings and published in Technical Support Documents

H3 Commercial Space Heating Stock



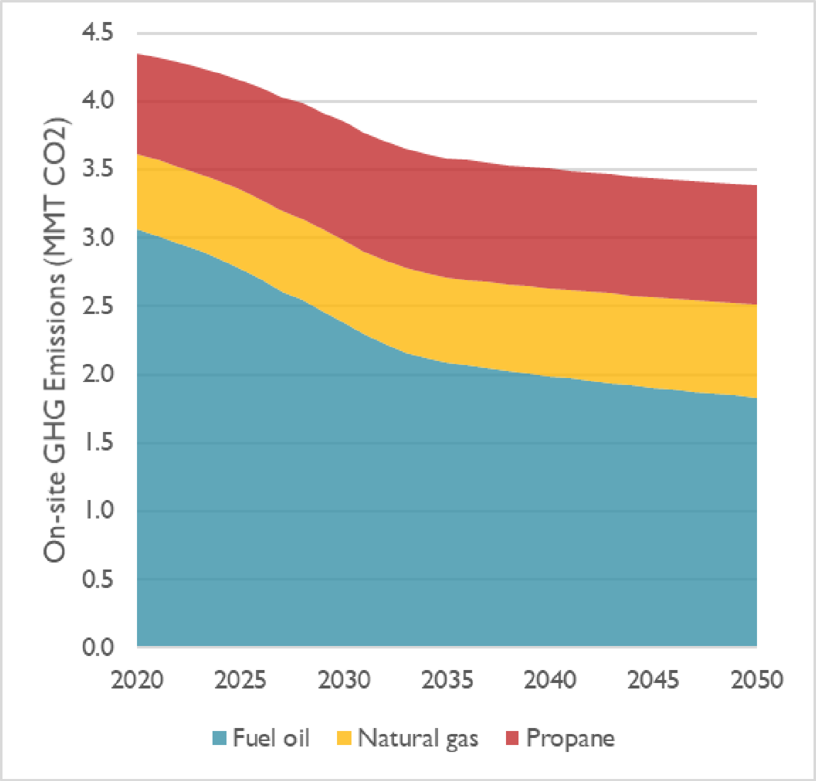
- By 2050, 60% of all commercial building space is heated with heat pumps
  - That same year, 24% of commercial building space is heated with fuel oil/biodiesel and 15% is heated with natural gas/RNG

H4 Commercial Space Heating Stock



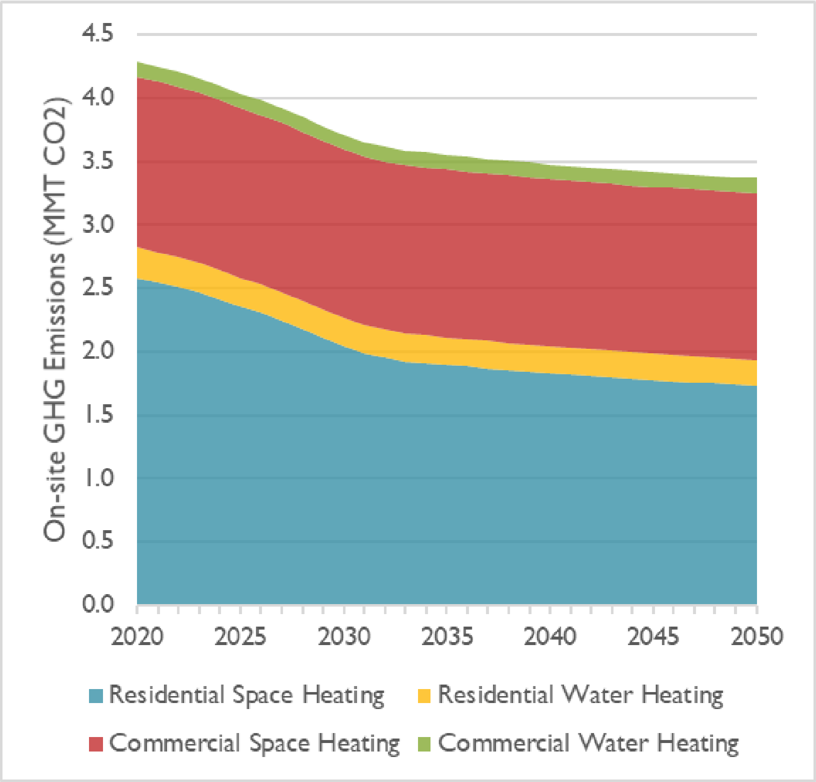
- By 2050, 90% of all commercial building space is heated with heat pumps
- Compared to H1/H2, heat pump adoption begins earlier in the 2020s
  - This leads to greater emissions reductions by 2030

Buildings Sector Baseline GHG Emissions



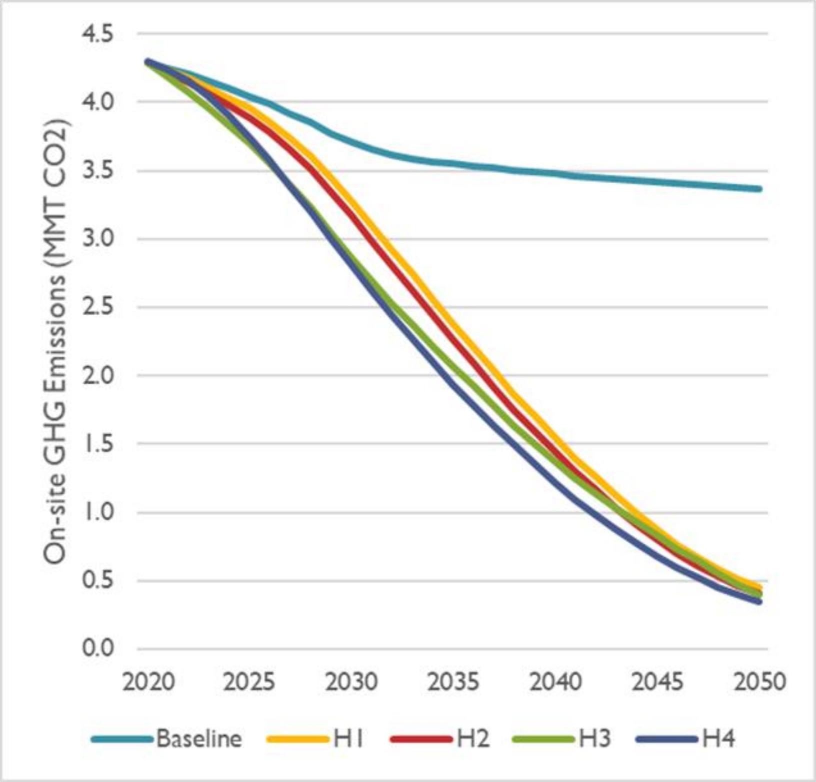
- Fuel oil accounts for most thermal sector emissions
- Fuel oil emissions also decrease the fastest as retrofit heat pumps are installed
- Natural gas and propane emissions grow over the projection period

Buildings Sector Baseline GHG Emissions



- Space heating is the largest emitting end use
- The residential sector produces more emissions than the commercial sector

Buildings Sector Scenarios GHG Emissions

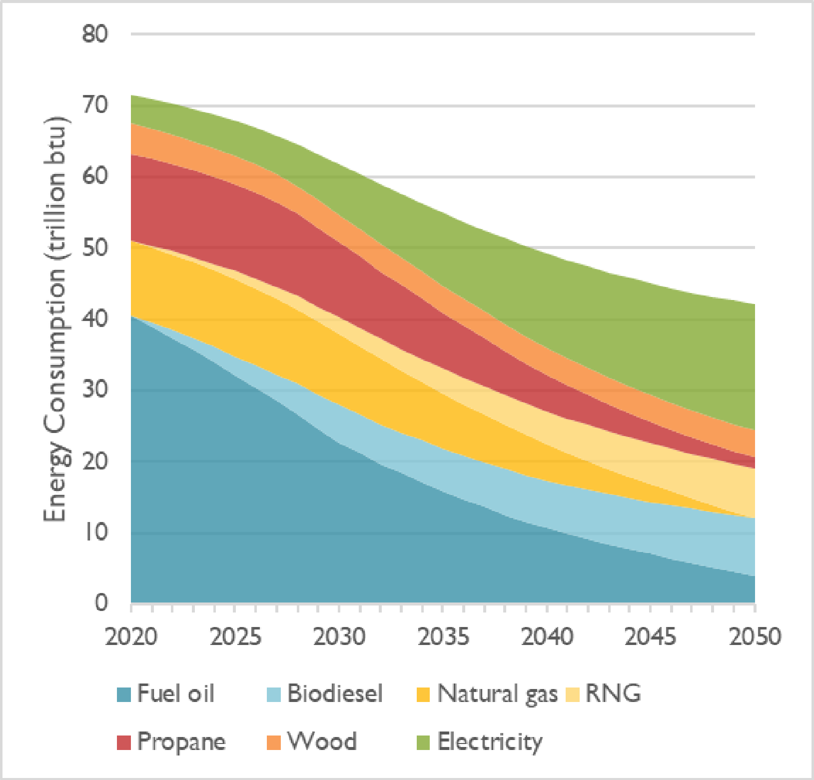


- The H3 and H4 scenarios lead to the greatest emissions reductions by 2030
  - In H3 this is due to assumed substitution of net zero emission biofuels for fuel oil and natural gas

