Massachusetts Comprehensive Energy Plan

Commonwealth and Regional Demand Analysis

Massachusetts Department of Energy Resources

December 12, 2018

DOER
Massachusetts Department of Energy Resources

Acknowledgments

On September 16, 2016 Governor Baker issued Executive Order No. 569, *Establishing an Integrated Climate Change Strategy for the Commonwealth*, which directed the Secretary of Energy and Environmental Affairs to publish a Comprehensive Energy Plan.

Massachusetts Secretary of Energy and Environmental Affairs (EEA) Matthew Beaton directed the Department of Energy Resources (DOER) to complete this Comprehensive Energy Plan. DOER was assisted by Synapse Energy Economics, Inc. and Sustainable Energy Advantage.

DOER Commissioner Judith Judson would like to acknowledge the following people for their assistance in the analysis of regional energy demand and drafting of this report.

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Executive Summary

Energy is connected to every aspect of the Commonwealth: we rely on energy to keep the lights on, power industry, heat our homes and meet our transportation needs. As the Massachusetts economy grows and technology evolves, the need for affordable and reliable energy is critical to support a strong and competitive economy benefiting residents, businesses and communities. The vast majority of greenhouse gas (GHG) emissions in the Commonwealth derive from the use of energy. Reducing GHG emissions from our energy supply is necessary to achieve our environmental goals and lead the way in the mitigation of climate change. These challenges present an opportunity to develop new, cleaner sources of energy, advance our energy efficiency and demand reduction programs, and leverage existing and new technologies to deliver this energy in smarter and more efficient ways. The objective of this Comprehensive Energy Plan (CEP) is to analyze potential scenarios going forward and to provide policy recommendations for achieving a clean, affordable, reliable energy future for the Commonwealth.

Energy Plan Overview

On September 16, 2016 Governor Baker issued Executive Order No. 569, *Establishing an Integrated Climate Change Strategy for the Commonwealth*, which directed the Secretary of Energy and Environmental Affairs (EEA) to publish a Comprehensive Energy Plan (CEP).[1] The CEP is part of a broader strategy to coordinate and make consistent new and existing efforts to mitigate and reduce greenhouse gas emissions and build climate change resilience. Specifically, the Executive Order requires that the CEP include and be based upon reasonable projections of the Commonwealth's energy demands for electricity, transportation, and thermal conditioning, and include strategies for meeting these demands in a regional context, prioritizing meeting energy demand through conservation, energy efficiency, and other demand-reduction resources in a manner that contributes to the Commonwealth meeting GHG emission limits.

The *Global Warming Solutions Act* (GWSA) requires GHG emissions be 80 percent below 1990 levels by 2050 In 2010, the Secretary of EEA set the 2020 emissions limit at 25 percent below 1990 levels and published the first Clean Energy and Climate Plan (CECP)[2], laying out measures necessary to meet this limit. In 2015, the CECP was updated. In 2020, a new CECP will be published setting a GHG emission limit for 2030 and outlining policies and strategies for achieving that limit. This CEP is designed to inform and complement the next iteration of the CECP as well as provide guidance to policy makers by examining the impacts of policies to reduce GHG emissions on cost and reliability.

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1 Executive Order No. 569., Establishing an Integrated Climate Change Strategy for the Commonwealth; https://www.mass.gov/executive-orders/no-569-establishing-an-integrated-climate-change-strategy-for-the-commonwealth

2 Massachusetts Clean Energy and Climate Plan for 2020; https://www.mass.gov/files/documents/2016/08/sk/2020-clean-energy-plan.pdf

In order to develop the CEP, the Secretary of EEA directed the Department of Energy Resources (DOER) to analyze the Commonwealth's energy use and supply in a regional context from now until 2030 under a variety of scenarios to determine optimal policies to achieve economic competitiveness and emission goals and maintain reliability.

Massachusetts Energy Policies

Under the Baker-Polito Administration, the Commonwealth has made tremendous strides towards increasing the amount of energy from clean and renewable sources and decreasing the demand for energy. According to the American Council for an Energy Efficient Economy (ACEEE), Massachusetts has been ranked the number one state in energy efficiency nationwide for eight consecutive years. In 2017, Massachusetts reduced annual consumption of electricity by 3.18 percent and natural gas by 1.20 percent, the highest of any state in the country. In August 2016, Governor Baker signed a landmark bipartisan energy bill to accelerate the Commonwealth's progress toward its clean energy goals. *An Act Relative to Energy Diversity* launched several important new clean energy initiatives, including authorizing the Commonwealth's largest procurements of both clean energy generation as well as offshore wind generation. In April 2016, Governor Baker signed solar legislation that has resulted in the creation of a new solar incentive program, Solar Massachusetts Renewable Target (SMART) that will support an additional 1600 MW of solar generation capacity in the Commonwealth at significantly reduced prices. To achieve additional emissions reductions, the Massachusetts Department of Environmental Protection (MassDEP) with EEA promulgated a Clean Energy Standard (CES) in 2017 and created emissions caps on power plants. Additionally, Massachusetts is a founding member of the Regional Greenhouse Gas Initiative (RGGI), a program that creates a cap-and-trade market for carbon emissions from power plants in member states. RGGI states have reduced power sector carbon dioxide (CO_2) pollution over 45 percent since 2005, while the region's per-capita GDP has continued to grow.

The Administration has fostered the development of innovative energy technologies through its Energy Storage Initiative (ESI) launched in May 2015 with $20 million provided to fund 26 advanced energy storage demonstration projects across the state. DOER set a 200 megawatt-hour (MWh) target for storage by January 1, 2020 and the Department of Public Utilities (DPU) has approved utility grid modernization and storage projects in recent rate cases and proceedings. To encourage consumers to purchase zero emission vehicles (ZEVs), such as electric vehicles (EVs), DOER has provided $20 million for its Massachusetts Offers Rebates for EVs (MOR-EV) program which provides consumers rebates to fund the purchase of EVs. In January 2018, Governor Baker signed Executive Order 579 establishing the Commission on the Future of Transportation. The Commission will explore anticipated changes in technology, climate, land use, and the economy to determine likely impacts on transportation between 2020 and 2040.

Massachusetts lawmakers continue to act through legislation, and at the end of the formal legislative session in 2018, the legislature passed and the Governor signed *An Act to Advance Clean Energy*, a bill setting forth several new clean energy initiatives. The bill increases the amount of electricity required to be supplied with renewable energy credits by increasing the Renewable Portfolio Standard (RPS), sets an energy storage target of 1,000 MWh by December 31, 2025, and establishes a first-of-its-kind Clean

Peak Energy Standard (CPS) to incentivize the utilization of clean energy during times of peak demand when our energy system is most strained, operating at its highest cost and emitting the most GHGs. These existing policies continue to reduce the Commonwealth's greenhouse gas emissions.

Massachusetts Energy Landscape

Massachusetts's energy demand was 1,074 trillion BTUs in 2016.[3] This demand derives from three sectors: electric, transportation, and thermal.[4] The electric sector is the smallest sector in terms of energy demand (17 percent) with transportation being the largest (44 percent). All three sectors are supplied by a majority of fossil fuel with either natural gas or motor gasoline being the dominant fuels. Renewable energy is most prominent in the electric sector.

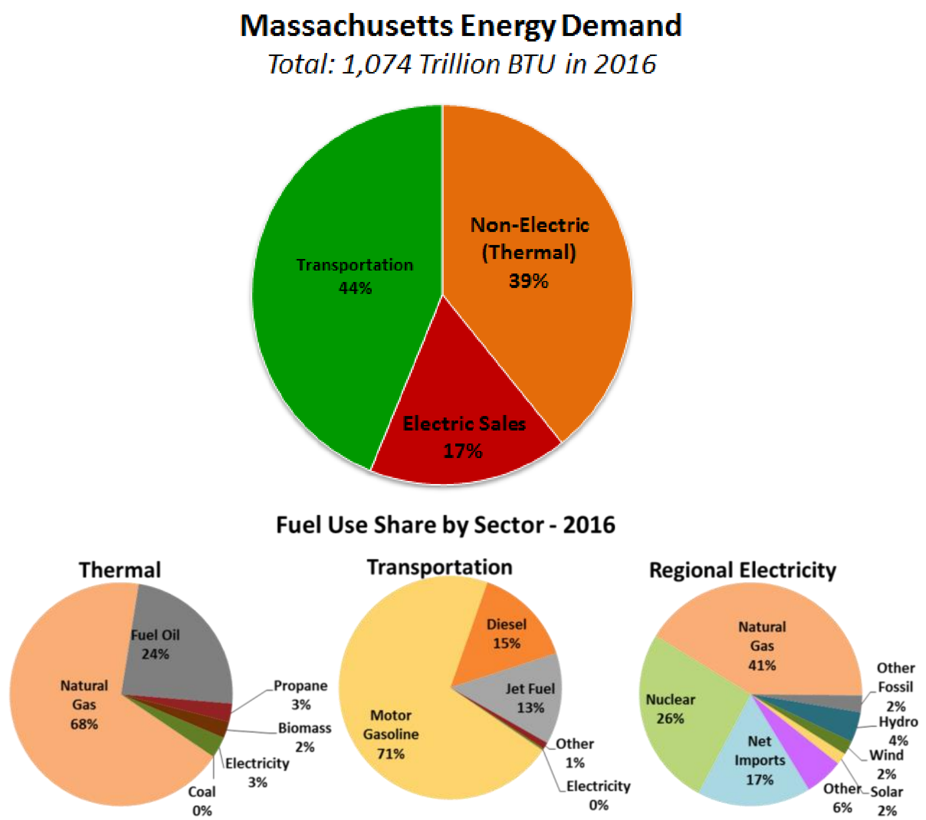

Figure 1: Massachusetts Energy Demand and Fuel Mix by Sector - 2016[5]

Electric generation is our smallest use of energy in the Commonwealth, but it is where the greatest progress in reducing emissions has been made. Figure 2 shows the impact on emissions over time from the three sectors.

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3 Not including electric sector losses that are needed to supply demand. These losses are accounted for in state emissions.

4 Thermal demand data shown here also includes all non-electric fuel use such as industrial processes.

5 Data compiled from EIA and ISO-NE. Electric sector is presented for all of New England.

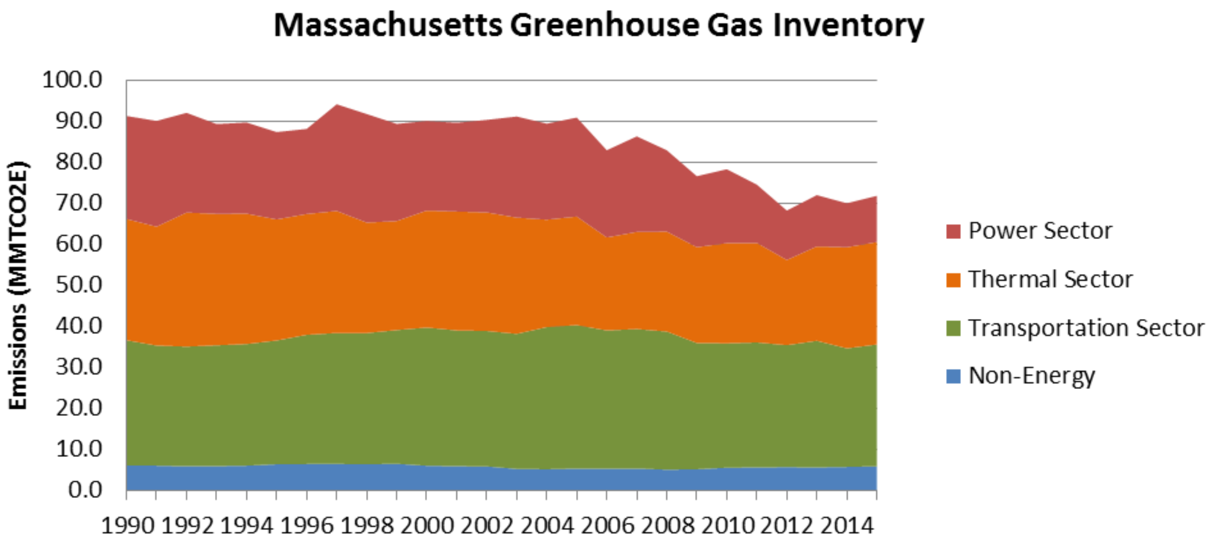

Figure 2: Massachusetts Greenhouse Gas Inventory

Massachusetts Energy Challenges

Despite the progress we are making towards our energy goals, particularly in the electric sector, there are currently challenges to achieving clean, affordable, and reliable energy for consumers. Massachusetts ratepayers pay one of the highest rates in the country for electricity. The average retail residential electric rate was 18.92 cents/kWh in 2017. For all sectors including commercial and industrial, Massachusetts was the seventh highest cost state in the country for electric rates. High electric rates create challenges for businesses in the Commonwealth to be competitive with businesses in other states and for residents, particularly lower income households, to afford their utility bills. Regionally, the rates paid in the six New England states are in the top eleven most expensive electric rates in the country (Figure 3).

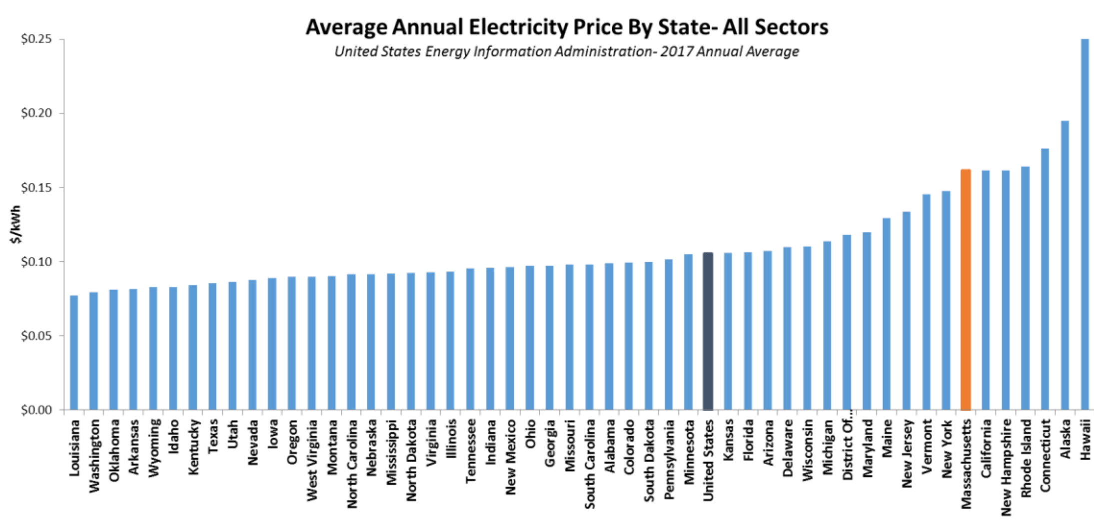

Figure 3: State Retail Electricity Rates

Reliability and affordability during winter continue to challenge the region. In the winter, demand for natural gas to heat our buildings and generate electricity exceeds the amount of natural gas that the existing pipeline infrastructure can deliver into the region. This causes wholesale energy costs to spike and the generators within the Independent System Operator of New England (ISO New England or ISO-NE) control area, to rely on liquefied natural gas (LNG) and carbon-intensive fuel oil to generate electricity to maintain electric reliability. Last winter when natural gas supplies were constrained, the region nearly depleted its allowed oil reserves for generation, putting the grid at a reliability risk.[6] As the cold snap continued and fuel supplies decreased, the wholesale electricity daily average price spiked to $288/MWh (or 28.8 cents/kWh) from its annual average of $34/MWh (or 3.4 cents per kWh).(Figure 4)

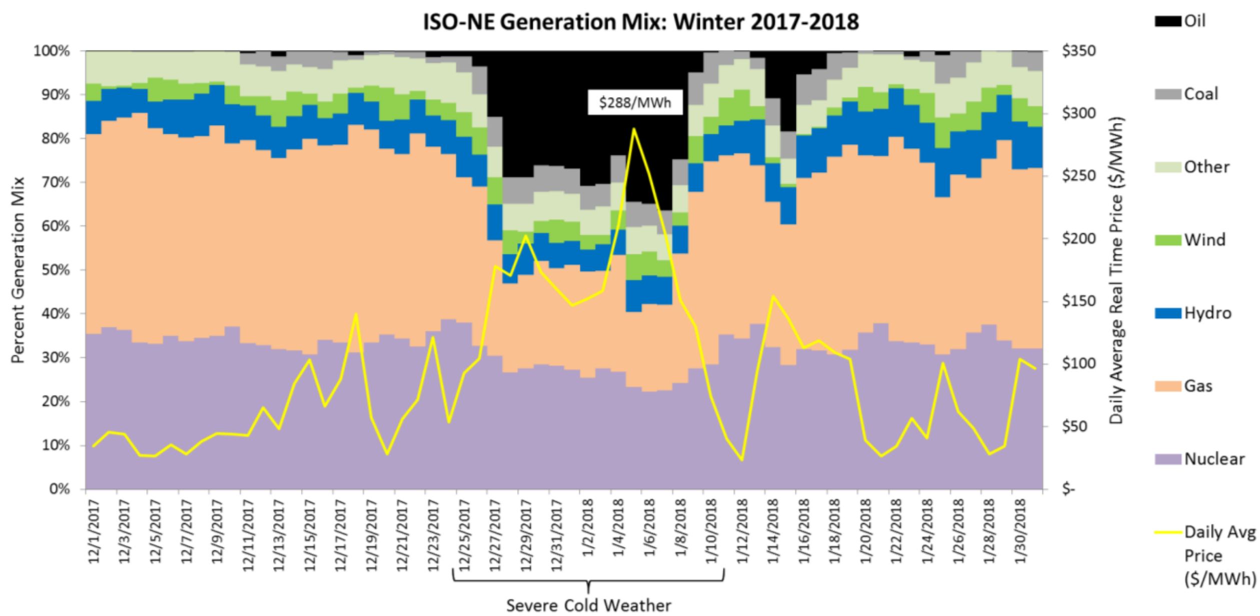

Figure 4: ISO-NE Generation Mix During Winter 2017-2018

Oil has a higher CO_2 content than natural gas resulting in more CO_2 released when burned, 161.3 versus 117.0 pounds of CO_2/BTU.[7] During the severe cold weather event of 2017-2018, daily electricity generation emissions in New England nearly tripled from 80,000 metric tons to 225,000 metric tons of CO_2.[8] The increase was due not only to the increase in electric energy consumption associated with the cold weather but also the shift from lower emissions natural gas to higher emissions oil for electric generation.

Many factors have contributed to emission reductions in the electric sector while other sectors have faced more challenges. The electric sector is highly regulated, making it easier for policymakers to

6 ISO-NE, Post Winter 2017/18 Review; https://www.iso-ne.com/static-assets/documents/2018/04/a3_2017_2018_isone_post_winter_review.pdf

7 EIA, Frequently Asked Questions, https://www.eia.gov/tools/faqs/faq.php?id=73&t=11

8 ISO-NE Post Winter 2017/18 Review: Electric/Gas Operations Committee 5/11/2018; slide 22.
https://www.iso-ne.com/static-assets/documents/2018/05/2018-05-11-egoc-a2.1-iso-ne-post-winter-1718-review.pdf

implement changes in this sector while the transportation sector is less centralized and primarily dependent on consumer choices. The transportation sector remains highly dependent on fossil fuel to power vehicles and emissions from this sector have remained relatively similar to 1990 levels. (Figure 2)

The thermal sector has seen a small reduction in emissions from 1990 levels, despite increased growth in building square footage, primarily due to the Commonwealth's effective energy efficiency programs. However, similar to the transportation sector, progress in reducing emissions in the thermal sector is limited by the lifetime use of equipment and consumer choices when assets or building envelopes are replaced or improved. Heating equipment has long useful lives, and frequently equipment is not replaced until the point of failure during times of emergency or need, limiting the consumer's ability to consider alternatives for replacement. Consumer education on the value of heating choices and efficiency improvements will be key to the deployment of cleaner and more efficient types of heating. Similarly, buildings are long-term assets and choices made in building construction today, have impacts that easily last 20, 30 or even 50 or more years.

Energy Plan Methodology

The CEP modeled various future assumptions for the way we will generate and consume energy across the power, thermal, and transportation sectors between now and 2030 to determine the impact on the amount of emissions we produce, the reliability of our system, and consumers' cost of energy. The modeling was performed using average weather conditions and then a complementary extended cold weather analysis was completed to understand the impacts when our energy system is stressed.

Scenarios and Assumptions

The CEP contains five modeling runs representing a spectrum of possible energy futures and assumptions. The scenarios measure the impact of different energy drivers, assuming that full policy outcomes are achieved, with the results dependent on the chosen assumptions. These runs therefore do not reflect the relative *difficultly* in implementing each of these assumptions and do not represent policy plans. Instead, the results show the relative *impact* of different policy outcomes to help policy makers determine the relative importance of policy priorities.

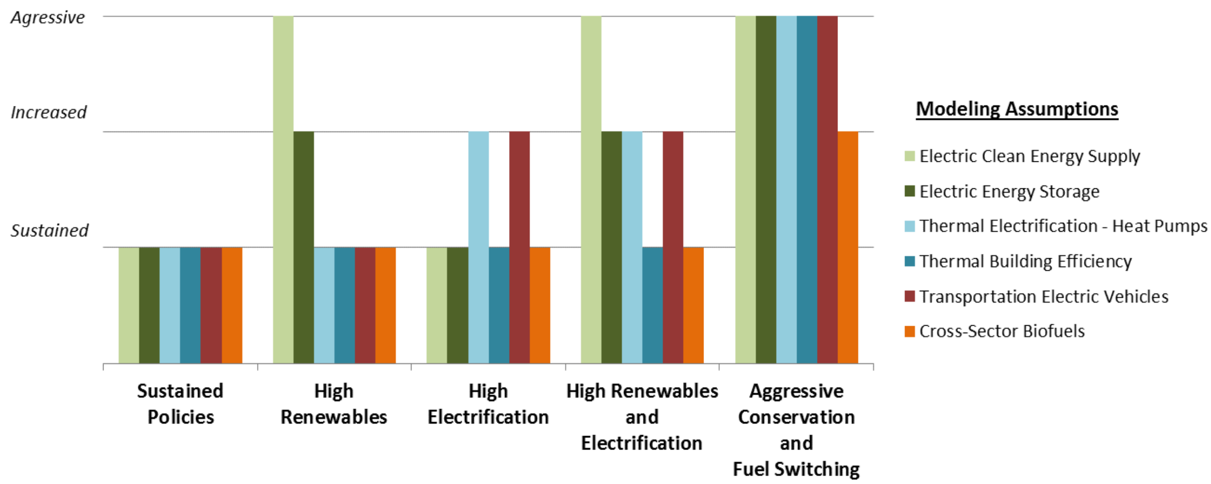

Figure 5: Overview of Scenario Policy Drivers

Sustained Policies

This model run shows the impact of our current energy policies without significant new policies.[9] This includes:

Clean Energy Supply: Implementing the 2016 energy legislation, with 1,600 MW of offshore wind and a 9.45 TWh of hydroelectric power to come online starting in 2023. Additional in-state renewable supply is implemented through the SMART program which is expected to add 1,600 MW of solar power in Massachusetts by 2022. Also assumes the obligations under the RPS and CES will be achieved, which require 25 percent of our electricity to be renewable and 40 percent of our electricity to be clean by 2030, respectively. Additional clean energy generation from the hydroelectric energy procurement results in approximately 45 percent of the Commonwealth's retail energy as clean electricity.[10]

Storage: Achieving the 200 MWh storage target in 2020 and reaching approximately 500 MWh by 2030.

Efficiency: Energy efficiency programs that achieve similar levels of energy savings as to today.

Electrification: Increasing adoption of new thermal technologies, such as air source heat pumps, to approximately 2 percent of single family homes by 2030. The scenario assumes the increasing use

[9] The Sustained Policy scenario excludes initiatives in An Act to Advance Clean Energy that was passed by the Legislature on July 31, 2018 and signed by Governor Baker on August 9, 2018.

[10] Clean energy is defined as eligible for 310 CMR 7.75, Clean Energy Standard

of electric vehicles (EVs) at the current accelerating pace of adoption, which achieves 160,000 ZEVs by 2025 and 1.2 million by 2030.

High Renewables

This model run shows the impact of additional clean electric generation sources, but no increase of electric consumption in the thermal and transportation sectors. As compared to the Sustained Policies scenario, this scenario increases, by 2030, the amount of clean electric generation to approximately 65 percent of the retail electric load from 45 percent or 16TWh in total (4,000 – 7,000 MW depending on the capacity factor of the renewable technology) and increases the amount of energy storage on the electric grid to 1800 MWh, approximately three times the amount of storage in the Sustained Policies scenario.

High Electrification

This model run shows the impact if consumers increased the use (consumption) of electricity in the thermal and transportation sectors.[11] This scenario increases the adoption of heat pumps beyond those modeled in the Sustained Policies scenario to an average of 25 percent of oil-heated and 10 percent of gas-heated buildings,[12] and approximately doubles the number of EVs in 2025 to 300,000 EVs in Massachusetts, consistent with the ZEV MOU target, growing to 1.7 million in 2030.

High Renewables and Electrification

This model run combines the assumptions from the High Renewables and the High Electrification scenarios.

Aggressive Conservation and Fuel Switching

This model shows the impact of aggressive energy efficiency and fuel switching, both electrification and biofuels, in addition to the assumptions included in the High Renewables and Electrification scenario. It includes additional energy storage for peak reduction along with an even higher penetration of EVs. These assumptions include improved building envelope efficiency so that an average building in 2030 utilizes only 75 percent of the energy the average building does today, representing an approximate three-fold increase in the pace of weatherization and building efficiency improvements over today. Peak demand is reduced through a total of 2 gigawatts (GW) (approximately 7,500 MWh) of storage by 2030, more than 250 percent of the storage in the High Renewables scenario. Electrification is maximized to have 30,000 more EVs in 2025 and 200,000 more in 2030 for a total of 1.9 million light duty EVs. Additionally, 5 percent of freight travel is powered by electricity and 5 percent is powered by biofuels.

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11 The increase of use of electricity in the thermal and transportation sectors is met by advanced technologies including high efficiency air source heat pumps and electric vehicles.

12 Heat pumps are also utilized as a primary cooling resource and provide secondary heating. For the purposes of this modeling, a customer can be in two different thermal classes.

Winter Reliability Analysis

An additional analysis was completed focusing on a peak winter day in the winters of 2022 and 2025, the year before and the year after significant energy supply is added through the hydroelectric and offshore wind procurements. This analysis captured the increased cost and emissions associated with possible extended winter events. During cold weather, consumers demand more natural gas for heating which reduces the natural gas supply for the electric sector. This detailed, extended cold weather analysis measures the impact that these events may have on daily or short-term reliability, price volatility and emissions that is not captured in the multiyear average weather analysis. The winter weather analysis shows two scenarios, measuring the impact of two separate natural gas prices for both a (1) constrained natural gas supply and (2) a mitigated natural gas constraint for the same winter peak day.

Modeling Outputs

The following outputs were produced for each scenario:

Emissions: The expected additional reduction in GHG emissions relative to the Sustained Policies scenario baseline utilizing the methodology from the MassDEP greenhouse gas emissions inventory.

Energy Costs for Consumers:

- Average residential retail rate for electricity measuring the impact of policy and program costs as well as changes in the cost of wholesale energy between the scenarios.
- Total monthly energy burden which is the average monthly costs a resident will pay for their electric bill, their heating bill, and their gasoline or charging costs for their light duty vehicle.[13] This metric captures the impact of fuel switching, energy efficiency, and cost of electricity. In order to calculate the total monthly expenditures, the total consumption of each sector was divided by total customers for each heating class and transportation costs were calculated for both EVs and combustion engine vehicles. This analysis is not a projection of anticipated bills but allows a comparison across fuel types.

Winter reliability: The impact on cost and emissions when regional demand for natural gas from the thermal and electric sectors must be met with stored fuels such as LNG and oil for electric generation on peak winter days.

Results Summary

Table 1 shows the output of the model on costs, emissions and reliability for each model run in 2030.

13 To determine an average customer's bill the total consumption for each sector is divided by the number of customers in that class. For example, each household is assumed to have 1.5 light duty vehicles.

As described in more detail in Key Findings below, Table 1 shows that the Aggressive Conservation and Fuel Switching scenario most significantly reduces 2030 greenhouse gas emissions. This scenario shows emissions reduced beyond the Sustained Policies scenario by approximately 9 million metric tons of CO_2 ($MMTCO_2$). This scenario features increased renewable energy supply, increased electrification, decreased consumption in the thermal sector, and decreased peak demand. In all scenarios, the region continues to be at risk for price spikes and emission increases during extended cold periods when the region utilizes LNG and oil to help meet demand for natural gas.

Summary of Average Weather Analysis

2030								*Winter Peak Day Regional New England - 2025*	
Scenario	**Average Monthly Energy Expenditures per Household (2018$)**				**Annual Residential Retail Rate**		**Emission Reduction ($MMTCO_2$ Below Sustained Policies)**	**Percent of NG Demand that is met through LNG**	**Oil Use in Electric Sector on Peak Winter Day (thousand Barrels)**
	Electric	**Thermal**	**Transport**	**Total**	**Nominal $/kWh**	**2018$/kWh**			
CURRENT	$99	$139	$234	$472	$0.201[14]		Total: 76.3[15]	14%	
Sustained Policies	$79	$132	$140	$351	$0.256	$0.202	Total: 61.3	6%	42
High Electrification	$84	$127	$139	$350	$0.273	$0.215	-2.7	--	
High Renewables	$83	$134	$141	$358	$0.265	$0.212	-1.0	--[16]	
High Electrification + High Renewables	$82	$125	$137	$345	$0.265	$0.209	-3.8	7%	43
Aggressive Conservation and Fuel Switching	$80	$110	$136	$326	$0.259	$0.204	-8.9	4%	47

Table 1: Summary of Average Weather Analysis - 2030

The analysis below in Table 2 assumes for modeling purposes that, even with the additional renewable procurements coming on line in 2022, a winter event would produce a two-cent increase in the annual residential retail rate in 2022 for all hours in the year immediately following that winter event, consistent with the size and impact of recent severe winters with extended cold events. A winter of similar impact would add over $475 million of annual cost to residents, and including commercial and industrial customers, would be over $900 million in added costs, or a 9 percent increase in expenditures.

14 Average from May 2017-May 2018, US Energy Information Administration

15 2015 Massachusetts Greenhouse Gas Inventory, updated August 23, 2018

16 For the individual High Renewables and the High Electrification scenarios, no Winter Peak analysis was completed. It was only completed for the combined High Electrification and Renewables Scenario.

Summary of Extended Cold Weather Analysis

Scenario		2022 Annual Residential Retail Rate (nom $/kWh)	2022 Winter Event Emissions ($MMTCO_2$)	2025 Annual Residential Retail Rate (nom $/kWh)	2025 Winter Event Emissions ($MMTCO_2$)
Sustained Policies	*Average Winter*	*$0.23*	*3.94*	*$0.22*	*3.46*
	Extended Cold Event - **Constrained Natural Gas Pricing**	$0.25	4.47	*$0.25*	3.94
	Extended Cold Event – **Mitigated Natural Gas Constraint Pricing**	$0.25	4.39	*$0.23*	3.9
High Electrification and High Renewables	*Average Winter*	*$0.23*	*3.93*	*$0.24*	*3.49*
	Extended Cold Event - **Constrained Natural Gas Pricing**	$0.26	4.46	*$0.26*	3.99
	Extended Cold Event - **Mitigated Natural Gas Constraint Pricing**	$0.25	4.37	*$0.24*	3.94
Aggressive Conservation and Fuel Switching	*Average Winter*	*$0.23*	*3.84*	*$0.24*	*3.37*
	Extended Cold Event - **Constrained Natural Gas Pricing**	$0.25	4.35	*$0.26*	3.82
	Extended Cold Event - **Mitigated Natural Gas Constraint Pricing**	$0.25	3.72	*$0.24*	3.78

Table 2: Summary of Extended Cold Weather Analysis - 2022 and 2025

Key Findings and Takeaways

Reducing Emissions

- **The greatest amount of emissions reductions by 2030 are achieved by combining increased use of clean energy in all sectors with simultaneous decreases in overall energy consumption.**

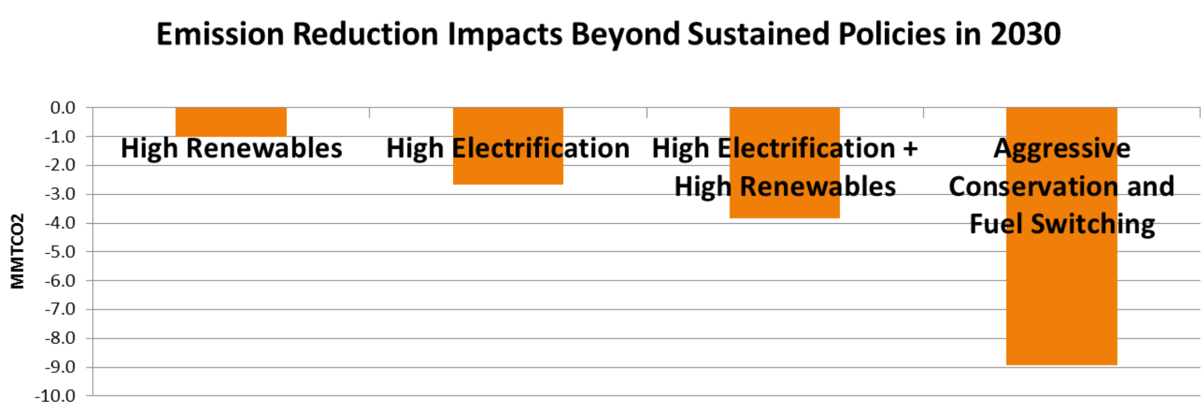

Figure 6: Model Run Emission Results

With the successful implementation of current policies (Sustained Policies scenario), Massachusetts is estimated to achieve a 35 percent emission reduction from 1990 levels by 2030 (61.3 MMTC02). As seen in Figure 6, the greatest additional greenhouse gas emission reductions beyond the Sustained Policies scenario are achieved in the Aggressive Conservation and Fuel Switching scenario. This energy future includes aggressive conservation through energy efficiency and demand reduction paired with a greater use of renewable energy and electrification reaching nearly 9 $MMTCO_2$ more reductions than the Sustained Policies assumptions. In contrast, the High Electrification and Renewables scenario produces 4 $MMTCO_2$ additional reductions. To achieve higher levels of emissions reductions it is necessary to prioritize energy demand reductions in each sector, particularly in the thermal and transportation sectors. Building efficiency, reductions in vehicle miles traveled (VMT), and peak demand will lessen our reliance on fossil fuels, while we transition to cleaner sources of energy.

- **Focusing clean energy policies primarily on the electric sector has diminishing returns going forward, increasing rates while realizing only modest decreases in GHG emissions**

Emission reductions have been achieved primarily in the electric sector, and policies in place will accelerate that progress. In the Sustained Policies scenario, Massachusetts significantly increases clean electricity through the implementation of new contracts for hydroelectric and offshore wind power, as well as expected increases in solar generation from the SMART program. Even with an additional increase of 50 percent more of clean electricity in 2030 in the High Renewables Scenario as compared to the Sustained Policy Scenario, the economy wide reduction in emissions reaches just an additional 1 $MMTCO_2$ reductions by 2030. To achieve additional reductions in emissions, changes must be made in the way energy is used in the thermal and transportation sectors.

- **Electrifying the thermal and transportation sector will leverage investments made in a clean electric grid, both reducing emissions and lowering cost**

Increasing electrification in the thermal and transportation sectors achieves greater emission reductions than increasing renewable supply alone (Table 3). Electrification of the thermal and transportation sectors allows for offsetting high emission and costly fuels with efficient heat pumps and EVs, as well as cleaner electric generation. The investments made by Massachusetts ratepayers in clean, renewable electricity will enable a "greater bang for their buck" by using that clean electricity in cars and residential heating.

Scenario	Emission Reduction $MMTCO_2$ Below Sustained Policies
High Renewables	-1.0
High Electrification	-2.7
High Electrification + High Renewables	-3.8

Table 3: Emission Reduction Comparison

- **Conservation and peak demand reduction are important as the use of electricity for heating and transportation grows.**

Conservation will reduce the emissions associated with increased electric load, while the reduction of peak demand reduces emissions from the burning of higher emitting fuels such as fuel oil to produce electricity.

- **Improving building envelope efficiency is important to decreasing emissions and costs in the thermal sector, since a majority of thermal conditioning uses fossil fuels for heating and cooling.**

One of the challenges of reducing emissions in the thermal sector is that heating technologies have long useful lifetimes, and are typically not replaced until the end of their useful life, and frequently at time of equipment failure limiting the consumer's choices for replacement. Even with aggressive electrification, 93 percent of the thermal sector consumption is forecast to be met through fossil fuels in 2030. Therefore, to impact emissions increased efficiency will be paramount as a transition to cleaner sources of heating occurs.

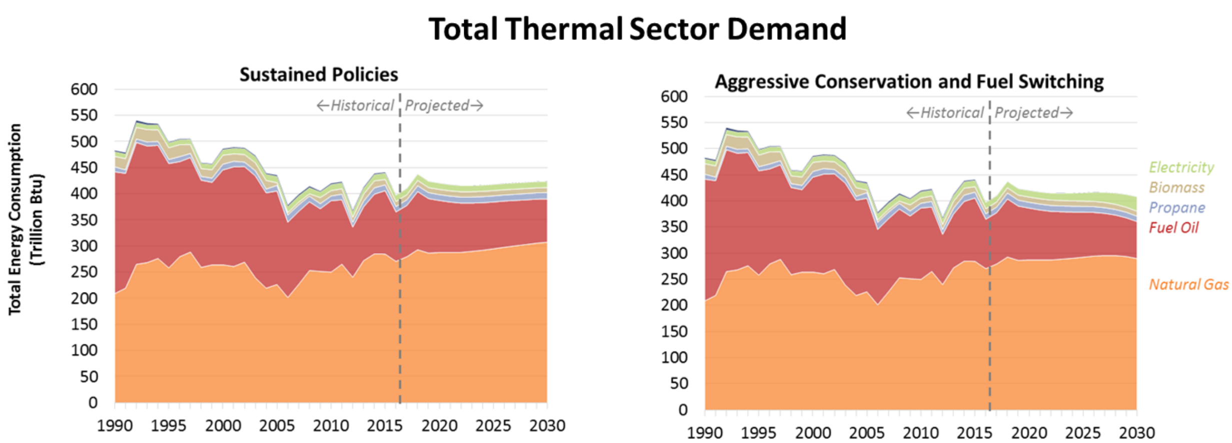

Figure 7: Thermal Sector Demand Comparison

- **Alternative fuels, such as biofuels, assist in transition to cleaner heating and transportation.**

Increasing the amount of biofuel used in place of oil in existing equipment will reduce emissions and cost for consumers. The Aggressive Conservation and Fuel Switching scenario assumes an increase in the amount of biofuel in the heating oil mix and the use of biofuels for freight vehicles that might not be well-suited for electrification. This allows for additional emission reductions beyond electrification alone, as electrification is limited in terms of the number of systems that can be replaced at the end of their useful lives. Biomass is utilized in the Sustained Polices scenario as part of the Alternative Portfolio Standard, incentivizing the use of renewable heating fuels. This allows for the reduction of cost and emissions for those customers that do not have access to lower emission fuels such as natural gas for heating for whom electrification of heating does not make sense.

Electric Rates

New England states have some of the highest electric rates in the country; however, sustained policies are predicted to mitigate the current spread between Massachusetts and the rest of the country.

- **All scenarios modeled show lower retail electric rates in 2030 than the U.S. Energy Information Agency (EIA) projections for 2030, primarily due to the cost-effective large-scale procurements coming on-line in mid-2020s**

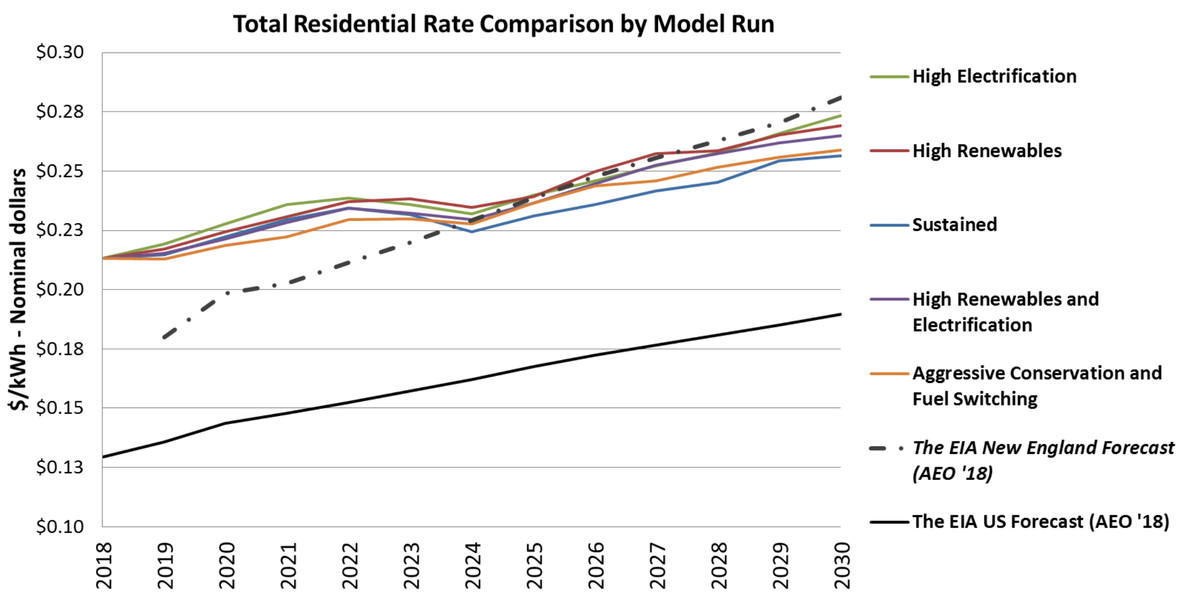

Figure 8: Residential Retail Rate Comparison

For each scenario, the forecasted residential retail rates were lower, starting in 2023, than the projected rate for New England from the Energy Information Agency's 2018 Annual Energy Outlook (Figure 8). All scenarios show a significant dip in the residential retail rate that correlates to the commercial operation of the hydroelectric and offshore wind procurements in 2023. These cost-effective procurements help Massachusetts comply with the RPS and CES at lower cost than projected.

- **However, all other scenarios show higher electric rates in the future than the Sustained Policies scenario.**

Each additional modeled scenario shows additional costs in the supply and/or delivery portions of the retail electric rate. However, all scenarios reduce the difference between the Massachusetts rate and the US average, supporting economic competitiveness. The lowest rates are achieved under the Aggressive Conservation and Fuel Switching scenario due to a reduction in demand for electricity, particularly during peak periods.

- **Energy efficiency and peak demand reduction are important for keeping electricity rates affordable, as demand for electricity in the thermal and transportation sector increase.**

Continued improvements in energy efficiency and other efforts to reduce demand are crucial to reduce the energy burden for consumers and help offset increases in electricity demand from electrification.

- **Finding low cost sources of clean electricity that can deliver in winter improves costs.**

Pursuing additional cost-effective sources of clean electricity beyond current policies, particularly those that can deliver during peak hours and during winter cold periods would improve costs for customers.

- **Fuel switching from expensive fuels for heating such as electric resistance heat, propane and fuel oil to lower cost fuels, such as electric air source heat pumps and biofuels can lower an average consumer's monthly energy bills.**

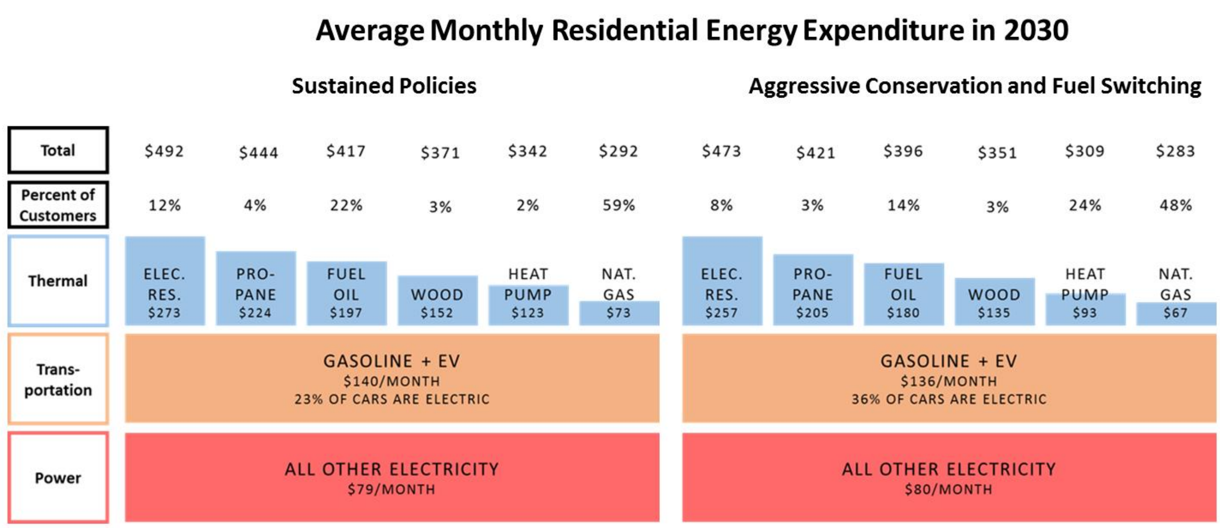

Figure 9: Average Monthly Residential Energy Expenditure (2018$) in 2030 - By Heating Class

Customers that switch from expensive thermal systems can save significantly. For example, a fuel oil customer switching to an air source heat pump could save almost $900 annually in 2030. Additionally, as more consumers switch from more expensive fuels such as fuel oil and gasoline for transportation, costs are reduced. In the High Renewables with High Electrification scenario, monthly thermal expenditures for the state as a whole are 5 percent less and transportation sector expenditures are 2 percent less than in the Sustained Policies scenarios (Figure 10).