Table 1. GHG Emissions Reductions

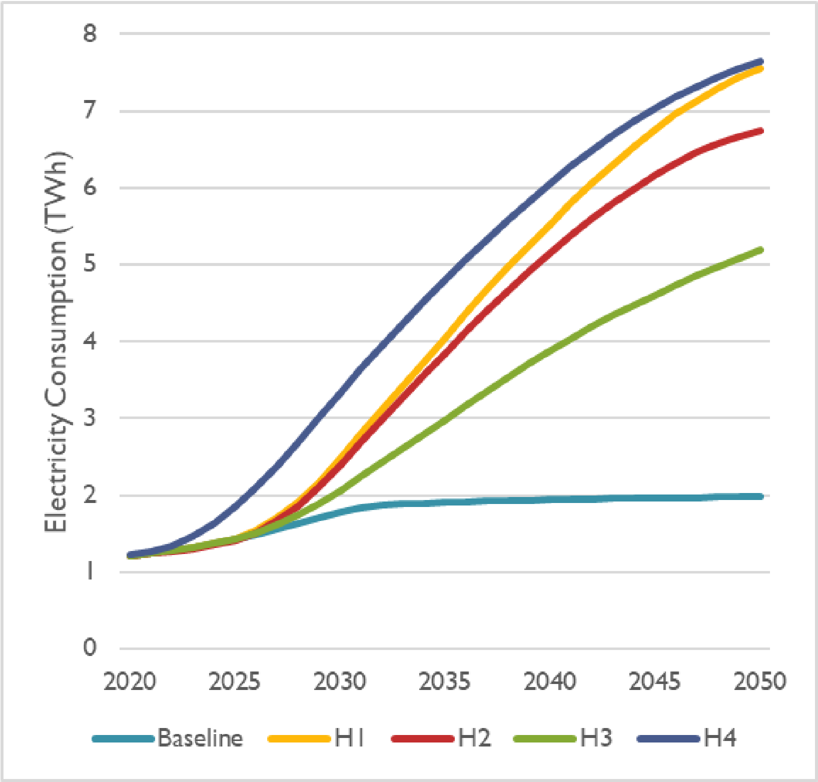
Scenario	2020-2030	2020-2050
Baseline	14%	21%
H1	24%	90%
H2	26%	91%
H3	33%	91%
H4	35%	92%

H3 Total Space and Water Heating Energy Consumption



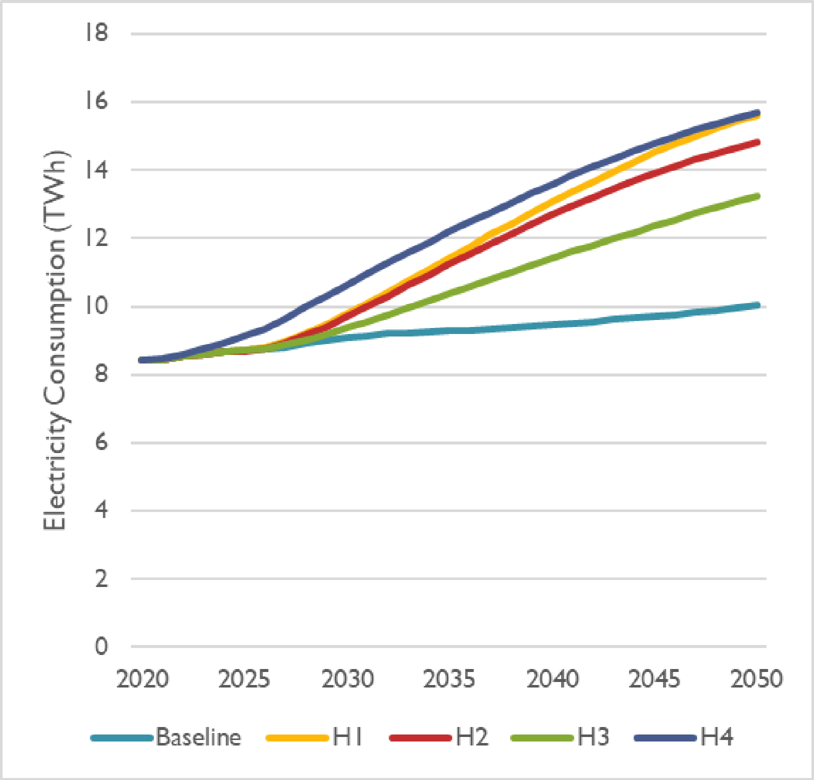
- By 2050, energy consumption for space and water heating decreases to 42 trillion btu, primarily due to the high efficiency of heat pumps
- RNG displaces all fossil natural gas consumption in 2050
  - Biodiesel displaces 67% of fuel oil consumption

Space and Water Heating Electricity Consumption



- By 2050 electricity consumption for space and water heating grows to between 5.2 and 7.7 TWh in the decarbonization scenarios
  - Maine's total electricity consumption in 2017 was 11.2 TWh
- Weatherization and biofuels reduce electricity consumption in the H2 and H3 scenarios respectively
- In H4, load increases earlier due to accelerated heat pump adoption
- Electricity consumption for space cooling is not included in the chart

Total Residential and Commercial Electricity Consumption



- This chart includes all building electricity consumption including space and water heating and all other end uses (lighting, refrigeration, electronics, etc.)
- Electricity consumption for end uses other than space and water heating is projected to grow slowly over time
  - This projection is the same in all scenarios

Electric Sector

Electric Sector: Results Overview

- These electric sector scenario results have been modeled to help inform strategies for meeting Maine’s emissions reduction targets
- The electric sector modeling results for the “sustained policy” baseline scenario (EB) and one “decarbonization policy” scenario (E1) are included in this slide deck
- The EB scenario used the increased load for EVs and heat pumps from the transportation baseline scenario (TB) and the thermal baseline scenario (HB)
- The E1 scenario used the increased load for EVs and heat pumps from the transportation decarbonization scenario (T1) and the thermal decarbonization scenario (H1)
- “Decarbonization policy” leverages the electric power system to drive deep carbon reductions in the transportation and buildings sectors

Assumptions for Transportation & Buildings Scenarios Used in Electric Sector Modeling

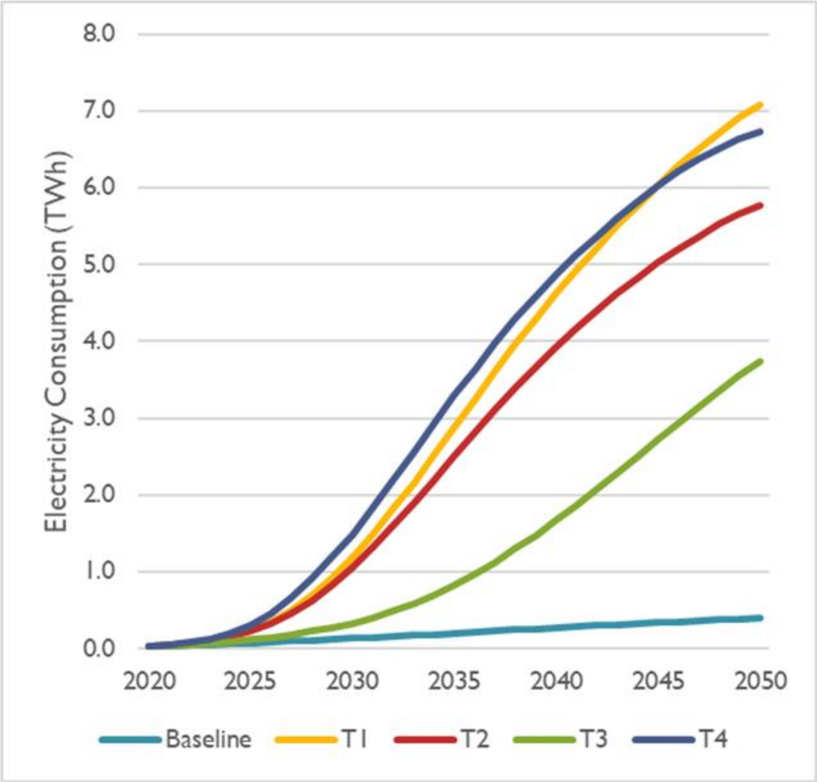
Baseline	T1
Worst case electrification—CAFE standards remain	**Electrification—baseline efficiency**
• 11% of LDVs are electric by 2050 • 0% of HDVs are electric by 2050 • VMT per LDV remains constant through 2050 • VMT per HDV remains constant • Fuel efficiency reaches 42 MPG for new cars and 30 MPG for new light trucks by 2050	• 90% of LDVs are electric by 2050 • 80% of HDVs are electric by 2050 • VMT per LDV remains constant through 2050 • VMT per HDV remains constant • Fuel efficiency reaches 42 MPG for new cars and 30 MPG for new light trucks by 2050 • Managed EV charging

Baseline	H1
Continued efforts to install residential retrofit heat pumps—baseline efficiency	**Full Electrification—baseline efficiency**
• 2.2% cumulative residential space heat energy reduction by 2050 through weatherization • 41% of households have heat pumps or legacy resistance heating by 2050	• 2.2% cumulative residential space heat energy reduction by 2050 through weatherization • 90% of households have heat pumps and 90% of commercial heating load is electrified by 2050

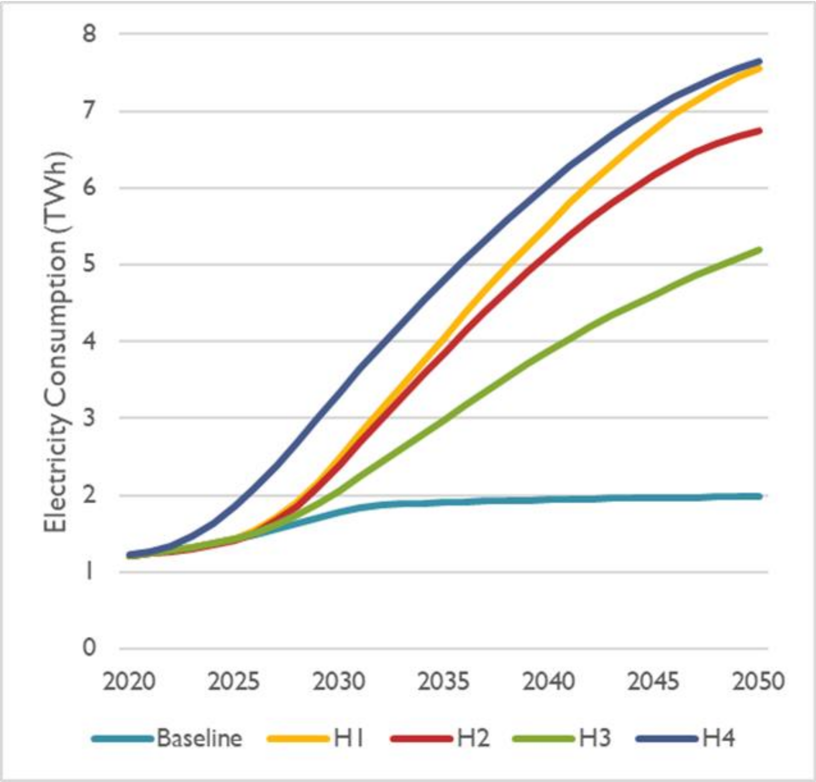
- Baseline results for the transportation and buildings sectors were used for the electric sector sustained policy scenario.
- Transportation 1 (T1) and Buildings 1 (H1) results were used for the electric sector decarbonization policy scenario.

Increased Demand for Electricity from EV Charging and Heat Pumps—The Challenge of Deep Decarbonization

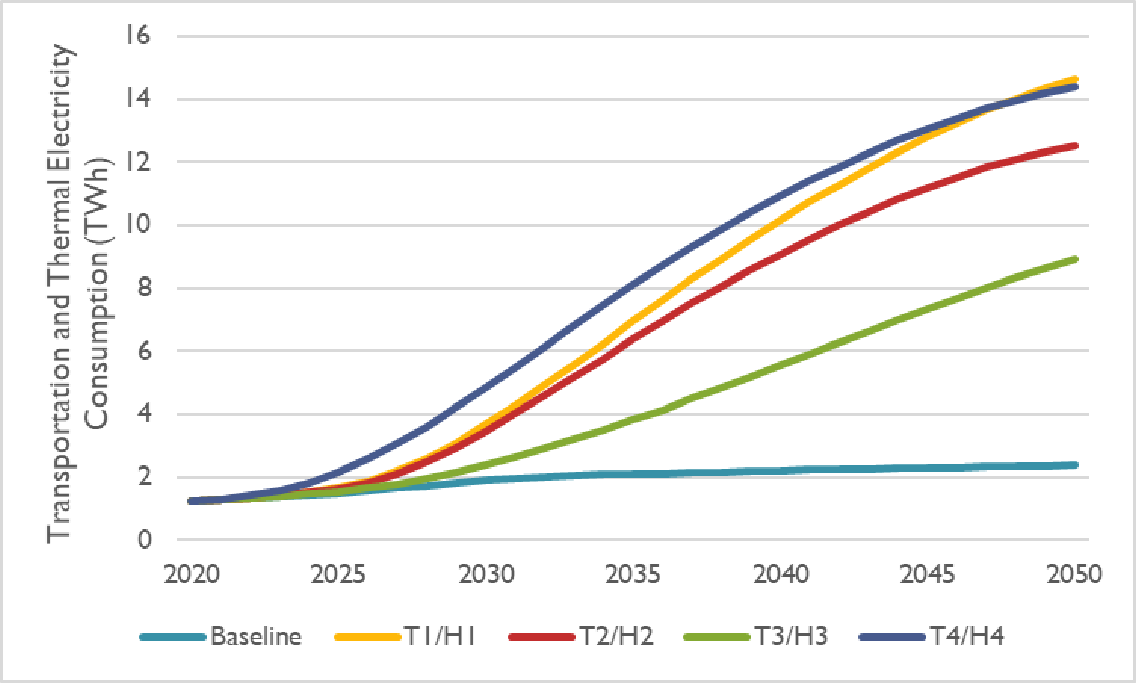
EV Charging Electricity Consumption



Space and Water Heating Electricity Consumption



Electric Sector: Scenarios Analyzed



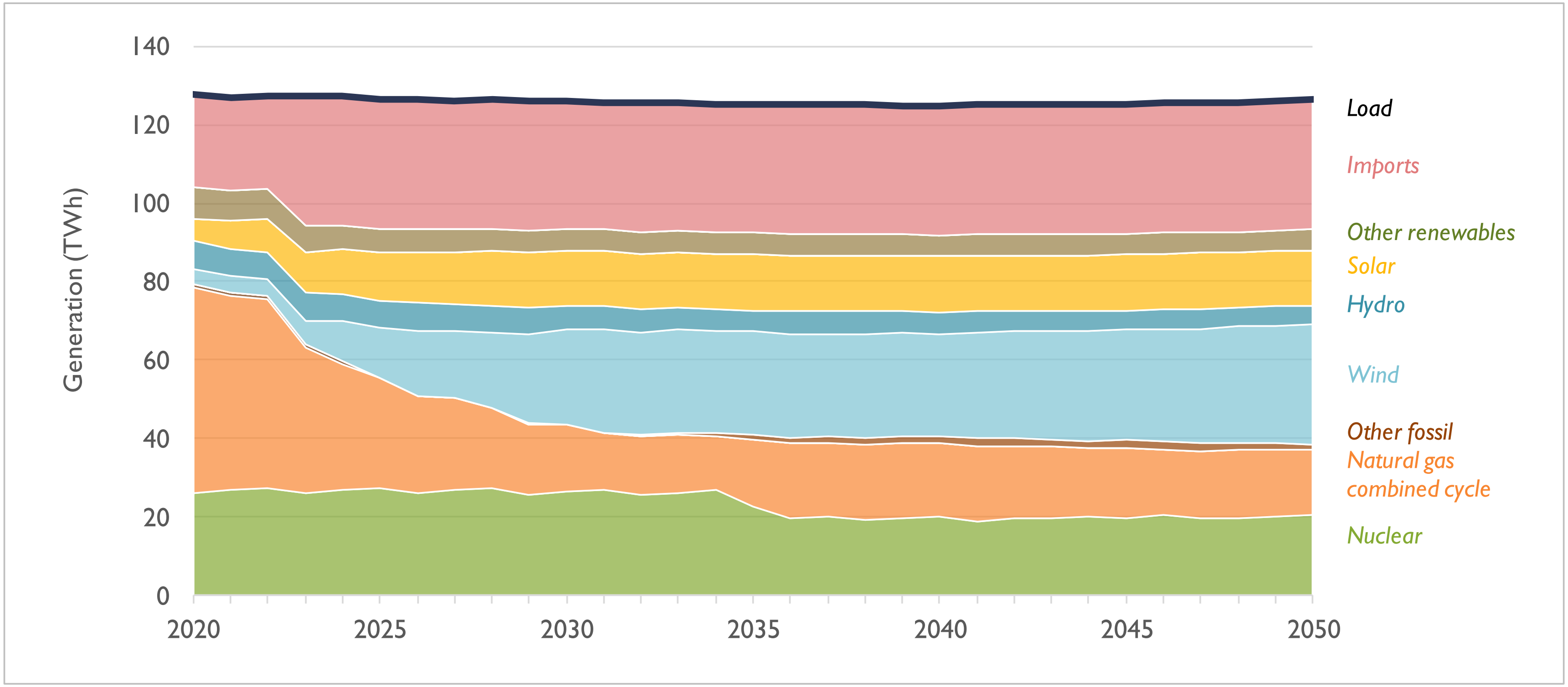
- Project timing did not allow for an update of the electric sector modeling with T4 and H4 load impacts.
- T4/H4 scenarios result in 1.16 TWh of electricity load above the T1/H1 scenarios in 2030
- This represents about 10% of Maine's 2019 total electricity consumption and 1% of New England electricity demand
- Limited impact on electric sector emissions given Maine's 80% by 2030 RPS

Electric Sector: Scenarios Analyzed

Baseline (EB)	E1
Continued Policies	**Decarbonization**
• TB load profile • HB load profile • 80% RPS in Maine by 2030 • EE in New England maintained at 1.5 – 2% per year through 2050, including AC efficiency • Nuclear units remain • NECEC built	• T1 load profile • H1 load profile • 100% RPS in Maine by 2050 (Class 1 increases by +2% per year from 2031 to 2040) • EE in New England maintained at 1.5 – 2% per year through 2050, including AC efficiency • Nuclear units remain • NECEC built

Electric Sector – Sustained Policy

Electric dispatch: sustained policy baseline (EB)



- The graph above displays the "sustained policy" baseline load and generation by resource from 2020 to 2050 for the New England electric grid.
- Millstone nuclear unit 2 goes offline at the end of 2035, but Millstone unit 3 remains online through the study period.
- "Other renewables" includes biomass, municipal solid waste, demand response, landfill gas, and other miscellaneous resources. "Other fossil" includes coal, gas turbines, steam turbines, and fuel cells.
- Imports are from New York, Quebec, and New Brunswick.

Electric dispatch detail – sustained policy (New England)

Generation and load (TWh)	2020	2030	2050
Imports	23.6	32.3	33.0
Other	7.8	5.5	5.4
Wind	4.0	24.2	30.7
Solar	5.8	14.3	14.2
Other fossil	1.1	0.1	1.4
Natural gas CCs	52.5	17.1	16.8
Hydro	7.0	6.1	4.7
Nuclear	25.8	26.3	20.3
Total Supply	127.6	125.9	126.3
Demand	127.6	125.9	126.3

Peak capacity and demand (GW)	2020	2030	2050
Imports	-	-	-
Other	1.8	1.7	2.8
Wind	1.4	6.5	8.1
Solar	4.6	10.2	10.5
Other fossil	8.9	6.9	4.0
Natural gas CCs	14.6	9.1	4.5
Hydro	3.4	3.5	3.2
Nuclear	3.3	3.3	2.5
Total Capacity	38.2	41.4	35.5
Demand	25.7	25.0	24.7

- Baseline loads are relatively flat through the full study period, as increasing levels of EE offset electrification.
- Wind and solar make up less than 8 percent of generation in 2020, but over 35 percent of generation by 2050.
- Natural gas CC generation declines steadily in the near-term and is replaced by renewables and imports.