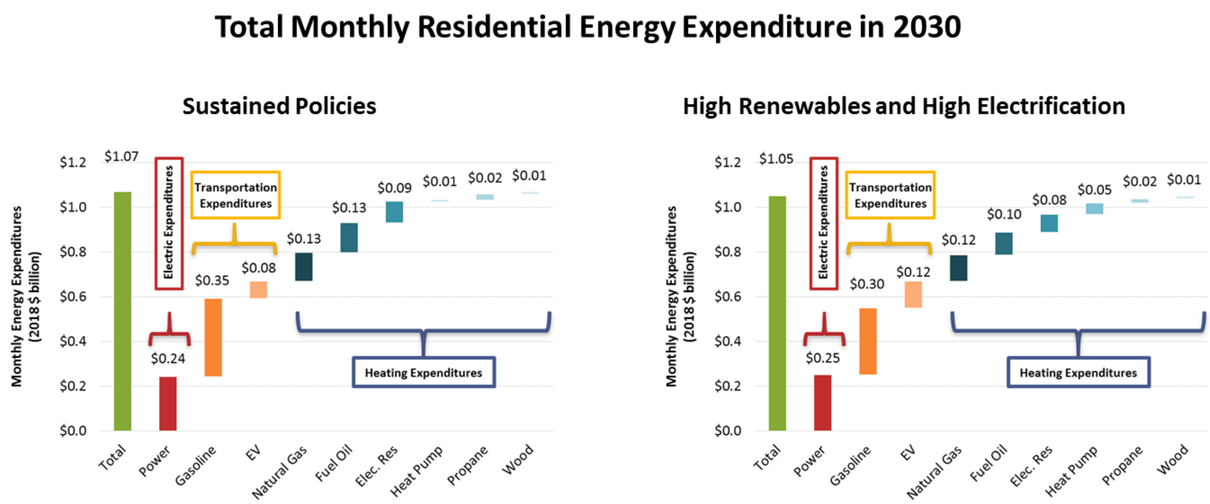

Figure 10: Total Monthly Residential Energy Expenditure in 2030 Comparison

- **Even with higher electric rates than the Sustained Policies scenario, other scenarios result in lower monthly expenditures for energy in 2030, driven by consumers that switch fuel sources and increase energy efficiency.**

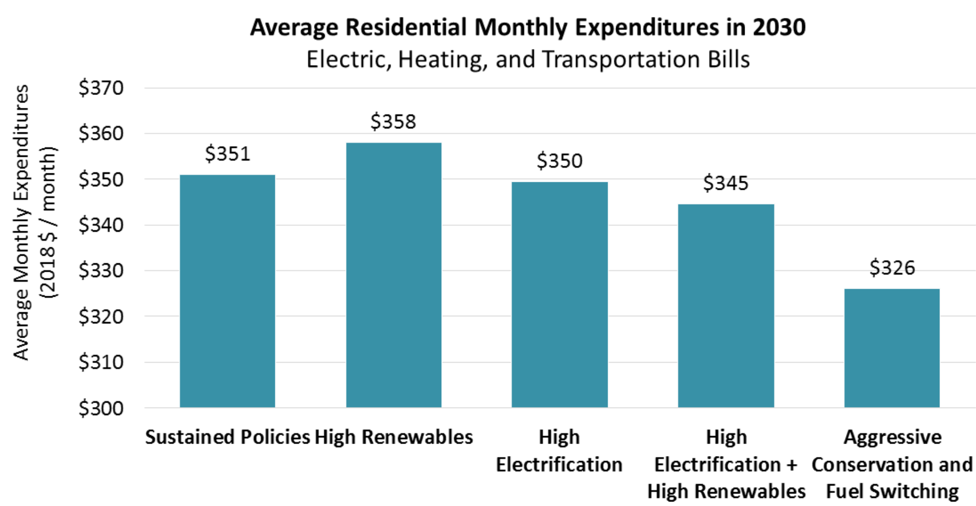

Figure 11: Average Monthly Residential Energy Expenditures Comparison

Figure 11 shows the average monthly expenditure for residential ratepayers in Massachusetts for each scenario. Aggressive Conservation and Fuel Switching reduces costs more than any other policy scenario due to the reduced consumption in the thermal sector and reduced electric rate due to peak demand reduction. The reduction of thermal demand provides benefits not only to winter heating expenditures but also for winter reliability, allowing the electric sector greater access to existing natural gas supplies. The Aggressive Conservation and Fuel Switching scenario also represents the largest switch to more efficient EVs, lowering the overall transportation costs for the state.

- **The lowest residential retail costs can be achieved by reducing peak demand coupled with significant efficiency and conservation in the thermal sector. Increased policy charges within the retail electric rates associated with expanded policies can be offset, in part, by reductions in costs for supply, transmission and distribution.**

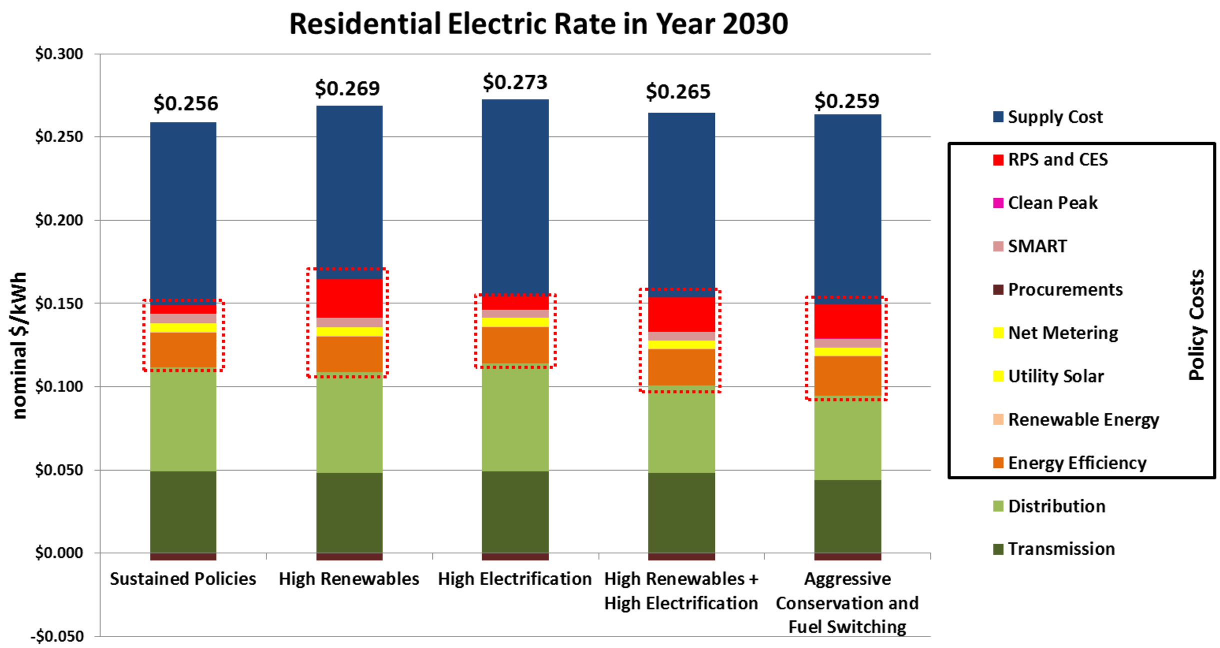

Figure 12: Residential Retail Rate Breakdown in 2030 Comparison

(Nominal $)	Sustained Policies	High Renewables	High Electrification	High Renewables + High Electrification	Aggressive Conservation and Fuel Switching
Supply Cost	$0.110	$0.104	$0.118	$0.111	$0.112
Distribution and Transmission Cost	$0.111	$0.109	$0.114	$0.100	$0.094
Policy Costs	$0.033	$0.051	$0.036	$0.049	$0.050
Residential Retail Rate	**$0.256**	**$0.269**	**$0.273**	**$0.265**	**$0.259**
Percent Policy Costs	13%	19%	13%	18%	19%

Table 4: Residential Retail Rate Breakdown in 2030 Comparison

To achieve higher levels of clean and efficient energy, it will likely require additional programs and incentives that will add to the charges on customer bills, however, as seen in Figure 12, even though these policy costs increase as a percentage of the total residential rate, rate reductions caused by policy implementation can partially offset the increase. The Aggressive Conservation and Fuel Switching rate is the lowest non-sustained policy scenario despite having the large percent policy costs (19 percent) (Table 4).[17]

- **Reducing peak electric demand lowers both supply costs and the distribution and transmission costs on customers' electric bills.**

Increased electrification in the transportation and thermal sectors my increase electric load and may increase peak load depending on the timing of energy use, especially the charging of energy storage and EVs. The addition of the Clean Peak Standard and technologies that shift peak, such as storage, flattens this load, especially as load shifts due to increased EVs, heat pumps, and behind-the-meter solar. Flattened load enables generators to run at more efficient heat rates, reducing costs and emissions. Further, it reduces the need for future investments in transmission and distribution infrastructure helping to lower costs of implementing future policies. From 2013-2015, the top 10 percent of peak hours accounted for 40 percent ($3 billion) of the Commonwealth's wholesale expenditure on electricity.[18]

Winter Reliability and Costs

The region continues to be at risk for price spikes and emission increases during extended cold periods.

- **In all scenarios, the demand for natural gas on a peak winter day forces the electric sector to rely on liquefied natural gas (LNG) or other stored fuels such as oil for generation, which puts the region at risk for price spikes and emission increases during extended cold weather events.**

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17 Policy costs are shown per year as part of the average residential retail rate although policies and programs may be structured to recover costs over multiple years

18 Massachusetts DOER, "State of Charge," 2016; page ii.

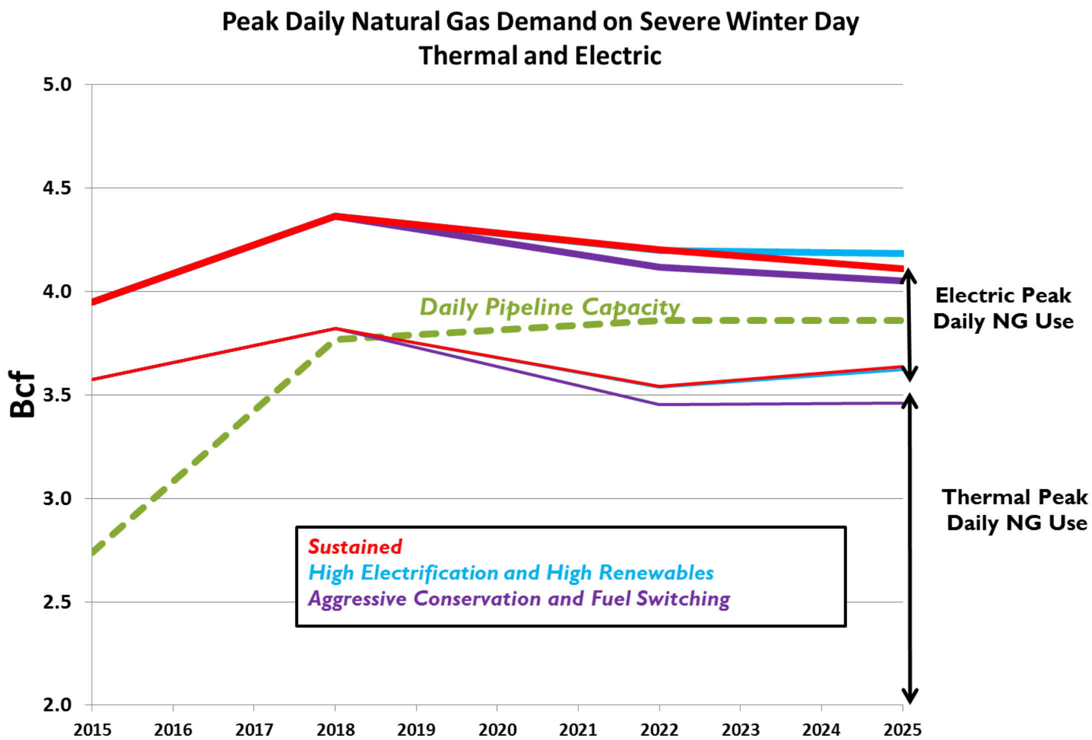

Figure 13: Peak Daily Natural Gas Demand on an Extremely Cold Day - Thermal and Electric

Figure 13 shows the total natural gas demand from both the thermal and electric sectors on a peak winter day currently and in 2022 and 2025. In all scenarios, the total demand (thermal and electric) exceeds the anticipated pipeline capacity, meaning the region will continue to rely on stored LNG during extreme winter conditions. Increased LNG storage combined with current infrastructure could alleviate these constraints, particularly in the short term. However, sufficient supplies of LNG are not always available due to the more favorable economics associated with exporting domestic supplies rather than consuming them in the United States and delivery restrictions associated with the Jones Act.

While New England's LNG infrastructure is sufficient to meet peak winter day consumption requirements, the refueling of LNG storage tanks requires substantial logistics and forward planning such as long-term contracts entered into before winter starts. As such, there is a potential reliability concern if storage tanks are not sufficiently filled and scheduled for refilling during an extended cold weather event. Due to LNG market and logistics structures, there are risks associated with the reliance on timely LNG delivery outside of prearranged contracts.

- **In all scenarios, there is sufficient electric generation capacity to meet the needs of any increased electrification**.

While the model is constrained to not endogenously retire power plants, the model is free to build additional conventional capacity as needed for reliability and as is cost-effective. However, in all scenarios, the model does not construct additional conventional capacity.

- **State policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, reduce but do not eliminate reliance on oil and LNG.**

In all policy scenarios, natural gas demand is decreased by 2022 due to the increased renewable generation from recent procurements and from additional efficiency gains. The Aggressive Conservation and Fuel Switching scenario shows the greatest reduction in total natural gas demand supported by a significant decrease in the thermal demand on a winter day due to increase electrification and building shell efficiency. However, even significant increases in all mechanisms to reduce natural gas demand, such as conservation, fuel switching, and additional clean electricity generation; these mechanisms are not enough to eliminate the risk of constrained and expensive natural gas supplies for electricity.

- **Even in scenarios with aggressive clean and efficient energy policies, reducing the cost of natural gas through mitigating natural gas constraints reduces the reliance on stored fuel oil, lowering emissions during winter events, and keeps residential rate increases lower in subsequent years.**

An additional peak winter day analysis was completed where the price of natural gas was reduced from a constrained price ($27/Mcf) to a price closer but slightly greater than the regional average natural gas price ($12/Mcf). This price reduction could be achieved through a portfolio of actions including increasing the amount of stored LNG and reducing regional New England natural gas demand in both the thermal and electric sectors. This lower price for natural gas in the electric sector reduces the amount of oil utilized on a peak day, which in turn causes a reduction in cost and emissions.[19] Figure 14 shows that, in all scenarios, a reduced natural gas price decreases the amount of oil burned on a peak winter day as compared to the same scenario with a constrained natural gas price. This reduction in oil use is seen in both 2022 and 2025.

[19] As the method of mitigating the natural gas constraint to the region is not pre-determined as part of this analysis and may be a combination of multiple policies, the cost of mitigating the constraint may not be fully included in the rate analysis

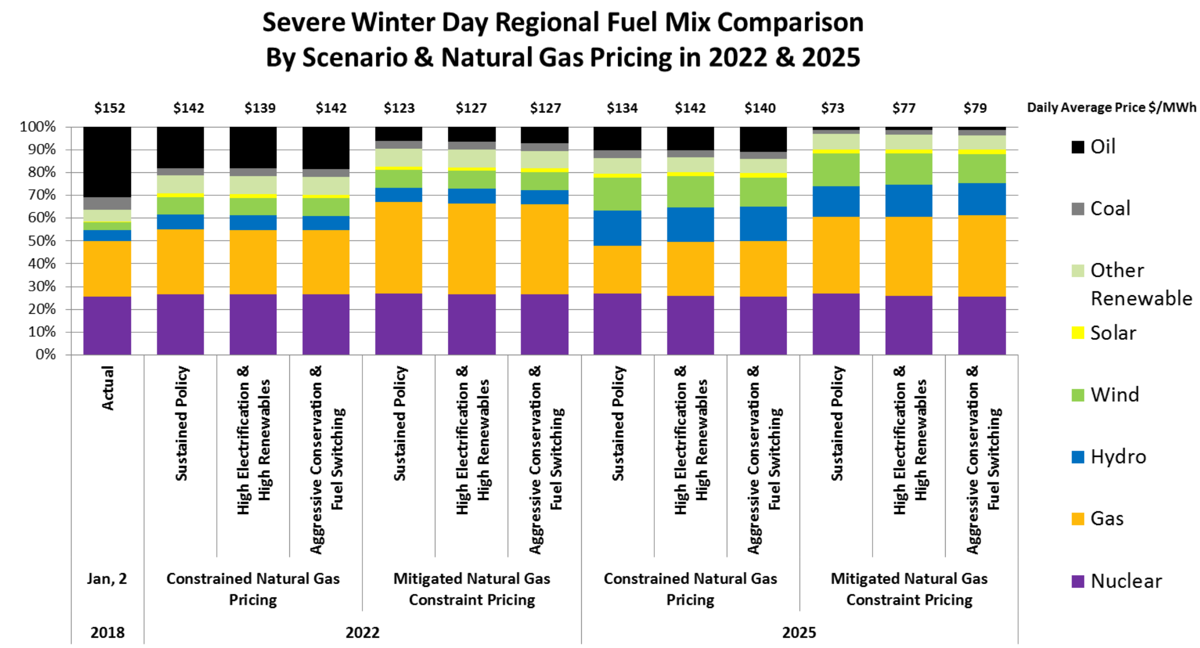

Figure 14: Severe Cold Day Fuel Mix Comparison

- **The added costs from a winter event increase retail rates in subsequent years across all classes of ratepayers.**

Extended cold weather creates price spikes that will be incorporated into future annual electricity rates.

- **The addition of large amounts of hydroelectricity and offshore wind generation that are available in the winter from the procurements will lower costs and emissions, as well as improve winter reliability when they come on-line in 2023.**

New clean electricity, especially from those resources that provide energy during the winter, benefits consumers by lowering the use of expensive, carbon-intensive fuels such as oil and reducing overall our reliance on natural gas for electric generation. The procurements of 9.45 TWh of hydroelectricity and 1600 MW of offshore wind generation, authorized in *An Act Relative to Energy Diversity*, are scheduled to be in service between 2023 and 2024. This energy, especially clean energy that is available in the winter, helps contribute to significantly reduced prices during a winter event when paired with decreased natural gas pricing associated with mitigated natural gas constraints. As shown in Figure 15, in 2022, reduced natural gas price results in decreased average energy costs on a winter day of 11-13 percent. In 2025, after the increase in wind and hydroelectric energy, the same reduced natural gas price results in decreased average energy costs of 45 percent. This is caused by the significant reduction of use of expensive oil on a severe winter day.

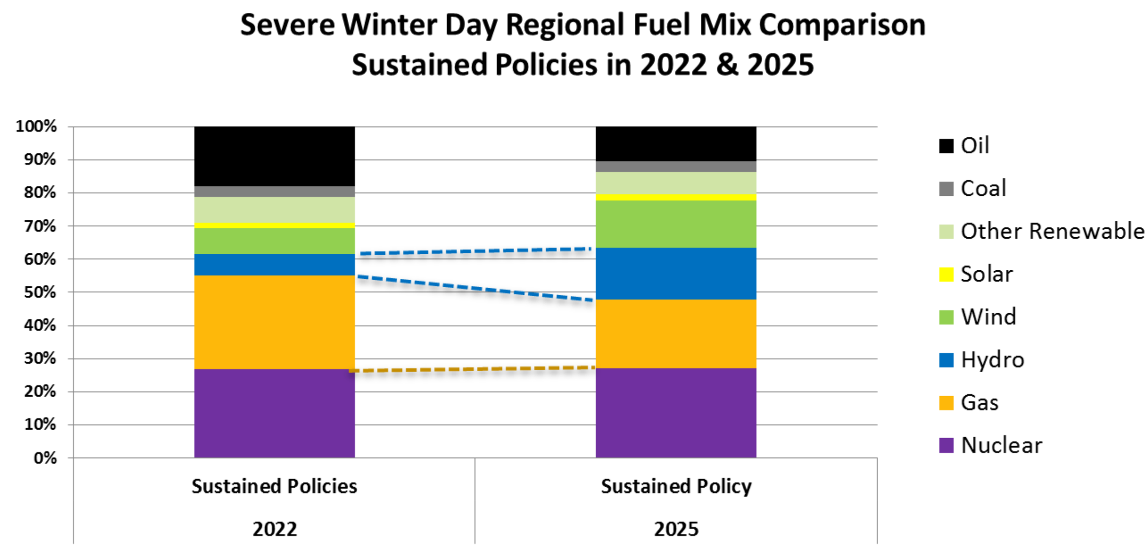

Figure 15: Severe Winter Day Fuel Mix Comparison - Sustained Policies

Additionally, as seen in Figure 15, in 2025, the increase in clean energy from the procurements reduces the use of gas on a severe winter day by 27 percent as compared to a severe winter day in 2022, decreasing the reliability risk by contributing to mitigation of constrained natural gas supply.

- **Mitigating natural gas constraints lowers the impact of extended cold weather on subsequent residential retail rates in all scenarios.**

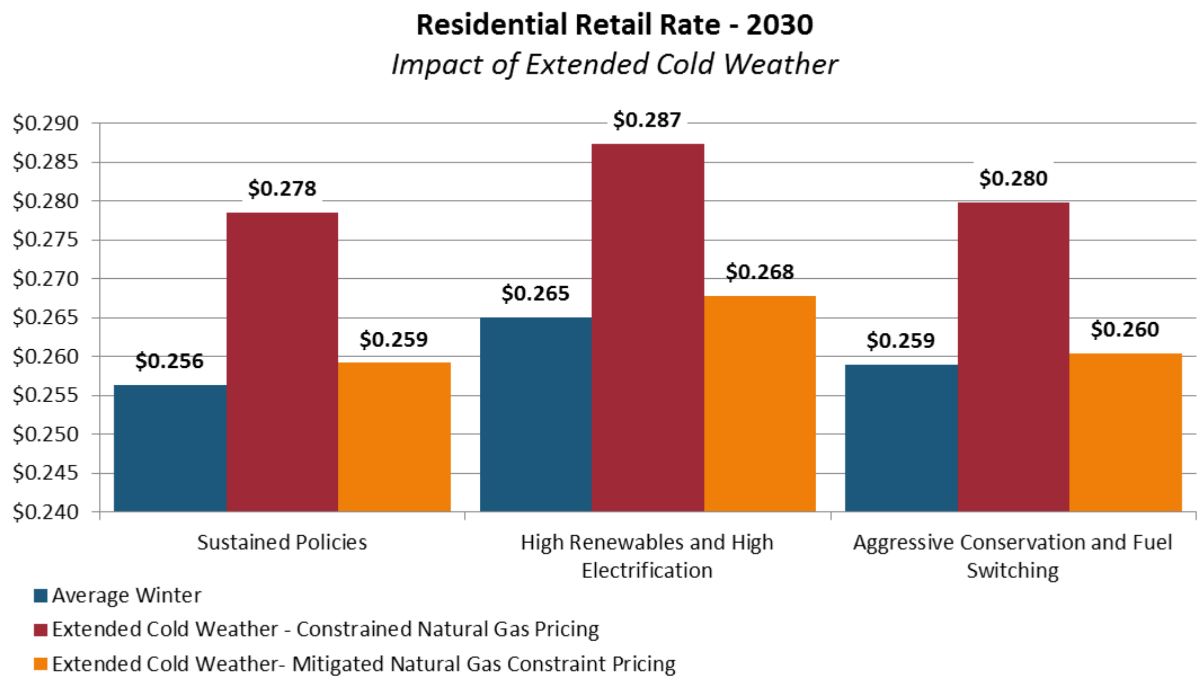

Figure 16: Impact of Extended Cold Weather Events on Residential Retail Rate

In all scenarios, an extended cold weather event increases the annual average residential rate (Figure 16) due to an increased demand for electricity and the use of more expensive fuels to meet that increased demand.

- **Reducing demand in the thermal sector (heating and cooling) reduces cost and emissions for consumers.**

Scenario		2022 Residential Retail Rate (nominal $/kWh)	Emissions From Winter Event: Thermal Sector	Emissions From Winter Event: Electric Sector	Emissions From Winter Event: Total
High Electrification and High Renewables	*Average Winter*	*$0.233*	*2.24*	*1.68*	***3.93***
	Extended Cold – **Constrained Pricing**	$0.256	2.56	1.90	**4.46**
	Extended Cold – **Mitigated Constraint**	$0.251		1.82	**4.37**
Aggressive Conservation and Fuel Switching	*Average Winter*	*$0.228*	*2.12*	*1.72*	***3.84***
	Extended Cold - **Constrained Pricing**	$0.252	2.42	1.92	**4.35**
	Extended Cold - **Mitigated Constraint**	$0.247		1.86	**3.72**

Table 5: Cost and Emissions in Extended Cold Weather Comparison

As shown in Table 5, reducing the amount of natural gas consumption in the thermal sector during these extended cold weather events increases the availability of natural gas to the electric sector and reduces emissions.

Policy Priorities and Strategies

Based on the results and findings from the analysis of these four scenarios, under both average and extended cold weather conditions, the following strategies are recommended to achieve a clean, affordable, and resilient energy future for the Commonwealth.

Electric Sector

Pursue additional cost-effective sources of clean electricity beyond current policies and implement strategies to lower electric use at peak periods, in order to reduce emissions from the electric sector and accommodate growth in electric demand from the transportation and thermal sectors. Explore options for ensuring reliability and mitigating price volatility in the winter months, issues that continue to be a challenge for New England.

<u>Continue to increase cost-effective renewable energy supply</u>

- **Investigate policies and programs that support cost-effective clean resources that are available in winter to provide both cost and emission benefits to customers.** These additional policies may include continued clean energy procurements, especially if strategic electrification policies are successful and total demand for electricity increases. Modeling aggressive renewable energy in the High Renewables and Aggressive Conservation and Fuel Switching scenarios included approximately 16,000,000 MWh of clean energy to approximate an outcome with significant emissions reductions by 2030. The exact amount of additional clean resources needed will depend on the 2030 GHG emission reduction limit selected and the extent of other complementary policies.

- **Consider policies to support distributed resources, including distributed solar development in the Commonwealth after the SMART program concludes, to continue lowering costs while providing benefits to ratepayers.** As DOER continues to implement the SMART program, it will periodically evaluate the impact of the program on development of solar generation and ratepayer costs. Potential policies could include extending the SMART program beyond 1600 MW by adding additional declining incentive blocks to the program.

Prioritize electric energy efficiency and peak demand reductions

- **Implement policies and programs, including the Clean Peak Standard**, **that incentivize energy conservation during peak periods.** Reducing energy demand at times of peak use creates the most value for consumers because it reduces reliance on the highest cost, less efficient generating resources. Also, by creating more level demand on the electric grid across all hours, transmission and distribution infrastructure can be utilized more efficiently, mitigating the need for additional new investment.

- **Develop policies to align new demand from the charging of EVs and heating/cooling with the production of clean, low-cost energy.** Review options including a Time-of-Use Rate for EV charging so charging aligns with periods when electricity prices are lowest and mitigates any added strain on the system from additional electric demand. Investigate incentives for the pairing of air source heat pumps with distributed solar and/or energy storage.

- **Include cost-effective demand reduction and additional energy efficiency initiatives in our nation-leading energy efficiency programs and plans**. As demand for electricity grows, programs to mitigate this demand provide large savings to consumers. Expanding Massachusetts' nation-leading energy efficiency programs to encourage efficiency and demand reduction initiatives at customers' homes and businesses in a cost-effective manner will deliver significant benefits to consumers.

- **Utilize our successful Green Communities and Leading By Example programs to continue to make state and municipal infrastructure clean and efficient.** These programs lower the operating costs of government, reduce emissions and promote consumer awareness about the benefits of efficiency.

Support grid modernization and advanced technologies

- **Promote cost effective microgrids to provide greater overall grid resiliency and reduce transmission and distribution costs from building out the grid to meet new demand.**

- **Review existing and possible new policies to support new technologies, including energy storage, that can align supply and demand and provide grid flexibility.** The electric sector is a just-in-time supply chain, where supply and demand must always be balanced. Historically, in order to assure the ability to meet that balance, we have built infrastructure to meet peak demand. Policies which align supply and demand enable the shift away from substantial overbuild of infrastructure while enabling flexibility to continue to adopt intermittent resources.

- **Examine potential strategies to lower the price of natural gas and mitigate natural gas constraints.** Even with aggressive investment in new clean electricity sources, demand reduction and energy efficiency measures, there remain reliability and price volatility risks in the winter for the electric sector. Mitigating natural gas constraints would eliminate the need to turn to high cost, carbon-intensive oil to satisfy demand during an extended cold weather event. Strategies could include:
    - **Encourage contracting with LNG supply ahead of the winter to ensure LNG supplies are available to be used by gas-fired generators.** LNG requires substantial logistical planning ahead of winter deliveries. While firm long-term LNG contracts may increase costs in mild winters, the combination of cost savings and fuel security may offset those costs in an extreme cold event winter. The terms of the contract would determine the magnitude and the impact of the associated cost allocation.
    - **Work with federal officials to explore modifying the Jones Act to facilitate shipping of LNG from domestic sources.** Enabling delivery of domestic LNG shipments into New England may reduce costs and improve our fuel security while reducing our energy reliance on foreign nations.
    - **Reduce thermal and electric sector demand, as described below, to reduce the region's demand for natural gas.** Reducing overall demand for natural gas by reducing thermal and electric sector demand through energy efficiency will reduce the constraints on the region's natural gas supply. Although results show that aggressive energy efficiency when paired with electrification may not eliminate constraints on the natural gas supply, it can be a part of a combination of policies that contribute to reduced constraints.

Thermal Sector

Encourage beneficial fuel switching from higher cost, higher emission fuel sources for heating to lower cost, lower emitting fuel sources for heating. Motivate consumers to make choices that improve the efficiency of their homes and businesses. Utilize cost-effective means to transform building envelopes in both new construction and building retrofits. Reducing heating demand in winter will help alleviate competing demands for natural gas during severe weather and help to mitigate constraints and resulting price spikes.

Leverage investments made in the clean energy sector through electrification

- Increase electrification of the thermal sector by providing program incentives for air source heat pumps for heating though MassSave.

Promote fuel switching in the thermal sector from more expensive, higher carbon fuels to lower cost, lower carbon fuels such as electric air source heat pumps and biofuels.

- **Promote, though the Alternative Portfolio Standard, conversion of oil to biofuels** as a measure to reduce emissions until equipment replacement is cost-effective. Encourage biomass for renewable heating, particularly as a replacement for oil and propane.

- **Encourage MassSave Program Administrators to implement a residential program redesign** that ensures all contractors that are making improvements to a home have access to energy efficiency incentives, and improves customer engagement by providing the homeowner access to their energy usage data.

<u>Reduce thermal sector consumption</u>

- **Explore possible ways to strengthen building codes to drive additional efficiency in new buildings**. As commercial square footage expands and the population grows, mitigating energy demand from the building sector will be necessary to meet our cost and emissions goals. Building codes can be a cost-effective way to make lasting and long-term change in building infrastructure. Code provisions to consider include maintaining the stretch code and creating an "envelope backstop" to preserve envelope performance in commercial buildings so that envelope improvement cannot be traded away for other measures.

- **Increase weatherization measures to improve building shell efficiencies and promote technologies targeted at winter gas savings through the MassSave gas efficiency programs**. Add a new performance metric for MassSave Program Administrators (PAs) tied to reducing winter gas demand, both active and passive. A performance metric could be used to encourage PAs to increase the amount of homes and businesses weatherized each year, utilize new technologies, such as Wi-Fi thermostats, to enable greater reductions of energy use in cold weather without disrupting comfort, and adopt programs for Commercial and Industrial customers who can reduce gas consumption for industrial processes during severe cold weather.

- **Promote high efficiency building construction, such as Passive House standards, to further reduce energy demand from the thermal sector**. Utilize our energy efficiency programs to provide incentives to developers to develop to Passive House standards.

<u>Drive market/consumer demand for energy efficiency measures and fuel switching</u>

- **Educate consumers about the benefits of energy efficiency and create a market incentive for consumers to invest in energy efficiency improvements through a "Home Energy Score Card" program**. Enabling homeowners and prospective homebuyers to have access to information about the anticipated energy efficiency characteristics of residences and recommended cost-effective energy efficiency improvements will help families be better informed about their homes' energy performance and how they can reduce costs through incentivized energy efficiency upgrades. Provide scorecards as part of Massachusetts energy efficiency providers' no cost home energy audits.

- **Address the split incentive between landlords and renters for investments in energy efficiency.** In many instances if a landlord invests in energy efficiency the benefits go to the renter in terms of lower utility bills or, even if the landlord is paying the utility bills, it is a "pass through" cost so there is little incentive for landlords to invest in efficiency improvements to their buildings. This is particularly problematic for Massachusetts residents because low and moderate-income residents make up a higher proportion of renters. Strategies could include:

- Encourage a "Renter Energy Score Card" so renters can make informed choices about the total cost of where they live and to encourage landlords to invest in energy efficiency.
- Create targeted programs for renters and landlords through our energy efficiency programs.
- Support programs that test the impact of whole building energy efficiency measures in affordable housing to maximize energy savings during times of refinance or capitalization.

Invest in research and development for clean fuels, such as renewable power-to-gas and hydrogen that can utilize existing infrastructure and contribute to emission reductions.

Transportation Sector

Significant reductions of emissions from the use of gasoline and diesel in the transportation sector are needed to meet GWSA goals. Development of high-level recommended actions to reduce VMTs and enable electrification is underway through Governor Baker's Commission on the Future of Transportation established by Executive Orders No. 579 and 580. The Commission is tasked to examine at least five key areas: climate and resiliency; transportation electrification; autonomous and connected vehicles; transit and mobility services; and land use and demographic trends. The following are some of the broad strategies recommended by the CEP for transportation electrification to be considered by the Commission.

- **Increase the deployment of EVs and charging infrastructure.** Demonstrate cost-effectiveness of EVs to encourage adoption by consumers. Develop an adequate charging infrastructure to be complementary with available ranges of commercially available vehicles.
- **Support development of liquid renewable fuels to provide alternative transportation fuels.** Support R&D and commercialization of liquid renewable fuels especially for vehicles that may be more difficult to convert to an electric power source such as freight.

The Commission on the Future of Transportation will provide a report on their findings and recommendations in December 2018.

Table of Contents

Figures and Tables

Acronyms

83C	*Offshore Wind Energy Generation Procurements*
83D	*Clean Energy Generation Procurement*
AC	*Air Conditioning*
ACES	*Advancing Commonwealth Energy Storage*
ACP	*Alternative Compliance Payment*
ACS	*American Community Survey*
AEC	*Alternative Energy Certificate*
AEO	*Annual Energy Outlook*
AESC	*Avoided Energy Supply Costs*
APS	*Alternative Portfolio Standard*
Bcf	*Billion Cubic Feet*
BEV	*Battery Electric Vehicle*
BTU	*British Thermal Unit*
CAFE	*Corporate Average Fuel Economy*
CARB	*California Air Resources Board*
CBECS	*Commercial Buildings Energy Consumption Survey*
ccASHP	*cold climate Air-Source Heat Pump*
CCERI	*Community Clean Energy Resiliency Initiative*
CEC	*Clean Energy Certificate*
CECP	*Clean Energy and Climate Plan*
CEI	*Clean Energy Imports*
CELT	*Capacity, Energy, Loads, and Transmission*
CEP	*Comprehensive Energy Plan*
CES	*Clean Energy Standard*
CHP	*Combined Heat and Power*
CNG	*Compressed Natural Gas*
CO_2	*Carbon Dioxide*
CPS	*Clean Peak Standard*
DEP	*Department of Environmental Protection*
DOER	*Department of Energy Resources*
DPU	*Department of Public Utilities*
DSM	*Demand Side Management*
Dth	*Dekatherms*
EDC	*Electric Distribution Companies*
EE	*Energy Efficiency*
EEA	*Energy and Environmental Affairs*
EEAC	*Energy Efficiency Advisory Council*
EERF	*Energy Efficiency Recovery Factor*
EGU	*Electric Generating Unit*
EIA	*Energy Information Administration*

EO	*Executive Order*
EPA	*Environmental Protection Agency*
ESI	*Energy Storage Initiative*
EV	*Electric Vehicle*
FCA	*Forward Capacity Auction*
FERC	*Federal Energy Regulatory Commission*
FHA	*Federal Highway Administration*
GCA	*Green Communities Act*
GDP	*Gross Domestic Product*
GHG	*Greenhouse Gas*
GWSA	*Global Warming Solutions Act*
HVAC	*Heating, Ventilation, Air Conditioning*
IECC	*International Energy Conservation Code*
InnovatEE	*Innovate Energy Efficiency Grant Program*
ISO-NE	*Independent System Operator - New England*
KW	*Kilowatt*
KWh	*Kilowatt-hour*
LBE	*Leading By Example*
LDC	*Local Distribution Company*
LDV	*Light-Duty Vehicle*
LED	*Light-emitting Diode*
LMP	*Locational Marginal Pricing*
LNG	*Liquefied Natural Gas*
LTRCA	*Long Term Renewable Contract Adjustment*
MAPC	*Metropolitan Area Planning Commission*
MassCEC	*Mass Clean Energy Center*
MassDOT	*Massachusetts Department of Transportation*
MCCC	*Massachusetts Clean Cities Coalition*
MECS	*Manufacturing Energy Consumption Survey*
MEPA	*Massachusetts Energy Policy Act*
MLP	*Municipal Light Plant*
MMcf	*Million Cubic Feet*
$MMTCO_2$	*Million Metric Tons of Carbon Dioxide*
MOR-EV	*Massachusetts Offers Rebates for EVs*
M-SEM	*Multi-Sector Emissions Model*
MSW	*Municipal Solid Waste*
MW	*Megawatt*
MWh	*Megawatt-hour*
NCPC	*Net Commitment-Period Compensation*
NECEC	*New England Clean Energy Connect project*
NEMA	*Northeastern Massachusetts*
NERC	*North American Electric Reliability Corporation*
NG	*Natural Gas*

NGCC	*Natural Gas Combined Cycle*
NMRS	*Net Metering Recovery Surcharge*
NYMEX	*New York Mercantile Exchange*
PA	*Program Administrator*
PACE	*Property Assessed Clean Energy Program*
PHEV	*Plug-In Hybrid Electric Vehicle*
PMT	*Passenger Miles Traveled*
PON	*Program Opportunity Notice*
PRD	*Price-Responsive Demand*
PSI	*Pound Per Square Inch*
PUC	*Public Utilities Commission*
PV	*Photovoltaic*
R&D	*Research and Development*
RCS	*Residential Conservation Services*
REC	*Renewable Energy Certificate*
RECS	*Residential Energy Consumption Survey*
REMO	*Renewable Energy Market Outlook*
RFO	*Residual Fuel Oil*
RGGI	*Regional Greenhouse House Initiative*
RIE-EV	*Regional Income Eligible Electric Vehicle Rebate Program*
RNS	*Regional Network Service*
RPS	*Renewable Portfolio Standard*
SEDS	*State Energy Data System*
SEMA	*Southeastern Massachusetts*
SMART	*Solar Massachusetts Renewable Target*
SRECs	*Solar Renewable Energy Credits*
SUV	*Sport Utility Vehicle*
TW	*Terawatt*
TWh	*Terawatt-hour*
VMT	*Vehicle Miles Traveled*
WCMA	*Western/Central Massachusetts*
WTE	*Waste to Energy*
ZEV	*Zero Emission Vehicle*

1 Energy Plan Overview

1.1 Introduction

Energy use is connected to every aspect of the Commonwealth's economy. We rely on energy to keep the lights on, power industry, heat our homes, and meet our transportation needs. As the Massachusetts economy grows and technology evolves, planning for our future energy needs becomes even more important to ensure an energy system that is cost-effective, reliable, and preserves a healthy environment.

In August 2008 the Global Warming Solutions Act (GWSA) was signed into law, making Massachusetts one of the first states in the nation to move forward with a comprehensive regulatory program to address climate change.[20] The GWSA requires the Commonwealth to reduce GHG emissions 80 percent below 1990 levels by 2050. In 2010, the Secretary of Energy and Environmental Affairs (EEA) set a 2020 limit on emissions at 25 percent below 1990 levels and published the first Clean Energy and Climate Plan (CECP)[21], laying out measures necessary to meet this limit. In 2015, EEA released an updated 2020 CECP.[22] In 2015, as a member of the New England Governors and Eastern Canadian Premiers, Massachusetts joined a resolution that the 2030 reduction marker be between 35 percent and 45 percent below 1990 levels in order to remain on track to meet the 2050 goal.[23]

Currently, the majority of greenhouse gas (GHG) emissions in the Commonwealth derive from our use of energy. In the future, reducing these GHG emissions, while also maintaining an adequate energy supply, presents both a challenge and an opportunity to develop more efficient, cleaner, and renewable sources of energy.

On September 16, 2016 Governor Baker issued Executive Order No. 569 *Establishing an Integrated Climate Change Strategy for the Commonwealth*.[24] The Executive Order included a directive for the Secretary of EEA to publish "a comprehensive energy plan which shall include and be based upon reasonable projections of the Commonwealth's energy demands for electricity, transportation, and thermal conditioning, and include strategies for meeting these demands in a regional context,

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20 Acts of 2008, Chapter 298; https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter298

21 Massachusetts Clean Energy and Climate Plan for 2020; https://www.mass.gov/files/documents/2016/08/sk/2020-clean-energy-plan.pdf

22 Massachusetts Clean Energy and Climate Plan for 2020, 2015 Update; https://www.mass.gov/files/documents/2017/01/uo/cecp-for-2020.pdf

23 39th Annual Conference of New England Governors and Eastern Canadian Premiers, Resolution 39-1: Resolution Concerning Climate Change; http://www.coneg.org/Data/Sites/1/media/39-1-climate-change.pdf

24 Establishing an Integrated Climate Change Strategy for the Commonwealth; www.mass.gov/executive-orders/no-569-establishing-an-integrated-climate-change-strategy-for-the-commonwealth

prioritizing meeting energy demand through conservation, energy efficiency, and other demand-reduction resources in a manner that contributes to the Commonwealth meeting [GHG] limits."

In order to develop the CEP, the Secretary of EEA directed the Department of Energy Resources (DOER) to analyze the Commonwealth's energy use and supply in a regional context from now until 2030 under a variety of scenarios to determine which policies will best balance costs, emissions, and reliability.

The objective of this Comprehensive Energy Plan (CEP) is to analyze competing pathways going forward and to provide strategy recommendations for achieving a clean, affordable, resilient energy future for the Commonwealth. This CEP is informed by, and will inform, the broader energy planning effort within the Commonwealth as we look to 2030 and beyond. To guide development of the CEP, DOER hosted a series of stakeholder sessions across the Commonwealth in July 2018 to solicit feedback on the plan's design and key modeling assumptions. DOER is grateful to stakeholders for their feedback, which informed the subsequent analysis and writing of this final report. Details about the stakeholder process and a summary of stakeholder comments are provided in Appendix B.

This CEP investigates the relative impacts of multiple potential energy futures between now and 2030 to provide guidance to policy makers by examining the impacts of, and possible challenges from, these potential futures. The future energy supply and demand of the Commonwealth will be dependent on a number of drivers, some of which are interdependent of each other, and hence difficult to predict. Some of these drivers are general economic drivers like the economic productivity of the state, population growth, and technological innovation. Other drivers are directly related to energy policies such as our ongoing efforts to improve energy efficiency and transportation infrastructure, and to incentivize renewable energy.

Additional and complementary energy planning efforts include more detailed sector-specific studies such as the Energy Efficiency Advisory Council (EEAC) and the Three-Year Energy Efficiency (EE) plans,[25] the Commission on the Future of Transportation in the Commonwealth,[26] and the Zero Emission Vehicle (ZEV) Commission.[27] The CEP is also designed to contribute to larger planning efforts including the CECP process that establishes the policies the Commonwealth will use to meet its greenhouse gas emission reduction commitments under the GWSA and the recently announced long-range comprehensive study outlining strategies to achieve 80 percent reductions by 2050 (80 by 50 Study).