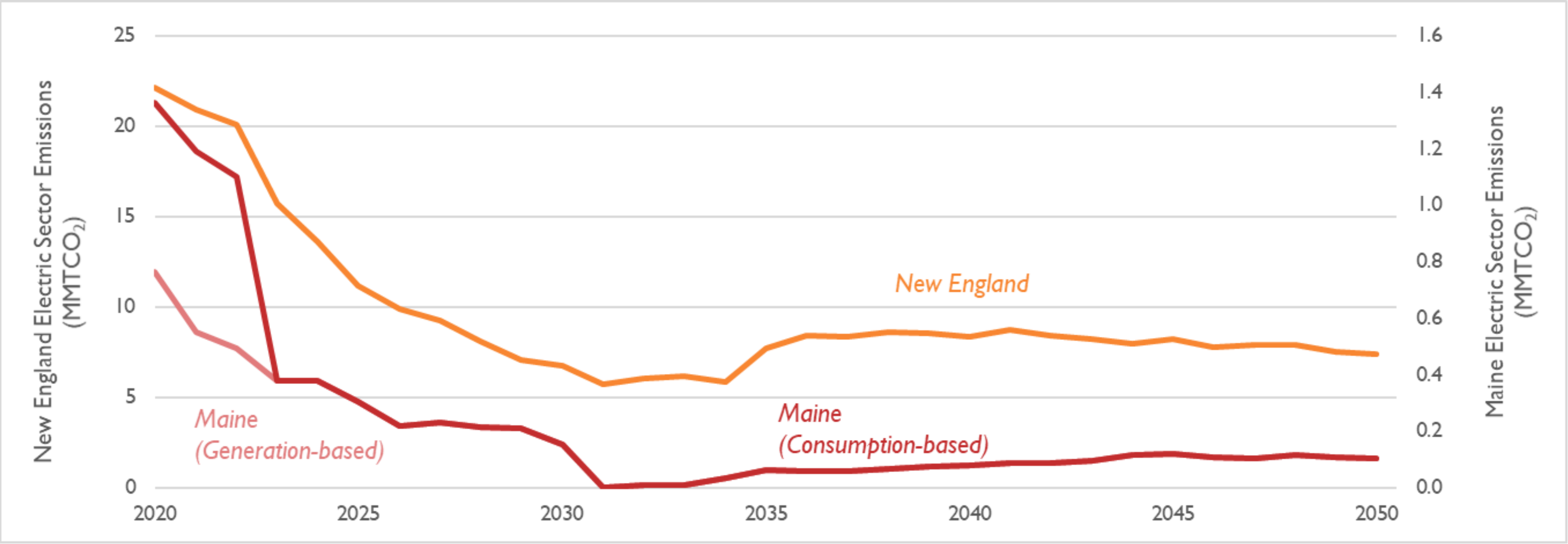
Electric dispatch detail – sustained policy (Maine)

Generation and load (TWh)	2020	2030	2050
Imports	-	-	-
Other	2.1	1.6	1.6
Wind	2.4	2.9	6.2
Solar	0.2	2.5	2.4
Other fossil	0.0	0.0	0.2
Natural gas CCs	1.7	0.3	0.0
Hydro	3.5	3.5	3.0
Nuclear	0.0	0.0	0.0
Total Supply	9.9	10.9	13.5
Demand	12.9	13.8	15.6

Peak capacity and demand (GW)	2020	2030	2050
Imports	-	-	-
Other	0.5	0.3	0.5
Wind	0.9	1.0	1.8
Solar	0.1	1.5	1.6
Other fossil	1.0	1.0	0.8
Natural gas CCs	1.4	0.7	0.0
Hydro	0.7	0.8	0.7
Nuclear	0.0	0.0	0.0
Total Capacity	4.7	5.5	5.4
Demand	2.1	2.3	2.6

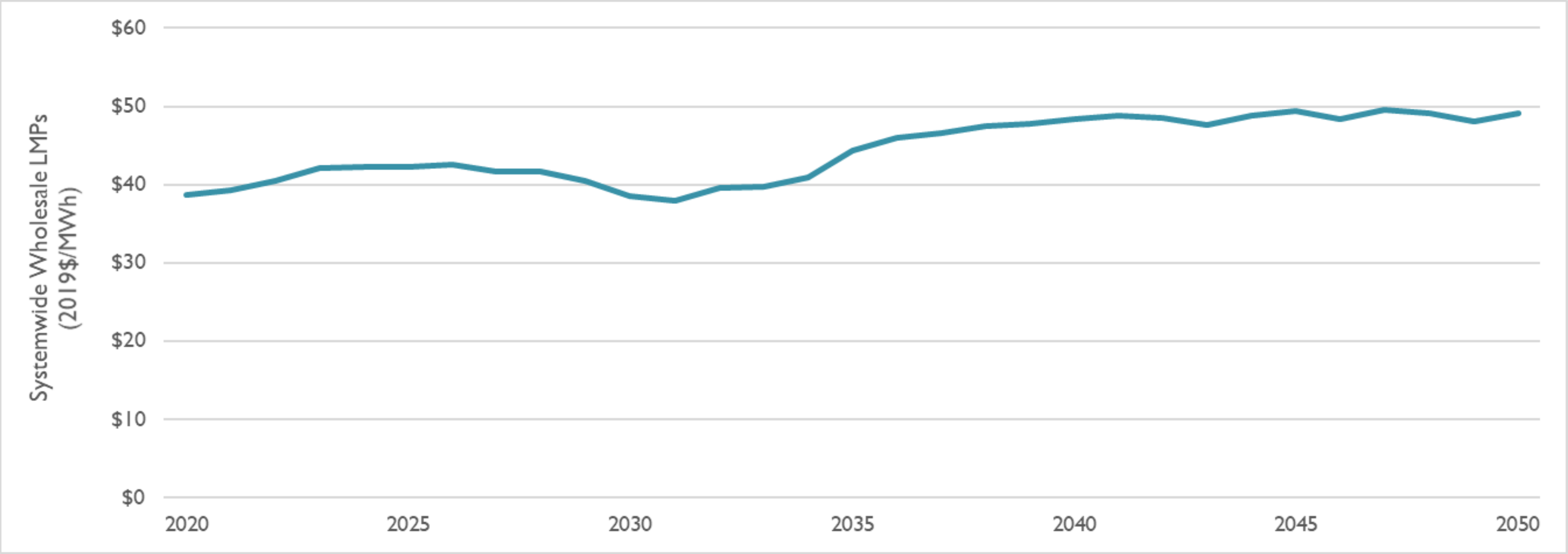
- Maine makes up 8 percent of in-region generation in 2020 and 11 percent of in-region generation in 2050.
- Maine makes up 10 percent of in-region electricity demand (TWh) in 2020 and 12 percent of in-region electricity demand in 2050.
- Between 2020 and 2050, Maine's peak demand increases by 24%.
  - Maine sees 2.4 GW of additions and 1.7 GW of retirements
  - Net 700 MW of additions
- Solar represents distributed generation (DG) and non-DG resources.
  - In 2020, 60 MW is DG and 25 is non-DG
  - In 2050, 730 MW is DG and 860 MW is non-DG

Electric sector emissions: sustained policy



- In the baseline, emissions from Maine generation make up 3 percent of regional emissions in 2020 and only 1 percent of regional emissions in 2050.
- Decrease in emissions throughout the study period is tied to the decrease in natural gas combined cycle generation, driven by plant retirements, flat loads, and increasing renewables, most notably wind.
- "Maine (Generation-based)" are only the emissions from generators located in Maine, whereas "Maine (Consumption-based)" are the emissions from generators located in Maine plus emissions associated with non-renewable electricity imports into the state.

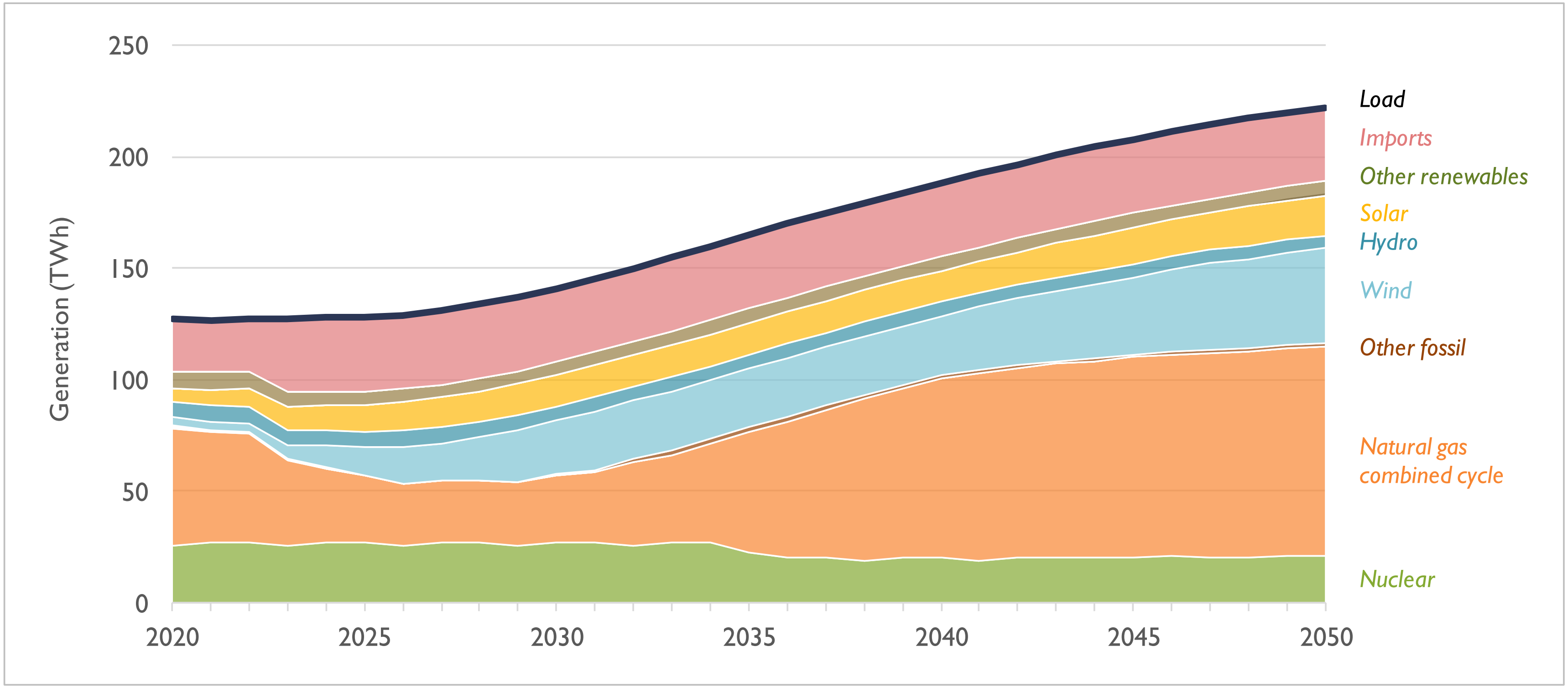
Wholesale energy prices NE: sustained policy



- In the baseline, systemwide locational marginal prices (LMPs) remain relatively flat through the mid-2030s (in real terms), then increase from around $40/MWh to almost $50/MWh by 2050.
- Wholesale energy prices have two main underlying drivers:
  - Natural gas prices—our long-term projections are based on the Reference Case from Annual Energy Outlook 2020
  - RGGI prices—ours are an extrapolation of RGGI Inc.'s through the mid-2030s, and assumes that VA joins RGGI

Electric Sector – Decarbonization Policy

Electric dispatch: decarbonization policy (E1)



- The graph above displays the decarbonization policy case load and generation by resource from 2020 to 2050 for the New England electric grid.
- Millstone nuclear unit 2 goes offline at the end of 2035, but Millstone unit 3 remains online through the study period.
- "Other renewables" includes biomass, municipal solid waste, demand response, landfill gas, and other miscellaneous resources. "Other fossil" includes coal, gas turbines, steam turbines, and fuel cells.
- Imports are from New York, Quebec, and New Brunswick.