25 The Energy Efficiency Advisory Council; http://ma-eeac.org/

26 Commission on the Future of Transportation; https://www.mass.gov/orgs/commission-on-the-future-of-transportation

27 Zero Emission Vehicle (ZEV) Commission ; https://www.mass.gov/service-details/zero-emission-vehicle-zev-commission

1.2 Massachusetts Energy Goals

The state's energy policy strives to achieve three goals: clean, affordable, and reliable energy. While many energy policies or actions advance more than one of these goals, others have mixed impacts. This tension requires that the state adopt a portfolio of policies that strikes a reasonable balance.

1.2.1 Clean

The state's energy supply is transforming to an increasingly cleaner portfolio of sources, driven in part by policies developed to help meet the GWSA emission limits. Additional information on these policies is available in the 2015 Update to the Commonwealth's 2020 CECP.

In 2015, annual GHG emissions from energy totaled 70.2 $MMTCO_2e$ in Massachusetts, contributing to a 19.2 percent reduction in total emissions from 1990.[28] Of this total, the transportation sector comprised the largest share (42 percent) of total energy GHG emissions, followed by the thermal sector at 36 percent, and the power sector at 22 percent. The power sector includes emissions associated with both in-state electricity production and imports from other states sufficient to meet the demand from Massachusetts homes and businesses. The thermal sector includes end-use emissions produced by residences and businesses. This does not include GHG emissions associated with non-energy use and natural gas distribution system leaks, which totaled approximately 6 $MMTCO_2e$ in 2015.

Shifting our energy supply to cleaner sources has a number of identified benefits. It furthers the Commonwealth's leadership in the development and deployment of clean energy technologies and related industries, thus serving as a powerful business and economic driver in our state. Additionally, it provides numerous public health and environmental benefits to our residents through the reduction in local air emissions, cleaner water, and can improve our energy resilience. Finally, incentivizing the development of clean energy may reduce the overall cost of future energy sources by providing a level of price predictability, and provides financial benefits to in-state and regional suppliers and consumers by supporting a local clean energy economy.

1.2.2 Affordable

Maintaining energy affordability is important both for residents to afford basic services and for businesses to remain competitive with those in other regions of the United States and abroad. In 2017, the annual average residential retail electric rate in Massachusetts was 18.92 cents/kWh. For all sectors including commercial and industrial, Massachusetts was the 7th highest cost state in the country as measured by electric rates. High electric rates create challenges for businesses in the Commonwealth to be competitive with businesses in other states and countries and for residents, particularly lower

[28] Massachusetts Department of Environmental Protection, Appendix C: Massachusetts Annual Greenhouse Gas Emissions Inventory: 1990-2015, with Partial 2016 & 2017 Data; https://www.mass.gov/lists/massdep-emissions-inventories

income households, to afford their utility bills. Regionally, the electric rates in the six New England states are all ranked in the top eleven most expensive in the country (Figure 17).

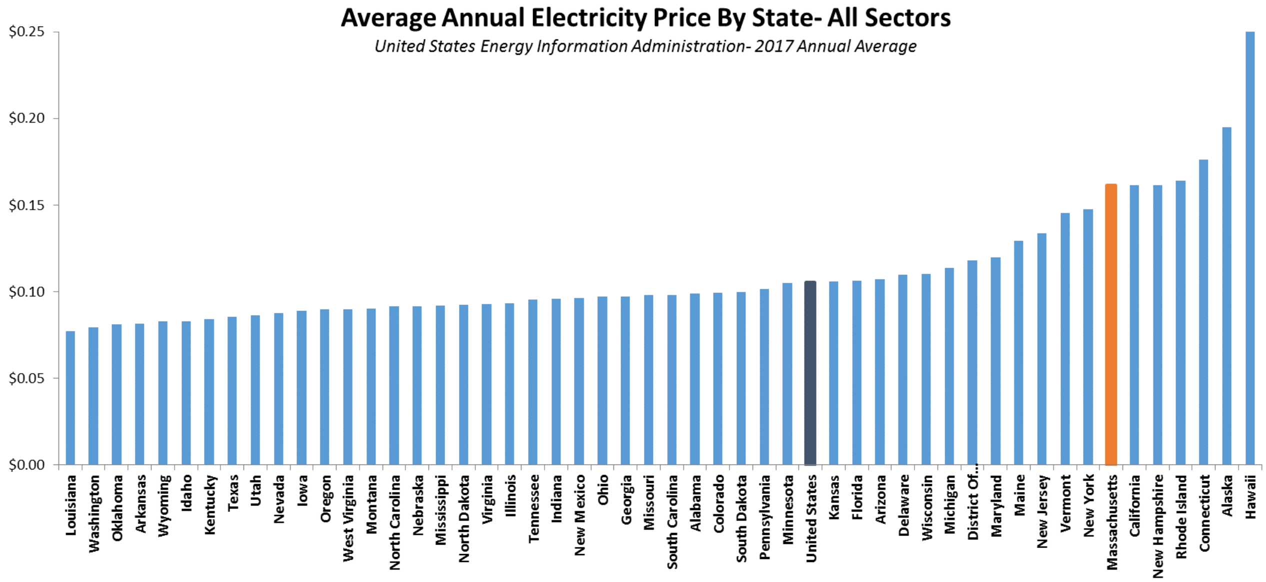

Figure 17: State Retail Electricity Rates

Energy costs typically present the greatest financial burden for low-income households and those on fixed incomes. Although on average Massachusetts residents spend about 2-3 percent of their income on home energy use, for residents at or below the poverty level, energy costs alone represent 10 percent of household income.[29] Those customers who are the most vulnerable are those who often see the highest costs for their energy and the least opportunity to independently reduce their own expenditures. Further, energy costs have impacts on the Commonwealth's competitiveness as a place to live and work. Home heating and cooling costs can impact where people and businesses chose to live and conduct business. For many residents and businesses energy cost predictability is an important factor in this decision-making process.

Energy affordability can be addressed in two key ways. First, policies can reduce the overall cost of energy, and second, policies can reduce the amount of energy customers need to buy, thus decreasing expenditures. Both of these methods can reduce monthly bills and reduce the overall energy burden across all sectors on residents and businesses. Additionally, to support customers' budgeting and understanding of their energy bills, polices can increase the predictability of costs.

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[29] Massachusetts Department of Energy Resources and Department of Housing and Community Development and Massachusetts Clean Energy Center with Technical Assistance from Meister Consultants Group; Affordable Access Working Group Final Report, pg. 1; https://www.mass.gov/files/documents/2017/09/12/aacee-report.pdf

While reducing the cost of or demand for energy can reduce consumer expenditures, determining the true full cost of energy policies is complex. Many energy investments require upfront capital outlays to reduce costs over a long period of time. Financial considerations must recognize that such investments take time to become cost effective and may run the risk of creating stranded assets as technologies and energy efficiency grows in future years.

1.2.3 Reliable

Reliability can be defined as the ability of the system to deliver energy in the quantity, and with the quality, demanded by users and do so on an ongoing and consistent basis.

Actions and policies put in place in Massachusetts can improve grid reliability and ensure consumers have access to all forms of energy. Our actions and policies must be transparent and communicated to the Independent System Operator – New England (ISO-NE), a federally regulated independent agency with the responsibility to ensure reliability of regional electricity generation and transmission.

In the winter, demand for natural gas to heat our buildings and generate electricity can exceed the amount of natural gas that the existing pipeline infrastructure can deliver into the region. This causes wholesale energy costs to spike and generators within the ISO-NE control area to rely on liquefied natural gas (LNG) and carbon-intensive fuel oil to generate electricity to satisfy demand. Last winter when natural gas supplies were constrained, the region nearly depleted its allowed oil reserves for generation, putting the grid at risk of rolling black outs. As the cold snap continued and fuel supplies decreased, the wholesale electricity daily average price spiked to $288/MWh (or 28.8 cents/kWh) from its annual average of $34/MWh (or 3.4 cents per kWh). (Figure 18).

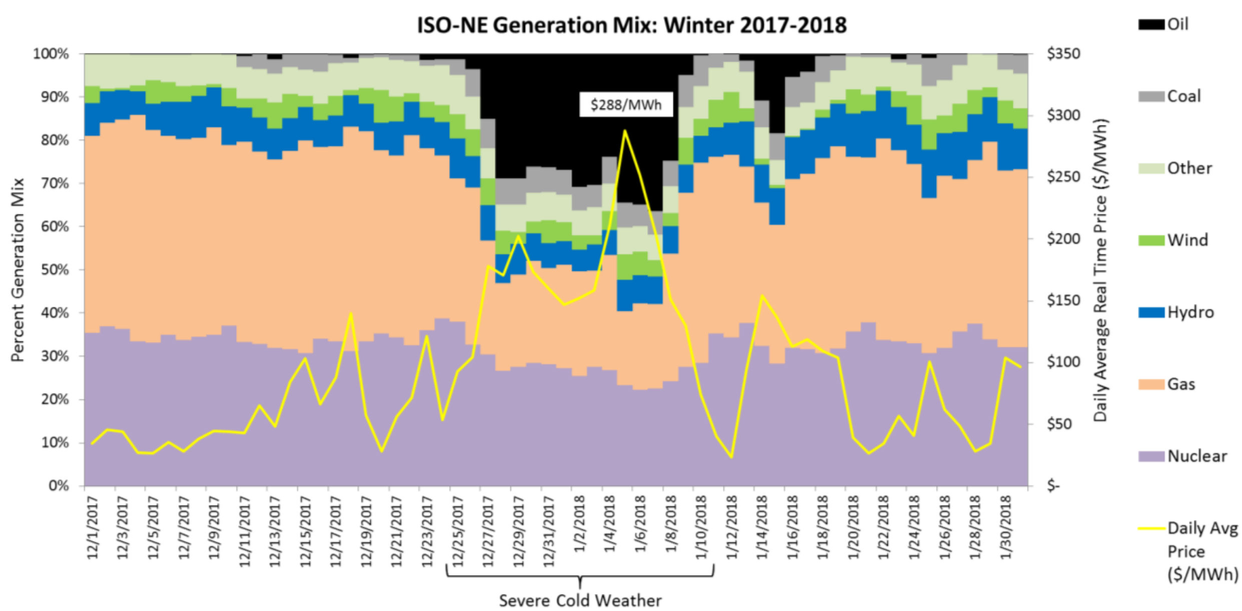

Figure 18: ISO-NE Generation Mix During Winter 2017-2018

Oil has a substantially higher CO_2 emissions rate than natural gas. During the severe cold weather event of 2017-2018, daily electricity generation emissions in New England nearly tripled from 80,000 metric tons to 225,000 metric tons CO_2.[30] The increase was due not only to the increase in electric energy consumption associated with the cold weather but the shift from lower emissions natural gas to higher emissions oil for electric generation.

1.2.4 Impacts of Meeting Energy Demand

Energy policy impacts our larger policy goals of reducing emissions, improving reliability and resiliency, and controlling the cost of energy to maintain affordability.

Emissions and Other Environmental Impacts: When fossil fuels are burned to generate energy, whether for electricity or on-site use such as heating systems and traditional gasoline cars, they create emissions. These emissions include not only greenhouse gases but also particulate matter and air pollution that have impacts on public health. Renewable energy generation such as wind and solar do not create air emissions but may be spatially limited due to siting or land use issues, and temporally limited due to the intermittency of their source.

Cost: The cost implications of energy supply can be complex. The full cost of any strategy includes the upfront costs of technologies and lifetime system costs. Electric costs are regulated by federal state authorities and municipal utilities, or municipal light plants, but may not capture all the benefits new technologies can provide. Thermal costs include not only the technology and fuel to heat but are also dependent on the efficiency of the building. A customer's transportation costs include a wide range of different costs including insurance, maintenance, fuel, parking, tolls, fares, and vehicle purchases.[31]

Reliability: The energy sector is becoming increasingly integrated and interdependent. For example, in 2017, natural gas supplied 40 percent of the region's electricity.[32] As population grows, the region may become more dependent on natural gas. Ensuring a reliable supply of natural gas for both the thermal and power sectors during times of high demand becomes an issue for electric reliability. As seen in Figure 18 and discussed further in Chapter 4, when natural gas demand exceeds supply, the region becomes dependent on stored fuels such as fuel oil. ISO-NE has expressed concern that if we continue to burn oil to generate electricity for an extended period of time, oil supply may become depleted and cause rolling blackouts.[33]

[30] ISO-NE Post Winter 2017/18 Review: Electric/Gas Operations Committee 5/11/2018; slide 22.
https://www.iso-ne.com/static-assets/documents/2018/05/2018-05-11-egoc-a2.1-iso-ne-post-winter-1718-review.pdf

[31] For this report, analysis will focus on customers' energy or fuel costs although there are likely costs to implement programs to capture benefits/reductions to customers' energy costs.

[32] ISO-NE, Resource Mix; https://www.iso-ne.com/about/key-stats/resource-mix/

[33] https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

1.3 Current Energy Policies

Massachusetts has made tremendous strides in terms of increasing clean energy supply and decreasing our overall demand for energy. Massachusetts is a leader in energy policy in the Unites States, having been ranked the number one state in energy efficiency nationwide for the past seven years.[34] Under the Baker-Polito administration we have made tremendous progress in decreasing the overall demand for energy in our state and increased the amount of energy from clean and renewable sources. For example, in 2017 we reduced our annual consumption of electricity by 3.18 percent and natural gas by 1.20 percent, the highest of any state in the country.[35] The benefits of meeting these energy policy goals include: lower cost energy, improved grid resiliency, reductions in greenhouse gas emissions, and other associated economic and health benefits.

Massachusetts is also a leader in terms of switching to lower-emitting sources of energy, recently building on existing policies like the Renewable Portfolio Standard with a series of clean energy procurements including 9.45 TWh of hydroelectric energy and 800 MW of offshore wind.

In August 2018, Governor Baker signed the Commonwealth's newest energy legislation, An Act to Advance Clean Energy.[36] This law increases the RPS by 2 percent each year (up from 1 percent) between 2020 and 2029, sets an energy storage target of 1,000 MWh for 2025, and establishes a first-of-its-kind Clean Peak Standard to incentivize clean energy resources (namely, qualified RPS resources, qualified energy storage systems or a demand response resources) that generate, dispatch or discharge electricity to the electric distribution system during seasonal peak demand periods, or alternatively, reduce load during seasonal peak demand periods. Due to the timing of this report's preparation and publication, the policies in this most recent legislation are not directly reflected in this Comprehensive Energy Plan.

This most recent legislation builds on the comprehensive, bipartisan Energy Diversity Act signed by Governor Baker in 2016.[37] The Act authorized the Clean Energy Generation (83D) and Offshore Wind Energy Generation (83C) procurements, created the Property Assessed Clean Energy Program (PACE) to help finance energy upgrades for commercial buildings, and directed DOER to research and set a target for procuring advanced energy storage.

The Energy Diversity Act builds on the existing clean energy law and policy for the Commonwealth, including the Green Communities Act (GCA) of 2008.[38] The GCA established many of the key energy

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[34] American Council for an Energy-Efficient Economy (ACEEE), The State Energy Efficiency Scorecard; http://aceee.org/state-policy/scorecard

[35] Massachusetts Energy Efficiency Advisory Council; Plans and Updates; *2016-2018 THREE-YEAR ENERGY EFFICIENCY PLAN;* http://ma-eeac.org/plans-updates/

36 An Act to advance clean energy; https://malegislature.gov/Bills/190/H4857

37 https://malegislature.gov/Bills/189/House/H4568

38 https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter169

policies and programs that continue to shape the energy sector today, including the development of three programs, introduced in January 2009:[39]

- Renewable Portfolio Standard (RPS) Class I - evolved from the original RPS program from 1997
- RPS Class II – provides incentives for the continued operation of qualified pre-1998 renewable and waste-to-energy generation units
- Alternative Energy Portfolio Standard (APS) – designed to support technologies that reduce the consumption of fossil fuels such as combined heat and power (CHP), and those that provide frequency regulation services, such as flywheel storage.[40]

The GCA also directed utilities to pursue all cost-effective energy efficiency, required regular adoption of model building energy codes, and established a Green Communities program to assist municipalities in achieving clean energy goals. Additionally, the GCA implemented a net metering policy for distributed renewable energy, and directed utilities to begin soliciting long-term contracts for renewable energy.

39 https://www.mass.gov/service-details/program-summaries

40 Later expanded by the Energy Diversity Act of 2016 to support fuel cells, and waste-to-energy and renewable thermal technologies.

2 Energy Supply and Demand in Massachusetts

2.1 Overview of Demand and Supply

2.1.1 Demand for Energy

The power, thermal conditioning, and transportation sectors comprise the Commonwealth's energy demand and the majority of greenhouse gas emissions.

- **Power:** refers to the electricity that consumers in homes and businesses use, including lighting, refrigeration, laundry, cooking, televisions, and computers.[41]

- **Thermal Conditioning:** refers to the energy demand for heating and cooling in the residential, commercial, and industrial sectors. This includes heating and conditioning spaces in homes and businesses, heating water for use in cleaning and cooking, and industrial process heat.

- **Transportation** refers to the needs of Massachusetts residents and businesses to move themselves and material from one location to another. Transportation energy demand includes gasoline for cars and light duty trucks, diesel for heavy duty vehicles, electricity for trains, jet fuel for airplanes, and other energy expended to move people and materials.

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[41] Electricity is also used in the thermal and transportation sectors. For the analysis in this Report, electric use in the thermal and transportation sectors is included in the power sector, and not the thermal and transportation sectors, in order to avoid double counting.

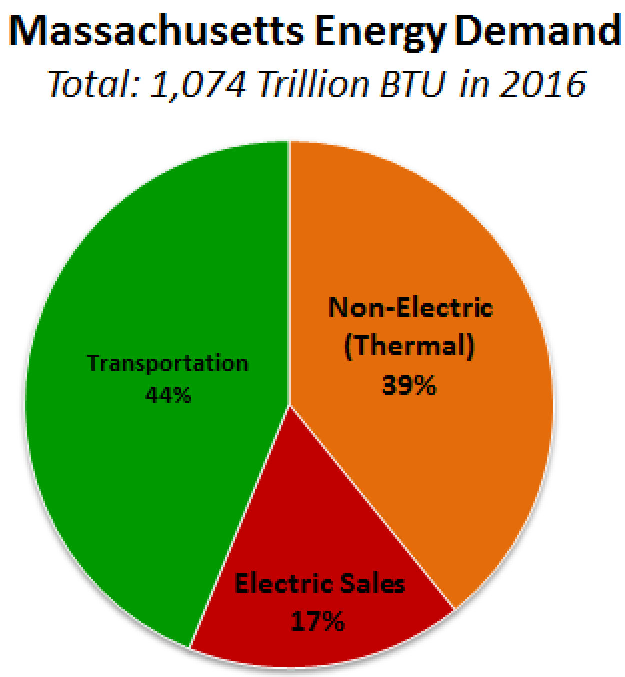

Figure 19: Massachusetts Energy Demand in 2016 - BTUs

In 2016, the non-electric or transportation sector comprised the largest share (44 percent) of Massachusetts' total energy demand. This was followed by the thermal sector (at 39 percent) and the electric sector (at 17 percent).[42]

There are a number of factors that contribute to how much energy Massachusetts consumes, commonly referred to as demand drivers. Demand drivers are closely linked to population and economic growth as well as aspects beyond policy controls, such as severe cold or hot weather. Another important demand driver is technology and associated technology efficiency. More efficient technologies can provide the same service while consuming less energy. Consumer choice for services is also an important demand driver. These services include heat, light, cleaning, computing, entertainment, and travel. Energy demand is therefore intrinsically linked with consumer behavior, correlating with work and home patterns, weather conditions, and the devices we use.

2.1.2 Supplying Energy

There are two ways to meet customers' demand for energy services. The first is by generating the energy, through electric generation or on-site fuel combustion, and the second is consumption

[42] In these values, the power sector only includes energy consumed at the retail level, and does not include losses. In the remainder of this report, losses are included in the analysis. The non- electric sector includes end-use energy consumed in residences and businesses for all thermal uses, not just space conditioning uses.

reduction, achieved by increasing the efficiency of end-use technology. Efficiency improvements include increasing building insulation to reduce heating consumption, increasing vehicle efficiency to reduce transportation sector consumption, or increasing load efficiency such as LED lightbulbs to decrease electric sector consumption. Both generating energy and energy efficiency face implementation challenges. Additionally, these two methods have different impacts on emissions, costs, and reliability. Generating energy, including electricity, requires the purchase of fuel, the operation of generation technologies, the transportation of energy or fuel, and the associated emissions from fossil fuel use. Energy efficiency avoids the need for generation and its associated impacts, but can only reduce and not eliminate the need for energy generation.

2.1.3 Policy Challenges

Massachusetts policy makers face multiple challenges when developing strategies to shape the state's future energy use. These challenges include:

- Consumer Choice: Because energy is used to provide consumer services, future energy trends are defined by what consumers choose to buy and use. Policy makers do not have control over consumer choice but can develop programs and incentives to promote certain technologies and consumption patterns.
- Infrastructure and Technology Turnover: Infrastructure and consumer technologies are often not replaced until the end of their useful lives, limiting the opportunity for policies to change demand drivers quickly. Replacing infrastructure or technologies before the end of their useful lives may have energy efficiency benefits but will result in stranded costs.
- New Technologies: Future energy use will be greatly impacted by the development and growth of new technologies. Although policymakers can support the development of game changing technologies, development is hard to predict and cannot be forced.
- Jurisdictional Issues: Many aspects of energy use are regulated by federal authorities. States have limited power to affect interstate commerce issues in particular, and must be mindful of the regional and national nature of energy regulation and laws. Residents of one state may not have the same goals for energy supply and demand as another. Further, energy related infrastructure (refineries, terminals, pipeline, solar and wind farms) may serve the needs of several states based on supply and demand economics.
- Other Drivers: Economic growth, population changes, and weather, including increased frequency or duration of extreme weather events, can each impact and change demand for energy. Policy makers cannot control these drivers, and in cases such as economic growth, do not want to limit these drivers.

2.2 Power

The power sector includes energy use related to the consumption or production of electricity. On the demand side this includes uses such as lighting, computing, and refrigeration as well as the demands for electricity from the other sectors, including electric heating/cooling and electric vehicles. In order to avoid double-counting demand, electricity used for heating, cooling, and transportation is not accounted for in the thermal conditioning and transportation sectors in the modeling results.

2.2.1 Demand

Today's demand for electricity can be primarily attributed to three different sub-sectors:

a) Residential – Single and multi-family homes

b) Commercial – Small and medium-sized businesses

c) Industrial – Very large businesses, warehouses, and production facilities

Since the early 1990s, electricity consumption in the residential sector has made up about one-third of Massachusetts' demand for electricity.[43] The industrial sector has shrunk from about one-fifth of the electricity demand in the early 1990s to about 15 percent in recent years. Simultaneously, the commercial sector has expanded from about 40 percent of demand in the early 1990s to half of demand today. This is in keeping with the general shift away from manufacturing to a service-based economy in Massachusetts and New England.

Demand for electricity within the residential sector is widely fragmented across a number of uses (see Figure 20).[44] The largest components of demand relate to space conditioning: cooling and heating; together these are responsible for one quarter of consumption. Refrigeration, lighting, water heating, TVs and computers together make up over one-third of residential demand. Cooking, clothes washing, and miscellaneous uses add up to the remaining more than one third of all residential consumption—miscellaneous uses include security systems, battery chargers and power supplies, and dehumidifiers, among many diverse uses.[45]

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43 Data on electricity sales is available from the EIA at https://www.eia.gov/electricity/data/eia861/

44 Data on residential demand components is from EIA's 2015 Residential Energy Consumption Survey (RECS), available at https://www.eia.gov/consumption/residential/data/2015/, and EIA's 2018 Annual Energy Outlook, available at https://www.eia.gov/outlooks/aeo/. Massachusetts- and New England-specific data are used wherever possible, with supplements from national-level data.

45 See "Analysis and Representation of Miscellaneous Electric Loads in NEMS" at https://www.eia.gov/analysis/studies/demand/miscelectric/pdf/miscelectric.pdf for a discussion of miscellaneous loads

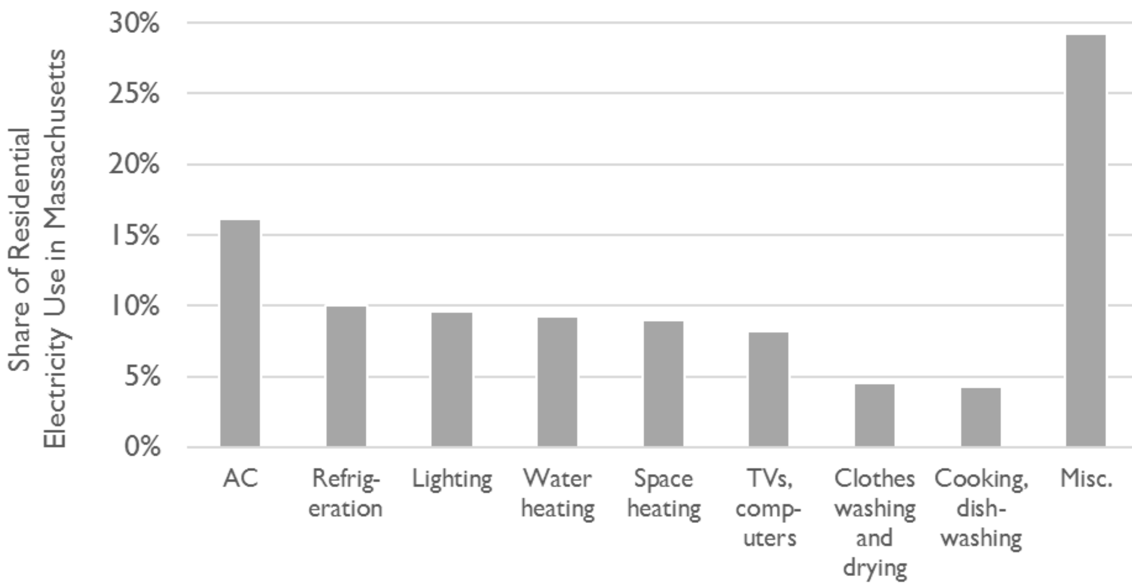

Figure 20: Share of residential electricity use in Massachusetts

Demand for electricity within the commercial sector is similarly fragmented (see Figure 21).[46] The largest component of demand in the commercial sector is refrigeration, followed closely by lighting, ventilation, computers, and air conditioning. Space and water heating, cooking, and miscellaneous uses add to the final quarter of demand. Miscellaneous uses in the commercial sector include laboratory equipment, IT equipment, and security systems, among many diverse uses.

[46] Data on commercial demand components is from EIA's 2012 Commercial Building Energy Consumption Survey (CBECS), available at https://www.eia.gov/consumption/commercial/. Non-heating electric use data presented here is representative of New England as a whole; it is assumed that end uses in Massachusetts are not dissimilar.

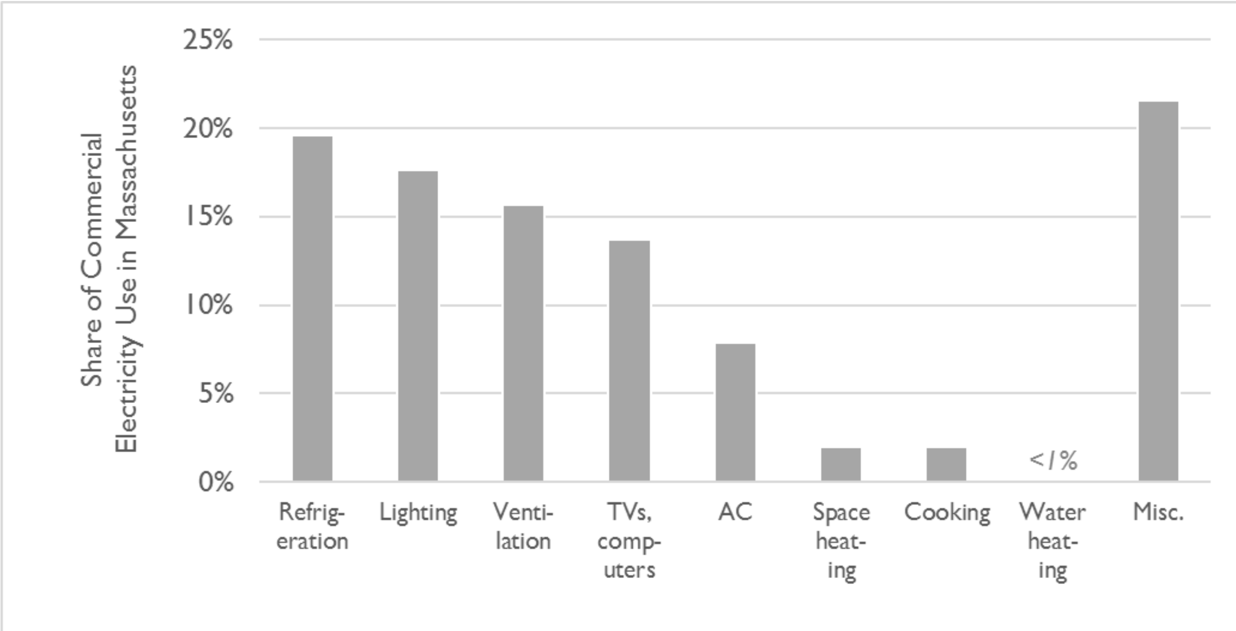

Figure 21: Share of commercial electricity use in Massachusetts

Note that the recent growth in commercial floor space, as the result of a growing service and information-based economy in the Commonwealth, has resulted in increased commercial energy demand. Commercial building natural gas use in Massachusetts has nearly doubled in the last decade. Projected future development in Massachusetts as shown in MassBuilds, managed by the Metropolitan Area Planning Council (MAPC),[47] is expected to increase energy demand in the commercial sector.

2.2.2 Supply

Electricity generation and transmission is coordinated by ISO-NE who has been delegated authority from the Federal Energy Regulatory Commission (FERC) to manage the wholesale energy markets for the six New England states. These energy markets competitively procure electricity services including the wholesale electricity market which provides real time electricity, capacity markets which are designed to ensure sufficient generation capacity in the future, transmission tariffs, and multiple markets that support the reliability of the New England electric grid. Massachusetts participates in the ISO-NE stakeholder processes and ISO-NE considers many state policies in their market structures but, ultimately, the federal authorities have jurisdiction over the regional electricity markets. There is a diverse portfolio of electric generation units which provide electricity to the New England wholesale

[47] www.massbuilds.com

markets. In 2017, generation was met through natural gas, nuclear, renewables such as wind, solar, and wood, hydroelectric, coal, oil, and imported electricity from external regional grids.[48]

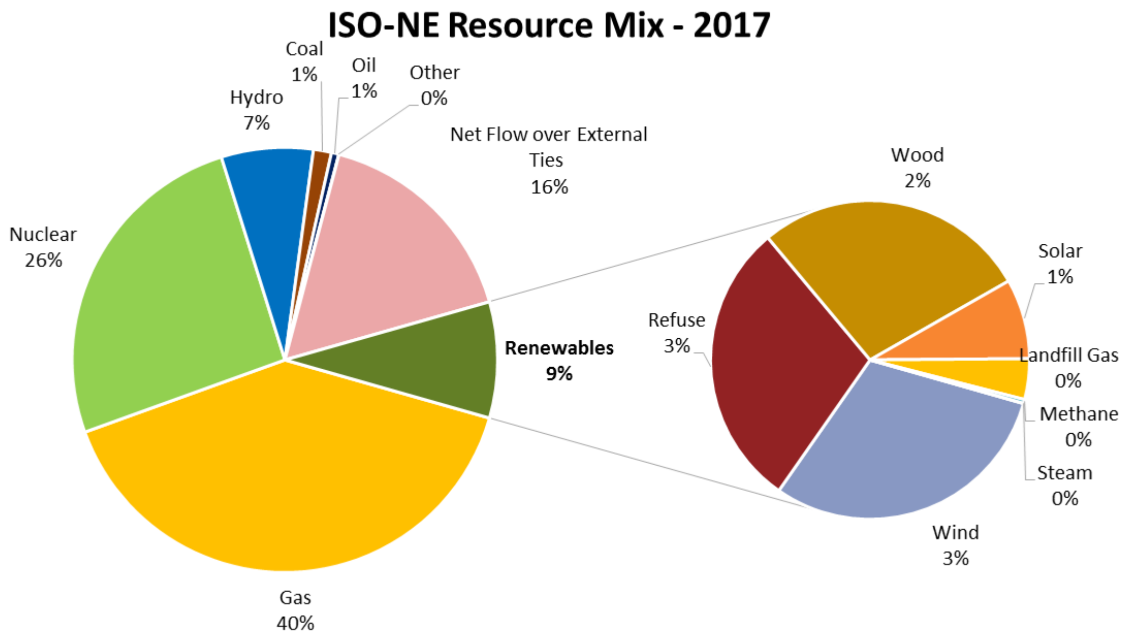

Figure 22: ISO-NE Resource Mix 2017[49]

Most electricity in New England is produced by utility-scale central station facilities. Electricity is also increasingly produced from facilities that are located on the distribution system, also known as distributed resources, such as cogenerating resources and distributed solar facilities (e.g., rooftop solar panels). Massachusetts is home to 350 central station facilities, or about 13,300 MW of electric generating capacity.[50] In all of New England, there are about 740 central station power plants, totaling about 35,700 MW of capacity.[51] Electricity from these in-region power plants are supplemented by electricity imports from outside New England, primarily from Québec, New York, and New Brunswick.

In addition to conventional power generating facilities, New England's electric grid also features renewable resources. As of September 2018, the Commonwealth is home to 2,240 MW of installed solar

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[48] ISO-NE, Resource Mix; https://www.iso-ne.com/about/key-stats/resource-mix/

[49] ISO-NE, Resource Mix; https://www.iso-ne.com/about/key-stats/resource-mix/; Resource Mix does not include behind-the-meter solar. Resources presented as 0 percent are less than 0.5 percent of the resource mix.

[50] See the U.S. Energy Information Administration (EIA)'s 860 database at https://www.eia.gov/electricity/data/eia860m/ for more information. Note that each individual power plant may be made up of more than one generating "unit". At any given power plant, these units may or may not be the same fuel type. Therefore, there may be discrepancies in power plant counts between data sources depending on definitions used.

[51] Ibid.

capacity in 86,112 projects,[52] 113 MW of installed on-shore wind capacity in 129 projects and 483 MW of installed combined heat and power (CHP).[53] In all of New England there are 2,400 MW of installed solar capacity and 1,300 MW of installed on-shore wind capacity.[54] The majority of Massachusetts' solar installations are connected at the distribution level, meaning the ISO-NE does not have visibility into the operations of the solar resources. The result is that the solar production in Massachusetts is viewed as demand reduction from ISO-NE's perspective. In addition, Massachusetts is home to 2 pumped storage facilities and 54 battery storage facilities operating and in development.

Since 2010, New England has shifted from relying primarily on fossil generation to an increased reliance on renewables and imported electricity (the vast majority of which is hydroelectricity from Québec). Total electricity generation from fossil sources has decreased from a 55 percent share in 2010 to a 43 percent share in in 2017 (see Figure 23). Meanwhile, the share of electricity from non-fossil, non-nuclear sources has increased from 15 percent in 2010 to 31 percent in 2017.

52 Many solar facilities are residential rooftop facilities and are considered "behind the meter" (BTM). This means that these facilities are not managed by the regional grid operator, ISO-NE, and instead are seen as reducing demand or offsetting the need to the grid operator to produce electricity.

53 See Massachusetts Installed Renewable Energy Snapshot for current totals at https://www.mass.gov/service-details/renewable-energy-snapshot

54 ISO-New England Power Grid Profile 2017-18 https://www.iso-ne.com/static-assets/documents/2018/02/ne_power_grid_2017_2018_regional_profile.pdf

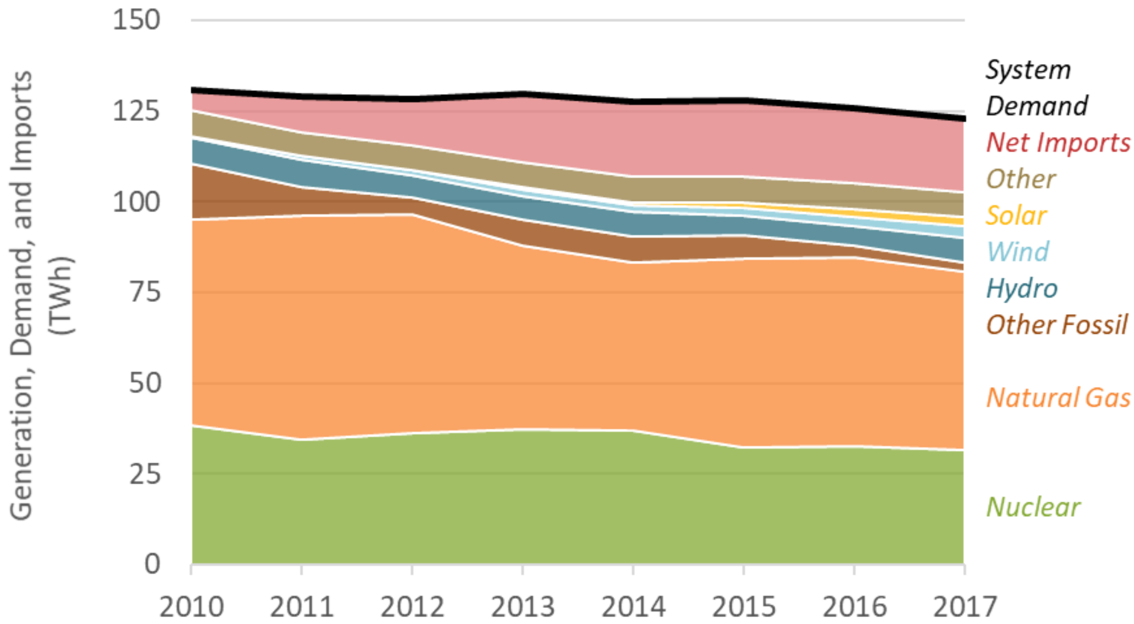

Figure 23. New England-wide electricity demand and supply by resource type[55]

Looking forward, the electricity sector in Massachusetts and the wider New England region is expected to continue to undergo substantial change. In addition to a continued expectation of low or decreasing electricity demand caused by the increase of energy efficiency and new distributed behind the meter resources, new and existing state legislation and regulations, regional agreements, and market forces all point to a drastically different future for electricity generation over the next ten to fifteen years.

2.2.3 Challenges

Massachusetts is part of the New England restructured electricity market, meaning generators sell their electricity in a competitive market to companies that then supply that energy to customers. Customers can choose to purchase electricity from a competitive retail supplier or receive basic service from their electric utility. There are three investor-owned electric distribution companies (EDCs) operating in Massachusetts – National Grid, Eversource, and Unitil – as well as 41 municipal owned light plants (MLPs) serving all or part of 50 communities.[56] The investor-owned utilities are regulated by the Department of Public Utilities (DPU) and must file business actions for DPU approval. The Massachusetts state legislature can pass laws that direct and shape the actions of these regulated utilities.

[55] Note: "Other fossil" includes generation from coal- and oil-fired facilities. "Other" includes landfill gas, methane, refuse, and other miscellaneous resource types.

[56] Massachusetts Municipally owned light plants: https://www.mass.gov/info-details/massachusetts-municipally-owned-electric-companies

All of the participants in the power sector, including ISO-NE, generators, suppliers, the utilities, and the state, face significant and unique challenges to help maintain a reliable power system.

2.2.3.1 Peak Demand

Electric use varies hour to hour and day to day. Currently, peak electric demand occurs in the late afternoon and early evening when people come home from work and turn on their lights, open their fridge, and adjust their air conditioning or their heat, while businesses are still open and commercial load is still operating. This trend in peak energy demand has intensified as the economy shifts from manufacturing to service-oriented business, relying less on constant energy use for manufacturing to more day-use office space. In order to ensure that there is sufficient generation to meet peak demand, there must be generating facilities that turn on specifically during times of increased demand. ISO-NE forecasts and tracks real-time demand and uses market signals to incentivize these generators to be available for use during periods of peak demand.

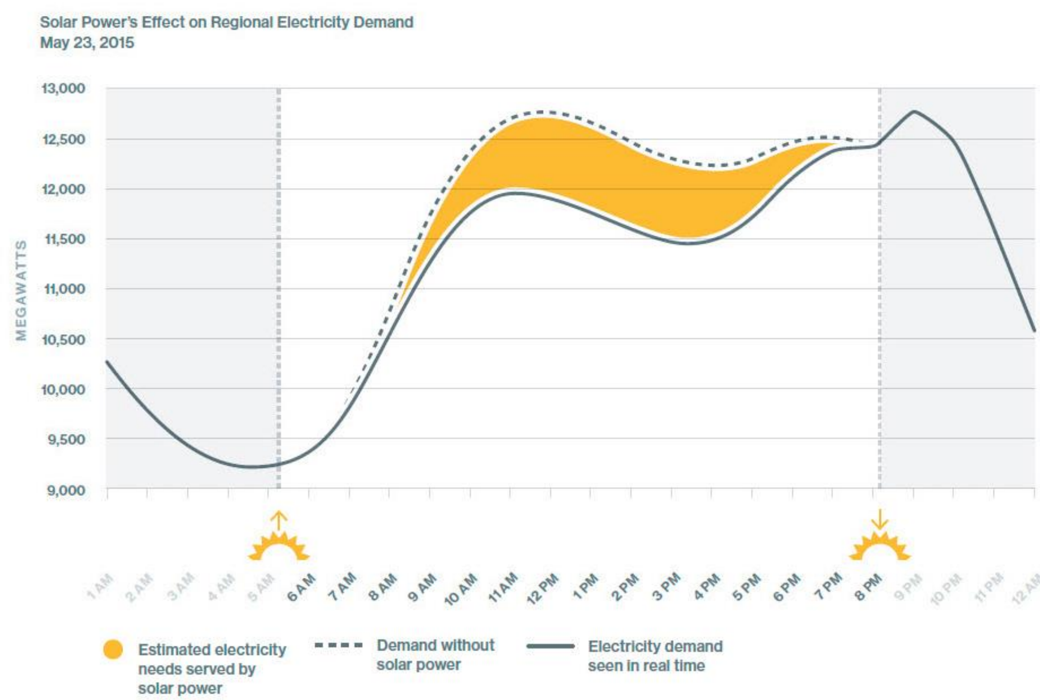

Figure 24: Impact of Solar on Regional Demand[57]

One growing challenge for ISO-NE in forecasting when peak demand will occur is the rise of behind the meter solar. As seen in Figure 24, solar facilities generate at their maximum capacity during the sunniest times of the day. As these facilities act as a demand reduction, the peak shifts away from times during

[57] http://isonewswire.com/updates/2016/10/26/new-iso-ne-webpage-highlights-the-growing-impact-of-solar-po.html

the day and moves closer to the evening hours when the sun has set. In order to accurately predict the size and timing of peak, ISO-NE must also predict how sunny the day will be and how much solar energy will be generated.

In order to meet the peak, there must be sufficient infrastructure to generate and deliver the peak amount of energy, no matter which day or hour it occurs. This includes the generation fleet, the fuel delivery infrastructure, and the wires to transmit and distribute the electricity. Additionally, the thermal sector relies on the same fuel delivery infrastructure and cold winter days that cause peak demand for the thermal sector often coincide with high demand for the electric sector.[58] Sizing infrastructure to meet peak demand is essential for reliability but can also be expensive. Energy storage (whether fuel storage or other) is a method to save energy from periods of relatively low demand, and to dispatch and offset periods of peak demand, enabling the achievement of reliability without the substantial infrastructure costs of building the system to meet peak loads.

2.2.3.2 Fuel Security

Fuel security in New England has been an issue of increased concern over the past decade. The growing dependence on natural gas for power generation and heating, and associated infrastructure constraints, coupled with the increasing retirement of coal, oil and nuclear resources, has led to concerns that regional dependency on a single energy source increases our vulnerability to disruptions. Industry and the grid operator have raised concerns that existing natural gas infrastructure may not always be adequate to deliver the gas needed for both heating and power generation during winter. These factors, coupled with the fact that the vast majority of the fuels we depend on to meet energy demand are imported from outside New England, contribute to fuel security as a growing issue in New England.

Ensuring the availability and reliability of fuel sources to meet our power needs is critical to both our economic security and safety. In January 2018 ISO New England, the region's independent electrical grid operator, published a Fuel Security Analysis[59] assessing fuel security and grid reliability for New England under different scenarios for winter 2024/25. That report found that planned retirements of nuclear and coal generators in the region, combined with potentially constrained natural gas supply from pipelines and Liquefied Natural Gas (LNG), could result in fuel shortages and system reliability problems under several possible scenarios for winter 2024/25.[60] In July 2018, FERC ordered ISO-NE to permanent tariff revisions to improve market design for regional fuel security concerns.[61]

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58 For more information on the connection between the thermal and electric sectors' demand for natural gas and reliability, please see Chapter 4.

59 January 2018 ISO New England Fuel Security Analysis at https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

60 January 2018 ISO New England Fuel Security Analysis, study results pages 32-46. https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf;

61 164 FERC 61,003, Order Denying Waiver Request, Instituting Section 206 Proceeding, and Extending Deadlines

2.2.3.3 Integrating Renewable Energy

Many types of renewable energy resources, such as solar and wind, are intermittent, meaning they provide electricity at a varying rate throughout the day based on natural resource availability. The amount of power generated by a wind farm can increase or decrease significantly throughout the day as wind speeds change and vary between onshore and offshore facilities. A rooftop solar system generates some power in the morning, maximum power at midday, and no power after sunset and can vary quickly throughout the day as cloud cover changes. This intermittency contrasts with dispatchable energy resources like natural gas or nuclear power plants, which can use stored or supplied fuels to generate power on demand throughout the day. Since the electrical grid requires a near-instantaneous balance between generation and consumption of electricity, the intermittent nature of renewable energy generation can present a challenge for integrating these resources on the grid and maintaining a reliable system. ISO-NE relies on a set of sophisticated tools to forecast future demands, including forecasting generation from wind and solar resources. In addition, typical daily patterns associated with renewables can also work advantageously for balancing the grid: for example, solar power generation partly coincides with demand peaks on hot summer days when there is a large amount of demand from air conditioning demand. The integration of large-scale renewable energy resources has been successful in the New England grid to-date, but will require continued careful management to ensure reliability as more of these resources displace conventional generation.

2.3 Thermal Conditioning

The thermal sector includes all energy use related to heating, ventilation, air conditioning (HVAC) and water heating in homes and businesses. More generally, this sector concerns any on-site consumption of natural gas, fuel oil, propane, or biofuels for space heating and water heating, as well as electricity use for direct heating and cooling This sector also includes fuels burned in industrial processes.

2.3.1 Demand

The demand for thermal energy in Massachusetts can be split into three sub-sectors:

- Residential thermal demand: This includes the demand for HVAC, cooking, and water heating in single- and multi-family homes. These end uses are met using furnaces, boilers, air conditioners, heat pumps and water heaters. Residential buildings generally require significantly more heating than cooling in the New England climate.

- Commercial thermal demand: This includes the demand for HVAC, cooking, and water heating in small- and medium-sized businesses. As in the residential sector, these end uses are met using furnaces, boilers, air conditioners, heat pumps and water heaters. Larger commercial buildings typically have significant distribution system loads (pump motors and fans) higher cooling and ventilation demands, and also use a significant amount of electric resistance heating coils to deliver targeted heating where needed to supplement central distribution HVAC systems. These larger buildings thus generally have a balance of natural gas and electric loads, but can also tap into district heating or combined-heat-and-power (CHP) systems where available.

- Industrial thermal demand: This primarily includes the demand for process heat (typically fossil fueled) in manufacturing and industrial facilities. In addition to meeting these end uses with boilers, furnaces and heat pumps, buildings within this sector may also use large-scale district heating and CHP equipment.

Of these categories, the residential sector is the largest consumer of non-electric end-use fuels in Massachusetts, with demand at nearly half of all fossil fueled thermal end-use energy in 2016 (Figure 25). The commercial sector is the next largest, demanding about one third of all fossil end-use energy, and is a larger consumer of electricity. The industrial sector in Massachusetts is the smallest, demanding about one-fifth of all direct thermal end-use energy in 2016. Cooling for all buildings (residential and commercial combined) comprises about 4 percent of all thermal energy use in Massachusetts.

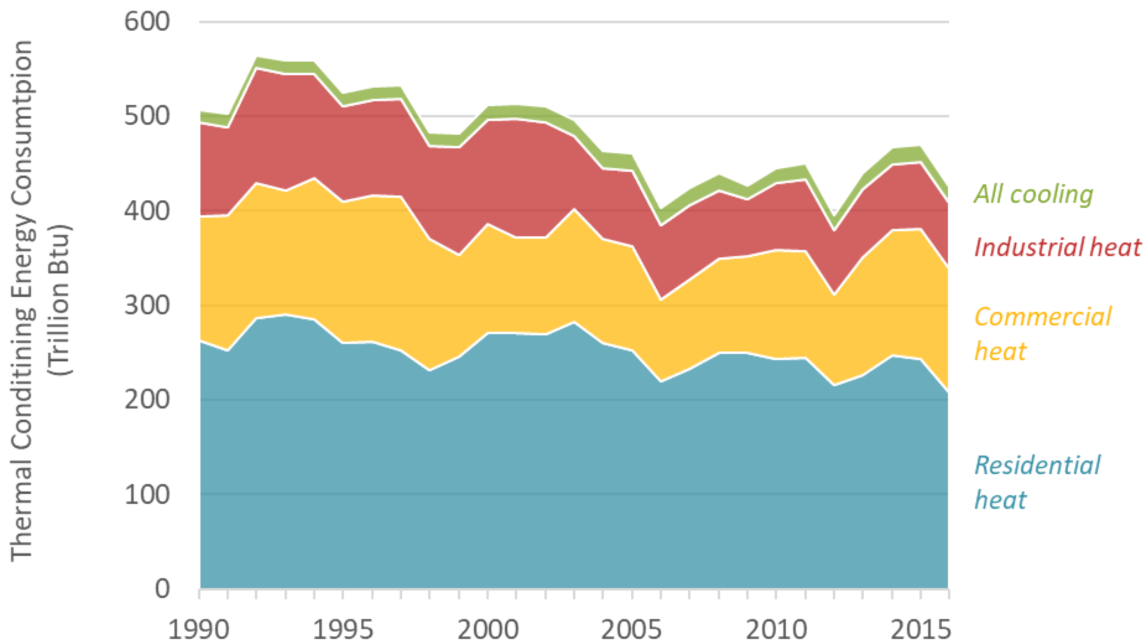

Figure 25. Thermal conditioning energy use in Massachusetts

2.3.2 Supply

Today, non-electric thermal demand in Massachusetts is primarily met using fossil fuels. However, over time the components of this supply have evolved.

2.3.2.1 Residential sector

In the residential sector, most demand for thermal conditioning is met using natural gas. Over time, the share of natural gas used to meet non-electric residential demand has increased from 44 percent in 1990 to 59 percent in 2016. Since 1990, a large portion of consumers in Massachusetts have switched from fuel oil to natural gas, with the oil market share declining from 47 percent in 1990 to 33 percent in 2016.

The majority of homes and businesses in Massachusetts have access to or directly connect to the natural gas distribution system operated by their local natural gas utility (Figure 26). Those buildings that are not connected to natural gas distribution must heat with other delivered fuels, such as propane, heating oil, and wood, or use electric heating from either resistance heating or heat pumps. Additionally, some buildings that are served by natural gas utilities cannot switch to natural gas for their thermal needs because of moratoriums on new customers. These moratoriums limit new customers because of infrastructure limitations. Other fuel options, chiefly propane and biomass, constitute the remaining 8 percent of thermal customers. An important consequence of this change in residential fuel sources has been a switch to not only cleaner fuels but newer and more efficient furnaces and boilers.

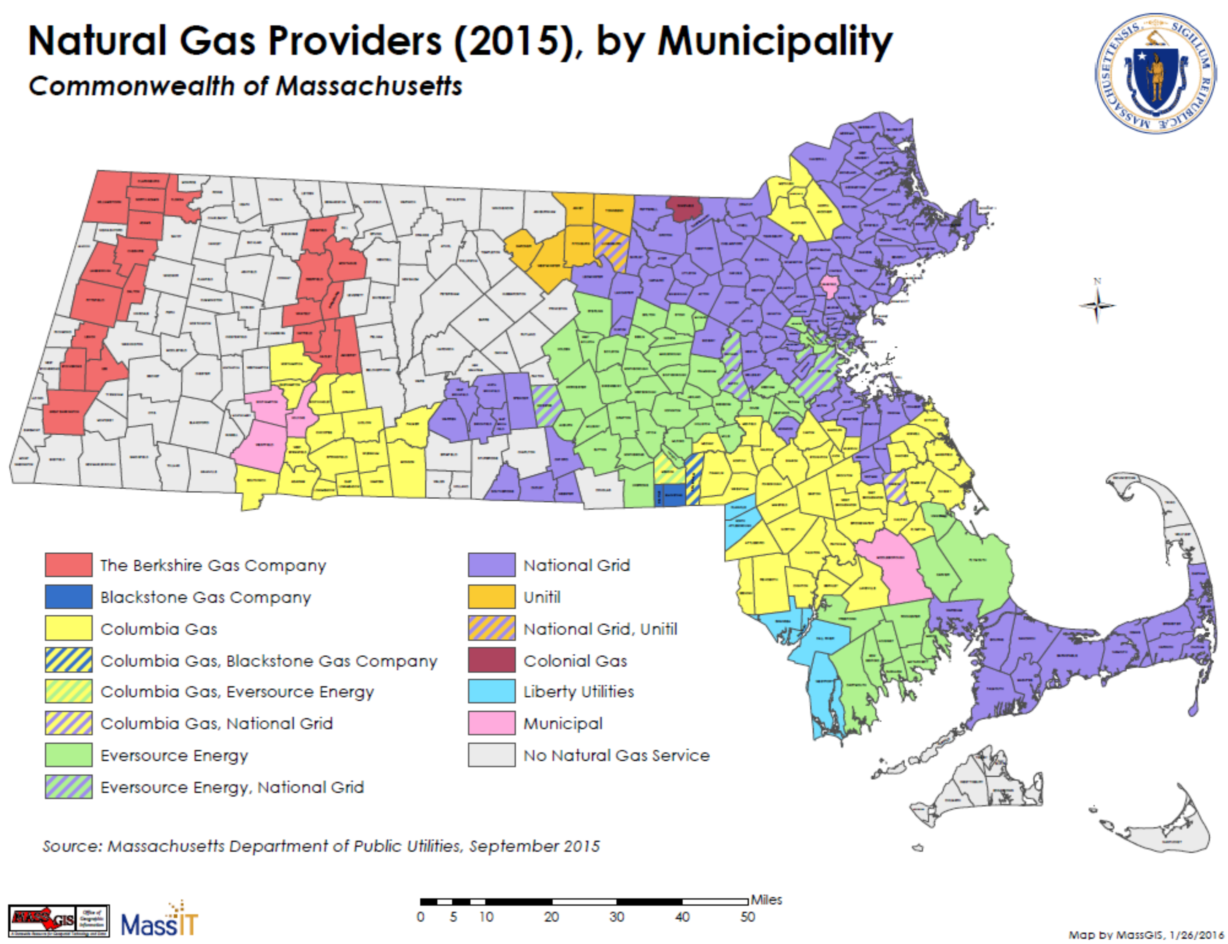

Figure 26: Massachusetts Natural Gas Providers (2015), by Municipality (Commonwealth of Massachusetts)[62]

[62] MassGIS; https://www.mass.gov/files/documents/2017/01/xl/naturalgas2015.pdf

2.3.2.2 Commercial sector

The commercial sector includes both large and small businesses. This sector also includes institutional and public buildings, municipal buildings, schools, and hospitals. Businesses in Massachusetts, to an even greater extent than residents, meet thermal demand using natural gas. In 2016, the commercial sector met 84 percent of its total non-electric end use demand with natural gas (versus 40 percent in 1990). The use of fuel oil in the commercial sector has dropped precipitously, from 56 percent in 1990 to 12 percent in 2016.[63] Other fuels, primarily propane and biomass, make up the remaining 4 percent of supply.

Historical demand for non-electric end use fuels has been marked by two major trends over the past 25 years. First, a significant amount of non-electric energy use dropped off in the late 1990s. While part of this trend was due to a decrease in the number of observed heating degree days, the decrease coincided with a significant shift in the economy, away from more energy-intensive commercial activities such as light manufacturing, and towards less energy-intensive commercial activities, such as services, as well as some electrification of commercial HVAC equipment.

The second major trend observed in the commercial sector in recent years has been a marked increase in the consumption of natural gas since the mid-2000s – a period of time when natural gas has been consistently cheaper than heating oil. While some of this increase can be explained through variations in heating degree days and a general price-driven trend away from fuel oil consumption and towards natural gas consumption, a substantial component of this increase has been due to an increase in new commercial square footage.

2.3.2.3 Industrial sector

As in the residential and commercial sectors, industrial facilities in Massachusetts also meet most of their thermal conditioning demand using natural gas. In 2016, the industrial sector met 56 percent of its total non-electric end use demand with natural gas (versus 43 percent in 1990). The share of fuel oil in the industrial sector has dropped from 45 percent in 1990 to 34 percent in 2016. Other fuels, again primarily propane and biomass, have made up the remaining 10 percent of supply, on average.

Following the commercial sector, consumption of non-electric fuels in the industrial sector decreased substantially in the early 2000s as Massachusetts' economy continued its transition from a manufacturing-based economy to a services-based economy. Since the mid-2000s, total non-electric fuel consumption by the industrial sector has remained relatively constant, with a minor amount of switching away from fuel oil to natural gas and biomass.

[63] Fuel oil consumption in the commercial sector is more varied in than in the residential sector, containing small but nonzero amounts of kerosene, residual fuel oil, and motor gasoline.

2.3.3 Challenges

Promoting a cleaner, more resilient, and more affordable thermal energy sector in the Commonwealth faces several key challenges. These challenges include current building code standards, consumer demand and choice related to the types of residential heating and cooling systems installed, and other issues such as the geographic availability of certain fuels and issues related to financial burden and incentives for fuel switching to certain types of fuel.

Building codes play a major role in determining the energy efficiency of buildings and thus the amount of energy needed to heat and cool them. Massachusetts sets state building codes that meet international standards for energy efficiency. Additionally, 241 municipalities in Massachusetts have chosen to adopt the Stretch Code[64], which sets even more ambitious energy efficiency standards for buildings. Although there has been widespread adoption of the Stretch Code among Massachusetts cities and towns, it is ultimately a voluntary choice by communities to adopt it, and affects only new construction and major renovations.

Individual businesses and consumers make choices about the type of heating and cooling systems to install, which determines the fuel mix for the thermal conditioning sector. Often these heating and cooling systems are replaced on an emergency basis, typically requiring the business or consumer to make a quick decision on replacement type (and fuel used). Due to familiarity, many systems are replaced with similar fueled systems, albeit more efficient ones.

Once installed, thermal conditioning systems are typically in operation for several decades. Switching out heating systems requires professional installation, imposes high upfront costs, and may deter consumers from fuel switching, even if more energy efficient systems exist and would offer benefits in the long run. While new and highly efficient thermal technologies, such as cold climate air-source heat pumps (ccASHP), ground-source heat pumps (GSHP), and supplemental heating technologies such as solar thermal, can offer significant energy and cost savings over current average systems, they suffer from low consumer awareness. While the Commonwealth administers incentive programs to encourage fuel switching to more efficient thermal systems, infrastructure turnover rates and consumer choice play a major role in the adoption and success of such programs.

There are other factors outside of the Commonwealth's jurisdiction that influence energy demand in the thermal sector. For example, the natural gas distribution network, administered by utilities, does not extend to some rural parts of the state, constraining the fuel choices for thermal customers there. Fuel prices for natural gas, oil, and biomass are set by larger commodity markets but have a major influence on both the affordability and reliability of thermal energy for Massachusetts consumers. Finally, weather is a major and unpredictable factor in thermal energy demand: especially cold winter weather and

64 A summary of Massachusetts State Building Code to include the stretch code is available at https://www.mass.gov/service-details/building-energy-codes

unusually hot summers can spike energy demand, a problem that is likely to get worse as climate change contributes to more extreme weather in the New England region.

The thermal sector also faces equity-related challenges while pursuing a more affordable, clean, and resilient energy system. Energy for home heating presents a major financial burden for low-income families, who spend a much larger share of their income on home heating.[65] Low- and moderate-income families often live in older, less energy-efficient homes and rely disproportionately on inefficient thermal systems like electric resistance heat in urban areas and oil heat in rural areas. These residents also face a variety of barriers to access energy efficiency and renewable energy technologies that could reduce their energy burden, including poor access to credit and the "split incentive problem" that discourages landlords from investing in energy improvements that would benefit tenants.[66]

The industrial sector poses unique challenges. Unlike residential customers or small businesses, industrial customers may be few but can consume a significant amount of energy. Industrial customers may be motivated by different economic drivers. Policies are therefore hard to develop unless targeted at specific industries or drivers. Although developing targeted policies may impact only a few energy customers, the energy reductions can be significant and provide both the state and the industry significant savings.[67]

2.4 Transportation

2.4.1 Demand

Massachusetts residents and businesses use energy to move people and material from one location to another. Transportation demand includes the use of vehicles, public transportation, movement of freight, and other modes of transportation such as air and maritime. Some of this demand is fully in-state: short trips within a town or city or regional movement from one area of the Commonwealth to another. Other demand involves interstate or international movement of people or goods and materials. Still other demand is transitory— demand created as the result of Massachusetts being a "way through" to another final destination.

Demand across transportation types is not easy to measure on a single, aggregate basis. Instead, two metrics are often used to approximate transportation demand: vehicle miles traveled (VMT) and passenger miles traveled (PMT). VMT is the metric most frequently applied to vehicles that use highways and state- and locally-owned roads, whereas PMT is the metric typically applied to vehicles

65 Affordable Access to Clean and Efficient Energy, Final Working Group Report https://www.mass.gov/files/documents/2017/09/12/aacee-report.pdf

66 Affordable Access to Clean and Efficient Energy Final Working Group Report, April 2017 https://www.mass.gov/files/documents/2017/09/12/aacee-report.pdf

67 See Industrial Energy Efficiency Programs; https://aceee.org/topics/industrial-energy-efficiency-programs

that use other transportation infrastructure (such as air travel or rail travel, though this category may sometimes also include passenger buses).

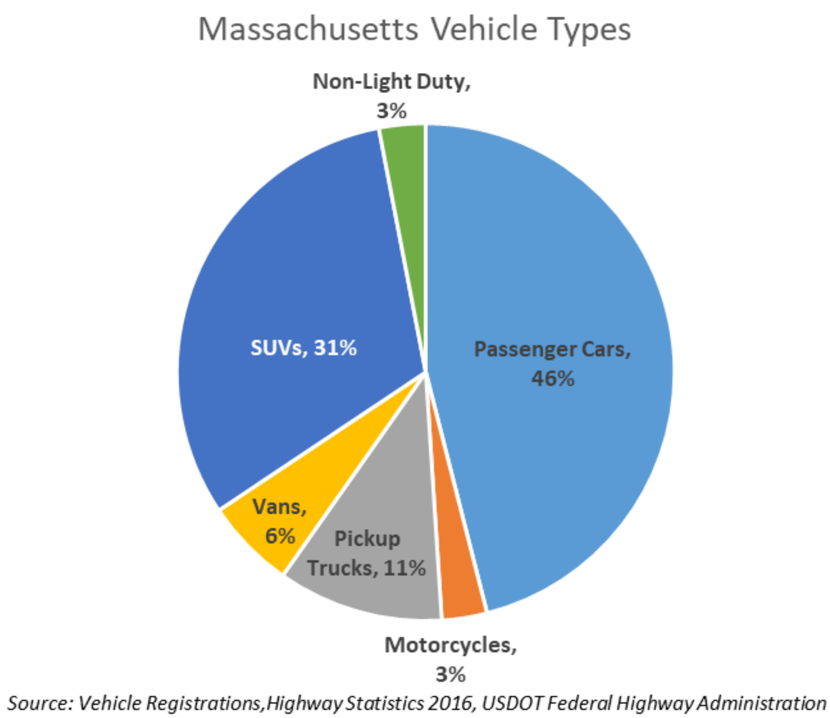

Figure 27: Massachusetts Vehicle Types

Demand for transportation is frequently categorized according to the type of vehicle used to meet the transportation requirement. There are three general categories of transportation vehicles:

- **Light-duty vehicles**: Light-duty vehicles (LDVs) are cars, motorcycles, SUVs, and light trucks. They are typically restricted to the types of vehicles owned by private individuals and small businesses. LDVs make up the vast majority of number of vehicles in Massachusetts at around 97 percent. Today's LDVs are most commonly powered using motor gasoline or a motor gasoline blend (i.e., with ethanol).

- **Heavy and medium duty vehicles**: These are vehicles that are used to move freight or large quantities of passengers. These may include medium-sized trucks (e.g., delivery trucks or mail trucks), dump trucks, school buses, municipal buses, interstate buses, and large trucks. These vehicles are most commonly powered using diesel, although in some cases they are powered using natural gas, motor gasoline, or a motor gasoline blend. These vehicles make up a small number of total vehicles, but have a larger share of vehicle miles travelled as these vehicle types spend a much greater amount of their lifetime active on the road than LDVs.

- **Other vehicles**: A large variety of other, miscellaneous vehicles are used to transport goods and people. These include airplanes, boats and ferries, trains, subways, and trolleys. These vehicles are powered using a wide variety of fuels, including jet fuel, diesel, residual fuel oil (RFO), and electricity.

In addition, a small portion of Massachusetts' transportation demand is met without the use of vehicles. Data from the U.S. Census' American Community Survey (ACS) indicates that 6 percent of all commuting trips in Massachusetts are accomplished through walking or biking.[68]

In 2016, non-LDVs (including delivery trucks, mail trucks, buses, freight trucks, and other miscellaneous medium to large vehicles) comprised just 3 percent of all vehicles in Massachusetts. However, these vehicles have an outsized impact on energy demand and emissions. Despite making up just 3 percent of all vehicles, medium- and heavy-duty vehicles are estimated to make up 9 percent of vehicle miles traveled and 14 percent of total energy consumption.

In 2016, the makeup of non-LDVs in the transportation sector was estimated to consist of 65 percent heavy-duty trucks, 36 percent medium-duty trucks, and 3 percent buses.

2.4.2 Supply

Today, a majority of vehicle miles traveled in Massachusetts are powered by fossil fuels. Since 2010, while vehicle miles traveled have steadily increased, total energy use (measured in British thermal units or Btu) has not increased due to a number of factors. For example, the consumption of motor gasoline has remained flat, despite increasing vehicle miles traveled from light-duty vehicles (the primary consuming vehicles of this fuel type). This is due in large part to the increasing efficiency of motor vehicles—between 2010 and 2016, the average miles per gallon efficiency rating for light-duty vehicles increased by about 5 percent.[69]

The efficiency standards for vehicles are regulated by the federal Corporate Average Fuel Economy (CAFE) standards.[70] These standards have ensured a reduction in energy use despite an increasing consumer preference for SUVs and crossover vehicles, which typically have a lower mile-per-gallon rating than sedans or compact cars. The analysis for this report utilizes the Annual Energy Outlook (AEO) from the Energy Information Administration (EIA) that assumes future, already promulgated updates to the federal CAFE standards will remain in place.

The second major source of energy in the transportation sector is diesel. Diesel is primarily consumed by medium and heavy-duty vehicles, such as buses, refuse trucks, short-haul delivery trucks, and long-haul trucks. Over time, the amount of diesel consumed in Massachusetts has incrementally increased and today represents about 15 percent of total fuel consumed in-state.

The third category of energy consumed by the transportation sector is "other fossil". This consists of natural gas, residual fuel oil, propane, and lubricants. While this category is an important source of fuel

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68 See https://www.census.gov/programs-surveys/acs/ for more information.

69 https://www.eia.gov/outlooks/aeo/ and https://www.eia.gov/outlooks/archive/aeo13/

70 National Highway Traffic Safety Administration (NHTSA) Corporate Average Fuel Economy standards https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy

for some transportation types (notably public transportation and rail), it is a very small part of the total transportation energy use, at less than 1 percent of total energy consumption.

The last source of energy consumed in the transportation sector is electricity. Historically, the main types of vehicles that have consumed this source of energy are subways, trolleys, and interstate trains. However, a small but increasing number of light-duty vehicles now rely on electricity for part or all of their fuel consumption. As of 2018 about 15,000 BEV and PHEV are on the road in Massachusetts, less than 0.75 percent of light-duty vehicles.

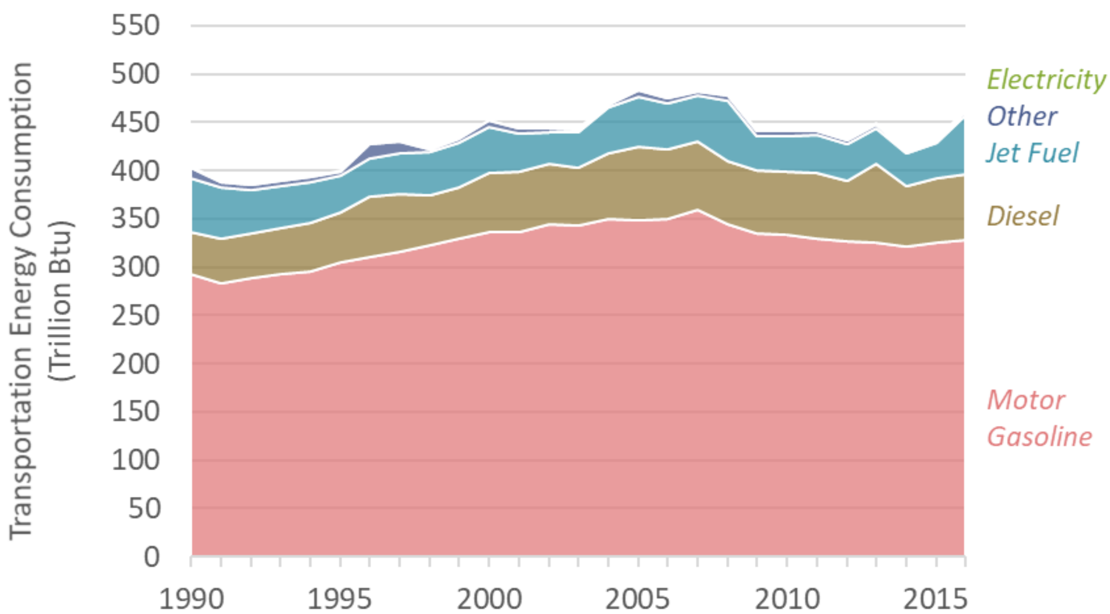

Figure 28. Energy consumed by the transportation sector in Massachusetts

2.4.3 Challenges

Many of the policies and regulations that influence transportation energy use require regional coordination and/or federal regulation. For example, vehicle efficiency standards are set by the federal government under the CAFE standards. While Massachusetts does not have the authority to set its own vehicle fuel efficiency standards, it is one of several states that have voluntarily adopted the more stringent vehicle efficiency standards set by California, which receives a waiver from the Environmental Protection Agency (EPA) to set its own standards. The Commonwealth also does not have jurisdiction over the production of transportation fuels like gasoline, jet fuel, and diesel, all of which are produced and refined out-of-state, but may be consumed in state.

In addition, a transformation of the transportation sector and related infrastructure projects will require a turnover of vehicle fleets for both individuals and businesses to reduce emissions and increase sector efficiencies in terms of energy used per unit of travel. Such turnover typically occurs across a multi-year timeline, and many gasoline powered cars sold in Massachusetts today will still be on the road a decade from now.

A rapid transformation of the sector would require a corresponding increase in the turnover/replacement rate of light duty vehicles, replacing fossil fuel emitting vehicles with cleaner and more efficient electric vehicles. Further challenging is the lack of charging infrastructure to support electric vehicles today or in the near-term. While existing infrastructure for gasoline-powered vehicles is robust, in part due to a hundred-year history of internal combustion engines powering the sector, infrastructure investment in electric vehicle refueling remains in its relative infancy. Our transition to a cleaner future for the transportation sector in Massachusetts will likely require a parallel investment in infrastructure to support the transition. In addition, transitioning the transportation sector towards more electrification will require technological progress in battery technology and electric vehicle range and availability across vehicle price points and types.

Medium and heavy-duty vehicles present a different set of challenges in terms of electrification than light-duty vehicles. These categories comprise a wide range of vehicle uses, including long-haul freight trucks which travel many hundreds of miles per day (well beyond the range supported by current battery technology), or which are in active use for many hours of the day with only brief interruptions for re-fueling. Furthermore, few commercially viable examples of medium- and heavy-duty electric vehicles exist in 2018, likely delaying widespread adoption of this technology until after 2030. However, a number of attributes of electric vehicles lend themselves particularly well to medium- and heavy-duty vehicles, and vice versa. First, because large, heavy vehicles require more torque to move heavy loads, they commonly rely on diesel engines, which can provide higher torque, particularly at low speeds. Electric motors provide low-speed torque. Meanwhile, electric vehicles are quieter and emit fewer or no particulate emissions, valuable benefits in urban areas where a large portion of medium- and heavy-duty vehicles are concentrated. In addition, a significant number of medium- and heavy-duty vehicles, including buses and mail trucks, rarely travel more than 100 miles from a "home base".[71] This allows for easier, more concentrated siting and management of charging infrastructure. Highlighting these turnover and infrastructure challenges in the transportation sector provides an important baseline on future challenges that may constrain transformation of the sector.

Although there are over 40 zero-emission vehicle models available[72], auto manufacturers still overwhelmingly produce gasoline-powered vehicles. Electric vehicle models remain more expensive than comparable gasoline vehicles and the availability of charging infrastructure for consumers at home, work, and on the road also present a barrier to purchasing an EV.

Individual consumer decisions also heavily influence transportation energy use. For example, choices consumers make about what type of vehicle to buy, which modes of transportation to use, and where to

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[71] https://www.uspsoig.gov/document/postal-vehicle-service-fuel-cost-and-consumption-strategies

72 https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/

live. Consumers in Massachusetts, like those across the country, are increasingly purchasing light-duty SUVs, which have lower average fuel economy than light-duty sedans. Choices about where to live can also affect transportation energy use, since residents living outside of urban centers travel longer distances and are more reliant on driving to meet their transportation needs. Housing costs, in turn, influence decisions about where Massachusetts residents choose to live, meaning that housing markets and policies also have a significant influence on transportation patterns and subsequent energy use.

Low-income residents in Massachusetts spend a higher share of their income on transportation and may have fewer options for meeting their transportation needs. [73] Rural residents in areas that lack public transportation infrastructure may be exclusively dependent on private vehicles for their transportation needs. In sum, changes to the transportation sector will affect people differently across the Commonwealth depending on their transportation needs and resources, which has considerable equity implications.

2.5 Energy Costs and Expenditures

Massachusetts residents pay for energy in several ways: electricity bills, heating bills, gasoline at the pump, and indirectly in many of the goods and services they consume. Total residential energy expenditures in Massachusetts in 2016 were $6.462 billion.[74] As the leading state for energy efficiency in the nation, Massachusetts has been successful at finding ways to use less energy to provide the services people need. Efficiency audits and building retrofit programs have led to improved residential, commercial, and industrial building energy efficiency and homes and businesses that use less energy to heat and cool their homes to comfortable temperatures. Improving vehicle efficiency standards and expanding public transportation options has meant people require less gasoline to move among home, work, and other daily activities. The Commonwealth has a variety of policies and programs in place to help ensure access to energy is affordable for people and businesses in Massachusetts. Other more targeted programs ensure low-income residents have access to a range of energy efficiency programs and assistance to help meet their energy needs.

Electric distribution companies (EDCs) and municipal light plants (MLPs) issue electricity bills to their distribution customers. The final price of electricity shown on a bill reflects the sum of several separate charges. The two main components of electricity rates are the supply charge and the delivery charge: the supply charge represents the cost of generating the electricity, while the delivery charge represents the cost of bringing that electricity to the customer's home. The supply side includes costs incurred purchasing energy on the wholesale electricity market as well as clean energy policy compliance costs. The delivery charge includes distribution network costs (poles and wires), long-distance transmission, as well as charges for clean energy, energy efficiency, and other reconciling charges.

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73 *Decarbonizing Transportation: Challenges and Opportunities*, MassDOT Secretary and CEO Stephanie Pollack, http://www.raabassociates.org/Articles/Pollack%20Presentation%20Final%206.15.18.pdf

74 EIA SEDS database; https://www.eia.gov/state/data.php?sid=MA#ConsumptionExpenditures

Supply	Clean Energy	Renewable Portfolio Standards (RPS Class I and II)
		Alternative Portfolio Standard (APS)
		Clean Energy Standard (CES)
		Clean Peak Energy Standard (CPS) (*Anticipated*)
	Wholesale	Energy (LMP)
		Capacity
		Ancillary Services
		Net Commitment-Period Compensation (NCPC)
		Other Charges
	Supplier Costs and Risk Premium	
Delivery	Base Distribution	
	Transmission	
	Renewable Energy Charge	
	Energy Efficiency Recovery Factor (EERF)	
	Net Metering Recovery Surcharge (NMRS)	
	Long Term Renewable Contract Adjustment (LTRCA) (*Procurements*)	
	SMART Factor (*Anticipated*)	
	Other Reconciling Charges	

Table 6 shows a simplified breakdown of the components of EDC electricity rates in Massachusetts.[75]

Supply	Clean Energy	Renewable Portfolio Standards (RPS Class I and II)
		Alternative Portfolio Standard (APS)
		Clean Energy Standard (CES)
		Clean Peak Energy Standard (CPS) (*Anticipated*)
	Wholesale	Energy (LMP)
		Capacity
		Ancillary Services
		Net Commitment-Period Compensation (NCPC)
		Other Charges
	Supplier Costs and Risk Premium	
Delivery	Base Distribution	
	Transmission	
	Renewable Energy Charge	
	Energy Efficiency Recovery Factor (EERF)	
	Net Metering Recovery Surcharge (NMRS)	
	Long Term Renewable Contract Adjustment (LTRCA) (*Procurements*)	
	SMART Factor (*Anticipated*)	

75 Policy costs include the renewable portfolio standard and the energy efficiency reconciliation factor, only apply to the regulated EDCs and their customers.

	Other Reconciling Charges

Table 6: Components of Massachusetts Residential Retail Rates[76]

Heating costs vary depending on the size of home, type of fuel used (natural gas, heating oil, electricity, or other), and, importantly, the weather. Thermal energy consumption varies considerably year-to-year depending on how cold the winter is. Each year, the Commonwealth publishes a winter heating report to help residents plan for expected heating costs during the winter months.[77] This winter heating report estimates the fuel consumption and cost for the various heating customer classes for the upcoming winter based on current projections for fuel prices and winter weather. These predictions are made for the upcoming winter only as weather and fuel prices can be difficult to predict.

Transportation energy costs vary based on the mode of transportation used: residents pay for transportation energy directly by purchasing gas for their cars, or indirectly when they buy tickets for buses, trains, and planes or pay for taxis or ride services. Most transportation energy use in Massachusetts is in the form of gasoline for light-duty vehicles (cars and small trucks), making current transportation energy costs highly dependent on petroleum prices, which are set in global commodity markets and through taxes.

2.6 Current Emissions

The Massachusetts Department of Environmental Protection's (MassDEP) Greenhouse Gas Inventory is the database used to track the state's progress towards the GWSA target. [78] As required by the GWSA, the Inventory accounts for all greenhouse gas emissions associated with the state's electricity consumption, meaning that if the electricity is used within the state, the Inventory accounts for associated emissions even if the electricity was generated in another state. Estimates of thermal and transportation sector emissions are based on data provided by US EIA. Massachusetts is a net importer of electricity, meaning the state consumes more electricity than Massachusetts generates. Imported electric sector emissions are calculated considering the generation of each New England state and the transfer of renewable energy certificates for states' environmental compliance.

76 Summary of charges from ISO-NE and EDC tariff filings

77 https://www.mass.gov/service-details/mass-projected-household-heating-costs

78 MassDEP Emissions Inventories, https://www.mass.gov/lists/massdep-emissions-inventories and *Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection Update*, https://www.mass.gov/files/documents/2016/11/xv/gwsa-update-16.pdf

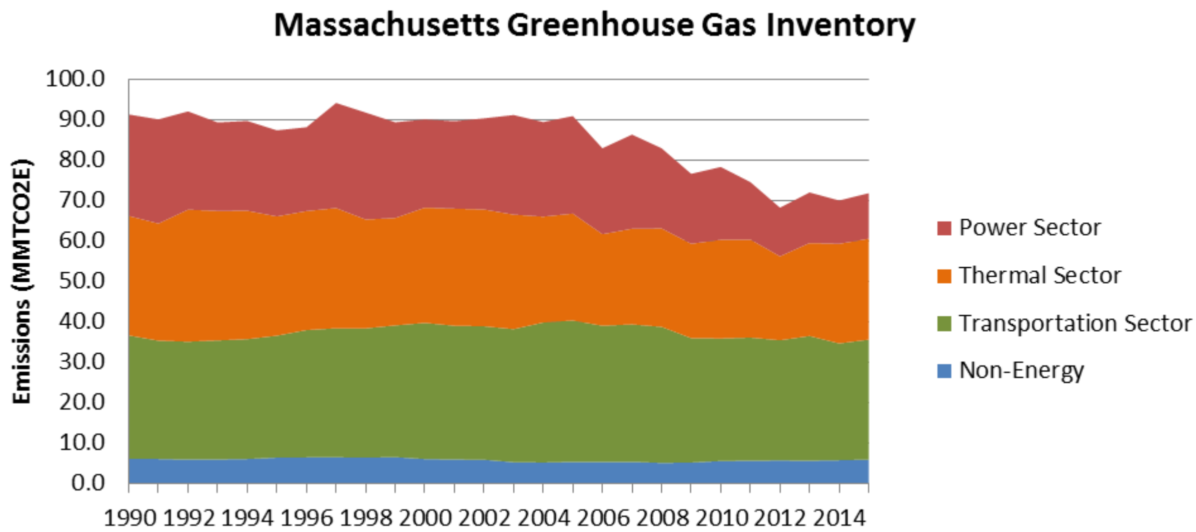

Figure 29: Historical Massachusetts GHG Emissions from Energy Consumption

3 Current Massachusetts Energy Policies

Summary of Some Massachusetts Energy Policies		
Power Sector	**Thermal Sector**	**Transportation Sector**
Renewable Portfolio Standard Clean Energy Standard Procurements SMART Energy Storage Initiative Clean Peak RGGI MA CO_2 cap Demand Response Clean Energy Resiliency Initiative	Green Communities Act Energy Efficiency Advisory Committee Mass Save Affordable Access Report Building Codes Alternative Portfolio Standard Renewable Thermal Grants Leading By Example Property Assessed Clean Energy	Future of Transportation ZEV Task Force MOR-EV Mass Drive Clean Clean Cities Coalition Electric School Bus Pilot GreenDOT State Vehicle Fleet MassEVIP

3.1 Power Sector Policies

On August 8, 2016, Governor Baker signed a landmark, bipartisan energy bill to accelerate the Commonwealth's progress towards a clean, affordable, and resilient energy system. *An Act Relative to Energy Diversity* [79] launched several important new policies, including major clean energy procurements for offshore wind (83C) and clean energy, including clean energy generation (83D), a new program for commercial building energy efficiency upgrades, and required a target to be set for energy storage installations in the Commonwealth.

3.1.1 Clean Energy Generation Procurement (83D)

Under section 83D of the Energy Diversity Act, Massachusetts Electric Distribution Companies (EDCs) are required to procure 9.45 TWh of clean energy generation.[80] Under 83D, clean energy is defined as either hydroelectric generation alone, new Class I RPS eligible-resources firmed up with hydroelectric generation, or new Class I RPS eligible resources. These resources must be contracted by January 2023.

In March 2018, EDCs and DOER announced the selection of the New England Clean Energy Connect project, which will import 100 percent hydroelectricity from Quebec via a transmission line through

79See https://malegislature.gov/Bills/189/House/H4568

80 See https://macleanenergy.com/83d/ for more information.

Maine. This single project fulfills the requirements of 83D, and is equivalent to about 8 percent of regional electricity demand or enough electricity to power 1.3 million households in Massachusetts. The contract sets a fixed 20-year rate for the electricity, which at 5.9 cents per kilowatt-hour (real 2017 dollars) is expected to reduce Massachusetts ratepayers' electric bills by 2-4 percent all other costs being equal.[81]

3.1.2 Offshore Wind Energy Generation Procurements (83C)

Several New England States (Massachusetts, Rhode Island, and Connecticut) have enacted legislation authorizing EDCs to procure long-term contracts for offshore wind.

Section 83C of An Act Relative to Energy Diversity requires Massachusetts EDCs to solicit 1600 MW of offshore wind by June 2027. In May 2018, the EDCs and DOER announced their selection of the first round of bids, selecting the 800-MW Vineyard Wind project. This project proposes to build 800 MW of offshore wind with delivery starting in 2022.[82] By 2030, all 1,600 MW allocated to Massachusetts under 83C will be equivalent to about 6 percent of regional demand. This will be enough to provide power to 975,000 homes in Massachusetts. Simultaneously, Rhode Island selected the proposed Deepwater Wind project, which calls for 400 MW online by 2023[83]. Additionally, in a separate Request for Proposals, Connecticut selected a Deepwater Wind offshore wind project totaling 200 MW.[84] Combined, the three selected projects will produce about 4 percent of regional electricity demand in 2023, which will help the broader New England region further reduce emissions in the power sector.

3.1.3 SMART program

The Solar Massachusetts Renewable Target (SMART) Program is the Commonwealth's latest major initiative to promote solar energy deployment. Established as part of solar energy legislation signed by Governor Baker in 2016, the SMART program will support an additional 1,600 MW (AC) of behind-the-meter solar by providing incentives in the form of a declining block tariff. The goal of this block tariff is to promote clean energy generation from distributed solar energy projects by providing a predictable, financeable, incentive payment, while keeping programmatic costs for ratepayers low. Essentially, the first 200 MW of solar projects will receive compensation at specified rates, with the second 200 MW of solar projects being compensated at a lower rate, depending on project size, type, and utility service territory. This progression continues until all 1,600 MW is procured by 2025.[85] This quantity of solar is

81 RE: Petitions for Approval of Proposed Long-Term Contracts for Renewable Resources Pursuant to Section 83D of Chapter 188 of the Acts of 2016, DPU 18-64, 18-65, 18- 66; https://macleanenergy.files.wordpress.com/2018/07/doer-83d-filing-letter-dpu-18-64-18-65-18-66july-23-2018.pdf

82 See https://macleanenergy.com/category/83c/ for more information.

83 Rhode Island and Massachusetts Announce Largest Procurement of Offshore Wind in Nation's History https://www.ri.gov/press/view/33287

84 Gov. Malloy and DEEP Announce Selection of 250 MW of Renewable Energy Projects https://www.ct.gov/deep/cwp/view.asp?A=4965&Q=603300

85 See www.masmartsolar.com/_/documents/SMART-Program-Overview.pdf for more information

expected to produce the equivalent of 2.1 TWh, or about 2 percent of regional electricity demand. This is enough electricity to power 293,000 households in Massachusetts.

The SMART program is designed to promote cost-effective and diverse solar energy projects that serve residents, business, and institutions located in investor owned utility service territories. The program includes additional incentives for projects that are optimally sited, such as those on brownfields/landfills, rooftops, and parking lots, as well as projects that serve particular groups of customers, such as community solar, low-income populations, and public facilities. Lastly, the program also provides additional incentives to facilities that combine solar with energy storage to maximize benefits to the grid.

3.1.4 Renewable Portfolio Standards and Clean Energy Standard

In addition to renewable energy procurements, Massachusetts and the other New England states currently have renewable portfolio standard (RPS) programs in effect.[86] RPS policies require retail electricity suppliers to procure a (usually increasing) amount of power from renewable resources in each year. Resource eligibility varies by state, but typically includes resources like onshore and offshore wind, utility-scale and distributed solar, landfill gas, small-scale hydroelectric, woody biomass, liquid biofuel, biogas, tidal, geothermal, and ocean thermal energy. In all New England states, resources are only eligible to participate in an RPS if they are geographically located in New England, or in an adjacent region (such as New York or Québec), and export their electricity into ISO-NE. Resources that qualify for procurements (offshore wind, clean energy, or SMART) are typically also eligible to participate in RPS or CES programs.

86 Massachusetts Renewable Energy Portfolio Standard https://www.mass.gov/renewable-energy-portfolio-standard

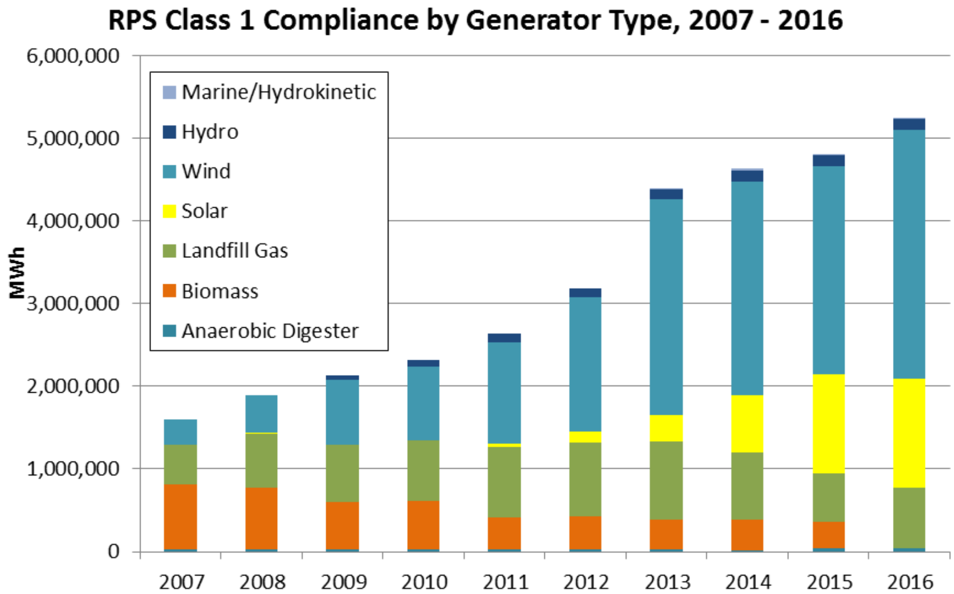

Figure 30: RPS Class I Compliance by Generator Type, 2007 - 2016[87]

Often, RPS standards are split into different "classes" or "tiers". These different classes may restrict eligibility to a certain resource vintage (e.g., new or existing) and to a certain amount by year. Table 7 details the current RPS targets for new resources.