Electric dispatch detail – decarbonization policy (New England)

Generation and load (TWh)	2020	2030	2050
Imports	23.6	32.9	32.9
Other	7.8	5.6	6.3
Wind	4.0	24.2	43.1
Solar	5.8	14.3	19.4
Other fossil	1.1	0.4	1.1
Natural gas CCs	52.5	30.6	94.2
Hydro	7.0	6.4	5.7
Nuclear	25.8	26.6	20.8
Battery	-	-	-1.3
Total Supply	127.6	141.1	222.3
Demand	127.6	141.1	222.3

Peak capacity and demand (GW)	2020	2030	2050
Imports	-	-	-
Other	1.9	1.8	12.6
Wind	1.4	6.5	11.4
Solar	4.6	10.2	14.3
Other fossil	8.9	6.9	4.0
Natural gas CCs	14.6	9.4	23.4
Hydro	3.4	3.5	3.2
Nuclear	3.3	3.3	2.5
Total Capacity	38.2	41.6	71.3
Demand	25.7	25.6	49.8

- Policy case loads increase throughout the study period as a result of thermal and transportation electrification.
- Wind and solar make up less than 8 percent of generation in 2020, but 28 percent of generation by 2050.
- Millstone 2 nuclear plant retirement in late 2030s coupled with a plateau in RPS increases and increasing loads produce resurgent generation from natural gas.

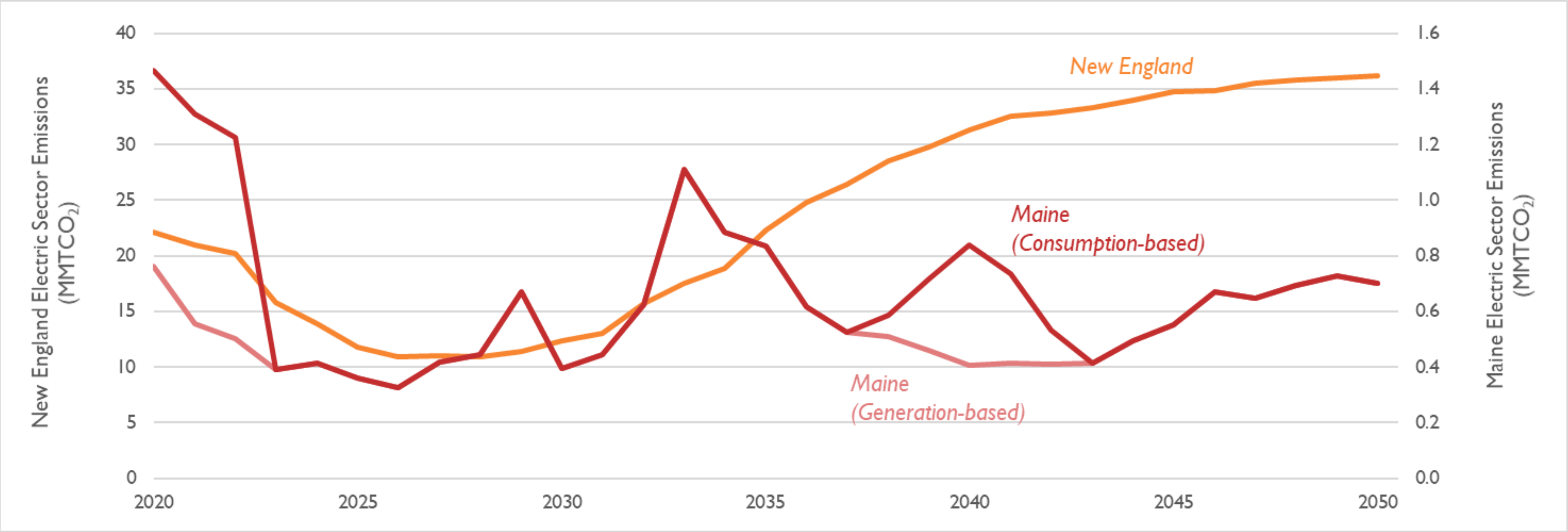
Electric dispatch detail – decarbonization policy (Maine)

Generation and load (TWh)	2020	2030	2050
Imports	-	-	-
Other	2.1	1.6	1.6
Wind	2.4	2.9	17.7
Solar	0.2	2.5	3.2
Other fossil	0.0	0.0	0.2
Natural gas CCs	1.7	0.9	1.3
Hydro	3.5	3.7	3.1
Nuclear	0.0	0.0	0.0
Battery	-	-	-0.2
Total Supply	9.9	11.6	26.9
Demand	12.9	15.6	28.6

Peak capacity and demand (GW)	2020	2030	2050
Imports	-	-	-
Other	0.5	0.4	2.1
Wind	0.9	1.0	4.8
Solar	0.1	1.5	2.1
Other fossil	1.0	1.0	0.8
Natural gas CCs	1.4	0.7	0.5
Hydro	0.7	0.8	0.7
Nuclear	0.0	0.0	0.0
Total Capacity	4.7	5.5	11.1
Demand	2.1	2.7	6.5

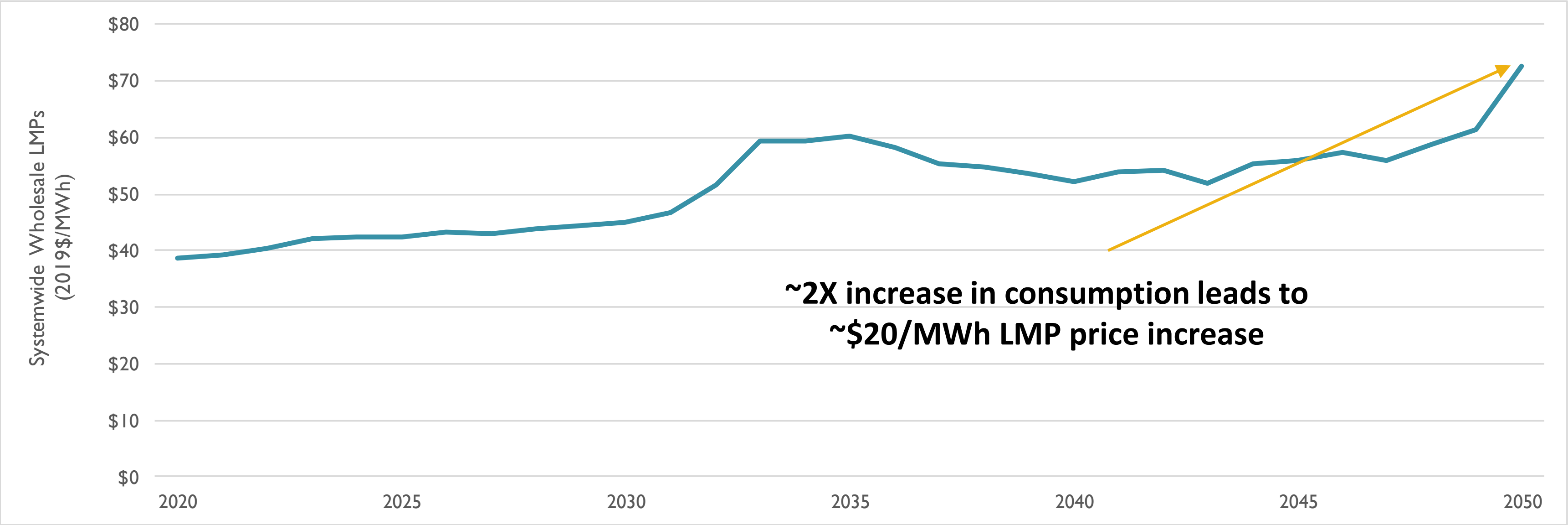
- Maine makes up 8 percent of in-region generation in 2020 and 12 percent of in-region generation in 2050.
- Maine makes up 10 percent of in-region electricity demand (TWh) in 2020 and 13 percent of in-region electricity demand in 2050.
- Between 2020 and 2050, Maine's peak demand increases by nearly 4.4 GW.
  - Maine sees 7.6 GW of additions and 1.2 GW of retirements
  - Net 6.4 MW of additions
- Solar represents distributed generation (DG) and non-DG resources.
  - In 2020, 60 MW is DG and 25 MW is non-DG
  - In 2050, 730 MW is DG and 1,400 MW is non-DG

Electric sector emissions: decarbonization policy



- In the policy case, emissions from Maine generation make up 3 percent of regional emissions in 2020 but only 2 percent of regional emissions in 2050.
- The other New England states are assumed to have similar levels of electrification without comparable RPS policies; therefore, New England emissions increase significantly after 2030 as electrification ramps up.
- “Maine (Generation-based)” are only the emissions from generators located in Maine, whereas “Maine (Consumption-based)” are the emissions from generators located in Maine plus emissions associated with non-renewable electricity imports into the state.

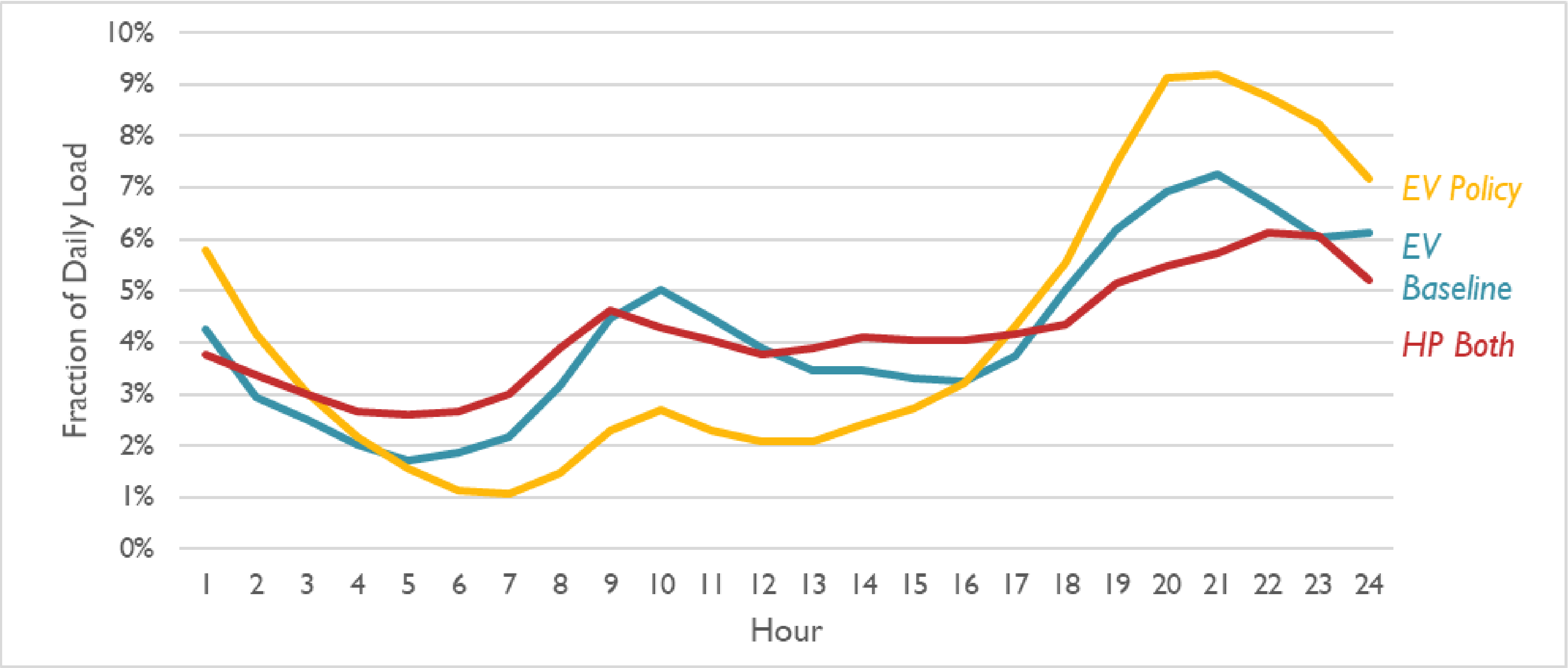
Wholesale energy prices NE: decarbonization policy



- In the policy case, systemwide locational marginal prices (LMPs) increase rapidly in the mid-2030s (in real terms) in response to nuclear retirements, then stabilize through the early and mid-2040s before increasing to over $70/MWh by 2050.
- Wholesale energy prices have two main underlying drivers:
  - Natural gas prices—our long-term projections are based on the Reference Case from Annual Energy Outlook 2020
  - RGGI prices—ours are an extrapolation of RGGI Inc.'s through the mid-2030s, and assumes that VA joins RGGI

Electric Sector Summary

Heat Pump and EV Load Shapes



- The graph above displays normalized daily load profiles for Maine EVs and heat pumps for April.
- We use a different load shape for each season.
- Each state gets its own load shape.

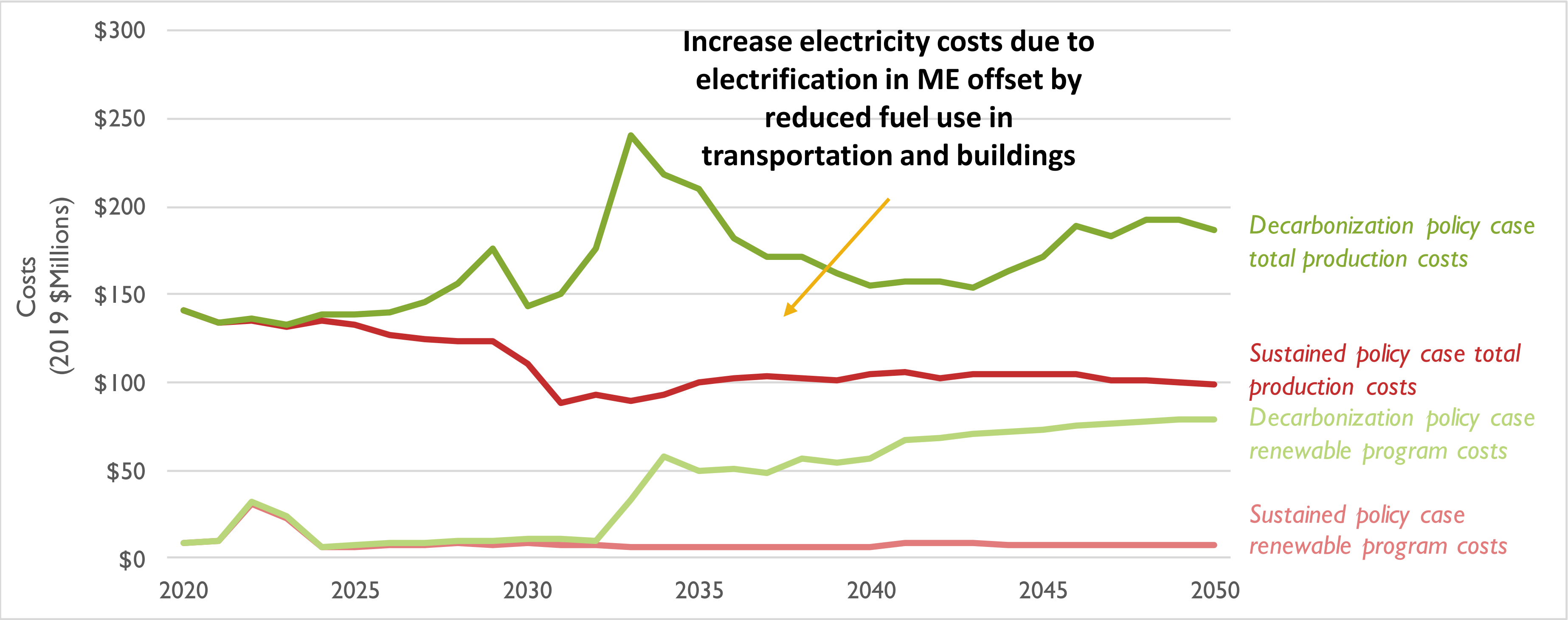
Maine Summary – 2030

Resource/Emission	2020	Sustained Policy Baseline	Decarbonization Policy
Wind (TWh)	2.4	2.9	2.9
Wind (MW)	880	1,037	1,037
Solar (TWh)	0.2	2.5	2.5
Solar DG (MW)	59	614	614
Solar non-DG (MW)	26	857	857
Storage (MW)	16	16	16
DR (MW)	102	125	125
Generation-based GHG Emissions ($MMTCO_2$)	0.8	0.2	0.4

Maine Summary – 2050

Resource/Emission	2020	Sustained Policy Baseline	Decarbonization Policy
Wind (TWh)	2.4	6.2	17.7
Wind (MW)	880	1,820	4,840
Solar (TWh)	0.2	2.4	3.2
Solar DG (MW)	59	733	733
Solar non-DG (MW)	26	857	1,382
Storage (MW)	16	16	1,644
DR (MW)	102	125	125
Generation-based GHG Emissions (MMTCO$_2$)	0.8	0.1	0.7

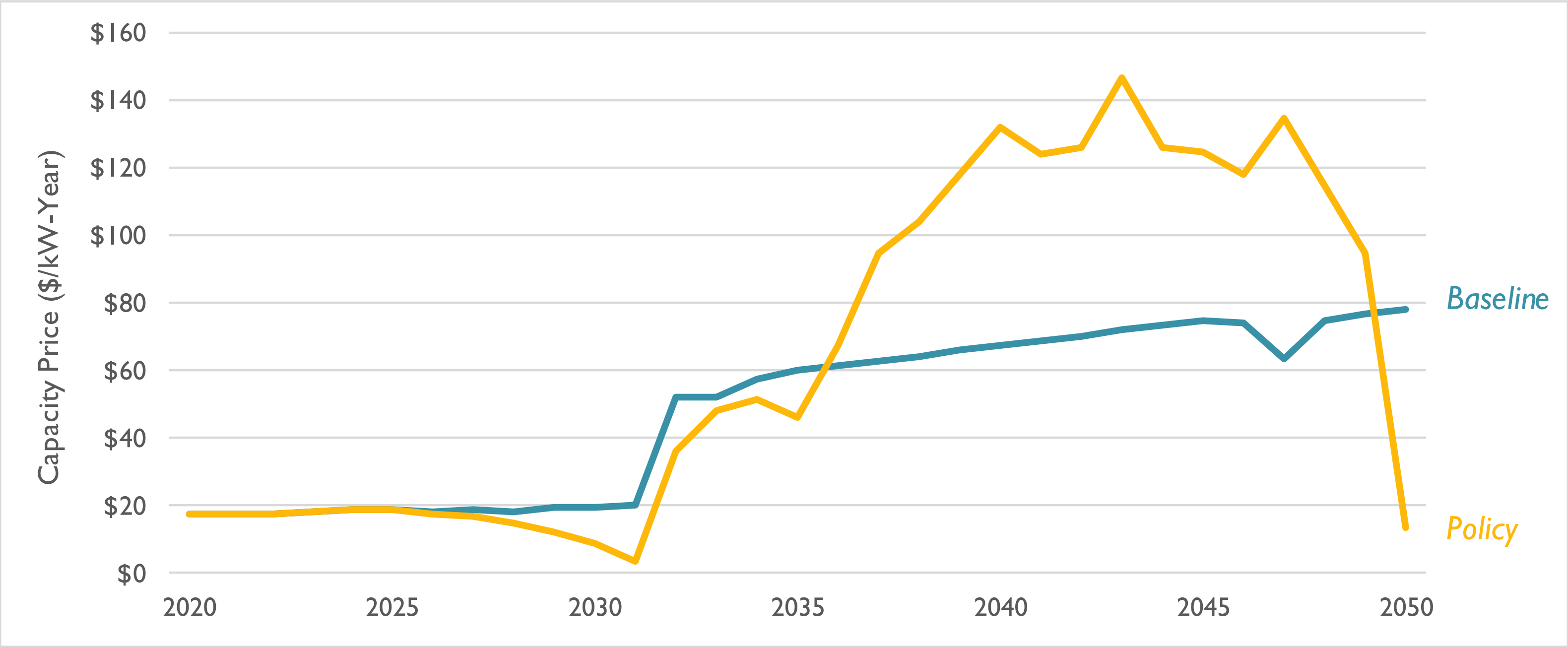
Total Production and Renewables Costs (Maine)