Massachusetts has three "new" resource RPS classes, and two "existing" RPS classes. They include:

- Class I Renewable: Resources eligible for this requirement include new wind, solar, and other resources built on or after January 1998. This requirement began in 2003 and increases by one percentage point per year. The recently passed clean energy legislation will increase the RPS by 2 percent in 2020, resulting in a 35 percent obligation in 2035. Generation from eligible Class I resources receives Renewable Energy Certificates (RECs) that are purchased by EDCs and Load Serving Entities (LSEs) to meet their RPS requirements. Within the Class I requirement, a specific resource carve-out exists for distributed solar, which receives Solar Renewable Energy Credits (SRECs).
- Clean Energy Standard (CES): The CES, created by MassDEP in 2017, complements the RPS by increasing demand for clean energy.[88] Resources qualify for the CES based on their emissions level: any low- or zero-emitting energy resource built after 2010 with lifecycle emissions less than half that of natural gas generation can qualify, which includes all Class I renewable resources as well as nuclear power, carbon capture and sequestration, and large hydropower. In addition, clean energy import resources procured through 83D are eligible for the CES.

87 Massachusetts DOER, RPS and APS Annual Compliance Report 2016

88 310 CMR 775, https://www.mass.gov/guides/clean-energy-standard-310-cmr-775

- Alternative Portfolio Standard (APS): The APS creates an incentive for the installation of alternative energy systems that deliver low-carbon and efficient thermal energy. The goal of the APS is to reduce emissions and promote energy efficiency in the thermal conditioning sector. Resources that are eligible for this category include combined heat-and-power (CHP), waste-to-energy thermal, air source heat pumps, ground source heat pumps, solar hot water, and eligible biomass, biogas, and biofuel heating systems. Flywheel energy storage and fuel cell systems also qualify under the APS.

- Class II (Renewable): This category includes the same set of renewable energy resources eligible under Class I, but only those built prior to January 1998 (class I covers resources built only after that date).

- Class II (Waste-to Energy or WTE): Only resources which produce electricity from the combustion of municipal solid waste (MSW) are eligible for this category.

	New resource categories					Existing resource categories	
	RPS-I[1]	CES[2]	RPS + CES	APS	RPS + CES + APS	RPS-II RE	RPS-II W2E
2018	13.0%	3.0%	16.0%	4.5%	20.5%	2.6%	3.5%
2019	14.0%	4.0%	18.0%	4.8%	22.8%	3.6%*	3.5%
2020	16.0%	4.0%	20.0%	5.0%	25.0%	3.6%*	3.5%
2021	18.0%	4.0%	22.0%	5.3%	27.3%	3.6%*	3.5%
2022	20.0%	4.0%	24.0%	5.5%	29.5%	3.6%*	3.5%
2023	22.0%	4.0%	26.0%	5.8%	31.8%	3.6%*	3.5%
2024	24.0%	4.0%	28.0%	6.0%	34.0%	3.6%*	3.5%
2025	26.0%	4.0%	30.0%	6.3%	36.3%	3.6%*	3.5%
2026	28.0%	4.0%	32.0%	6.5%	38.5%	3.6%*	3.5%
2027	30.0%	4.0%	34.0%	6.8%	40.8%	3.6%*	3.5%
2028	32.0%	4.0%	36.0%	7.0%	43.0%	3.6%*	3.5%
2029	34.0%	4.0%	38.0%	7.3%	45.3%	3.6%*	3.5%
2030	35.0%	5.0%	40.0%	7.5%	47.5%	3.6%*	3.5%

*Notes: (1) This is the gross MA-I target, inclusive of carve-outs. (2) This is the portion of the CES target that is incremental to the Class I RPS. * Subject to annual adjustment by MA DOER.*

Table 7. Summary of Massachusetts RPS targets by resource category

3.1.5 Massachusetts-specific CO_2 cap

MassDEP regulation 310 CMR 7.74 assigns declining limits on total annual GHG emissions from over twenty identified emitting power plants within Massachusetts.[89] This includes existing plants as well as other plants that are under construction and proposed plants expected to be subject to the regulation. The emissions limit starts at 9.1 million metric tons in 2018. It then declines by 2.5 percent of the 2018 emissions limit to 8.7 million metric tons in 2020, and 6.4 million metric tons in 2030.[90]

3.1.6 Storage

The Baker-Polito Administration launched the Energy Storage Initiative (ESI)[91] in May 2015, with the goal of advancing the energy storage segment of the Massachusetts clean energy industry by:

- Attracting, supporting and promoting storage companies in Massachusetts
- Accelerating the development of early commercial storage technologies
- Expanding markets for storage technologies, and valuing storage benefits to clean energy integration, grid reliability, system wide efficiency, and peak demand reduction
- Recommending and developing policies, regulations and programs that help achieve those objectives.

The ESI aims to find the most cost efficient and effective way to help transform the market. DOER has allocated $20 million to pursue a multi-pronged approach to establish an energy storage market structure as well as build strategic partnerships and support storage projects at the utility, distribution system, and customer side scale. DOER partnered with Mass Clean Energy Center (MassCEC) for a study of Energy Storage use in Massachusetts. Entitled *State of Charge: A Comprehensive Study of Energy Storage in Massachusetts*, key subjects covered by the study included:

- Ratepayer cost benefits from energy storage associated with reduced peak demand, deferred transmission and distribution investments, reduced GHG emissions, reduced cost of renewables integration, deferred new capacity investments, and increased grid flexibility, reliability and resiliency
- Identification and economic evaluation of energy storage use cases
- Identification of current barriers to energy storage adoption in the Commonwealth
- Policy and program recommendations to properly value energy storage

89 https://www.mass.gov/guides/electricity-generator-emissions-limits-310-cmr-774
90 Under the regulation, the emissions cap continues through 2050.
91 https://www.mass.gov/energy-storage-initiative

- Near and long term economic and workforce benefits to Massachusetts by implementing energy storage

The ESI demonstration projects are supported by the Advancing Commonwealth Energy Storage (ACES) program. The ACES Program provides funding to 26 individual energy storage demonstration[92] projects across the Commonwealth, and leverages $32 million[93] in private matching funds.

These projects are aimed at piloting innovative, broadly-replicable energy storage use cases/business models with multiple value streams in order to prime Massachusetts for increased commercialization and deployment of storage technologies.

3.1.7 RGGI

All six New England states are founding members of the Regional Greenhouse Gas Initiative (RGGI),[94] a program that creates a cap-and-trade market for carbon emissions from power plants in member states. Under the current program design, the six states (along with New York, Maryland, and Delaware) conduct four auctions in each year in which carbon dioxide (CO_2) allowances are sold to emitters and other entities. The amount of CO_2 allowances for each state is binding and is determined by legislation or specified by state regulation and decreases over time by about 2.5 percent per year. The current program design applies to all years up to and including 2030.

From 2015 through 2017, the RGGI states conducted a 2016 Program Review. Previous program reviews implemented new auction rules and reduced the number of available allowances. In August 2017, the RGGI states announced a set of proposed program changes for Years 2021 through 2030.[95] Under this extended program design, the RGGI states would continue to reduce CO_2 emissions through 2030, achieving a CO_2 emissions level 30 percent below 2020 levels. This proposed program design also put forth a number of changes to the "Cost Containment Reserve" (a mechanism that allows for the release of more allowances in an auction if the price exceeds a certain threshold) and the creation of an "Emissions Containment Reserve" (a mechanism which withholds a number of available allowances if the allowance price remains below a certain threshold). These changes will be codified in new regulations which are expected to be completed by the end of 2018.

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92 MassCEC, Advancing Commonwealth Energy Storage Awardees; http://files.masscec.com/Advancing%20Commonwealth%20Energy%20Storage%20%28ACES%29%20Awardees.pdf

93 MassCEC, Advancing Commonwealth Energy Storage: Awardee Summary; http://files.masscec.com/ACES%20Project%20Details.pdf

94 The Regional Greenhouse Gas Initiative (RGGI) is the first mandatory market-based program in the United States to reduce greenhouse gas emissions. https://www.rggi.org/

95 The official announcement can be found at http://rggi.org/docs/ProgramReview/2017/08-23-17/Announcement_Proposed_Program_Changes.pdf.

At the time of this writing, several states, including Virginia and New Jersey, are in various stages of exploring the potential for their states to join RGGI.[96] The impact of these states on the RGGI plan was not considered within the scope of this analysis.

3.1.8 Demand Response

Resources which participate in demand response agree to either curtail or shift electric usage to off-peak hours for compensation. From interruptible rates to time-varying rates, voluntary and non-voluntary participation in utility or aggregator programs, and at the residential, commercial or industrial level, demand response can take a number of different forms.

Through the first six Forward Capacity Auctions (FCAs) in ISO-NE, installed demand response capacity increased steadily to a total of 1,400 MW as providers became more comfortable with the structure and mechanics of the Auction. However, installed demand response capacity dropped significantly in 2016 forward (FCA 7 and beyond), due in large part to market rule changes that imposed significant new data requirements on DR providers while requiring them to offer into the day-ahead and real-time energy markets. This “must offer” requirement came into effect on June 1, 2018 (FCA 9 delivery year). Cleared DR capacity dropped as low as 372 MW, but has climbed back to 624 MW for 2022 (FCA 12).[97] Historically, demand response resources only were called in capacity deficiency situations on the grid, and were not tied to a certain price threshold. Under the new construct, called “Price-Responsive Demand” (PRD), demand response resources will now bid into energy and reserve markets.

3.1.9 Energy Resiliency

The Massachusetts Department of Energy Resources (DOER) develops and implements policies and programs aimed at ensuring the adequacy, security, diversity, and cost-effectiveness of the Commonwealth's energy supply and to create a clean, affordable and resilient energy future for residents, businesses, communities, and institutions.

DOER works to address resiliency concerns across all of its various programs and initiatives, and working to ensure resiliency is addressed in specific terms as well. For example, DOER has established the Community Clean Energy Resiliency Initiative (CCERI) to help address service interruptions caused by severe weather.[98] This $40 million grant program funds technical assistance and project implementation for police and fire dispatch, emergency shelters, hospitals, and critical water infrastructure facilities to use clean energy technologies, including combined heat and power, solar PV, and energy storage, to mitigate the potential impacts of climate change on our critical infrastructure.

96 UtilityDive, *How big can New England's regional cap-and-trade program get?*; https://www.utilitydive.com/news/how-big-can-new-englands-regional-cap-and-trade-program-get/522375/

97 ISO-NE, *Forward Capacity Market (FCA 12) Result Report*; https://www.iso-ne.com/static-assets/documents/2018/05/fca-results-report.pdf

98 Mass DOER, *Community Clean Energy Resiliency Initiative;* https://www.mass.gov/community-clean-energy-resiliency-initiative

3.2 Thermal Sector Policies

3.2.1 Energy Efficiency and Green Communities

As the leading state in energy efficiency, Massachusetts administers a variety of programs to reduce overall energy use and peak energy demand in the thermal conditioning sector.

The Green Communities Act (GCA) requires Massachusetts electric and gas utilities to pursue all cost-effective energy efficiency and demand management solutions in order to eliminate energy waste whenever doing so is cheaper and more cost-effective than purchasing more energy supply.

The GCA also established the Energy Efficiency Advisory Council (EEAC) to inform the development of coordinated statewide[99] energy efficiency plans and programming. To set targets for efficiency, the EEAC collaborates with the utility Program Administrators (PAs) to publish the Three-Year Energy Efficiency Plan, comprehensive guidelines for how PAs will reduce gas and electricity use over a three-year period. The plans include saving and spending targets, implementation strategies, and descriptions of various initiatives that steer residents and businesses towards improving energy efficiency in the Commonwealth. Once the EEAC has reviewed and approved a plan, the Council tracks and monitors the utilities implementation work.

The Residential Conservation Services (RCS) program preceded and now is implemented in conjunction with the Three-Year Energy Efficiency Plan. Updated regulations and guidelines have been issued by DOER which allow for greater transparency and detail in the delivery and reporting of residential retrofit programs. Since 2010, these combined statewide efficiency programs, operated under the Mass Save® branding.

The GCA also established the Green Communities Program, which provides grants and technical assistance to help municipalities implement local clean energy and efficiency projects and motivates local adoption of the stretch energy code. This program has helped 210 municipalities in Massachusetts become designated Green Communities, which represents a local commitment to reducing GHG emissions by promoting building energy efficiency, local renewable energy production, and low-emission vehicles.

In order to expand access to energy programs for low-income residents, Massachusetts convened a multi-agency working group on Affordable Access to Clean and Efficient Energy in April 2017. Led by the Department of Energy Resources, the Department of Housing and Community Development, and the Massachusetts Clean Energy Center, the working group examined challenges and opportunities related to affordable housing development, landlord-tenant incentives, and program design related to energy improvement programs. The final working group report laid out strategies for housing developers,

[99] Statewide plans cover all investor-owned utility territory in MA. There are also 40 municipal utilities that do not participate in the Mass Save® programs.

Program Administrators, and clean energy companies to intervene in the housing capital cycle and target energy improvement programs to better serve the needs of low- and moderate-income Massachusetts residents.

The following are additional Massachusetts initiatives to expand building energy efficiency and promote market innovation.

Residential Contractor Working Group

Convened by Secretary Beaton, the Residential Contractor Working Group led to the development and funding of the Home MVP pilot program. This is a contractor-driven home energy retrofit program that monitors real-world performance and savings. This implementation model is testing an alternative to the Mass Save® residential retrofit program and is also able to serve municipal electric customers.

Residential Home Energy Scorecards

Massachusetts has been in the vanguard of a national move towards providing home energy scorecards to residential customers, to raise awareness of their home energy performance and the cost-effective opportunities available through our nation-leading energy efficiency programs. The Baker-Polito administration has sponsored legislation that would enable the widespread adoption of energy scorecards. The commonwealth has also partnered with the Federal Department of Energy and multiple states to develop and field test scorecards delivered as part of home energy audits.

Innovate Energy Efficiency (InnovatEE) Grant Program[100]

The InnovatEE Grant Program was developed in response to the 2016-2018 three-year Energy Efficiency Plan commitment to innovation and technology. DOER has dedicated funds to grant applicants that will demonstrate innovative technologies and delivery methods that can be adopted into energy efficiency programs at scale. To support these innovation efforts, this $5 million grant program will provide financial support to demonstrate the savings potential of new energy efficiency technologies as well as new energy efficiency program delivery methods. The goals of the InnovatEE Grant Program include:

1. Support new opportunities for cost effective energy savings in the Commonwealth of Massachusetts.
2. Evaluate potential technologies and programs to deepen energy savings available to residents and businesses throughout the Commonwealth.
3. Develop opportunities for increased energy savings for markets currently underserved by energy efficiency programs in the Commonwealth.
4. Identify potential technologies and programs to be incorporated in the next Three-Year Plan.

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100 The InnovateMass program provides up to $250,000 in grant funding and technical support to applicant teams deploying new clean energy technologies or innovative combinations of existing technologies with a strong potential for commercialization. http://www.masscec.com/innovatemass

Peak Demand Demonstration Grant Program

In 2017, DOER issued a Program Opportunity Notice (PON) for a program called the Peak Demand Management Grant Program (Program).[101] The Program was designed to stimulate demand management market activity while testing business models and identifying barriers to production-level demand management procurement. $4.69 million was awarded to 7 grantees for 9 projects, chosen to test approaches to demand management in all sectors and using a variety of technologies. These projects include technologies and strategies such as battery storage for demand reduction and distribution system reliability, demand management micro-grid, industrial gas demand response, controls-based demand reduction, and electric vehicle charging, and new strategies for peak electricity demand reduction.

3.2.2 Building Codes & MEPA

The Green Communities Act requires Massachusetts to update its state building codes every three years and to meet or exceed the standards for energy efficiency set in the International Energy Conservation Code (IECC).[102] In 2009, and then updated for the 2015 IECC adoption, Massachusetts published a supplemental appendix to the building code called the "Stretch Code," which outlines higher building energy code requirements to improve energy efficiency and promote onsite renewable energy systems. These advances in baseline building energy codes constitute one of the lowest cost ways to modernize and reduce energy demand in the building stock in the Commonwealth over time. Municipalities must adopt the Stretch Code in order to be designated a Green Community and as of June 2018, 241 municipalities in Massachusetts have adopted the Stretch Code. Recent analysis of the impact of the Stretch Code on residential properties shows that homeowners see a positive cash flow starting day 1 by purchasing a Stretch Code-compliant home compared to a base code home.[103]

The Massachusetts Energy Policy Act (MEPA) office reviews all major new construction developments in the commonwealth that require state agency action and considers whether developers are providing for greenhouse gas mitigation through building efficiency, onsite renewables and transportation impact mitigation. This review leads to substantial energy demand reductions particularly in large new commercial and mixed-use developments.

Other regulations contributing to energy efficiency in the Commonwealth are the federal appliance standards promulgated by the US Department of Energy. The 2009-2013 rulemaking process resulted in new federal standards that will contribute to increased efficiencies after 2020.

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101 The Massachusetts Peak Demand Reduction initiative is designed to test strategies for reducing Massachusetts' energy usage at times of peak demand. Information on the initiative, grantees and projects is available at https://www.mass.gov/service-details/peak-demand-reduction-grant-program

102 MGL Chapter 143 Section 94 §(o)-(r) as amended by Acts of 2008, Chapter 169 Section 55

103 Stretch Code Residential Cash Flow Analysis https://www.mass.gov/service-details/stretch-code-residential-cash-flow-analysis

3.2.3 Renewable Thermal Energy

The Alternative Energy Portfolio Standard (APS) was established in January 1, 2009, under the Green Communities Act of 2008 to complement the RPS and provide incentives and requirements for alternative energy technologies. The APS offers an opportunity for Massachusetts residents, businesses, institutions, and governments to receive an incentive for installing eligible alternative energy systems, which are not necessarily renewable, but contribute to the Commonwealth's clean energy goals by increasing energy efficiency and reducing the need for conventional fossil fuel-based power generation. Similar to the RPS, the APS requires a certain percentage of the state's electric load to be met by eligible technologies, which for APS include Combined Heat and Power (CHP), flywheel storage, fuel cells, waste-to-energy thermal, air source heat pumps, ground source heat pumps, solar thermal, biomass, biogas, and biofuel systems. The annual percentage requirement increases by 0.25 percent per year indefinitely.[104]

With regards to CHP and fuel cell systems, every MWh of electricity generated displaces traditional grid electricity, and thereby reduces the fuel consumption and GHG emissions of the ISO-NE operating fleet of gas fired units. Additionally, CHP systems and those used solely for thermal energy production directly displace natural gas, propane, and fuel oil consumed on-site. In this capacity, these technologies achieve a net reduction in the Commonwealths overall fossil fuel consumption while generating savings for end users. In addition, CHP and fuel cell units are designed to be able to operate in a grid independent mode, providing a very high level of resiliency to critical facilities with low tolerance for power outage events.

In addition to the APS, the Three-Year Energy Efficiency Plan includes a specific measure providing a capital expense award for CHP units that meet the definition of cost-effective efficiency, in recognition of the inherent efficiency and benefits (e.g. avoided peak capacity costs and relief congestion) to the electrical supply system.

Massachusetts also administers the Renewable Thermal Infrastructure Grant Program to expand the use of renewable heating and cooling systems in the Commonwealth. The grant program provides financial incentives to business that provide supply chain services for the renewable thermal sector. The first round of the program was launched in 2014 and awarded $3 million in funding to projects including a biomass pellet distribution facility, development of biomass boiler standards, and biofuel tanks. The second round of the program began in 2018 and is currently undergoing contract negotiations with grant recipients.

The Massachusetts Clean Energy Center (MassCEC) also administers rebate and grant programs to support adoption of clean heating and cooling systems. Individual households and commercial

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104 Massachusetts' Alternative Energy Portfolio Standard (APS) was established to complement the RPS Program, providing requirements and incentives for alternative electricity technologies. Additional information on the APS is available at https://www.mass.gov/alternative-energy-portfolio-standard

properties are eligible for rebates when they purchase and install efficient thermal energy systems like solar hot water or heat pumps. In 2017, MassCEC also launched the HeatSmart Mass program to help municipalities accelerate the adoption of energy efficient heating systems.[105] HeatSmart Mass provides grants to municipalities for outreach and education as they use a group purchasing model to competitively solicit bids from companies interested in providing efficient heating to residents. Seven communities are currently participating in the 2018 HeatSmart Mass Pilot round. HeatSmart Mass is modeled on the successful Solarize Mass program, which has helped increase adoption of residential PV systems in 64 communities across the Commonwealth.

3.2.4 Leading By Example

The Leading By Example (LBE) program coordinates efforts to promote clean energy and sustainability in state government agencies and public colleges and universities. LBE makes grants and provides technical assistance to install on-site clean energy generation, improve energy efficiency, and other projects to reduce GHG emissions. Initiatives under the LBE program include requirements that new vehicle acquisitions by state agencies meet fuel efficiency standards and that new state construction must meet the Massachusetts LEED Plus Standard for energy efficiency. LBE met its 2012 goal to reduce GHG emissions from state facilities by 25 percent and is currently working towards a goal of 40 percent reduction by 2020.[106]

3.2.5 Property Assessed Clean Energy

The Property Assessed Clean Energy (PACE) program for commercial buildings helps finance energy improvements on commercial and industrial properties in Massachusetts. PACE was established by the energy legislation signed by Governor Baker in August 2016. The goal of PACE is to enable property owners to undertake comprehensive energy upgrades that require longer payback periods, since the PACE mechanism enables liens that secure debt to stay with the property in a sale. Commercial, industrial, and multifamily buildings with five or more units are eligible for PACE financing for energy efficiency improvements, renewable energy projects, and natural gas line extensions.

3.3 Transportation Sector Policies

3.3.1 Future of Transportation Commission

In January 2018, Governor Baker signed Executive Orders No. 579 and 580 establishing the Commission on the Future of Transportation. The Commission’s 19 appointed members, representing a diverse range

105 MassCEC, *HeatSmart Mass*; http://www.masscec.com/heatsmart-mass

106 Through various initiatives and collaboration with multiple agencies, authorities, and public colleges and universities, LBE works to reduce the overall environmental impacts of state government, particularly those that contribute to climate change. Additional information on the program is available at https://www.mass.gov/service-details/leading-by-example-overview-and-contacts

of expertise on transportation-related matters, will advise the Governor on future transportation needs and challenges in the Commonwealth. The Commission will explore anticipated changes in technology, climate, land use, and the economy to determine likely impacts on transportation between 2020 and 2040. The Commission, meeting on a monthly basis, is focused on developing a solid grounding in facts and trends, the development of plausible future scenarios, and the formulation of recommendations to the Governor and Lieutenant Governor. The Commission has hosted a series of listening sessions throughout the Commonwealth and will provide recommendations to the Governor and Lieutenant Governor by December 1, 2018.

3.3.2 Zero-Emission Vehicles

Massachusetts has several existing policies in place to reduce emissions and fuel costs in the transportation sector. The Zero Emission Vehicle (ZEV) Commission was established by the legislature in 2015 to coordinate programs that promote adoption of ZEVs in the Commonwealth. Massachusetts is also a member of the Multi-State ZEV Task Force, a group of nine states working together towards a shared goal of increasing ZEV adoption. Massachusetts has committed to a goal of 300,000 ZEVs registered in the state by 2025. To help achieve this goal, Massachusetts operates the following programs.

The Massachusetts Offers Rebates for Electric Vehicles (MOR-EV) program offers residents a rebate of $2,500 towards the purchase of an EV. Since the start of the program in 2014, the MOR-EV program has distributed $16 million in rebates and has gotten more than 8,000 vehicles on the road, half of which were battery-electric vehicles. Starting on January 1, 2019, MOR-EV will be extended with changes to rebate amounts and qualifications in order to continue to sustain the funding for this successful, accelerating program. As part of MOR-EV, Massachusetts is also piloting the Regional Income Eligible Electric Vehicle Rebate Program (RIE-EV) in Worcester and Franklin counties, offering larger rebates up to $5,000 to help lower-income residents afford the switch to efficient electric vehicle technologies.

The Mass Drive Clean program provides opportunities for the public to test drive EV models to help increase consumer awareness about electric vehicles.

As part of the Massachusetts Clean Cities Coalition (MCCC), the Commonwealth is investing in 1,611 EV charging stations across that state to ensure there is sufficient infrastructure to support widespread adoption of EVs. Additionally, in coordination with the MCCC, DOER issued a grant opportunity through its' Clean Vehicle Program for public and private fleet vehicles operating within the Commonwealth. These grants provide partial funding for the retrofit or replacement of conventional vehicles with compressed natural gas, hybrid, biofuel, fuel cell, battery electric, or other alternative vehicle technologies.

The Vehicle-to-Grid Electric School Bus pilot program provides grants to Massachusetts schools to purchase electric school buses with the aim of reducing fuel costs and testing the clean energy benefits of electric vehicle technology.107 The goal of the four grants awarded to school districts across the Commonwealth thus far is to reduce petroleum use by approximately 22,680 gallons of gasoline equivalent. This pilot program will also test how electric buses can be used as energy storage devices.

The Massachusetts Electric Vehicle Incentive Program (MassEVIP) for Fleets is administered by MassDEP and it has provided incentives to municipalities, state agencies and public colleges and universities that operate vehicle fleets to acquire electric vehicles and install Level 2 dual-head charging stations. Since 2013, MassEVIP Fleets has utilized $2.66 million to fund 267 electric vehicles (EVs) and 92 publicly accessible EV charging stations. MassEVIP Fleets is intended to encourage and increase the deployment of zero-emission and plug-in hybrid vehicles that will provide significant air pollution emission reductions. These vehicles not only decrease greenhouse gas emissions, but also greatly reduce smog-forming emissions.

The Massachusetts Electric Vehicle Incentive Program (MassEVIP) Workplace Charging Program is administered by MassDEP and it provides 50 percent of the cost of the hardware of a Level 1 or Level 2 Charging Station(s) to eligible employers with 15 or more employees in a non-residential place of business. Since 2014, the Workplace Charging Program has utilized $1.3 million to fund 523 EV Charging Stations at 257 separate street addresses. By installing Workplace Charging, 213 employers across the Commonwealth:

- Allow access to EV charging for employees who may not be able to charge their vehicles at home.
- Demonstrate environmental leadership to employees, customers and the surrounding community.
- Improve employee commuting practices and reduce vehicle emissions of greenhouse gases and other pollutants.
- Enhance employee benefit packages, which can help with employee recruitment and retention.

3.3.3 GreenDOT

GreenDOT is the sustainability initiative of the Massachusetts Department of Transportation (MassDOT). Established by a Policy Directive in 2010, GreenDOT's goals are to: (1) reduce greenhouse gas (GHG) emissions, (2) promote the healthy transportation modes of walking, bicycling, and public transit, and (3) support smart growth development. GreenDOT also supports the Department's implementation of energy and climate-related laws and policies including the Green Communities Act and the Global Warming Solutions Act. Implementation activities include long-term transportation system planning, Complete Streets project design and construction, and outreach to support more efficient transportation modes.

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[107] DOER and Vermont Energy Investment Corporation, *Electric School Bus Pilot Project Evaluation*; https://www.mass.gov/files/documents/2018/04/30/Mass%20DOER%20EV%20school%20bus%20pilot%20final%20report_.pdf

3.3.4 State Vehicle Fleet Emissions Cap

The Massachusetts Department of Environmental Protection (DEP) issued regulations in 2017[108] to limit CO_2 emissions from the state fleet of passenger vehicles. The emissions cap is set to decline annually. This policy helps reduce transportation sector emissions from the state fleet in line with the Commonwealth's goals under the GWSA.

3.4 An Act to Advance Clean Energy

As referenced above, An Act to Advance Clean Energy, passed in August 2018, has several provisions that impact clean energy policies in the Commonwealth.[109] First, the Act raises the Renewable Portfolio Standards (RPS) escalation rate, from the current 1 percent increase per year to an escalation rate of 2 percent per year from 2020 and 2030. Second, the Act requires DOER to investigate the necessity, benefits and costs of requiring electric distribution companies (EDCs) to conduct additional offshore wind generation solicitations beyond what is required by the 83C procurement. Further, it authorizes DOER to require the EDCs to solicit and procure up to 1600 megawatts of additional offshore wind by December 31, 2035. Further, the Act permits DOER to include stand-alone transmission projects as long as the projects are cost-effective and are available to more than one wind energy generation project.

Third, the Act also requires DOER to establish a Clean Peak Standard (CPS) for all retail electricity suppliers that requires a minimum percentage of kilowatt-hour sales to customers from "clean peak resources" during periods of peak electricity demand starting in 2019 and ending in 2050.

Fourth, the Act amends the Energy Diversity Act of 2016 to require a 1000 MWh energy storage target, excluding Municipal Light Plants and authorizes DOER to consider a variety of policies to encourage energy storage deployment, including portfolio standards. The Act further requires EDCs to report annually on their energy storage efforts.

Fifth, the Act amends the Green Communities Act, authorizing program administrator investments in fuel switching and demand management strategies, such as cost effective strategic electrification, storage, and active demand management, in the Three-Year Energy Efficiency Plan for the Mass Save® program.

Finally, the Act amends the cost-effectiveness review requirement for the Three-Year Energy Efficiency Plan to a sector-level requirement, as opposed to previous program-level requirements.

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108 310 CMR 60.06 CO_2 Emission Limits for State Fleet Passenger Vehicles, establishes limits on carbon dioxide (CO_2) from passenger vehicles owned and leased by the Commonwealth's Executive Offices. This regulation establishes mass-based annually declining limits on GHG emissions. http://www.mass.gov/eea/docs/dep/air/climate/3dfs-fleet.pdf

109 https://malegislature.gov/Laws/SessionLaws/Acts/2018/Chapter227

4 Winter Energy Assessment

Access to energy during a Massachusetts winter is a safety issue as energy for heating is required to maintain safe living and working conditions for residents and businesses. The severity of a winter, particularly the severity and duration of extreme cold periods, can reduce the region's fuel security, increase the Commonwealth's annual emissions, and increasing the Commonwealth's annual electric rates, harming businesses and residents alike.

Massachusetts has been subject to variable winter conditions in recent years: the polar vortex extreme colds in the winter of 2013 -2014,[110] "snowmageddon" extreme precipitation in the winter of 2014 - 2015,[111] mild "winter that wasn't" during 2015 - 2016,[112] to the most recent winter of 2017 - 2018 extreme colds followed by repeated severe storms.[113] Winter weather can cause volatility in the energy market where fuel is dominated by natural gas and pricing is dependent on supply. The following section describes in more detail the connections among natural gas, thermal and electric demands, weather, and pricing.

4.1 Natural Gas Supply in New England

Natural gas is a methane-based fuel which is extracted from naturally occurring underground formations. In the 2000's, advances in drilling procedures increased the productivity of multiple natural gas fields in the United States, including the Marcellus natural gas play in the Appalachian Basin and the Bakken in North Dakota. The Marcellus is now the leading producer of natural gas in the United States and the EIA considers it to have the largest volume of recoverable gas of all U.S. formations.[114] Prior to the development of the Marcellus, New England along with the entire east coast primarily received natural gas via pipelines from the Gulf of Mexico and Western Canada. The Marcellus and Bakken developments, along with rapid advancements in drilling techniques which decrease the costs of

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110 Boston Globe, *It's freezing. Why? 10 things to know about the 'polar vortex'*; https://www.bostonglobe.com/news/nation/2014/01/07/why-cold-out-things-know/VDJfDX9Xl1mJZwBklTsjuK/story.html

111 Boston Globe, *Last winter's Snowmageddon, by the numbers*; https://www.bostonglobe.com/magazine/2015/11/08/last-winter-snowmageddon-numbers/RgkSKmB3nZJTXijQgRafYM/story.html

112 The Weather Channel, *Lower 48 States Just Experienced the Warmest Winter on Record*; https://weather.com/news/climate/news/record-warmest-winter-us-2015-2016

113Boston Globe, *US cold snap was a freak of nature, quick analysis finds*; https://www.bostonglobe.com/news/nation/2018/01/11/cold-snap-was-freak-nature-quick-analysis-finds/a1Tlhsr3AVUZjyM23VuJuJ/story.html; BBC News, *US shivers amid record-breaking low temperatures;* https://www.bbc.com/news/world-us-canada-42576978

114 EIA, *Appalachia region drives growth in U.S. natural gas production since 2012*; https://www.eia.gov/todayinenergy/detail.php?id=33972

extraction and increase recoverable volumes per well, resulted in the United States becoming a net exporter of natural gas in 2016.[115]

Even though gas today may originate in a formation that is closer to New England than sources of years past, the gas still needs to be transported from the source to the consumer. There are two primary methods of transporting natural gas; pipelines for over-land transportation and liquid natural gas (LNG) for over-sea transportation. Because the quantities of natural gas transmission and consumption are so large (measured in billions of cubic feet (Bcf) per day), the transport and delivery of natural gas requires significant regional planning and contracting. Following the transport of natural gas, the fuel must either be consumed directly from the pipeline infrastructure or stored. There are two primary methods of storing natural gas; as gas in large natural underground formations (not present in Massachusetts), or in large holding tanks. Massachusetts utilizes both pipeline-delivered natural gas as well as liquefied natural gas for both the thermal and electric sectors. Additionally, natural gas is consumed on-site for industrial processes and residential uses such as cooking and laundry. Typically, demand will be met first by the real-time delivery of pipeline natural gas, with a dependence on liquefied natural gas as a form of fuel storage to meet our peak demands and ensure reliability.

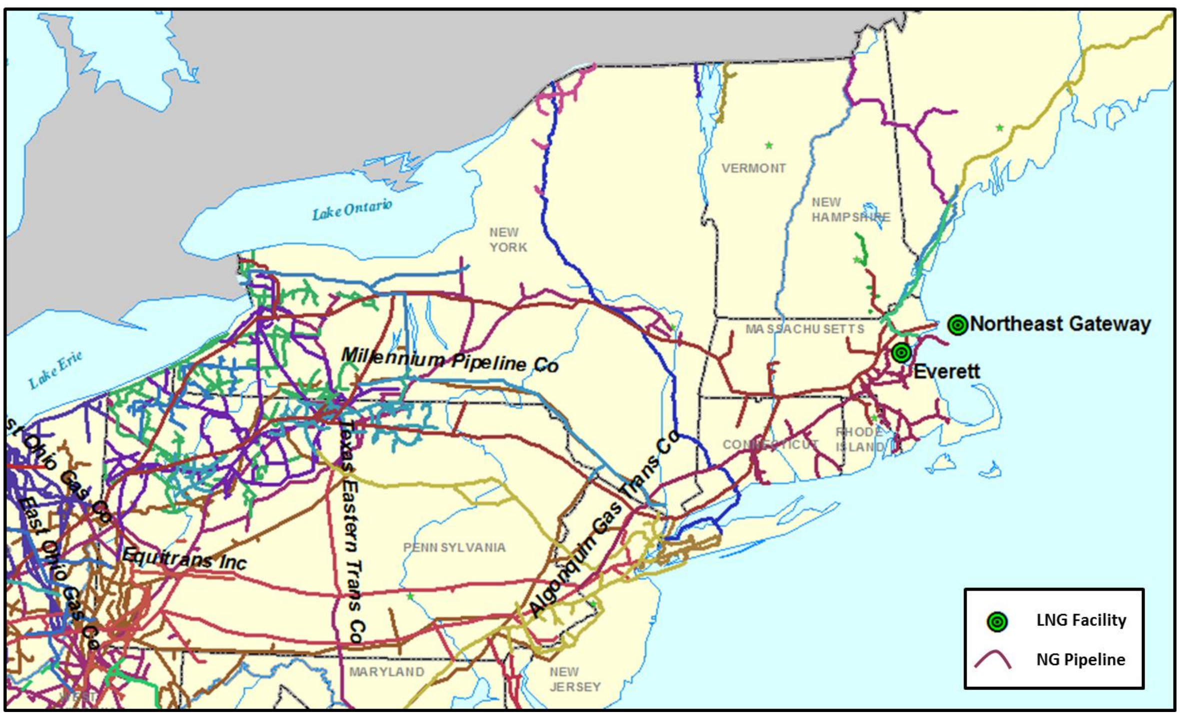

Figure 31: Map of LNG Facilities and Natural Gas Pipelines in the Northeast US[116]

115 EIA, The United States exported more natural gas than it imported in 2017; https://www.eia.gov/todayinenergy/detail.php?id=35392; Bloomberg, U.S. Becomes a Net Gas Exporter for the First Time in 60 Years; https://www.bloomberg.com/news/articles/2018-01-10/u-s-became-a-net-gas-exporter-for-the-first-time-in-60-years

Massachusetts is served by three interstate natural gas pipelines; Maritimes from the North, Tennessee from the West, and Algonquin from the South. Additionally, the Iroquois pipeline in New York and Portland pipeline in Maine interconnect these interstate pipelines and impact the capacity of natural gas available to Massachusetts consumers. There are approximately 1,000 miles of interstate gas transmission lines in Massachusetts. They are owned and operated by three companies: Algonquin Gas Transmission Company, Tennessee Gas Pipeline Company, and Maritimes and Northeast Pipelines Company. There are three LNG import facilities in Massachusetts, the only import/export facilities in New England, one onshore facility in Everett and two offshore facilities near Gloucester, Northeast Gateway and Neptune, although the Gloucester facilities have not received LNG imports since 2016.[117]

Local distribution gas pipelines connect to the interstate pipelines, and the distribution lines serve local consumers. Each of the seven local distribution companies ("LDCs") and four Municipal Gas Departments in Massachusetts has a distribution system connected to the transmission companies' pipelines at meter stations throughout the state. The distribution systems are composed primarily of two types of pipelines: mains and services. Mains are the pipelines that carry the gas from the meter stations throughout the distribution systems. Services carry the gas from the main to a customer's gas meter.

4.1.1 Fuel Security

Fuel security in New England has been an issue of increasing concern over the past decade. The growing dependence on natural gas for power generation and heating, and associated infrastructure constraints, coupled with the increasing retirement of coal, oil and nuclear resources, has led to concerns that regional dependency on a single energy source increases our vulnerability to disruptions. Industry and the grid operator have raised concerns that existing natural gas infrastructure may not always be adequate to deliver the gas needed for both heating and power generation during winter. These factors, coupled with the fact that the vast majority of the fuels the region depends on to meet energy demand are imported from outside New England, contribute to fuel security as a growing issue in New England.

ISO New England, the region's independent electrical grid operator, published a study in January 2018 assessing fuel security and grid reliability for New England under different scenarios for winter 2024-2025.[118] That report found planned retirements of nuclear and coal generators in the region, combined with constrained natural gas supply from pipelines and underutilized LNG infrastructure, could result in fuel shortages and system reliability problems under several possible scenarios for winter 2024-2025. Additionally, in July 2018, FERC ordered ISO-NE to permanent tariff revisions to improve market design

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[116] Data from EIA, *Layer Information for Interactive State Maps*; https://www.eia.gov/maps/layer_info-m.php

117 US EIA, *Massachusetts State Profile Analysis*, https://www.eia.gov/state/analysis.php?sid=MA

[118] ISO-NE, *Operational Fuel-Security Analysis*; https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

for regional fuel security concerns.[119] ISO-NE is currently developing market based solutions with regional stakeholders with the objective to "efficiently use the region's existing assets and infrastructure to achieve this risk reduction in the most cost-effective way possible" acknowledging the challenge that the solution should allow resources,= regardless of fuel or technology to meet the demand for electricity and required operating reserves.[120]

The ISO-NE Fuel Security report used different sets of assumptions than the scenarios analyzed in this plan and thus the results of these two studies are not directly comparable. Importantly, the Reference (baseline) case in the ISO-NE report does not include the Commonwealth's clean energy procurements for offshore wind and clean hydroelectricity imports in their 2024 - 2025 resource mix, while all scenarios examined herein (including Sustained Policies) assume these procurements come online as currently planned. However, ISO-NE found that in the study scenarios which do include the procurements, fuel security concerns were reduced or eliminated. The study demonstrates the fuel security benefits of Massachusetts' clean energy procurements which compensate for the loss of retiring baseload resources. That said, fuel security concerns remain, particularly in the near term.

4.2 Thermal and Electric Sectors Compete for Energy Supply in Winter

4.2.1 Demand for Heat and Demand for Electricity Both Increase with Cold Weather

During the winter in New England there is an increased heating demand for natural gas coincident with an increased demand for natural gas for electricity generation. These increased winter demands are directly correlated with temperature, making extreme winter weather events (extended periods of lower than average temperatures) the time when our natural gas supply is constrained (demand exceeds transmission ability to supply). For example, the chart below demonstrates the direct correlation between colder temperatures and increased daily electricity consumption.

[119] 164 FERC 61,003, Order Denying Waiver Request, Instituting Section 206 Proceeding, and Extending Deadlines

[120] ISO-NE, Winter Energy Security Improvements: Market-Based Approaches; https://www.iso-ne.com/static-assets/documents/2018/09/a9_presentation_winter_energy_security_improvements.pptx. See also, ISO-NE, Problem Statement and a Conceptual Approach to Address the Problem; https://www.iso-ne.com/static-assets/documents/2018/10/a9_presentation_winter_energy_security_improvements.pptx

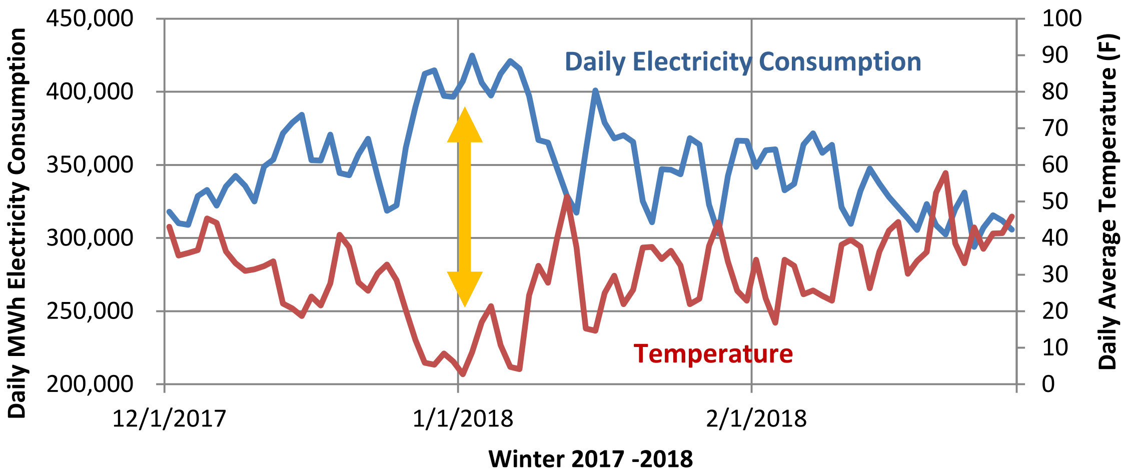

Figure 32: Temperature versus Electricity Demand for the Winter of 2017-2018[121]

Thermal load correlates to temperature inversely as colder weather drives more heating demand. Thermal load also correlates to a winter peak electric demand.[122] As seen in Figure 32, as temperature decreases, the consumption of electricity increases. This is caused not only by those customers that rely on electric heating but also the electric needs of other thermal systems such as the operation of fans or air circulators.

4.3 Natural Gas Pipeline Constraints

4.3.1 Constraint Conditions

Constraints on natural gas supply occur when the demand for natural gas from both the thermal and electric sectors exceeds or nears the capacity of natural gas pipelines.

[121] ISO-NE, Markets and Operations – ISO Express – Energy, Load, and Demand Reports, “2018 SMD Hourly Data”; https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/zone-info

[122] However, New England summer peak electric demand has historically been higher than peak winter demand

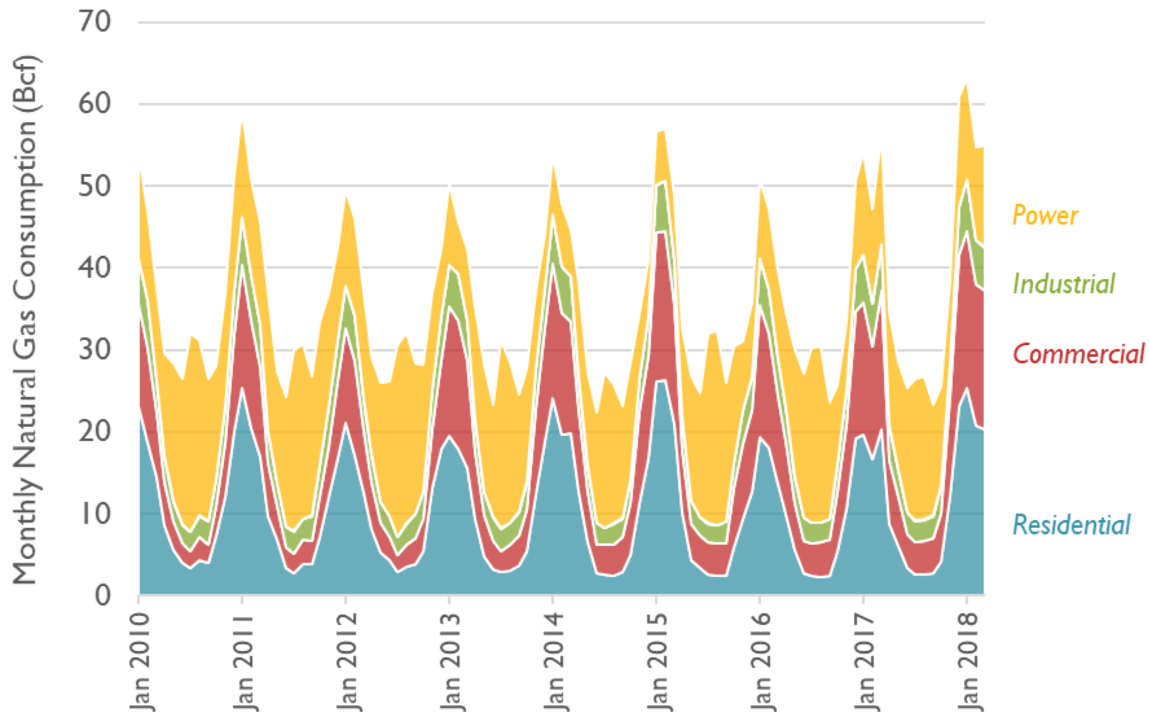

Figure 33: Massachusetts Natural Gas Consumption by End Use[123]

Figure 33 highlights the seasonal profiles of natural gas use. There is a rise in residential, commercial, and industrial natural gas consumption for winter. Natural gas use for electricity generation significantly decreases in the winter, due in part to constrained availability and associated increased price of pipeline gas.[124]

Pipeline capacity is determined by the diameter of the pipe (how much gas can flow through) and the number, power, and location of compressor stations (how well can pressure be maintained during high flow conditions). The compressibility of gas and the in-pipe storage lead to peak capacity being a daily measure, as compared to electricity transmission capacity which is measured in instantaneous power. The capacity of a pipeline is measured in volumetric (and/or thermal) units/day, that is, billion cubic feet per day (Bcf/d), million cubic feet per day (MMcf/d), and Dekatherms per day (Dth/d). [125]

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123 EIA, Natural Gas Consumption by End Use; https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SMA_m.htm

124 The Figure 32 power sector increases in summer are associated with natural gas electricity generation to meet increased cooling demand.

125 1 Bcf = 1,000 MMcf = 1,000,000 Dth

Gas constraints can result in high prices for natural gas purchased on the spot market for electricity generation, as observed in New England in recent years. Natural gas generators are frequently the marginal resource in the electricity system, meaning that the price paid to these generators is the price at which the wholesale market "clears", and is the price at which all resources are paid. As a result, during cold snaps when the desired demand for natural gas in the electricity systems nears or exceeds the available pipeline capacity, wholesale electricity prices are much higher than in other hours. A gas constraint can have a series of impacts, most importantly on price and energy assurance. Power plants are the marginal consumer of gas, meaning they set the price of non-contracted gas for both sectors. When the demand for gas exceeds or nears the available pipeline capacity, as in a constrained condition, the price of gas increases until other marginal fuels for electricity, such as LNG and fuel oil, sufficiently cover the unmet demand from the constraint. This increased gas price is paid for by all gas consumers, in both the electric and thermal sectors, for consumption in excess of their firm contracts.

4.3.2 Lessons from Recent Gas Constraints

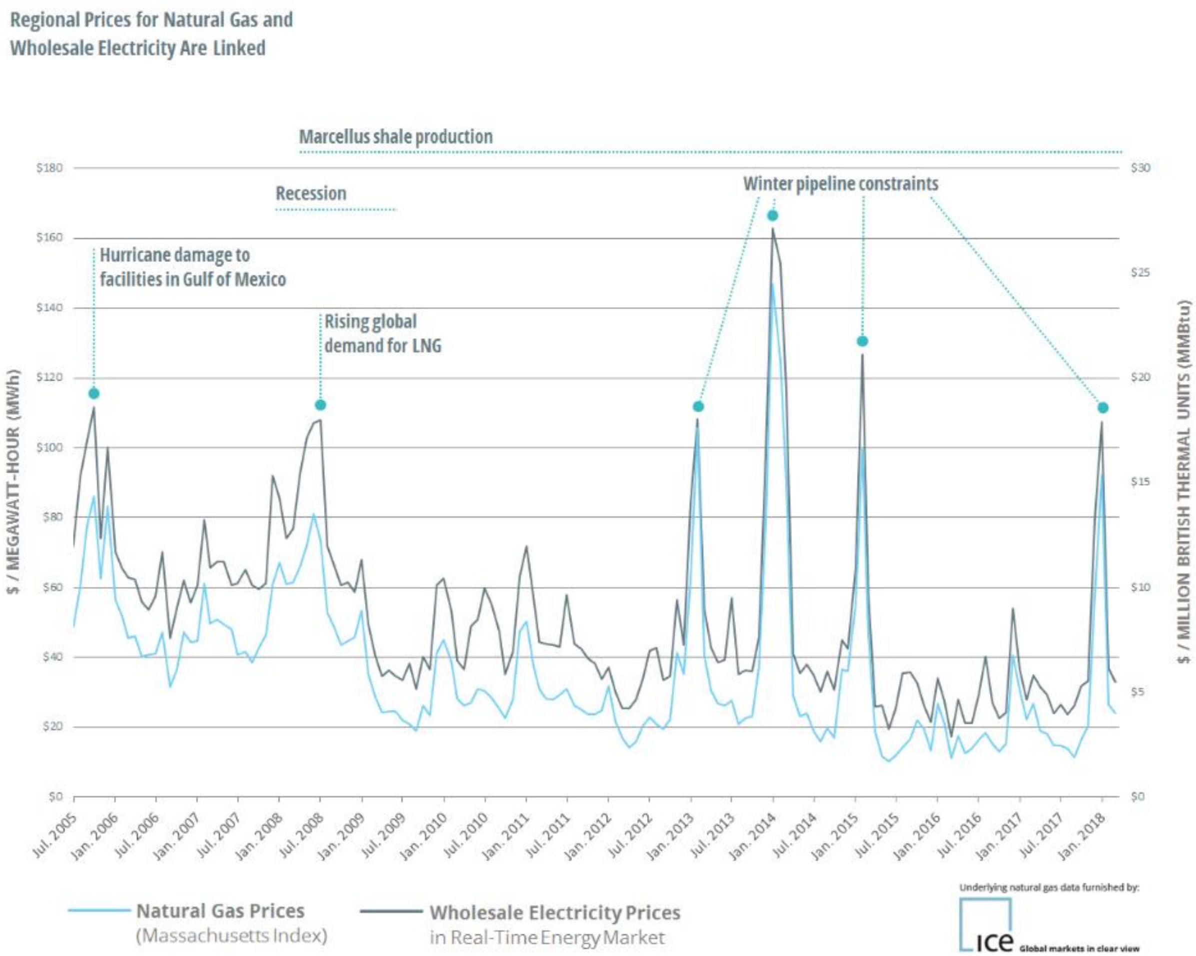

Figure 34: Natural Gas Prices and Wholesale Electricity[126]

Recent gas constraints have occurred during periods of extended cold (Figure 34). A recent constraint occurred when New England was gripped by a cold weather stretch for an extended duration between December 25, 2017 and January 8, 2018.[127] All major cities in New England had average temperatures below normal for at least 13 consecutive days, of which 10 days averaged more than 10 degrees Fahrenheit below normal. In Boston, for example, an Arctic air-mass brought one of the most extreme cold waves in 100 years with above average winds causing extended periods of frigid wind chill temperatures.[128]

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126 ISO-NE, About Us – Key Grid and Market Stats – Markets; https://www.iso-ne.com/about/key-stats/markets/

127 ISO-NE, Cold Weather Operations; https://www.iso-ne.com/static-assets/documents/2018/01/20180112_cold_weather_ops_npc.pdf

128 ISO-NE, *Post Winter 2017/18 Review*; https://www.iso-ne.com/static-assets/documents/2018/05/2018-05-11-egoc-a2.1-iso-ne-post-winter-1718-review.pdf

The frigid cold of this extreme weather event drove up regional demand for natural gas; this led to spikes in natural gas prices, which then led to spikes in wholesale electricity prices. With natural gas constrained, oil generation became economic, and some plants turned to LNG. LNG consumption peaked at approximately 1 Bcf on January 6, 2018.

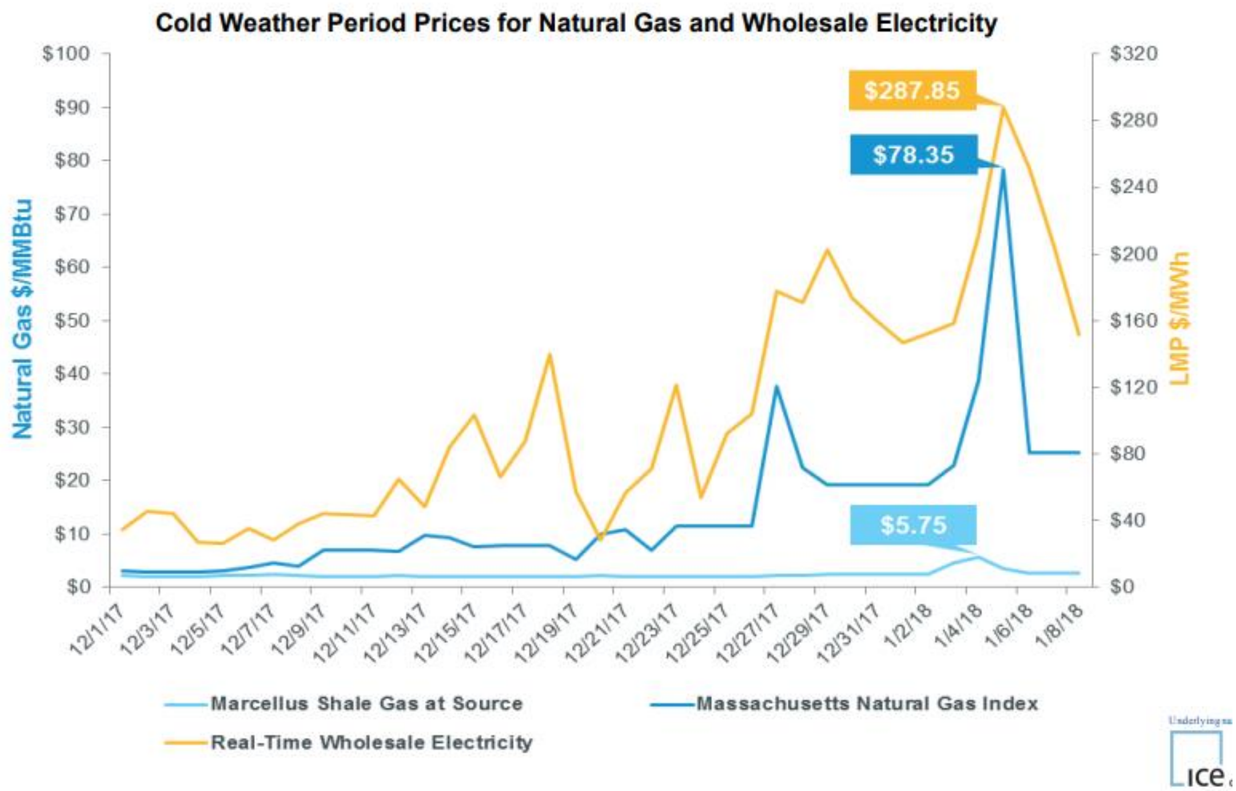

Figure 35: Cold Weather Period Prices for Natural Gas and Wholesale Electricity[129]

An added complication during this weather event was that the Pilgrim Nuclear Power Station shut down unexpectedly due to an off-site transmission line fault. This unplanned shutdown meant a loss of 683 MW of generation on January 4, 2018, further increasing the need for oil generation.

New England consumed approximately 3,000,000 barrels of fuel oil to produce electricity during this winter weather event. As the cold weather persisted, oil supplies were drawn down. Prior to the weather event, fuel oil available to generate electricity was at 68 percent of full capacity, and by the end of the event available fuel oil was down to 19 percent of capacity, a drop of over 70 percent of the starting capacity (Figure 36).

129 ISO-NE, *Post Winter 2017/18 Review*; https://www.iso-ne.com/static-assets/documents/2018/05/2018-05-11-egoc-a2.1-iso-ne-post-winter-1718-review.pdf

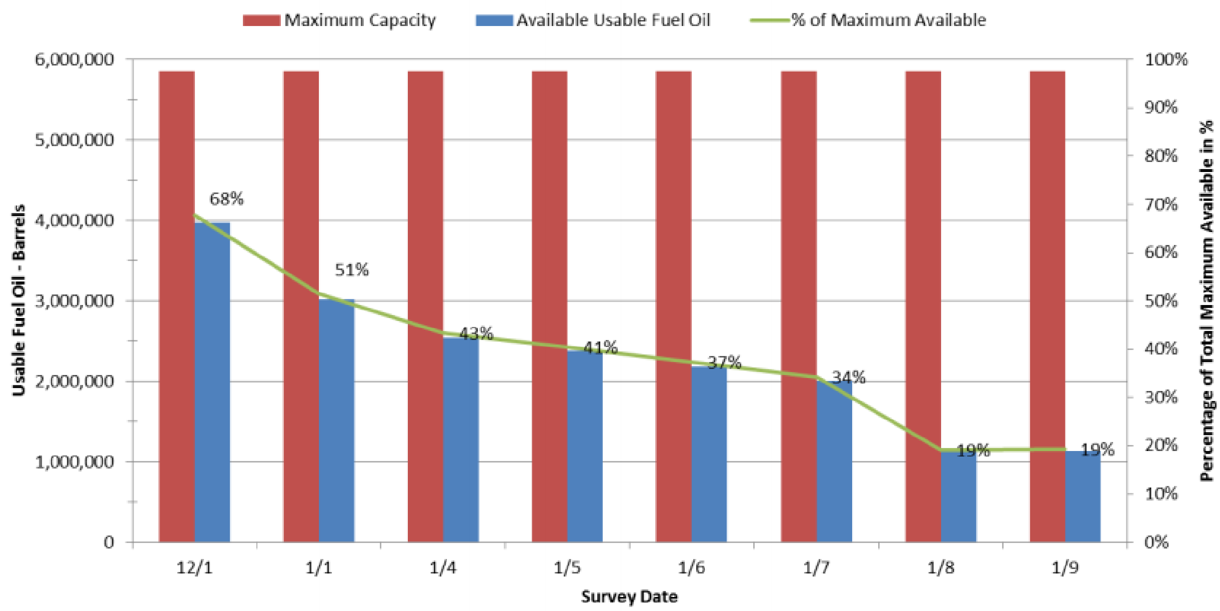

Figure 36: Total Amount of Usable Fuel Oil in New England[130]

ISO New England dispatches sufficient power plants to meet demand on a lowest-cost approach using energy bids placed by power plants. When wholesale electricity prices rise, non-pipeline natural gas fuels (such as oil, LNG, and coal) become economic and are dispatched. Frequently, non-natural gas fuels (oil and coal) are at the costliest end of the dispatch order, and are also the highest emitters of greenhouse gases and other air pollutants on a ton-per-MWh basis.[131] Daily CO_2 system emissions increased during the 2017-2018 winter extreme weather event due to combustion of non-natural gas fuels. Daily average CO_2 emissions were approximately 250,000 short tons with a total of 3.5 million short tons emitted over the two week cold snap. This is up from pre-snap daily emissions of approximately 90,000 short tons. The incremental quantity of CO_2 emissions produced from burning fuel oil rather than natural gas over the two-week cold period in 2017-2018 increased regional annual CO_2 emissions in the electric sector by less than 2 percent but also increased criteria and non-criteria pollutant emissions.

[130] ISO-NE, *Post Winter 2017/18 Review*; https://www.iso-ne.com/static-assets/documents/2018/05/2018-05-11-egoc-a2.1-iso-ne-post-winter-1718-review.pdf; This chart is the ISO's best approximation of useable oil discounting for unit outages, reductions, or emissions.

[131] Note that the combustion of LNG does not produce substantially different emissions than burning natural gas from pipelines.

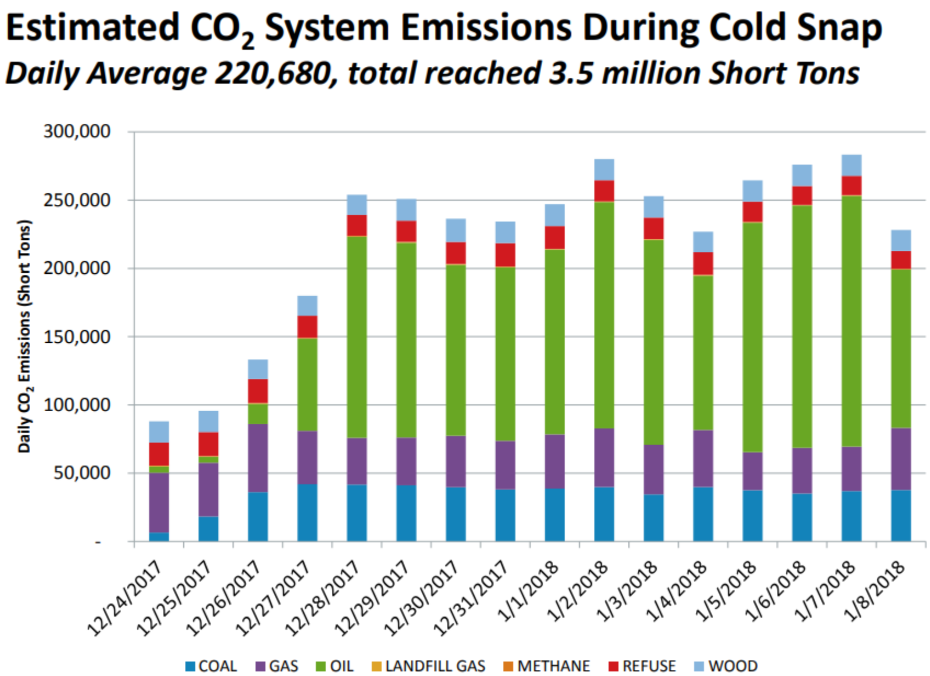

Figure 37: Estimated CO_2 System Emissions During Cold Snap[132]

4.3.3 Pricing Impacts

During the 2017-2018 cold snap, electricity prices were observed to increase in line with low temperatures (Table 8). Electric price volatility, or a lack of predictability in pricing, also increases substantially as gas price volatility increases and the generators dispatched are in a steeper portion of the ISO-NE bid curve.

January 2018: Temperature vs. Wholesale Electricity Price	
Temperature (Degrees Fahrenheit)	Average LMP ($/MWh)
< 10 Degrees	$ 212
10-20 Degrees	$ 140
20-30 Degrees	$ 116
30-40 Degrees	$ 54
40+ Degrees	$ 30

Table 8: Temperature versus Wholesale Electricity Prices: January 2018[133]

132 ISO-NE, *Post Winter 2017/18 Review*; https://www.iso-ne.com/static-assets/documents/2018/05/2018-05-11-egoc-a2.1-iso-ne-post-winter-1718-review.pdf

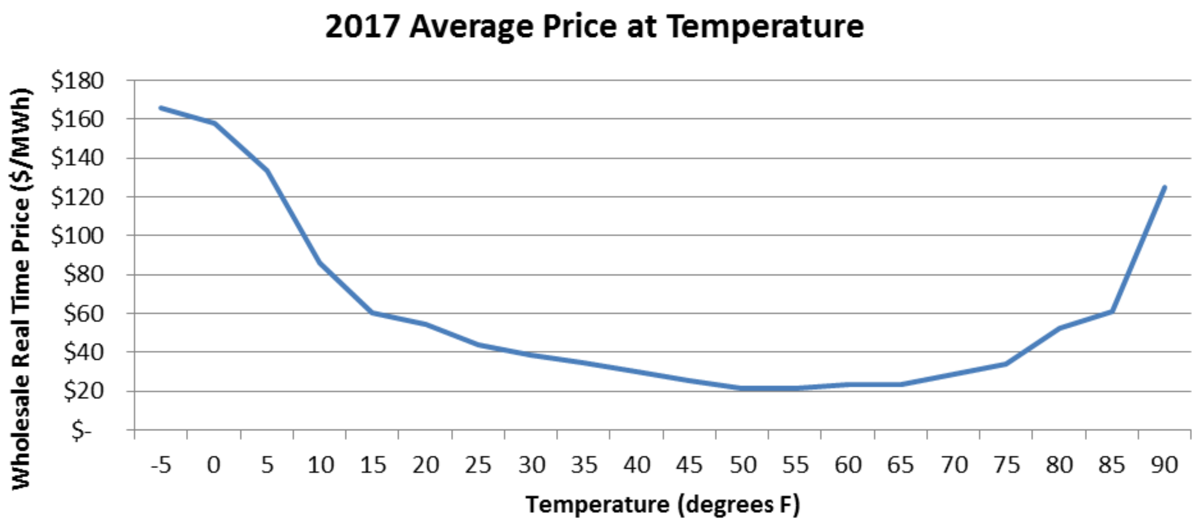

Figure 38: 2017 Average Price at Temperature[134]

The price of electricity trends very closely to the temperature. In winter, price trends with temperature as the thermal sector competes with the electric sector for access to natural gas. In the summer, price trends with temperature as electric demand for cooling results in peak electric demands. Price volatility also increases with both peak winter and peak summer demands.

The increased consumption (number of kWh of electric energy) and increased price ($/kWh) are multiplicative, increasing the economic impact on regional residents and businesses. While the increased natural gas prices are felt by consumers in the year in which the cold weather event occurs, the increased wholesale electricity prices are incorporated into retail rates with a one year delay. As such, most consumers are not aware of the impacts that their consumption patterns during an extreme cold event will have on future pricing. This is a result of the current disconnect between wholesale market prices and retail prices. Cost impacts of cold winters have been on the order of an additional 1 to 4 cents per kWh applied to rates for the entire year.[135]

In addition to electric energy cost impacts, "uplift payments", or Net Commitment-Period Compensations (NCPCs) are made when the ISO dispatches generator plants against the plant's economic best interests in order to achieve a reliable electric system. The NCPC covers the power plant's opportunity costs. In a severe winter with extended cold events, the ISO incurs larger NCPC costs in order to dispatch oil generation plants in a non-economic way. NCPC costs in the winter of 2017 – 2018

133 ISO-NE, Markets and Operations – ISO Express – Energy, Load, and Demand Reports, "2018 SMD Hourly Data"; https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/zone-info

134 ISO-NE, Markets and Operations – ISO Express – Energy, Load, and Demand Reports, "2018 SMD Hourly Data"; https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/zone-info

135 See basic service filings from 2015 and 2018; eg. DPU 18-BSF-D3, DPU 14-BSF-C-4, DPU 14-BSF-B-4; DPU 14-BSF-D-3, DPU 14-BSF-D-4; DPU 14-BSF-A-6

were $29 Million, a 61 percent increase over the NCPC costs incurred during the milder winter of 2016 - 2017.

4.3.4 New England and Regional Impacts

Daily generation mix changed dramatically throughout the cold snap across New England, New York and the Mid-Atlantic.[136] Specifically, all of these regions relied heavily on oil to cover energy needs during the peak demand of this extreme weather event.

If New England generators continue to burn oil to generate electricity for an extended period of time, ISO-NE has expressed concern that they may need to enact rolling-blackouts as oil supply runs low. The oil constraint is a result of a combination of power plant onsite oil tanks going empty as well as power plants which reach their local air quality emissions permit limits and are no longer allowed to burn oil.[137]

4.4 Considerations to Mitigate and Alleviate Constraints

There are several mechanisms by which a gas constraint and its impacts can be mitigated, including reducing consumption, increasing diverse supply, and encouraging thermal fuel switching. Our diverse energy approach including energy efficiency, clean energy procurements, and renewables deployment serves to improve our winter energy security. There are also several recent wholesale electric market changes which may help reduce constraint impacts in Massachusetts and in New England more broadly.

4.4.1 Reduce Consumption

Reducing demand for end-use fuels like natural gas and for electricity helps to alleviate the likelihood of a constraint in the first place. Decreasing the demand for natural gas from both the thermal conditioning and power sectors help to increase the odds that the existing pipeline capacity can meet demand during periods of extreme cold. While reducing demand reduces the likelihood of a constraint, it also helps mitigate the cost and emissions impacts if a constraint still occurs. Reductions from Massachusetts' nation leading energy efficiency programs can benefit not only the individual participants in terms of direct savings but also energy consumers across the state and the region through reducing the risk and impact of pipeline constraints.

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[136] EIA; Today in Energy; January's cold weather affects electricity generation mix in Northeast, Mid-Atlantic, JANUARY 23, 2018; https://www.eia.gov/todayinenergy/detail.php?id=34632

[137] ISO-NE, *Operational Fuel-Security Analysis*; https://www.iso-ne.com/static-assets/documents/2018/01/20180117_operational_fuel-security_analysis.pdf

4.4.2 Increasing Diverse Supply

There are multiple pathways to increasing the availability of natural gas supply in the region. This CEP analysis presents options, but does not include a cost analysis for these options.

4.4.2.1 Increased LNG Utilization

Over the past few winters, the region has underutilized existing regional LNG infrastructure, primarily due to the need for LNG to be contracted for in advance, and global LNG markets have made forward contracting for delivery in New England economically unattractive. LNG is stored in very large quantities (10s of Bcf regionally), and can be vaporized and injected into the pipeline during high price events. LNG can also be loaded into trucks for on-road deliveries.

Our past and ongoing foreign LNG deliveries must conform to federal Jones Act requirements, which in effect preclude shipment of domestic LNG to New England. The Jones Act, also known as the Merchant Marine Act of 1920, is a federal law that regulates maritime commerce in the United States. [138] It requires goods shipped between U.S. ports to be transported on ships that are built, owned and operated by United States citizens or permanent residents. A relatively small supply of American built, owned and operated vessels compared to the global supply of ships, combined with a constant to growing demand for goods, means shipping companies can charge higher rates intra-U.S. shipping because of a lack of competition, with the increased costs passed on to consumers. This impacts non-contiguous U.S. states and territories like Hawaii, Alaska, and Puerto Rico that rely on imports as well as states like Massachusetts that purchase LNG by restricting the number of vessels that can legally deliver goods from elsewhere in the United States.

The issue is magnified with regards to natural gas because the U.S. has cheap and plentiful natural gas, but no Jones Act-qualified carriers.[139] Accordingly, Massachusetts imports LNG from Trinidad and Tobago, while U.S. gas is sent overseas on foreign-flagged ships. When pipeline natural gas supply is constrained, the lack of a fleet of Jones Act qualified tankers means a bigger price spike due to the need to import LNG from foreign ports.[140] There is also no economic case to build qualified carriers.[141] According to industry representatives, U.S. carriers would cost about two to three times as much as similar carriers built in Korean shipyards and would be more expensive to operate. Based on a GAO analysis, using carriers subject to these costs would increase the cost of transporting LNG from the

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138 46 USC Subtitle V: Merchant Marine, Title 46—Shipping, http://uscode.house.gov/view.xhtml?path=/prelim@title46/subtitle5&edition=prelim

139 According to the General Accounting Office (GAO), LNG carriers have not been built in the United States since before 1980, and no LNG carriers are currently registered under the U.S. flag.

140 Bloomberg, Editorial Board, *The Jones Act Costs All Americans Too Much*, December 12, 2017 https://www.bloomberg.com/view/articles/2017-12-12/the-jones-act-costs-all-americans-too-much

141 United States Government Accountability Office, MARITIME TRANSPORTATION *Implications of Using U.S. Liquefied-Natural-Gas Carriers for Exports*, December 2015; https://www.gao.gov/assets/680/673976.pdf

United States, decrease the competitiveness of U.S. LNG in the world market, and may, in turn, reduce demand for U.S. LNG.[142]

As a result, while the U.S. has become a significant exporter of LNG, Massachusetts LNG deliveries are still all foreign (primarily Trinidad as Country of Origin). Table 9 shows that even with our reduced utilization of LNG, we remain one of the few locations in the U.S. still importing significant quantities of LNG. A solution would be to amend or grant an exemption to the Jones Act with regards to LNG. On several occasions, the U.S. government has granted temporary waivers on Jones Act requirements. This is typically done in the wake of a natural disaster, such as a hurricane, in order to increase the number of ships that can legally supply goods to an affected area[143] but could be done permanently or semi-permanently to ensure a reliable and affordable supply of LNG to Massachusetts consumers.

U.S. LNG Imports/Exports Summary 1/1/2018 - 6/30/2018			
		Bcf	Average $/MMbtu
Exports	Sabine Pass	444,870	$ 4.35
	Cove Point	46,428	$ 6.82
	Ft Lauderdale	148	$10.00
Imports	Everett, MA	29,129	$ 6.15
	All Other U.S.	8,721	$ 5.53

Table 9: US LNG Imports/Exports Summary[144]

The New England region largely depends on two LNG terminals, the Everett terminal in Massachusetts and the Canaport terminal in the Bay of Fundy, Canada. Terminals are locations where large LNG vessels can come into port and deliver large quantities (1.8 – 3.0 Bcf) of LNG.

Operating a LNG terminal requires substantial logistics. For example, the Everett LNG terminal needs to be nearly empty before it is economic to receive a delivery. The Everett LNG terminal has about 3.4 Bcf of storage capability, and can vaporize approximately 1 Bcf per day. The terminal can provide vaporized gas to two interstate pipelines (Algonquin and Tennessee), and can also supply the local gas distribution system. The Everett LNG terminal also supplies gas directly to the Mystic 8 and 9 power plants, which can produce up to 1,600 MW of electricity in direct proximity to the Boston load. Finally, the terminal has a capability to send out up to 100 trucks worth of on-road LNG per day (1.2 million gallons loaded to trucks per day). The terminal supplies many of the regional LNG storage tanks, such as those owned and operated by the thermal sector LDCs, which are typically filled from the terminal in the late fall in preparation for winter.

Terminal send out rate in winter is largely determined by the temperature, as LDCs and generators only turn to LNG during extended cold events when pipeline prices go up. As such, scheduling deliveries to

142 Ibid.

143 United States Government Accountability Office, MARITIME TRANSPORTATION *Implications of Using U.S. Liquefied-Natural-Gas Carriers for Exports*, December 2015; https://www.gao.gov/assets/680/673976.pdf

144 https://www.energy.gov/fe/downloads/lng-monthly-report-2018

terminals in advance can be difficult. However, terminal deliveries must be scheduled in advance, because the limited LNG vessel fleet is otherwise maximizing economics by shipping LNG to other locations. In addition, the price paid for LNG in other countries often exceeds the regional marginal price for natural gas, making delivery to New England difficult to justify without advance contracting. Advance contracting for terminal deliveries requires the terminals to have a level of assurance that they will require a refueling (be near empty) at a certain point in the winter. This assurance could be met by power plants entering into contracts for LNG. While these contracts may represent an increased energy cost during typical winters (as LDCs and power plants utilized LNG in non-constrained conditions), they may reduce our susceptibility to constraints and increase our fuel security, in effect acting as an insurance policy to ensure expanded natural gas supply.

Although currently underutilized, LNG terminals remain operational and in place for now, although there is a risk of retirement if underutilization continues. While LNG is a more expensive fuel than pipeline natural gas, utilizing LNG to mitigate capacity constraints in the near term requires no additional capital costs, and is available immediately.

Since the LNG terminals are located in the region and on the load side of pipeline constraints, New England can be considered "first in line" for LNG, whereas any pipeline loads upstream from us can draw down pressure before it arrives to us. LNG also has a security advantage of multiple supply sources; i.e. any LNG export facility can ship to New England, while pipeline deliveries by definition come through the pipelines where local events can disrupt our supply.

4.4.2.2 Alternative Supply

Future development may lead to viable alternative natural gas supplies, such as biogas, regionally sourced green gas through power-to-gas processes, hydrate solid natural gas storage, and regional clean hydrogen production, storage, and injection. The U.S. Department of Energy is researching emerging technologies in each of these fields, which if deployed may provide alternative gas supply for the region through constrained periods.[145] Biogas is methane associated with biologic process such as waste water treatment, municipal solid waste, and food and agricultural waste. If processes can capture and inject methane that would have either been vented or burned on site, emissions are net-shifted to a more useful purpose. More emerging technologies such as green gas through power-to-gas processes utilize excess local clean energy to create hydrogen gas through electrolysis. This hydrogen gas can be injected into the natural gas distribution system to create a blended gas or can be combined with captured carbon dioxide to create methane. These emerging technologies are currently limited in scale although development could create a role for alternative supply to supplement and/or replace natural gas for heating and electric generation.

145 NREL, *Renewable Hydrogen Potential from Biogas in the United States*; https://www.nrel.gov/docs/fy14osti/60283.pdf

4.4.2.3 *Fuel Switching*

If significant reductions in natural gas demand can be made in the thermal and electric sectors by relying more heavily on alternative fuels, constraints may be lessened or resolved. In the thermal sector, consumers could move from natural gas to biomass, or renewable thermal.[146] In the electric sector, generation may transition to stored LNG and renewable resources like hydro, wind, solar or biomass. Resources that are coincident with winter demand (such as hydro imports, onshore wind, and offshore wind) act to improve regional reliability and reduce the likelihood and impact of winter price spikes on wholesale electricity costs.

4.4.3 Recent Market Changes

There are several recent ISO-NE market changes which may also help reduce constraint impacts. First, in June 2018 ISO-NE established a pay for performance market with up to $3,500/MWh payment/penalties for performance during scarcity conditions. This is intended to incent power plants to be operational when the system needs them most, and one way for plant owners to remain operational is to enter forward contracts for LNG to mitigate penalty risk due to lack of fuel. ISO-NE also integrated demand response to participate in daily energy dispatch and reserve, similar to generators, essentially providing more resources to meet demand. Finally, ISO-NE has been using a new dispatch algorithm that enables wind to set real time locational marginal price (LMP), enabling reduced LMPs in the winter when wind is available and the market might otherwise see price spikes due to a gas constraint. Enabling wind to set the LMP has primarily benefited Maine in recent winters, given their substantial onshore developments; however, as Massachusetts continues to pursue offshore wind resources, the new dispatch algorithm may come to benefit our state as well.

ISO-NE will continue to implement market changes for the purpose of improving regional fuel security as directed by FERC. Ensuring the availability and reliability of fuel sources to meet our power needs is critical to both our economic security and safety.

[146] Where renewable thermal may include air source and ground source heat pumps and solar thermal technologies

5 Introduction to Modeling Energy Futures

In order to understand the impact on cost, emissions, and reliability of different potential futures for energy demand in Massachusetts, this report utilized scenario modeling. Modeling allows the projection of different possible versions of the future can be an effective way to highlight potential priorities for policy development as well as possible strategies that can be used to meet future levels of demand.

Modeling typically consists of two main components. The first component is the model or models itself; this is the engine through which different input parameters can be fed to produce different outputs. The second component is the modeling inputs. Any model is only as good as its input parameters, and the formulation of reasonable input parameters is an essential first step in ensuring that the model produces reasonable outputs. For modeling energy demand, input parameters must be created for assumptions relating to anticipated fuel costs, future growth of building construction, change in transportation trends, changes to energy supply (including increasing levels of renewable and energy efficiency), as well as other drivers such as existing or anticipated regulations and legislation.

Once the input parameters are established, the impact of adjusting particular inputs of interest can be measured. Implementing changes to inputs on fuel switching, level of future renewables, number of electric vehicles, among dozens of others, can yield drastically different modeled outputs. A collection of different changes to input components is often characterized as a "scenario." In any analysis, multiple scenarios may be run, each one representing a reasonable version of a particular future. Comparing the different scenarios helps us to understand the range of possible outcomes, given potential changes to energy demand in Massachusetts.

The CEP modeled energy futures based on different assumptions for ways the state generates and consumes energy across the power, thermal, and transportation sectors to determine the impact each set of policy outcomes could have on the amount of emissions the state produces, the reliability of the system, and the cost of energy for consumers in the future. These scenarios are modeled over a multiyear period until 2030 to enable policy makers to see long term effects of different assumptions. The modeling was done using average weather conditions and then a complementary extended cold weather analysis was completed to understand the impacts when our energy system is stressed. Demand analysis in the average weather modeling is based on historic demands and therefore correlates to historic weather trends. The Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), published in September 2018, notes that weather trends are anticipated to change as global climate changes. Predicting the severity of future weather events, both in temperature and duration, is complex and was not attempted as part of this study. Instead the extended cold weather analysis shows the effect of a 20-day event, although extended cold periods may happen more or less frequently in the future and they may be more or less than 20 days.

This additional analysis was completed focusing on a peak winter day in the winters of 2022 and 2025, the years before and after significant energy supply is added through the hydroelectric and offshore wind procurements. This analysis captured the increased cost and emissions associated with possible extended winter events. During cold weather, consumers demand more natural gas for heating which reduces the natural gas supply for the electric sector. The winter weather analysis shows both the impact on cost, emissions and reliability using both a constrained natural gas price and a price of natural gas that is reduced due to mitigation of natural gas constraints. Comparing these results shows the relative impact and benefit of lowered natural gas prices although the rate analysis may not include the full additional cost of mitigating the constraint because there are multiple strategies (as identified in Chapter 4.4. Further analysis would need to be completed to compare the relative cost impacts of the multiple pathways to mitigating natural gas constraints.

After developing each of the scenarios, we can then evaluate each one in terms of how they might meet Massachusetts' goals for a clean, affordable, reliable, and resilient energy system. In the context of this analysis, we measure each of these goals in the following ways:

- Clean: Does the scenario provide emission reductions to help us move towards meeting the targets set by the Global Warming Solutions Act?
- Affordable: Does the scenario reduce the cost of energy and reduce the amount of energy consumers need to buy?
- Reliable and resilient: On a peak winter day, does the fuel use exceed the region's pipeline capacity, making electric generation reliant on stored fuels such as LNG and fuel oil during possible extended cold weather events?

5.1 Modeled Scenarios and Assumptions

The CEP contains five modeling runs that measure the impact of different energy drivers, assuming that full policy outcomes are achieved. The scenarios represent a spectrum of possible energy futures with the Aggressive Conservation and Fuel Switching scenario representing an energy future with aggressive policy outcomes in all sectors and with all drivers. As seen in Figure 39, the Aggressive Conservation and Fuel Switching scenario represents an energy future where there is significant transformation in electric clean energy, energy storage, thermal sector adoption of air source heat pumps, efficiency of building shell envelopes, electric vehicles, and the use of biofuels. These modeling runs do not reflect whether these assumptions are feasible and do not represent policy plans. Instead, the results show the relative impact of different policy outcomes to help policy makers determine the relative importance of policy priorities.

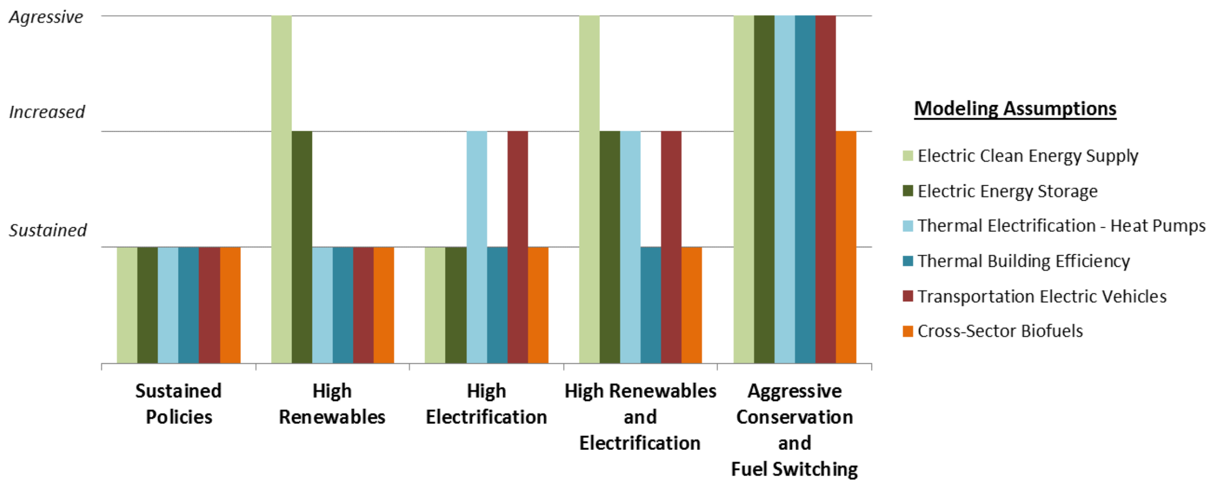

Figure 39: Modeling Assumptions

Sustained Policies

This model run shows the impact of our current energy policies without significant new policies.[147] This scenario includes the following policy outcomes:

Clean Energy Supply: The implementation of the 2016 energy legislation, with 1600 megawatts (MW) of offshore wind and a large transmission line of hydroelectric power to come online in 2023. Additional renewable supply is incentivized through the SMART program which is expected to double the amount of solar in Massachusetts by 2022. The obligations under the RPS and CES are achieved, which require 25 percent of our energy to be renewable and 40 percent of our energy to be clean by 2030.[148] With additional clean energy generation from the hydroelectric procurement, approximately 45 percent of the Commonwealth's retail energy is forecast to be clean energy by 2030.

Storage: The 200-megawatt hour (MWh) storage target is met in 2020 and reaches approximately 500 MWh by 2030.

Efficiency: Energy efficiency programs that achieve similar levels of energy savings as to today.

Electrification: Increased adoption of new thermal technologies, such as air source heat pumps,[149] to approximately 2 percent of single family homes by 2030. The scenario assumes the increasing

[147] The Sustained Policy scenario excludes initiatives in *An Act to Advance Clean Energy* that was passed by the Legislature on July 31, 2018 and signed by Governor Baker in to law on August 9, 2018.

[148] Clean energy is defined as in 310 CMR 7.75, the Clean Energy Standard.

[149] Assumptions in the modeling are based on the growth of air source heat pumps but results could be achieved with a combination of efficient heat pump technologies include ground and water source where cost effective.

use of electric vehicles (EVs) at the current pace of adoption which achieves 160,000 ZEVs by 2025 and 1.2 million by 2030.

High Renewables

This model run shows the impact of additional clean generation sources to the electric sector, but no increase of electric consumption in the thermal and transportation sectors. Compared to the Sustained Policies scenario, this scenario increases the amount of clean electric generation by approximately 50 percent or 15TWh and increases the amount of energy storage on the electric grid to 1800 MWh, approximately three times the amount in the sustained policies by 2030.

High Electrification

This model run shows the impact if consumers increased the use (consumption) of electricity in the thermal and transportation sectors.[150] This scenario increases the adoption, from that used in the Sustained Policies scenario, of heat pumps to an average of 15 percent of homes and businesses by 2030[151] and doubles the amount of EVs in 2025 to 300,000 EVs in Massachusetts growing to 1.7 million in 2030.

High Renewables and High Electrification

This model run shows the impact on costs, emissions and reliability from electrifying the thermal and transportation sectors, while simultaneously adding clean generation sources to the electric sector. This scenario combines the assumptions from the High Renewables and the High Electrification scenarios.

Aggressive Conservation and Fuel Switching

In addition to the assumptions included in the High Renewables and High Electrification scenario, this model shows the impact of aggressive energy efficiency and fuel switching, both electrification and biofuels, higher penetration of EVs and additional energy storage deployment for peak reduction. Further, it includes improved building envelope efficiency so that an average building in 2030 utilizes only 75 percent the energy the average building does today, which equates to approximately a threefold increase in the pace of weatherization and building efficiency that exists today. Peak demand is reduced through a total of 2 gigawatts (approximately 7,500 MWh) of storage by 2030, more than 250 percent of the storage in the High Renewables scenario. Electrification is maximized to have 30,000 more EVs in 2025 and to 200,000 more in 2030 for a total of 1.9 million light duty EVs. Additionally, 5 percent of freight travel is powered by electricity and an additional 5 percent is powered by biofuels.

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[150] The increase of use of electricity in the thermal and transportation sectors is met by advanced technologies including high efficiency air source heat pumps and electric vehicles.

[151] Assumptions in the modeling are based on the building transitioning to air source heat pumps but results could be achieved with a comparable load met with heat pump technologies as a secondary heating source.

Modeling Outputs

The following outputs were produced for each scenario:

Energy Costs for Consumers:

- Average residential retail rate for electricity measuring the impact of policy and program costs as well as changes in the cost of wholesale energy between the scenarios.
- Total monthly energy burden which is the average monthly costs a resident will pay for their electric bill, their heating bill, and their gasoline or charging costs for their light duty vehicle.[152] This metric captures the impact of fuel switching, energy efficiency, and cost of electricity. In order to calculate the total monthly expenditures, the total consumption of each sector was divided by the total number of customers for each heating class and transportation costs were calculated for both EVs and combustion engine vehicles. This analysis is not a projection of anticipated bills but allows a comparison across fuel types.

Emissions: The expected reduction in GHG emissions from Sustained Policies utilizing the methodology from the MassDEP Greenhouse Gas inventory.

Winter reliability: The total demand for natural gas on a peak winter day as a percent of natural gas pipeline capacity. When demand exceeds pipeline capacity, the region is reliant on stored fuels such as LNG and oil for electric generation on peak winter days.