- The graph above displays 1) the total annual production costs for both the decarbonization and the sustained policy cases, and 2) the total annual renewable program costs for both cases.
- The difference in costs between the two cases becomes larger after 2030, when electrification and renewable builds increase.

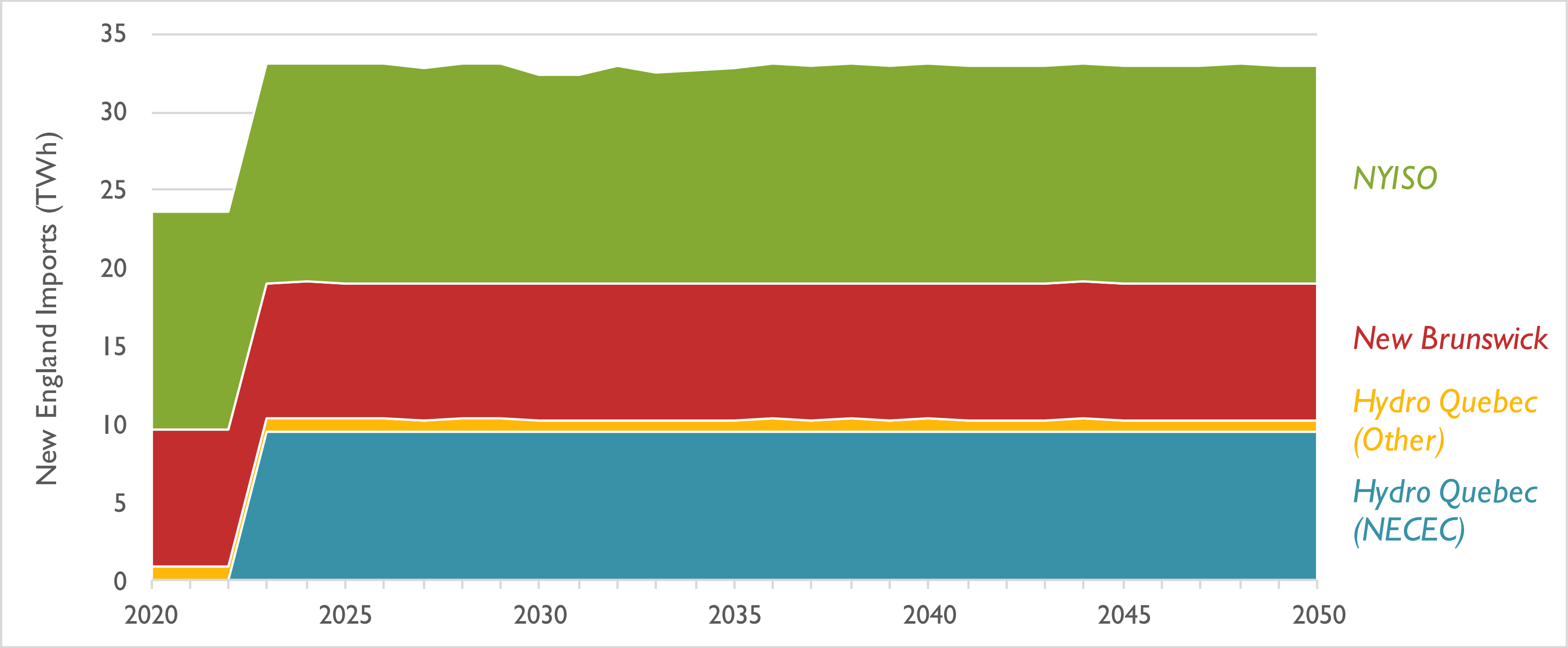
Electric Sector Supplemental Results

Maine Capacity Prices ($/kW-Year)

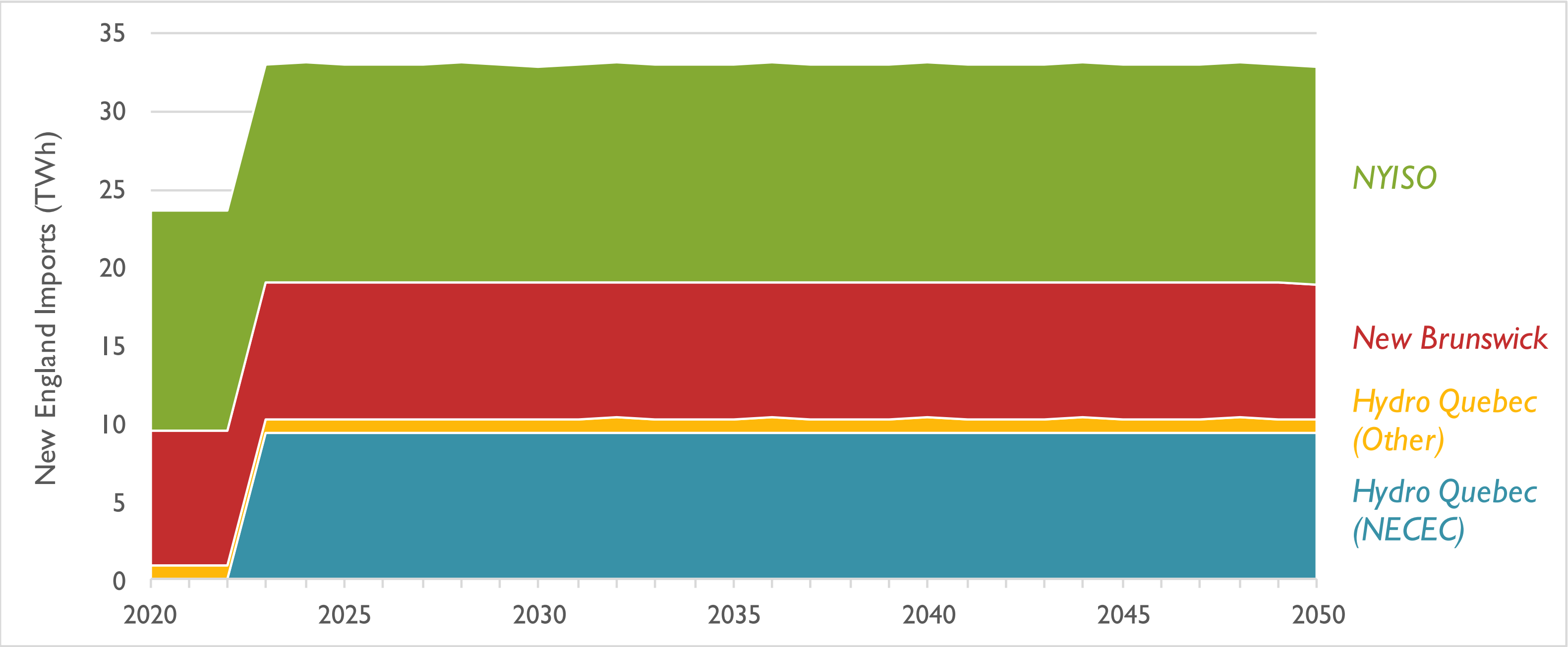


- In the sustained policy scenario, capacity prices remain relatively stable before 2030, and then increase as existing units retire and new capacity is needed to meet demand.
- In the decarbonization policy scenario, the capacity prices increase significantly after 2030 in response to increasing demand. Capacity prices decrease towards the end of the study period as enough new capacity is built to meet demand.

New England Imports– Sustained Policy Scenario (TWh)



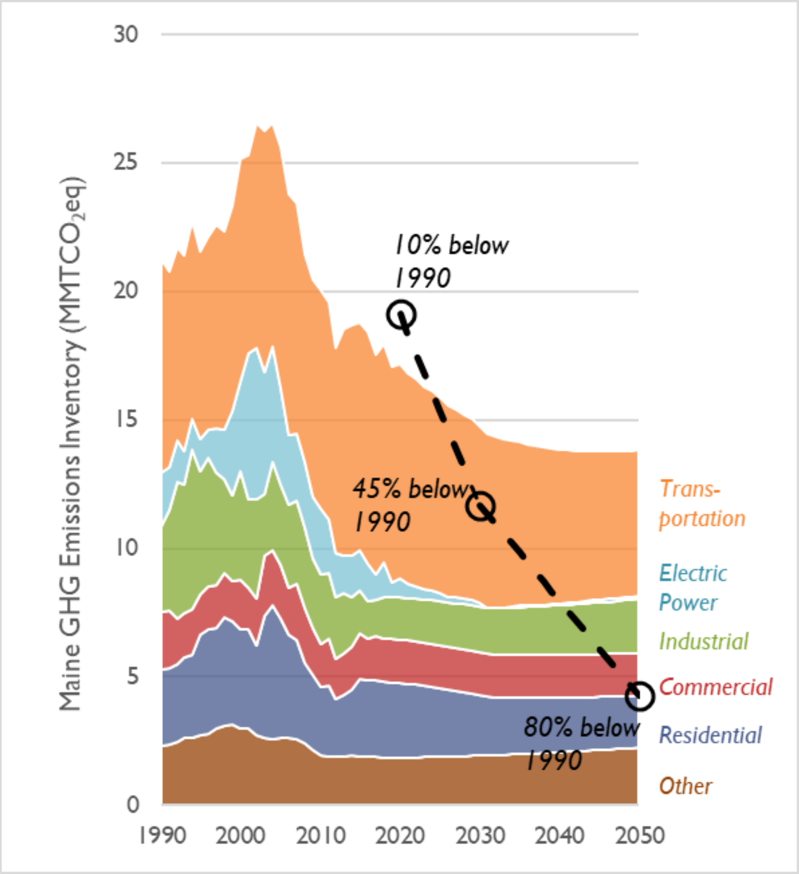
New England Imports – Decarbonization Policy Scenario (TWh)



- The level of imports into New England are very similar between the sustained policy and decarbonization policy scenarios.