	Power		Thermal				Transportation	
	Clean Energy Supply	Energy Storage	Electrification (Heat Pumps)	Building Efficiency	Industrial Efficiency	Biofuels and the APS	Electric Vehicles	Biofuels
Baseline	~20TWh of Clean Energy in 2030 **~ 45% Retail Load is Clean Energy in 2030**	500 MWh in 2030	A few thousand HPs per year.	Continue utility EE programs with levels of performance similar to today	Slight increase in industrial thermal consumption	APS remains at current levels, biofuel target reached	160,000 by 2025 Growth until 1.2 million in 2030	Minimal
Increased	~28 TWh of Clean Energy in 2030 **~50% Retail Load is Clean Energy in 2030**	1,800 MWh in 2030	25% of oil-heated buildings use HPs by 2030, and 10% of gas-heated buildings	1.5 to 2x increase in pace of building shell improvements, including through building codes and weatherization	Additional EE sufficient to reduce industrial energy use 5% from today, preferentially reducing oil	20% bioheat blend in heating oil	300,000 by 2025 Growth until 1.7 million in 2030	5% of freight ton-miles powered by biofuels (e.g. biodiesel blends)

[152] To determine an average customer's bill the total consumption for each sector is divided by the number of customers in that class. For example, each household is assumed to have 1.5 light duty vehicles.

Aggressive	~36 TWh of Clean Energy in 2030 **~65% Retail Load is Clean Energy in 2030**	7,500 MWh in 2030	33% of oil-heated buildings use HPs by 2030, and 20% of gas-heated buildings	2.5x to 3x increase in pace of building shell improvements, including through building codes and weatherization			370,000 by 2025 Growth until 1.9 million in 2030 5% of freight ton-miles for EV	

Table 10: Modeling Assumptions and Drivers

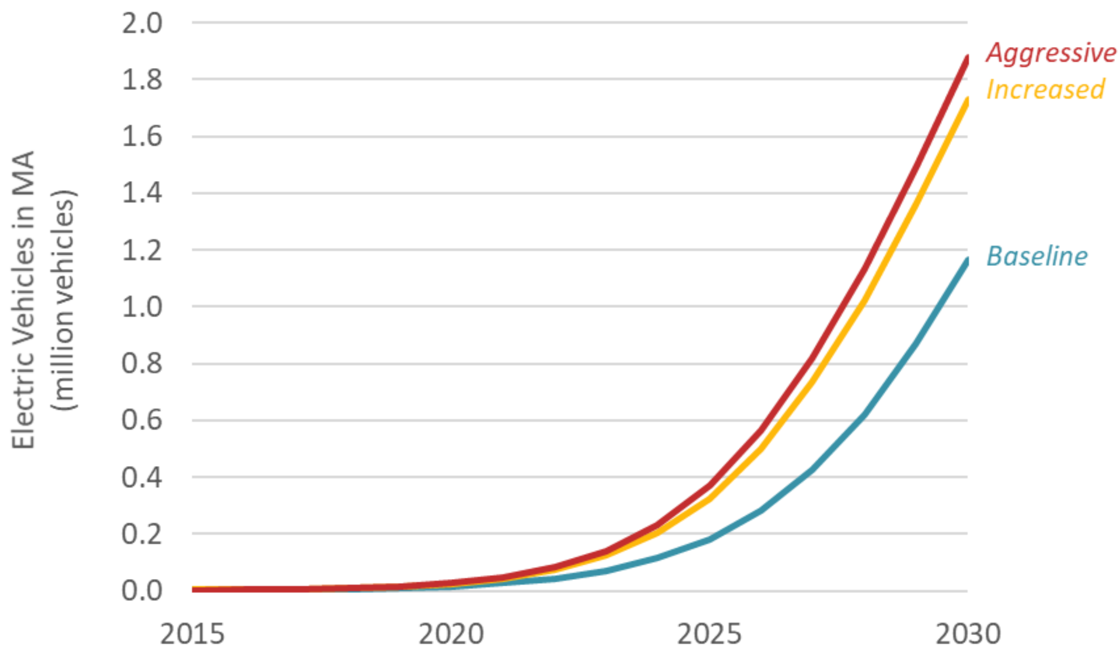

Figure 40. Modeled EV adoption

Electric vehicle penetration is not the only demand driver modified in the transportation sector. In the Aggressive Conservation and Fuel Switching scenario, medium- and heavy-duty vehicles are modified to include 5 percent of freight-ton miles served by electric vehicles and a further 5 percent powered through advanced biofuels by 2030. These additional changes reduce the demand for diesel by 10 percent, relative to the Sustained Policies scenario.

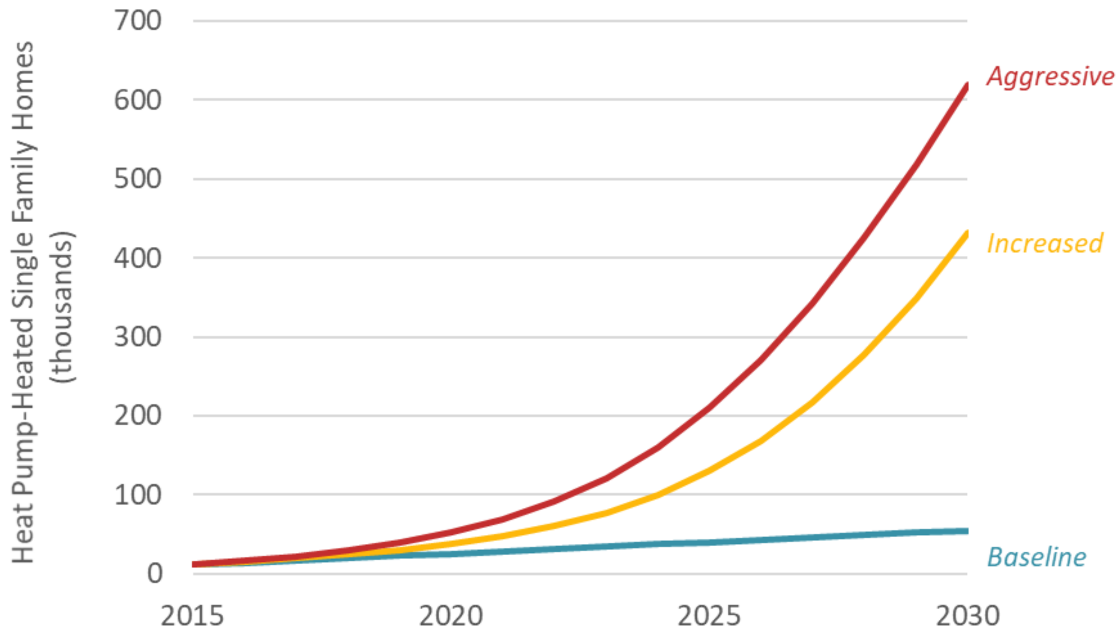

Figure 41. Heat pumps deployed in single-family residences in Massachusetts

5.2 Modeling parameters

The following sections describe both the models used in this analysis, along with the input parameters assumed. In most scenarios, the input parameters described in this section refer to the input parameters applied in the Sustained Policies scenario. The ways in which modifications were made to each parameter in each of the other scenarios is discussed below.

5.2.1 Models used

This modeling process applies three models to concurrently project Massachusetts's (and New England's) energy demand and supply for 2018 through 2030. These models include the EnCompass model, the Renewable Energy Market Outlook model and M-SEM.

5.2.1.1 The EnCompass model

Developed by Anchor Power Solutions, EnCompass is a single, fully integrated power system platform that allows for utility-scale electric power generation planning and operations analysis. EnCompass is an optimization model that covers all facets of power system planning, including the following:

- Short-term scheduling, including detailed unit commitment and economic dispatch
- Mid-term energy budgeting analysis, including maintenance scheduling and risk analysis
- Long-term integrated resource planning, including capital project optimization and environmental compliance

- Market price forecasting for energy, ancillary services, capacity, and environmental programs

EnCompass provides unit-specific, detailed forecasts of the composition, operations, and costs of the regional generation fleet given the assumptions described in this document. Synapse has populated the model with a custom New England dataset developed by Anchor Power Solutions and based on the 2015 Regional System Plan, which has been validated against actual unit-specific 2015 dispatch data.[153] Synapse integrated the New England dataset with the EnCompass National Database, created by Horizons Energy. Horizons Energy benchmarked their comprehensive dataset across the 21 NERC Assessment Areas and it incorporates market rules and transmission constructs across 76 distinct zonal pricing points. Synapse uses EnCompass to optimize the generation mix in New England and to estimate the costs of a changing energy system over time, absent any incremental energy efficiency or DSM measures.

EnCompass, like other production-cost and capacity-expansion models, represents load and generation by mapping regional projections for system demand and specific generating units to aggregated geographical regions. These load and generation areas are then linked by transmission areas to create an aggregated balancing area. Neighboring regions that are modeled in this study are New York, Quebec, and the Maritime Provinces. These regions are not represented with unit-specific resolution. Instead, they are represented as a source or sink of import-export flows across existing interfaces in order to reduce modeling run time.[154]

5.2.1.2 The Renewable Energy Market Outlook model

In addition to EnCompass, this analysis uses Sustainable Energy Advantage's New England Renewable Energy Market Outlook (REMO), a set of models developed by Sustainable Energy Advantage that estimate forecasts of scenario-specific renewable energy build-outs, as well as renewable energy certificate (REC) and clean energy certificate (CEC) price forecasts. Within REMO, Sustainable Energy Advantage can define forecasts for both near-term and long-term project build out and REC pricing.

Near-term renewable builds are defined as projects under development that are in the advanced stages of permitting and have either identified long-term power purchasers or an alternative path to securing financing. These projects are subject to customized, probabilistic adjustments to account for deployment timing and likelihood of achieving commercial operation. The near-term REC price forecasts are a function of existing, RPS-certified renewable energy supplies, near-term renewable builds, regional RPS demand, alternative compliance payment (ACP) levels in each market, and other dynamic factors. Such factors include banking, borrowing, imports, and discretional curtailment of renewable energy.

153 ISO New England. "2015 Regional System Plan." Available at: https://www.iso-ne.com/system-planning/system-plans-studies/rsp.

154 In this analysis, the Maritimes zone includes Emera Maine and Eastern Maine Electric Cooperative (EMEC) which are not part of ISO New England and, therefore, are not included in any of the New England pricing zones used in this study. These regions are not modeled as part of the Maine pricing zone and were modeled as part of the New Brunswick transmission area.

The long-term REC price forecasts are based on a supply curve analysis taking into account technical potential, resource cost, and market value of production over the study period. These factors are used to identify the marginal, REC price-setting, resource for each year in which new renewable energy builds are called upon. The long-term REC price forecast is estimated to be the marginal cost of entry for each year, meaning the premium requirement for the most expensive renewable generation unit deployed for a given year.

5.2.1.3 M-SEM

Synapse has developed the Multi-Sector Emissions Model (M-SEM), a state-specific model used for tracking historical energy use and emissions and for projecting future energy use and emissions based on a set of policy changes. This dynamic spreadsheet model includes state-specific information on energy use and emissions in the electric, residential, commercial, industrial, and transportation sectors. It employs historical data from the Energy Information Administration's (EIA) State Energy Data System (AEO) and Annual Energy Outlook 2018, the most recent release of the EIA's annual AEO report.[155]

5.2.2 Input parameters

The following section details the input parameters and assumptions used in the Sustained Policies scenario.[156]

5.2.2.1 Electric power inputs

For the purposes of this study, we characterize electric sector demand as the variables that impact the consumption of electricity within Massachusetts. Because the Massachusetts electricity grid is a component part of the wider New England electricity grid, we must also create assumptions relating to electricity demand in the other five New England states.

5.2.2.1.1 Demand for electricity

Demand in the electric power sector is measured in terms of electricity consumption. Future changes in electricity consumption are driven largely by changes to population and GDP. Increasingly, total levels of electricity consumption are also driven by ratepayer-funded energy efficiency programs and new codes and standards for lighting and appliances. In the future, electricity consumption is likely to also be increasingly driven by the adoption of electric vehicles and heat pumps.

Our projection of "baseline" electricity consumption is based on the projection issued by ISO New England in its 2018 CELT Report, which provides projections of annual electricity sales for Massachusetts and the other five New England states from 2018 to 2027.[157] Note that ISO New England's econometric

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155 Energy Information Administration. 2018. Annual Energy Outlook 2018, released February 6, 2018.

156 The ways in which modifications were made to each parameter in each of the other scenarios is discussed in Chapter 5.

157 The 2018 CELT Report is available at https://www.iso-ne.com/system-planning/system-plans-studies/celt/.

projection does not explicitly account for future sales increases associated with vehicle or end-use heating electrification.[158] Next, we developed an annual projection of the impacts of energy efficiency. These impacts may include effects of non-programmatic codes and standards, as well as the impacts of programmatic energy efficiency (e.g., the MassSave program).[159] In the Sustained Policies scenario, we assume that energy efficiency is implemented in Massachusetts and other New England states according to the projection developed by ISO New England in CELT 2018.[160] In addition to creating a projection of demand at the annual level, it is also important to develop a projection of demand at the sub-annual level. For this analysis, we use hourly CELT 2017 loadshape data from ISO New England.[161] Figure 42 illustrates the annual "baseline" load projected for Massachusetts and New England, both with and without energy efficiency, while Figure 43 shows two illustrative hourly load curves for the winter and the summer.

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158 More generally, ISO New England develops a projection of future electricity consumption based on an extrapolation of historical trends. Because a large-scale electrification of vehicles and end-use heating has not taken place in past years, they do not factor into ISO New England's projections of the future.

159 Note that ISO New England's CELT forecast includes the savings impacts of codes and standards in its "gross" forecast. As a result, its projection of energy efficiency savings are solely from ratepayer-funded programs.

160 As of August 2018, the energy efficiency program administrators are currently in the middle of developing energy efficiency plans for the next three-year period of 2019-2021. The energy efficiency deployed as part of these programs may end up being higher or lower than what is modeled in this analysis. Also note that since ISO New England began releasing an energy efficiency projection in the 2010 CELT Report, observers have commented on the persistent under-projection of energy efficiency by ISO New England, relative to subsequent observed actual data. See http://www.synapse-energy.com/sites/default/files/Updated-Challenges-Electric-System-Planning-16-006.pdf for Synapse's most recent documentation of discrepancies between ISO New England's energy efficiency and distributed solar forecast and current data and trends for these resources

161 CELT 2017 assumes hourly loadshapes consistent with hourly consumption in 2002, which it regards as particularly representative year in terms of meteorological conditions. However, this dataset may not accurately reflect present-day consumption, given increases in air conditioner use and a large-scale regional rollout of efficiency measures. Alternatively, Synapse could model a more recent year (e.g., 2015), or an average of a set of recent years (e.g., 2015 to 2017). Projected hourly data from CELT 2017 can be found at https://www.iso-ne.com/system-planning/system-forecasting/load-forecast/; historical hourly energy, load, and demand reports are available from ISO New England at https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/zone-info. Note that when running EnCompass at less granular temporal resolutions than hourly (as was done in the current Sustained Policies case), the model automatically develops monthly on-peak and off-peak values based on this hourly data.

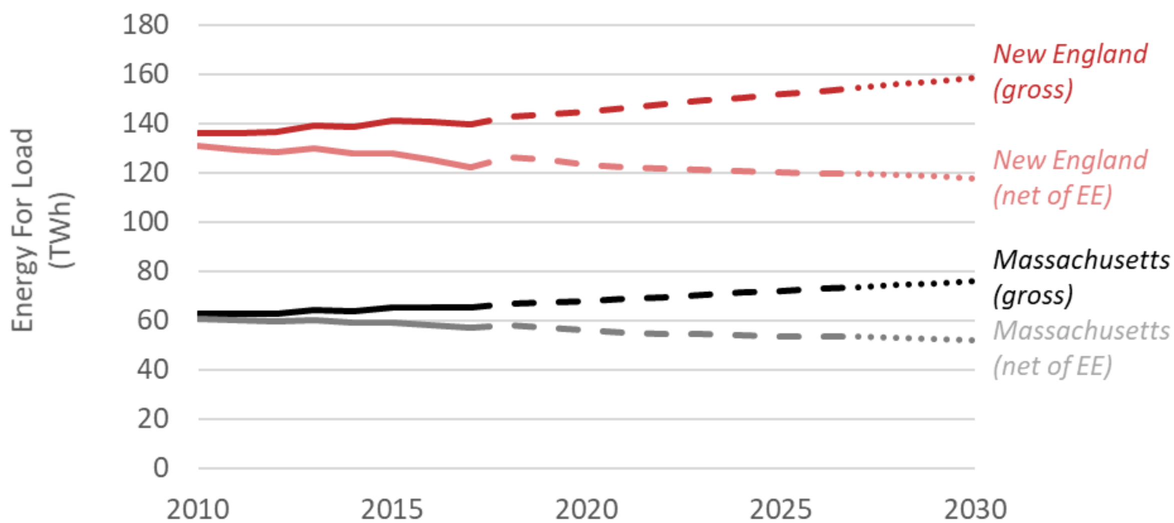

Figure 42. Historical and projected values for gross load and load net of energy efficiency in Massachusetts and New England

Note: Solid lines indicate non-weather-normalized historical values. Dashed lines indicate projected values by ISO New England. Dotted lines indicate projected values by Synapse, calculated using the cumulative average growth rate from 2018 to 2027.

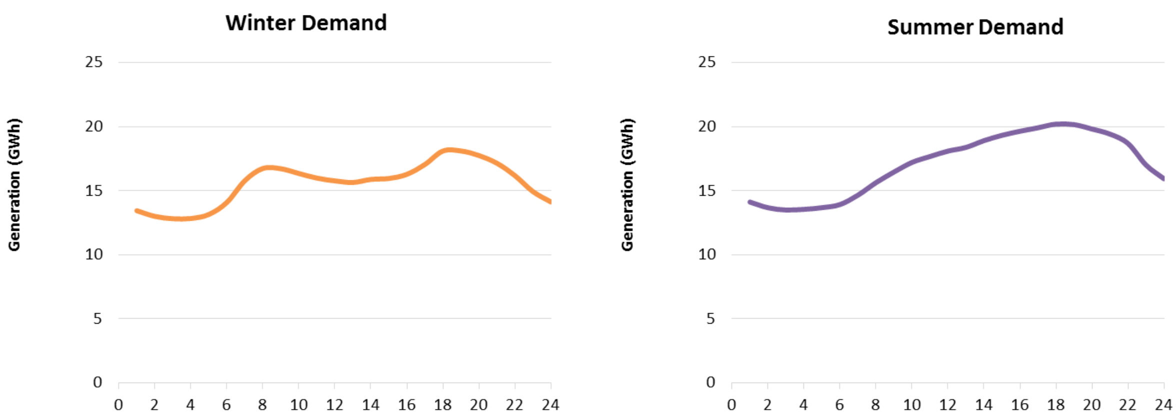

Figure 43. Illustrative winter and summer load shapes.

In addition, we developed a projection for the level of transportation supply that is expected to be increasingly powered by electric vehicles. In the Sustained Policies scenario, we assume that an increasing number of light-duty vehicles (LDVs) are battery-powered electric vehicles (BEVs or simply EVs). We assume that all New England states that have adopted California zero-emission vehicle requirements will meet the requirements of these zero-emissions vehicle (ZEV) rules, resulting in

366,000 electric vehicles region wide and 160,000 electric vehicles in MA specifically by 2025.[162] In 2025, this will represent about 16 percent of all light-duty vehicle (LDV) sales and 3.6 percent of all LDV stock. This level represents an estimate of the low end of electrification resulting from the ZEV rule, such as a case in which automakers shift compliance credits from California into other states rather than using actual vehicle sales here. We also assume that the states that have not adopted these rules will follow a similar trajectory.

To model the 2018 through 2030 period, we apply a market adoption Bass Diffusion Model (i.e., a logistic S-curve) to two known data points for EV market adoption: 2016 (0.2 percent) and 2025 (3.6 percent). This adoption curve implies that by 2030, there will be about 1.2 million EVs on the road, as shown in Figure 44. Figure 45 compares the "baseline" level of electricity demand (i.e., with energy efficiency) with the level of electricity demand modeled in the Sustained Policies scenario. In this scenario, electric load in 2030 returns to a level close to today's.

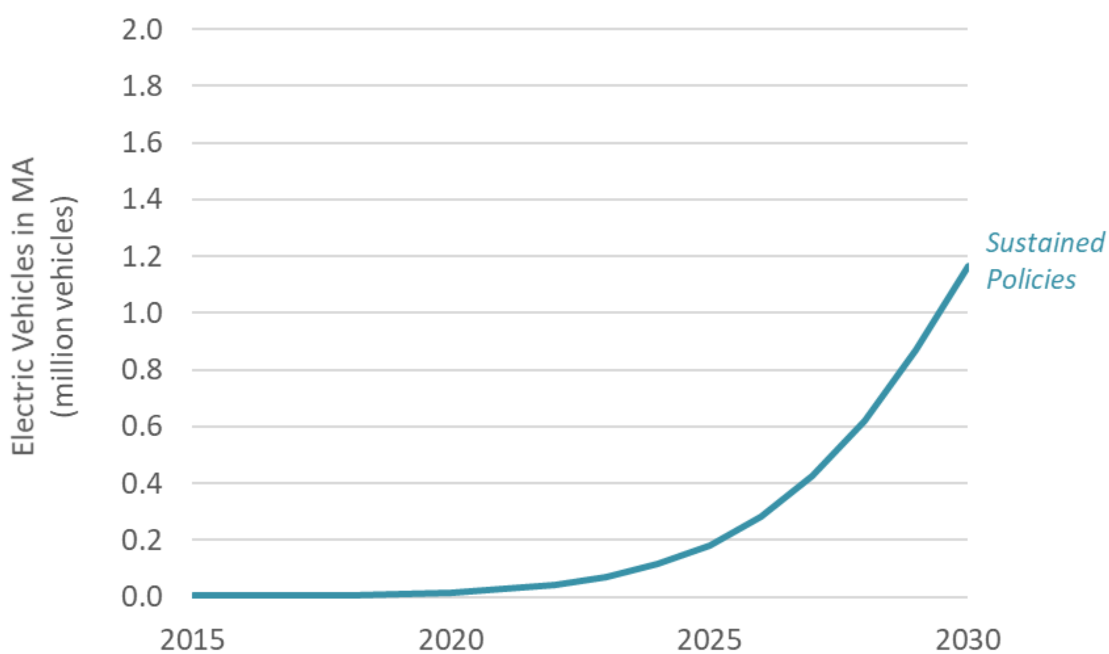

Figure 44. Projected electric vehicle market adoption in Massachusetts

[162] For Massachusetts, electric vehicle deployment associated with MA 310 CMR 60.05 is assumed to be a constituent part of this trajectory. Although New Hampshire does not follow the CARB regulations, we assume that its market for motor vehicles does not substantially differ from that of its neighbors, and that it follows the same trajectory.

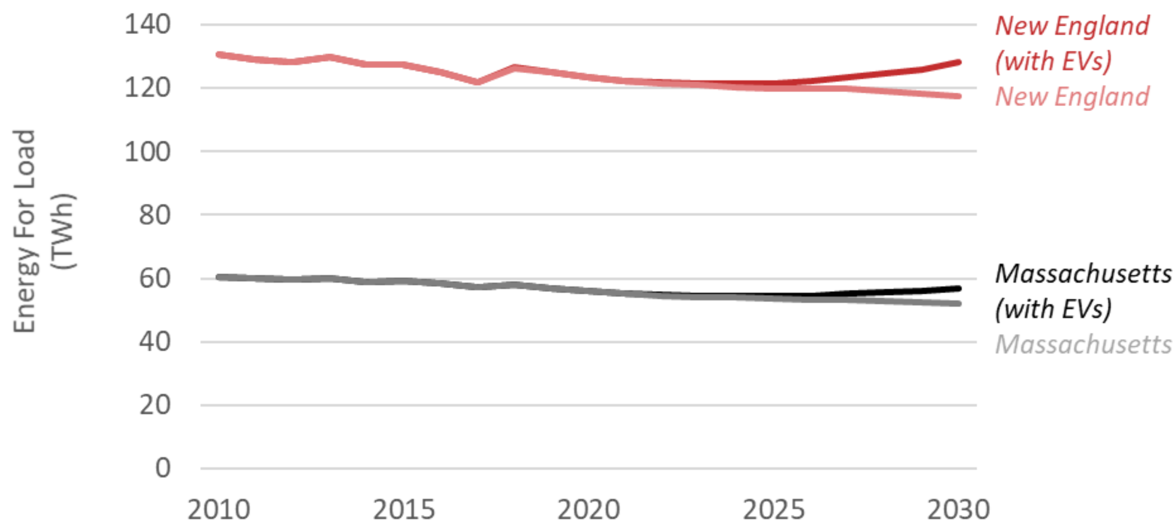

Figure 45. Electric load in the Sustained Policies scenario compared with the Baseline

In the Sustained Polices scenario, we assume that policies are implemented such that the charging of electric vehicles is focused in two main periods: while Massachusetts residents are at work and school, and again at night. Figure 46 displays the assumed load shape for electric vehicle charging.

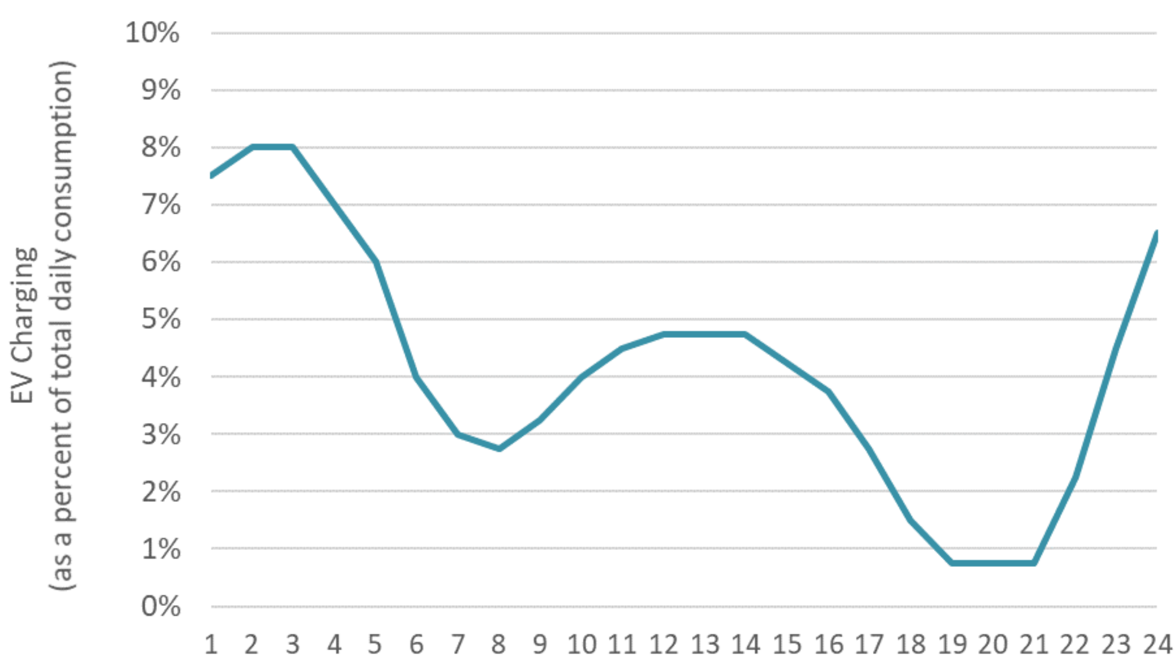

Figure 46. Assumed load shape for electric vehicle charging

In the Sustained Policies scenario, we project continued adoption of heat pumps at the rate the system has been adopted recently in the state (that is, several thousand units per year). In these scenarios, we assume that heat pump load shapes follow the same hourly heating trend observed in a typical year for consumers currently using natural gas heating.

5.2.2.1.2 New and retiring conventional power plants

Massachusetts is currently home to 350 power plants, or about 13,300 megawatts (MW) of electric generating capacity.[163] In all of New England, there are about 740 power plants, totaling about 35,700 MW of capacity. In the Sustained Policies scenario, we assume that the existing set of conventional power plants does not substantially change in the coming years. We do model the future retirement of Pilgrim Station in May of 2019 and Bridgeport Station 3 in June 2021, in line with announcements by the power plant owners, but otherwise do not assume any other retirements.[164] For new conventional power plants, we assume that a number of new power plants come online in the next several years, including Bridgeport Harbor 6 in June 2019 and Burrillville Energy Center 3 in June 2019.

While we constrain our model to not endogenously retire power plants, the model is free to build additional conventional capacity as needed for reliability and as is cost-effective. However, in all our scenarios, we find that the model does not construct additional conventional capacity.

Policies affecting electricity supply

Our analysis also accounts for the impact of regulation and legislation on the electricity sector. This includes regulations for Massachusetts' utilities to procure renewable energy through the renewable portfolio standard, SMART program, 83C procurements for 1600 MW of offshore wind, and 83D procurements for 9.45 TWh of Clean Energy Imports.[165] Importantly, since Massachusetts purchases its electricity from the regional electric grid, this assumption also applies to the renewable energy requirements in other states, including other states' renewable portfolio standards and long-term contracting requirements.

Our modeling also accounts for a number of other regulations impacting the electric sector. We include the Regional Greenhouse Gas Initiative (RGGI), which requires nine states in the Northeast to reduce

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163 See the U.S. Energy Information Administration (EIA)'s 860 database at https://www.eia.gov/electricity/data/eia860m/ for more information. Note that each individual power plant may be made up of more than one generating "unit". At any given power plant, these units may or may not be the same fuel type.

164 This includes the assumption that the Mystic combined cycle plant and all of New England's remaining nuclear power plants continue to exist and produce electricity throughout the study period.

165 The Sustained Policies scenario assumes a Massachusetts Class I RPS increase of 1 percent per year through 2030. Note that energy legislation enacted in August 2018 directs utilities to increase their procurement of renewable energy to 2 percent per year from 2020 through 2029.

CO_2 emissions from the electric sector through 2030.[166] We also include two regulations promulgated by Massachusetts Department of Environmental Protection (MassDEP)—310 CMR 7.74, which establishes a cap on CO_2 emissions specific to a subset of emitting generators in Massachusetts, and 310 CMR 7.75, which establishes a Clean Energy Standard (CES) for Massachusetts utilities.

Electricity imports

In addition to the incremental electricity imports procured under 83D, we model transmission between sub-regions of New England and adjacent balancing authorities in New York, Québec, and New Brunswick. In our modeling construct, transmission lines between these regions are grouped into aggregate links with aggregate transfer capacities. Over the past five years, net imports from neighboring electricity regions have constituted 16 percent of total electricity consumed in New England, with about two-thirds of these imports coming from Québec.

Fuel price projections

In our analysis, we model two main price projections for fuel consumed by power plants: one for natural gas, and one for fuel oil. Our development of fuel price projections follows the methodology used by Synapse in its 2018 report on Avoided Energy Supply Costs (AESC) for New England, as well as earlier studies.[167] Under this methodology, we use a combination of near-term price projections from NYMEX and long-term price projections from the Energy Information Administration's 2018 Annual Energy Outlook (AEO) to create continuous price projections for natural gas and fuel oils over the study period.

5.2.2.2 Transportation inputs

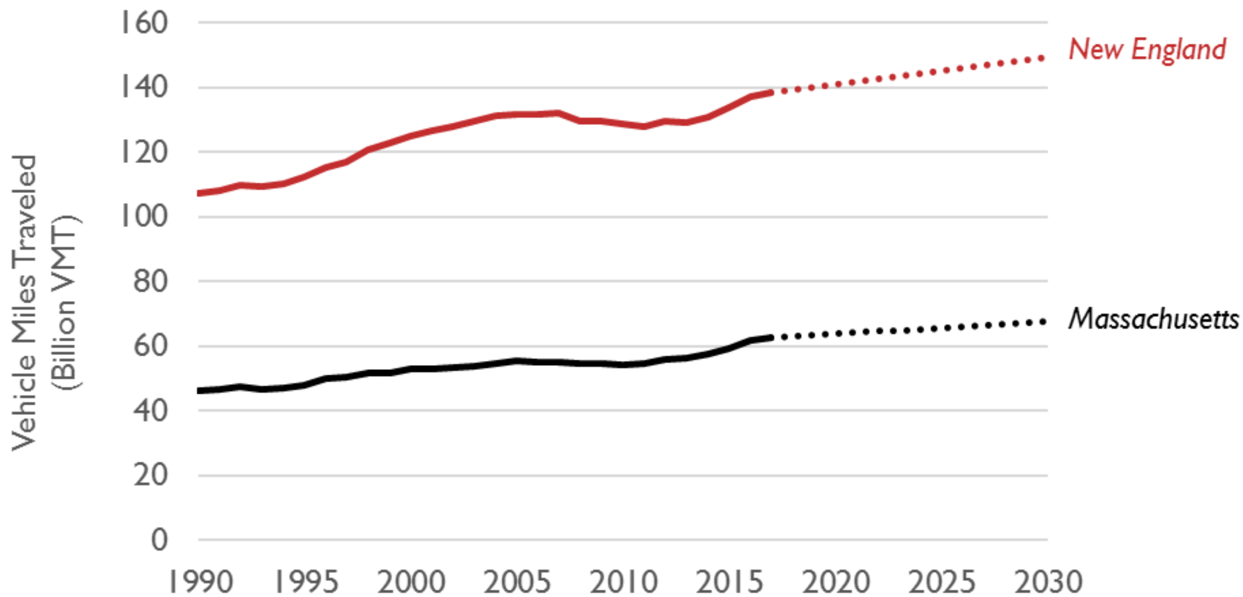
In addition to the electric vehicle projections described above, we also developed future projections for energy demand and supply for non-EV transportation, including energy projections related to the automotive, rail, water transit, and aviation sectors. In the Sustained Policies scenario, we primarily model Massachusetts' demand for energy in the transportation sector using data from U.S. Energy Information Administration (EIA)'s 2018 Annual Energy Outlook (AEO). Released each year, the AEO provides a national-level projection of energy use from the electric power, transportation, residential, commercial, and industrial sectors. As the AEO reports projected data on a national basis, we use historic data from EIA's State Energy Data System, the Federal Highway Administration (FHA)'s annual Highway Statistics report, and the FHA's monthly Travel Monitoring report for information on transportation sector energy use and vehicle miles traveled (VMT).[168] Under this framework, we have

166 Because the scope of RGGI expands beyond New England, our analysis models compliance RGGI as a dollar-per-ton-of-CO_2 price based on the latest modeling from RGGI, Inc. See http://rggi.org/design/2016-program-review/rggi-meetings for more information.

167 See http://www.synapse-energy.com/project/avoided-energy-supply-costs-new-england for more information.

168 See https://www.eia.gov/state/seds/seds-data-fuel.php?sid=US#DataFiles, https://www.fhwa.dot.gov/policyinformation/statistics/2016/execsumm.cfm, and https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm for more information.

developed projections of VMT for the Sustained Policies scenario (see Figure 47). For all scenarios, VMT was held constant. Although reducing VMT reduces demand in the transportation sector and has associated emission reductions, this report is focusing on issues of meeting demand and instead chose to focus on the impact of electrification on the electric sector. This report is not intended to determine a pathway to emission reductions and will defer to other planning efforts such as the Future of Transportation Commission and the CECP .



Source: Solid lines are data from the Federal Highway Administration's "Highway Statistics" series. Dotted lines are projections of VMT based on EIA's 2018 Annual Energy Outlook. Projections are based on the national 2018 to 2050 cumulative average growth rate (CAGR).

Figure 47. Vehicle miles traveled in Massachusetts and New England from all motor vehicles

A key input for modeling the energy demand for conventional automobiles is vehicle efficiency. For conventional vehicles: this is typically measured in miles per gallon. In the Sustained Policies scenario, we use average fuel economy levels for new conventional vehicles based on current federal Corporate Average Fuel Economy (CAFE) requirements that set fuel economy standards through 2025. Beyond 2025, we assume that average fuel economy levels remain consistent with AEO 2018.

5.2.2.3 Thermal inputs

Energy use in residential, commercial, and industrial sectors largely relates to consumption of end-use fuels (e.g., natural gas, fuel oil, propane, wood). The primary end-uses in these three sectors are heating and water heating (together, "thermal conditioning"). Other end-uses include cooking, clothes drying, and miscellaneous industrial uses.

We rely on AEO 2018 for projections of future energy demand by sector and fuel type (e.g., fuel oil, propane, natural gas, wood). As AEO presents data at the regional level, we develop state-level estimates of sectoral energy demand by applying the regional growth rates for New England from AEO to historical data from EIA's State Energy Data System. In addition, we also rely on data from AEO, EIA's Residential Energy Consumption Survey (RECs), EIA's Commercial Buildings Energy Consumption Survey (CBECS), and EIA's Manufacturing Energy Consumption Survey (MECS) for data on end-use energy consumption.[169]

Since the early 1990s, residential space and water heating energy consumption has decreased by about one-quarter. Under a Sustained Policies future, energy efficiency measures and fuel switching are expected to continue to reduce residential demand for thermal energy (see Figure 48). Conversely, in the commercial sector, demand for thermal energy has increased by about 40 percent since the mid-2000s, in large part due to increased construction of commercial buildings. Under a Sustained Policies scenario, energy efficiency measures and fuel switching are expected to partially offset continued increases in demand associated with new building construction.

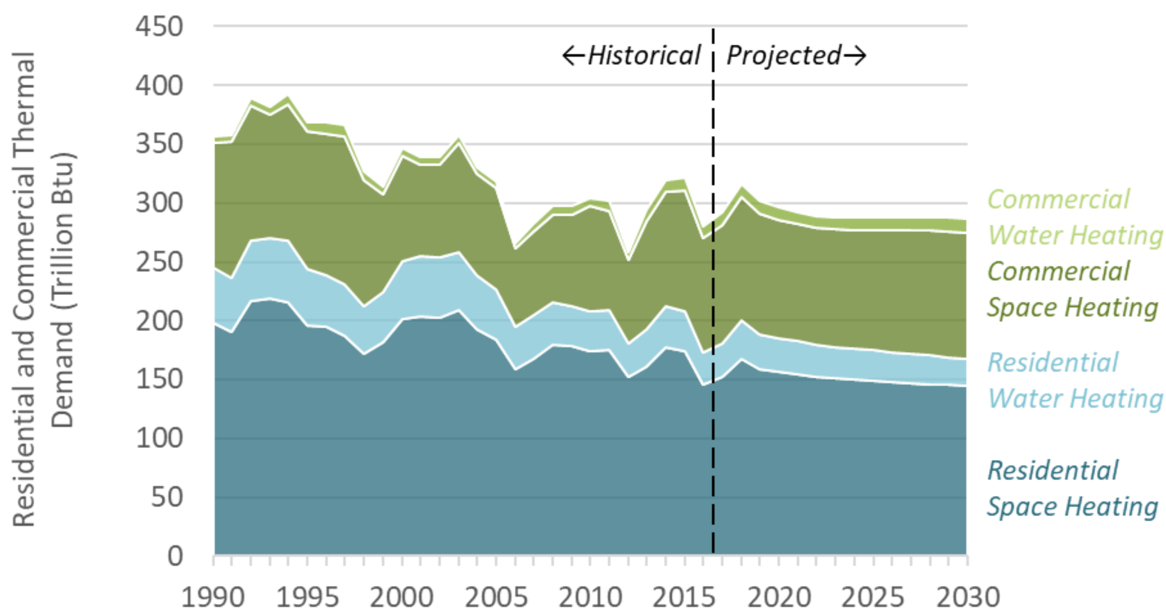


Figure 48. Thermal heating fuel demand in the residential and commercial sectors

5.3 Defining the metrics

Our objective is to examine the supply and demand of different future scenarios that are clean, affordable, reliable, and resilient. In order to do this, we have developed different metrics to measure the degree to which each scenario meets these goals.

169 See https://www.eia.gov/consumption/residential/, https://www.eia.gov/consumption/commercial/, and https://www.eia.gov/consumption/manufacturing/ for more information.

5.3.1 Clean

We evaluate whether a scenario is "clean" by measuring the level of greenhouse gases (GHG) emitted by Massachusetts' energy consumption in 2030. These emissions are measured using an approximation of the GHG inventory method described by MassDEP.[170] Under this approximation, we add the GHG emissions associated with transportation and thermal energy use to the GHG emissions associated with electric power energy use. Emissions from the transportation and thermal sectors are based on the level of energy consumed within Massachusetts in 2030.[171] Meanwhile, calculating emissions from the electric power sector is more complex: First the total demand is adjusted by the amount of clean energy that is used to meet Massachusetts' clean energy programs, the RPS and CES, reducing the total state electric demand. Second, the Inventory totals all emissions associated with facilities located within Massachusetts. Massachusetts has historical and will likely to continue to generate less electricity than its total demand. The additional electricity the state had to "import" to meet demand is equal to the total adjusted load minus the in-state electrical generation. Any emissions associated with the imported intra- and inter-New England imports needed to meet the adjusted demand are also allocated to Massachusetts. Totaled, the level of emissions is then compared to the level of GHG emissions in 1990, the level of GHG emissions in 2015, and the reduction in emissions relative to the Sustained Policies scenario (for scenarios other than the Sustained Policies scenario).

In order to measure the emissions impact of an extended cold period, the results from the winter peak day analysis are compared to an average winter day. This includes both additional emissions from the electric sector, accounting for both increased demand and an increased use of higher emission oil, and additional emissions from the thermal sector. The same length of extended cold was applied to each scenario in order to measure the relative impact of a similar winter event in each energy future. A future extended cold period may be more or less severe or longer or shorter in durations, than the 20 days assumed winter event in this analysis.

5.3.2 Affordable

In order to evaluate the affordability of a given scenario, we look at a number of metrics. These include analyzing the projected wholesale energy prices and renewable energy credit prices, assessing the impact of prices on high-demand winter days, and evaluating how these prices impact the typical residential customer in Massachusetts.

The electric rate analysis includes estimates and impacts for only residential customers within the EDC's basic service R-1 rate class tariff. In order to build out future estimates of the rates, the first step in the analysis was historical lookback of all the distribution and transmission charges across Eversource,

170 See https://www.mass.gov/lists/massdep-emissions-inventories.

171 Note that we also account for GHG emissions not associated with energy consumption, although these sectors were not a focus of the Comprehensive Energy Plan.

National Grid and Unitil service territories going back to January of 2008.[172] Additionally, the study looked back at the basic service filings (fixed price option only) for the supply portion of the residential bills, across the same three service territories.[173] All the historical analysis was weight averaged based on the total load share across the utilities to arrive at a generic historical total rate. Furthermore, the analysis looked at the past ISO-NE Real Time Load Cost Reports to determine what the wholesale costs were across Northeastern MA/Boston (NEMA), Southeastern MA (SEMA), and Western/Central MA (WCMA) zone and how they have historically changed.[174]

The future estimates of the rates were done on an annual average basis from 2018 to 2030. The analysis does not reflect service territory specific impacts, but rather a generic residential customer in Massachusetts.[175] For the supply portion of the estimates, energy modeling results were used to estimate locational marginal price (LMP), capacity, RPS and CES charges. The distribution rates are held flat compared to the most recent 2017 and 2018 average rates. The transmission rates future estimates included the rates effective as of June 2018 and the recent five-year forecast of the Regional Network Service (RNS) rates, which are then extended through the year 2030.[176] Peak load estimates used for the calculation of the RNS rates were derived from the energy load forecasts. Other distribution charges such as Energy Efficiency, SMART, and net metering were derived using DOER's policy estimates of the future costs of programs.[177] Any adjustments made for scenario specific rate analysis are a reflection of assumptions, such as additional efficiency efforts, clean peak demand reductions, and an increase in RPS obligations.

Finally, we evaluate the average energy burden for residential customers, which includes the impact of not only electricity costs, but also includes the amount of money typical residential consumers spend on thermal demand and gasoline. These values are calculated for each scenario then compared on a relative basis to the Sustained Policies scenario.[178]

In order to estimate the costs of an extended winter event, the winter peak analysis was compared to an average winter day to determine the additional wholesale cost. This additional cost would be the cost

172 The historical look back includes all the utilities across the three major service territories that were merged in the past 10 years: Fitchburg Gas and Electric Light Company, Massachusetts Electric Company, Nantucket Electric Company, NSTAR Electric Company, Western Massachusetts Electric Company, Cambridge Electric Company, Boston Edison Company.

173 Customers who participate in the competitive electric supply market and are in the municipally owned electric service territory (MLP) are not directly reflected in this analysis.

174 https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/mthly-whl-load-cost-rpt

175 Please note that this analysis assumes only the most recent utility rate cases, and does not reflect any rate cases that will occur within the future analysis period.

176 "RNS Rates: PTF Forecast ".The five year forecast was presented at the ISO-NE's Reliability and Transmission Committee Summer Meeting on July 18-19, 2017. The forecasted rates assumed a 55% load factor.

177 The Massachusetts Department of Public Utilities did not review or approve this rate analysis.

178 Note that this analysis does not examine a number of other metrics, including commercial or industrial electricity rates, economy-wide costs, new building costs, incremental costs to purchase EVs or savings from lower EV maintenance, public health benefits, or the social cost of carbon.

suppliers lose if their rates did not include adequate risk premium to account for winter weather. The total cost of an extended cold period also includes additional reliability wholesale costs. An inflated wholesale risk premium was applied to the additional cost to reflect suppliers needing to recoup lost costs in subsequent years. The same risk premium and length of extended cold was applied to each scenario in order to measure the relative impact of a similar winter event in each energy future. A future extended cold period may be more or less severe than the assumed winter event in this analysis.