Economy-wide emissions

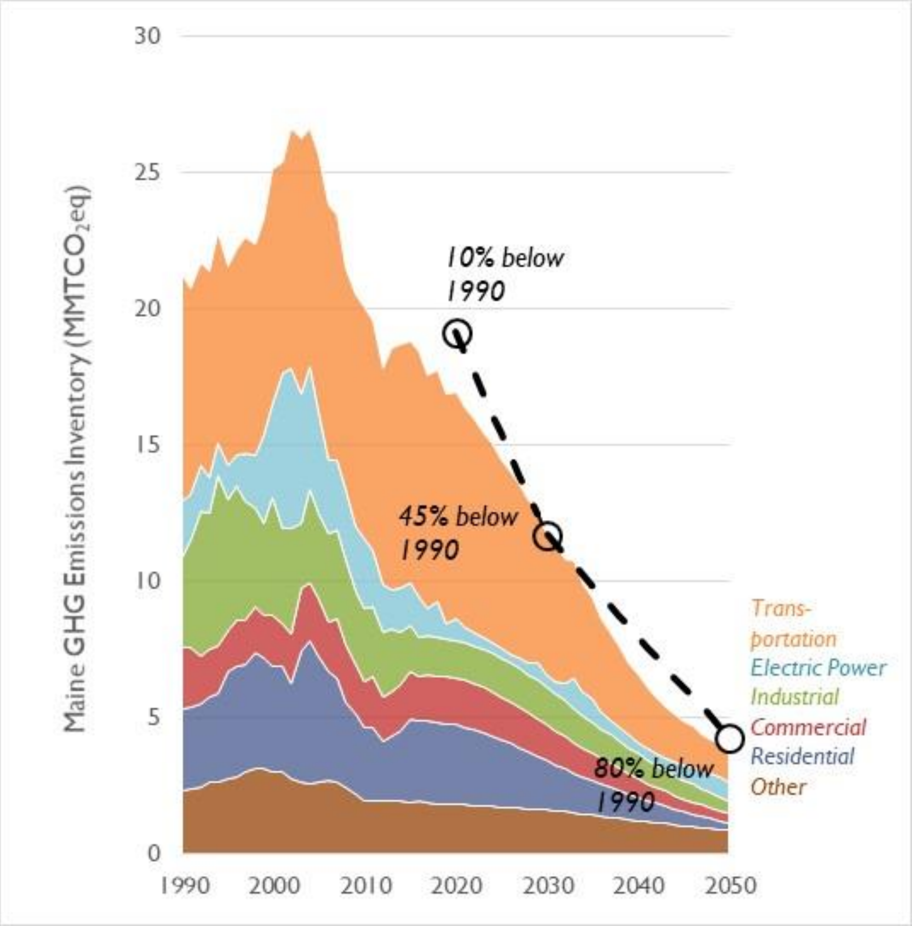
Sustained policy baseline emissions—Maine



Notes: "Other" includes emissions from industrial process, agriculture, waste, and non-CO_2 emissions from energy. Emissions from industrial, industrial processes, and agriculture, projected based on a 2013-2017 CAGR. Non-CO_2 emissions from energy projected based on the historical ratio of these emissions to CO_2.

- Emissions are projected to decline through 2030 and then flatten out in later years
- Total emissions in 2050 are 13.8 million metric tons, which is 9.6 million metric tons above the 2050 target
- The transportation sector continues to be the largest source of emissions in the state through 2050
  - In 2050, transportation accounts for 41% of emissions

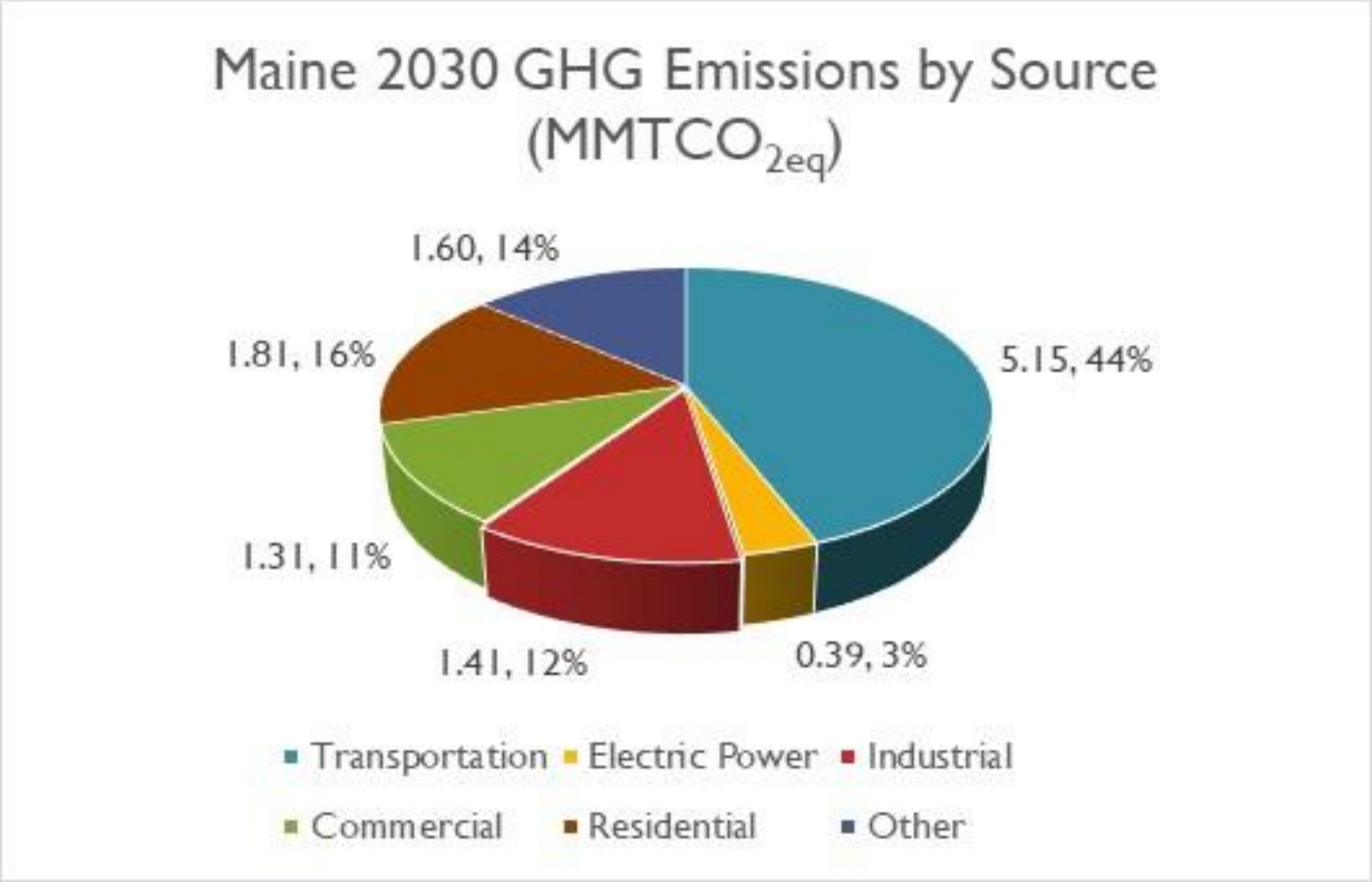
Decarbonization 2030 policy emissions—Maine



Notes: "Other" includes emissions from industrial process, agriculture, waste, and non-CO_2 emissions from energy. Emissions from industrial, industrial processes, and agriculture, projected based on a 2013-2017 CAGR. Non-CO_2 emissions from energy projected based on the historical ratio of these emissions to CO_2.

- Emissions are projected to decline through 2050
- Total emissions in 2030 are 11.67 million metric tons, just equal to the target of 45% below 1990 levels
- Total emissions in 2050 are 3.72 million metric tons, or 82% below 1990 levels

Decarbonization 2030 policy emissions—Maine (cont.)



Notes: "Other" includes emissions from industrial process, agriculture, waste, and non-CO_2 emissions from energy. Emissions from industrial, industrial processes, and agriculture, projected based on a 2013-2017 CAGR. Non-CO_2 emissions from energy projected based on the historical ratio of these emissions to CO_2.

Decarbonization 2030 policy emissions—Maine (cont.)

Sector	Metric	2025	2030	2050
Transportation	Number of Light-duty EVs on the Road	41,375	219,271	904,279
	EV Share of New Light-duty Vehicle Sales	28%	85%	100%
	Reduction in Light-duty VMT per Vehicle	10%	20%	20%
	ZEV Share of New Heavy-duty Vehicle Sales	12%	55%	100%
	Reduction in Heavy-duty VMT per Vehicle	2%	4%	4%
Buildings	Number of Households with Retrofit Heat Pumps (installed after 2018) and Legacy Fossil Systems	80,151	130,419	26,101
	Number of Households with Whole Home Heat Pump Systems	34,607	115,636	487,355
	Weatherized Households	20,000	40,000	80,000
All	GHG Emissions (MMT)	14.50	11.67	3.72
	Emissions Reduction from 1990 Levels	32%	45%	82%