In addition to running the winter peak day analysis assuming constrained gas prices resulting from anticipated future natural gas pipeline capacity, the winter peak day analysis was also run assuming a lower gas price caused by additional natural gas supply.

5.3.3 Reliable and resilient

Finally, we evaluate the reliability and resiliency of each scenario. This metric is measured in several different ways. First, the EnCompass model used to evaluate the electricity sector will not solve until it has found a solution under which electricity is provided reliably for every hour of the day. Second, the peak winter day analysis estimated the total demand for natural gas from both the thermal and electric sectors. For this study, the reliability metric presented is the percent of total daily demand that peak natural gas demand exceeds anticipated natural gas pipeline capacity. If a peak winter day exceeds pipeline capacity, the electric sector will rely on stored fuels such as LNG or oil for generation. These stored fuels are limited in supply and may not be able to be restocked if extended cold periods last a significant amount of time. Therefore, a higher percent of total daily demand over pipeline capacity for any scenario shows a greater reliance on stored fuels and a greater risk the region will use regional supplies more quickly during a winter event.

6 Presentation of Results

6.1 Sustained Policies

6.1.1 Scenario Description

This scenario shows the impact of our current energy policies without significant changes.[179] This scenario includes:

- Increasing the Commonwealth's **Clean Energy Supply** by implementing the 2016 energy legislation. This legislation requires 1,600 MW of offshore wind and a large transmission line of hydroelectric power to come online in 2023. Additional renewable supply will be implemented through the SMART program which is expected to double the amount of solar in Massachusetts by 2022. In this future, Massachusetts achieves its obligations under the RPS and CES, which require 25 percent of our retail energy to be renewable and 40 percent of our retail energy to be clean by 2030.

- Increasing the amount of **battery storage** by achieving the Commonwealth's 200 MWh storage target in 2020 and reaching approximately 500 MWh of storage by 2030.

- Leading the way on **energy efficiency** programs that continue to achieve similar levels of energy savings as today.

- Increasing the level of **electrification** by accelerating the adoption of new thermal technologies, such as air source heat pumps, to approximately 2 percent of single family homes by 2030. This scenario also assumes the increasing adoption of EVs, achieving 160,000 EVs by 2025 and 1.2 million by 2030.

[179] The Sustained Policy scenario excludes initiatives in *An Act to Advance Clean Energy* that was passed by the Legislature on July 31, 2018 and signed by Governor Baker into law on August 9, 2018.

SECTOR	POLICIES	*Continuation of existing policies*
Power	SMART	1600 MW (AC) of distributed solar by December 31, 2022
	Storage	All ACES Grants and current EDC approved storage projects move forward SMART: 80 MW/200 daily MWh when solar hits 1,600 MW (2020) Total by 2030: 164 MW/496 daily MWh
	RPS and CES	1 percent annual increase for RPS (10,800 GWh of Class I RECs in 2030) Current 2 percent annual increase for CES
	Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Procurements	83D: 9.45 TWh of Clean Energy Imports online by 2023 83C: 400 MW offshore wind online in 2022; 400 MW by 2023; 2,200 MW by 2030 Other: 600 MW offshore wind online by 2024 (RI and CT)
Thermal	Heating System Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Building Shell Efficiency	Continue utility EE programs with levels of performance similar to today New buildings (building codes) progress in line with AEO projections
	Electrification (Heat Pumps)	Current programs continue; continue to achieve a few thousand heat pumps per year
	Industrial Efficiency	Continue utility EE programs with levels of performance similar to today Energy use rises 15 percent by 2030
	Gas switching from oil/propane	Continue at AEO 2018 levels (160,000 by 2030)
	Biofuels and the APS	APS remains at current levels, biofuel target reached
Transportation	Electric Vehicles	160,000 light-duty EVs by 2025 Growth until 1.2 million in fleet by 2030 No heavy-duty electrification
	Biofuels	Continue at AEO 2018 levels
	VMT	68 billion miles driven in 2030, up from 63 billion in 2017

6.1.2 Scenario Takeaways

Increasing the amount of energy efficiency, clean energy supply, and electrified end uses produces a future in which 2030 GHG emissions from all sectors are reduced by 35 percent relative to 1990. Meanwhile, 2030 energy expenditures in Massachusetts from all sectors are reduced by 21 percent relative to 2018. In this scenario, Massachusetts and the rest of New England will continue to rely on higher cost stored fuels (such as LNG and fuel oil). As a result, the region will continue to be at risk for price spikes and emission increases during a severe winter extended cold event. However, state policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, may reduce but will not eliminate risks to reliability.

6.1.3 Supply Mix

6.1.3.1 Thermal

Improved efficiency reduces residential energy demand by 15 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year. Multifamily buildings are projected to be about 6 percent more efficient than they are today.

Despite improved energy efficiency, continued new construction is expected to increase total commercial thermal demand by 6 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year.

Industrial energy demand is projected to continue to gradually increase. Increased manufacturing is expected to more than offset improved energy efficiency, increasing energy demand by 14 percent by 2030.

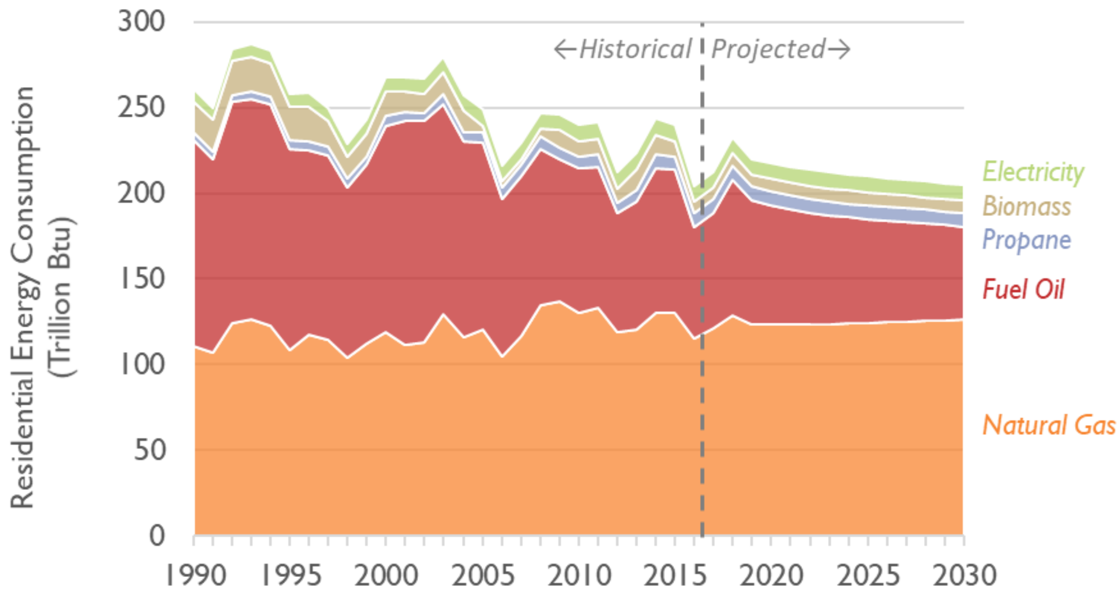


Figure 49. Thermal energy consumption, residential sector

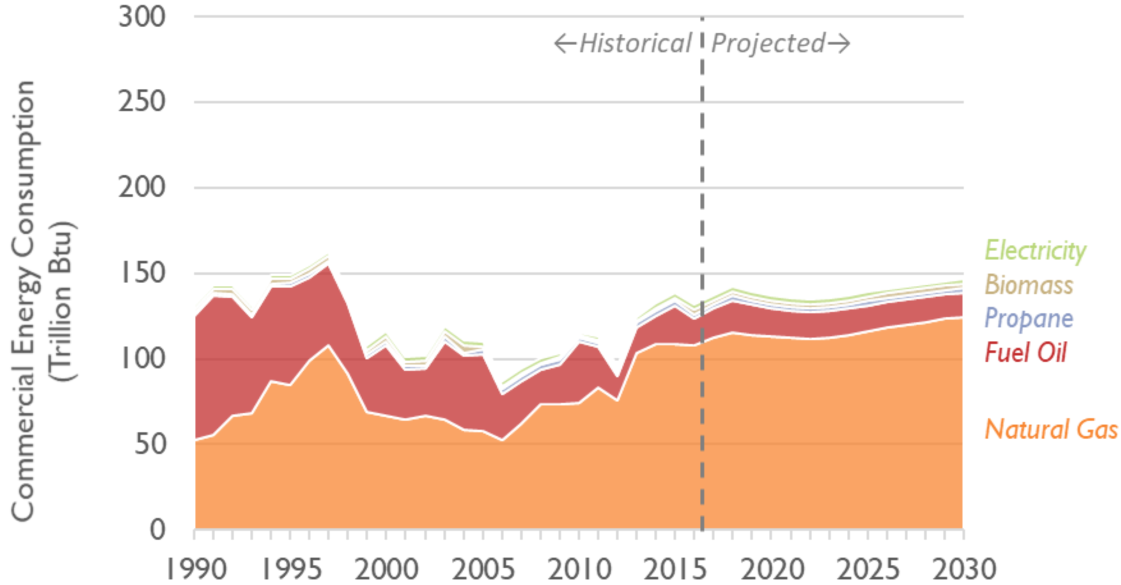


Figure 50. Thermal energy consumption, commercial sector

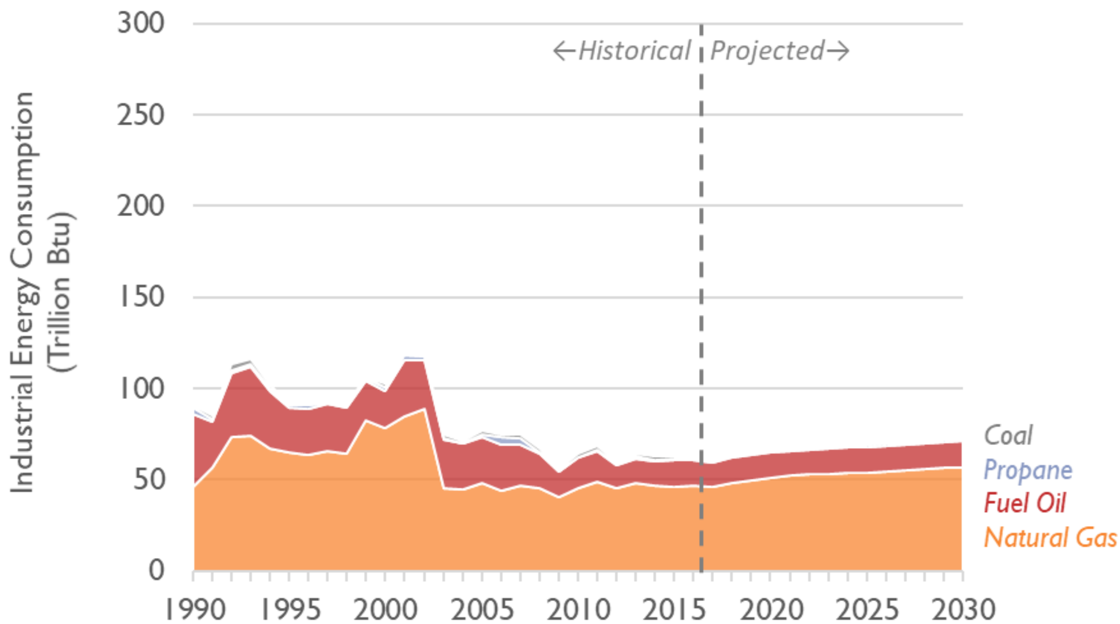


Figure 51. Thermal energy consumption, industrial sector

6.1.3.2 Transportation

While VMT is projected to continue to rise, improved efficiency is expected to reduce fuel consumption. By 2030, CAFE standards are projected to reduce gasoline consumption by 20 percent. Under a Sustained Policies future, 1.2 million EVs on the road in 2030 reduces gasoline consumption by another 13 percent. By 2030, 2 out of 3 vehicles purchased are EVs.

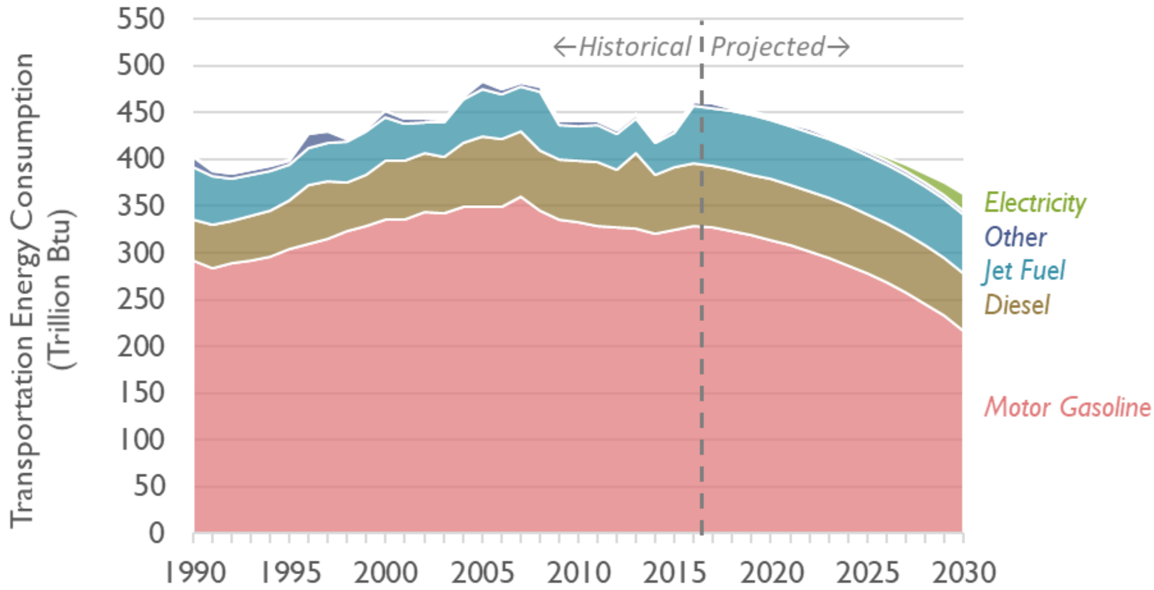


Figure 52. Transportation energy consumption

6.1.3.3 Power

By 2030, New England's fuel mix is 27 percent fossil fuel, a 13 percentage point reduction relative to 2018. By 2030, the fuel mix of wind, solar, hydro, and other renewables is 35 percent, a 19 percentage point increase relative to 2018.

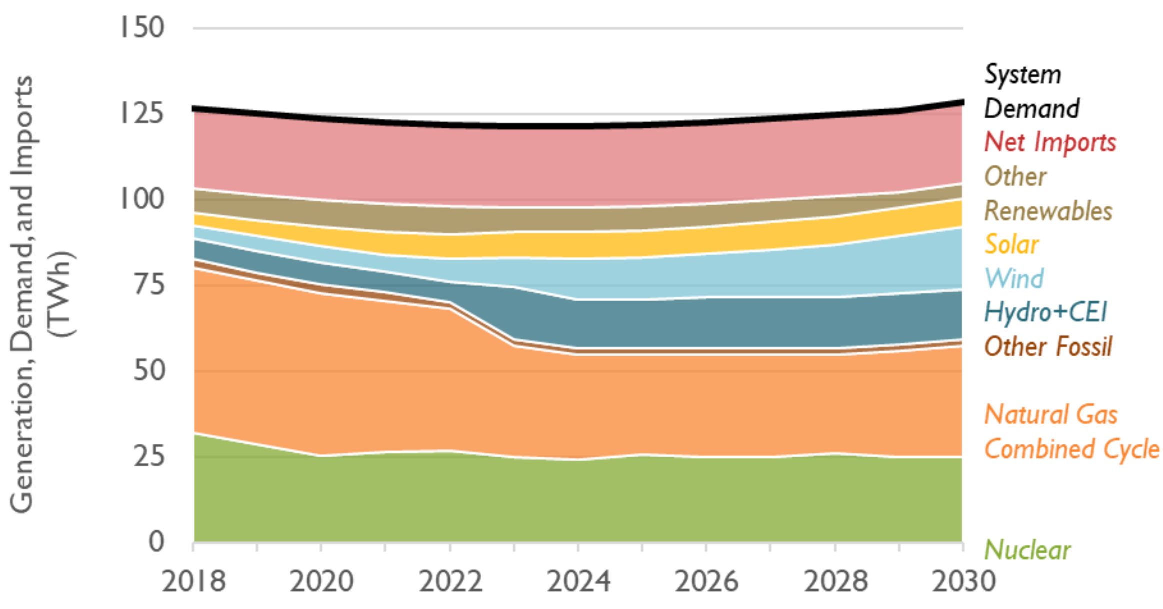


Figure 53. System demand and electricity generation, New England

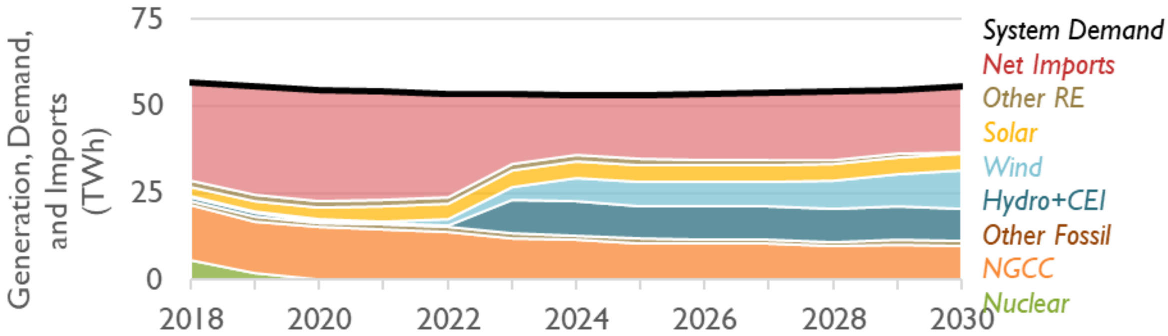


Figure 54. System demand and electricity generation, Massachusetts

6.1.4 Winter Reliability

On a peak winter day in 2022, New England's power sector is still reliant on a substantial amount of fuel oil in order to reliably supply electricity. By 2025, as the quantity of renewables increases (largely driven by polices incentivizing Clean Energy Imports and offshore wind), the quantity of fuel oil required to supply electricity decreases. In a separate future where additional natural gas pipeline is available, the quantity of fuel oil required on a peak winter day in both 2022 and 2025 is reduced even further. On a peak day in 2015, the Commonwealth's natural gas use was 44 percent above the available natural gas delivery capacity, making the region dependent on stored fuels such as LNG and fuel oil. In 2022 on a peak day, this percentage is projected to be reduced, with a peak daily natural gas demand being 6 percent available natural gas delivery capacity. In 2025, this percentage slightly increases to 9 percent.

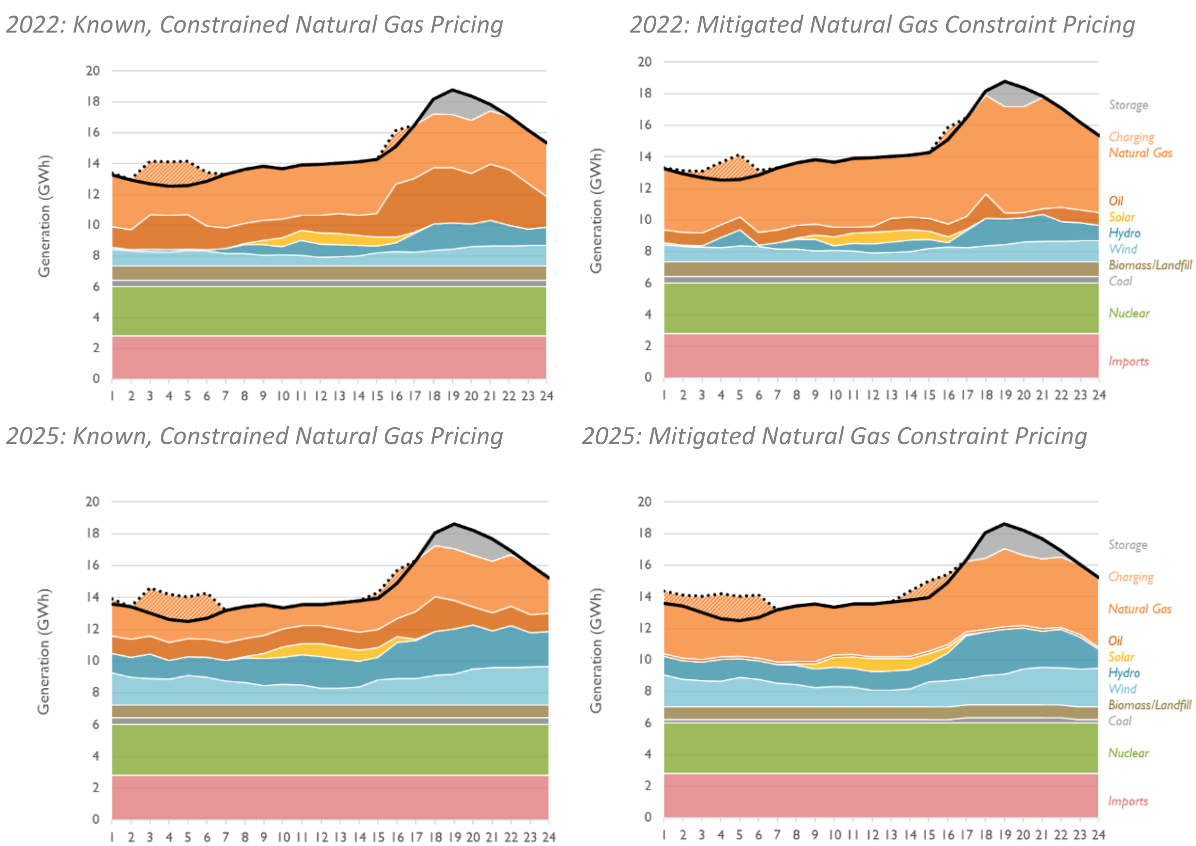


Figure 55. Peak winter day electricity demand and generation, New England

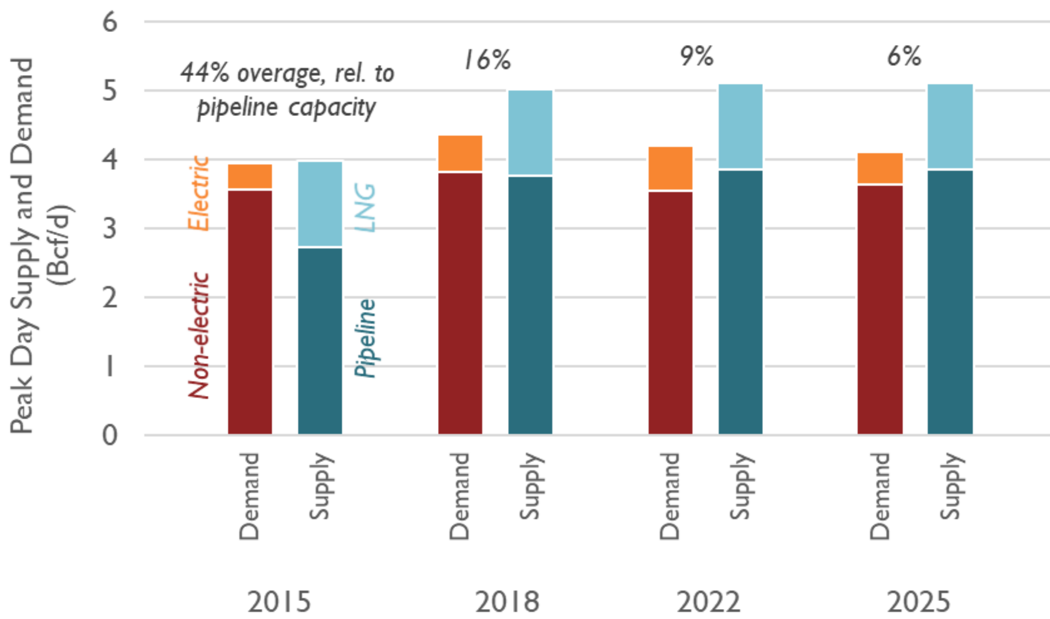


Figure 56. Peak winter day natural gas demand and supply, New England

6.1.5 Costs

In real-dollar terms, residential electricity rates are expected to remain relatively flat through 2030. However, the rate components making up the typical residential electricity rate do change over time as prices for renewable energy credits change and as costs to purchase from the wholesale energy market are replaced with renewable energy procurements.

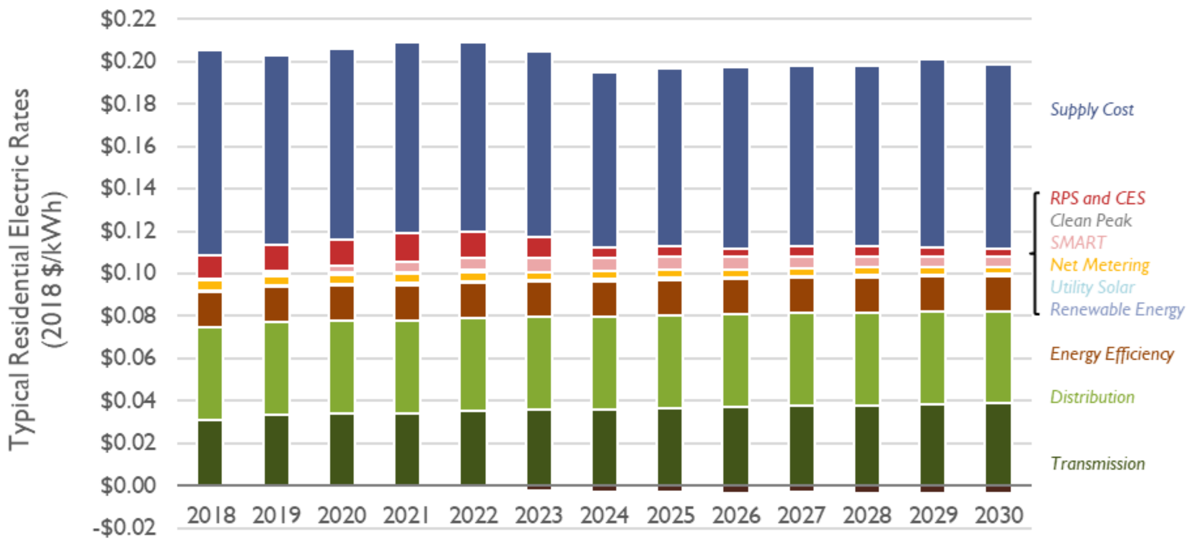


Figure 57. Typical residential electricity rate

By 2030, nearly 60 percent of residential customers are expected to use natural gas as the primary fuel for thermal demand. These customers are expected to pay the least in their total energy burden at $292 per month. The state as a whole is expected to spend $1.07 billion to meet residential energy demand, with a plurality of spending on gasoline, at $0.35 billion alone.

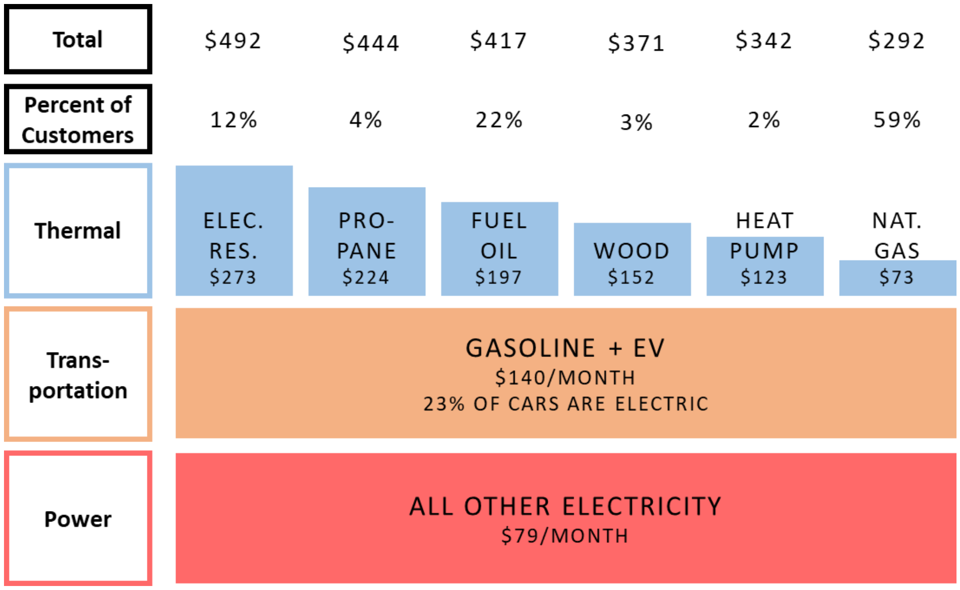


Figure 58. Average monthly energy burden for Massachusetts residents in 2030 (2018 $)

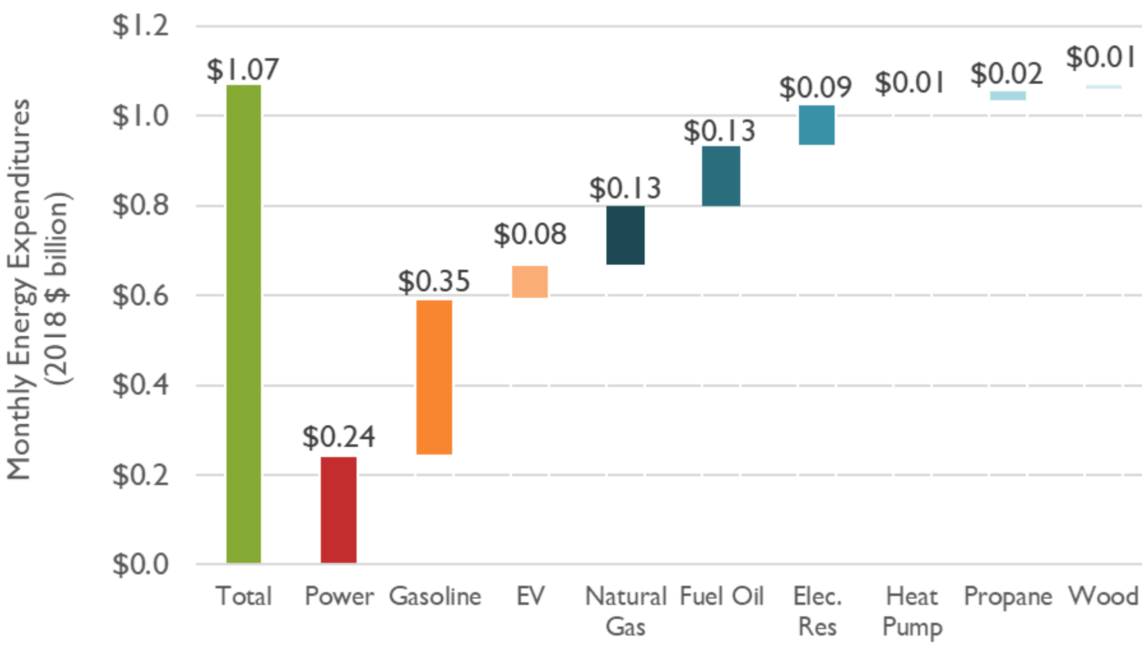


Figure 59. Total state expenditures on residential energy demand, 2030

Winter electricity rates are expected to decrease between 2022 and 2025. In futures in which a severe winter with extended cold occurs in either 2022 or 2025, winter electricity rates are likely to be higher.

	Average Winter	Severe Winter with Extended Cold: Constrained Natural Gas Pricing	Severe Winter with Extended Cold: Mitigated Natural Gas Constraint Pricing
2022	$0.217	$0.237	$0.232
2025	$0.213	$0.234	$0.216

Table 11. Annual residential electricity rates in Massachusetts (2018 $/kWh)

6.1.6 Emissions

By 2030, the Sustained Policies scenario achieves a reduction in all-sector GHG emissions of 35 percent relative to 1990 emissions. This represents a reduction in GHG emissions of 20 percent relative to estimated levels today.[180]

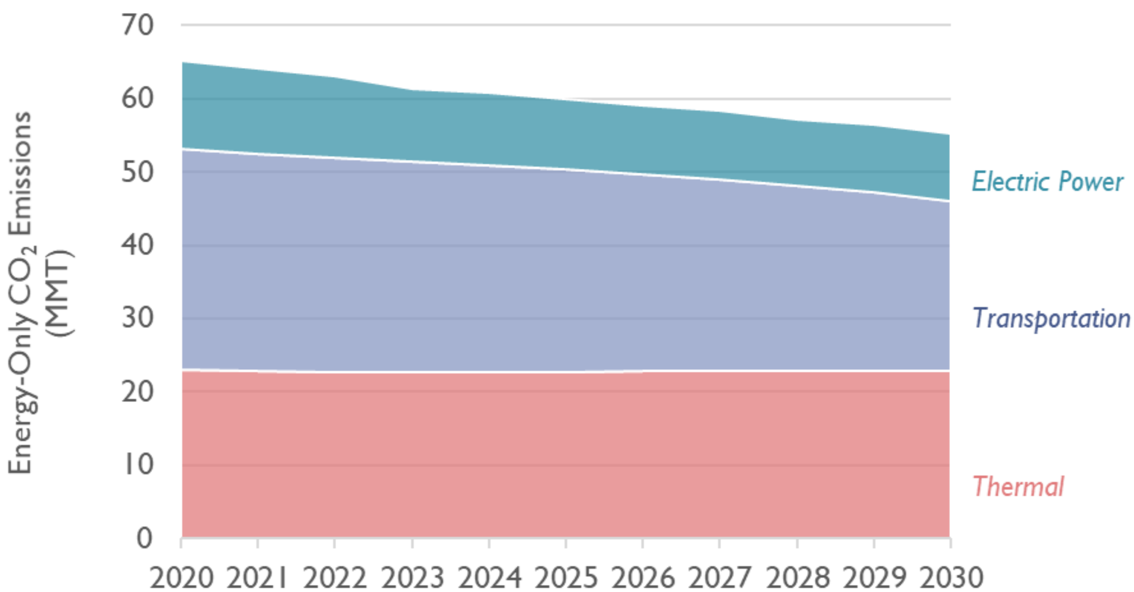


Figure 60. CO_2 emissions from energy

Winter CO_2 emissions from the thermal and power sector are expected to decrease between 2022 and 2025. In futures in which a severe winter with extended cold occurs in either 2022 or 2025, winter electricity rates are likely to be higher.

	Average Winter	Severe Winter with Extended Cold: Constrained Natural Gas Pricing	Severe Winter with Extended Cold: Mitigated Natural Gas Constraint Pricing
2022	3.9	4.5	4.4
2025	3.5	3.9	3.9

Table 12. Thermal and power sector CO2 emissions under a 20-day winter event (million metric tons CO2)

[180] As projected in this study. Actual results for the 2018 Inventory are not calculated.

6.2 High Electrification

6.2.1 Scenario Description

This scenario is the same as the Sustained Policies scenario, but features several key changes to thermal and transportation energy supply. These include:

- Increasing the pace of **heat pump** adoption. By 2030, 533,000 residences and 13 percent of commercial square footage are heated with heat pumps.

- Increasing the level of **vehicle electrification** by achieving 300,000 EVs in 2025 and 1.7 million by 2030.

SECTOR	POLICIES	***Continuation of existing policies with accelerated electrification of the thermal and transportations sectors***
Power	SMART	1600 MW (AC) of distributed solar by December 31, 2022
	Storage	All ACES Grants and current EDC approved storage projects move forward SMART: 80 MW/200 daily MWh when solar hits 1,600 MW (2020) Total by 2030: 164 MW/496 daily MWh
	RPS and CES	1 percent annual increase for RPS (12,200 GWh of Class I RECs in 2030) Current 2 percent annual increase for CES
	Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Procurements	83D: 9.45 TWh of Clean Energy Imports online by 2023 83C: 400 MW offshore wind online in 2022; 400 MW by 2023; 2,200 MW by 2030 Other: 600 MW offshore wind online by 2024 (RI and CT)
Thermal	Heating System Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Building Shell Efficiency	Continue utility EE programs with levels of performance similar to today New buildings (building codes) progress in line with AEO projections
	Electrification (Heat Pumps)	533,000 residences and 13 percent of commercial square footage are heated with heat pumps by 2030
	Industrial Efficiency	Continue utility EE programs with levels of performance similar to today Energy use rises 15 percent by 2030
	Gas switching from oil/propane	Continue at AEO 2018 levels (160,000 by 2030)
	Biofuels and the APS	APS remains at current levels, biofuel target reached
Transportation	Electric Vehicles	300,000 light-duty EVs by 2025 Growth until 1.7 million in fleet by 2030 No heavy-duty electrification
	Biofuels	Continue at AEO 2018 levels
	VMT	68 billion miles driven in 2030, up from 63 billion in 2017

6.2.2 Scenario Takeaways

Increasing the amount of energy efficiency, clean energy supply, and electrified end uses produces a future in which 2030 GHG emissions from all sectors are reduced by 38 percent relative to 1990. Meanwhile, 2030 energy expenditures in Massachusetts from all sectors are reduced by 22 percent relative to 2018. In this scenario, Massachusetts and the rest of New England will continue to rely on higher cost stored fuels (such as LNG and fuel oil). As a result, the region will continue to be at risk for price spikes and emission increases during a severe winter with extended cold events. By 2030, state policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, may reduce but will not eliminate risks to reliability.

6.2.3 Supply Mix

6.2.3.1 Thermal

Improved efficiency reduces residential energy demand by 15 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year. Multifamily buildings are projected to be about 6 percent more efficient than they are today.

Despite improved energy efficiency, continued new construction is expected to increase total commercial thermal demand by 6 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year.

By 2030, 25 percent of residential and commercial buildings that currently heat with oil are instead heated by heat pumps; 10 percent of gas-heated buildings use heat pumps. Between half and two-thirds of homes getting a heating system in 2030 choose a heat pump.

Industrial energy demand is projected to continue to gradually increase. Increased manufacturing is expected to more-than-offset improved energy efficiency, increasing energy demand by 14 percent by 2030. This sector is not modified in this scenario, relative to the Sustained Policies scenario.

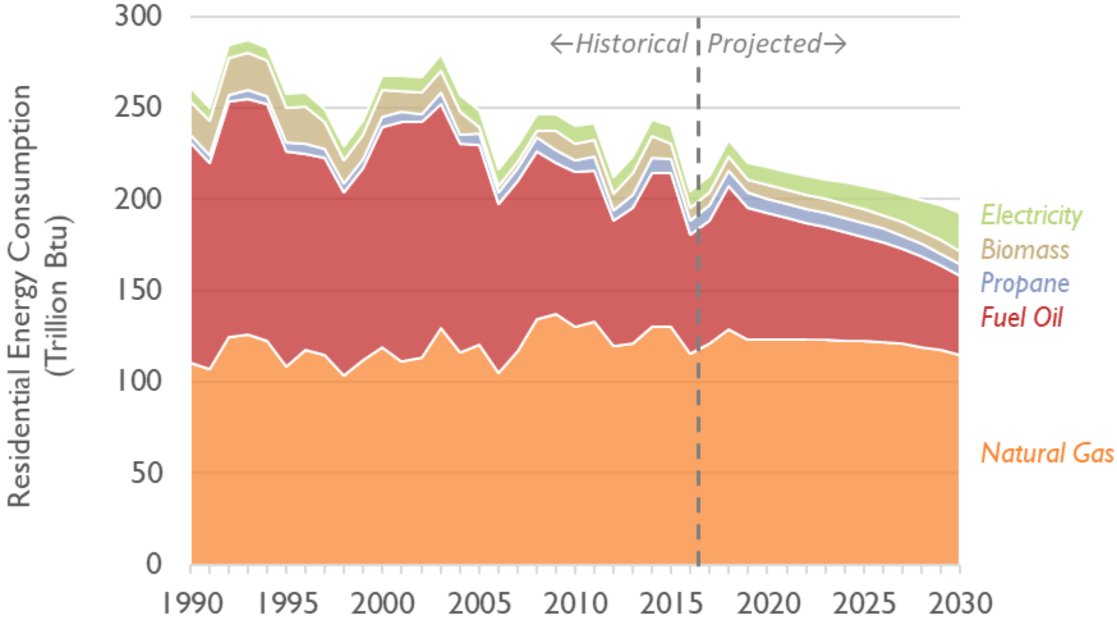


Figure 61. Thermal energy consumption, residential sector

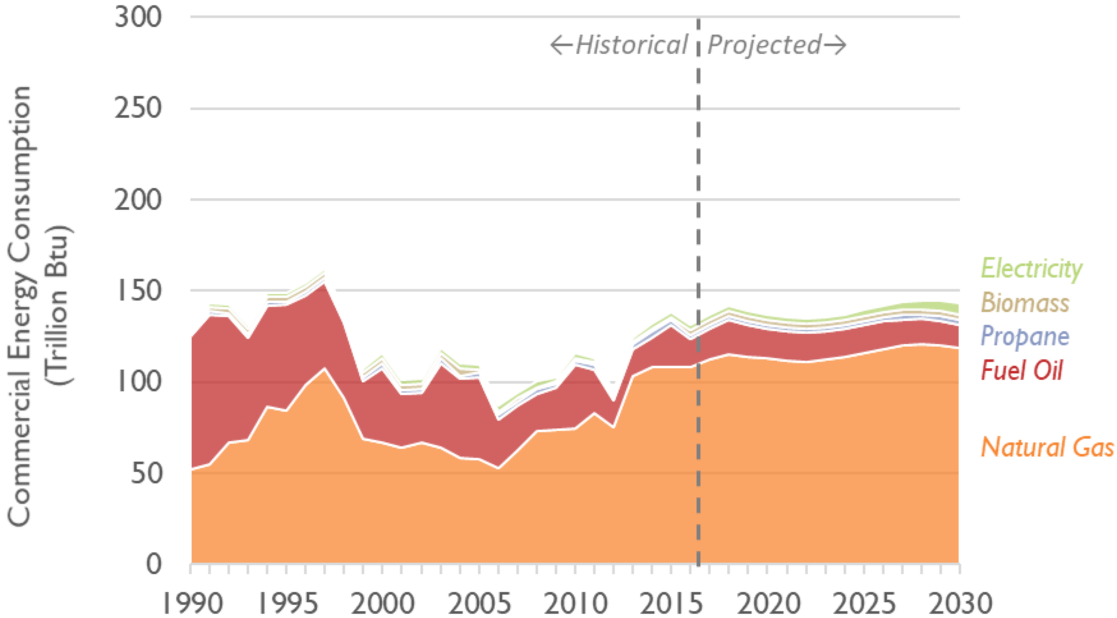


Figure 62. Thermal energy consumption, commercial sector

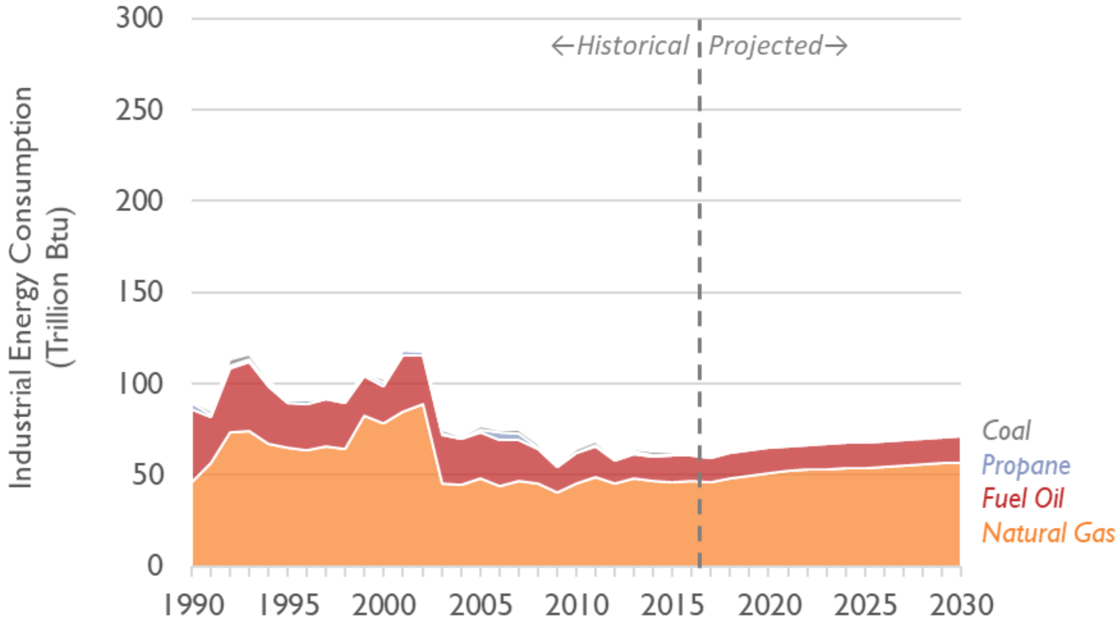


Figure 63. Thermal energy consumption, industrial sector

6.2.3.2 Transportation

While VMT is projected to continue to rise, improved efficiency is expected to reduce fuel consumption. By 2030, CAFE standards are projected to reduce gasoline consumption by 20 percent. Under this scenario, 1.7 million EVs on the road in 2030 reduces gasoline consumption by another 20 percent. By 2030, 6 out of 7 vehicles purchased are EVs.

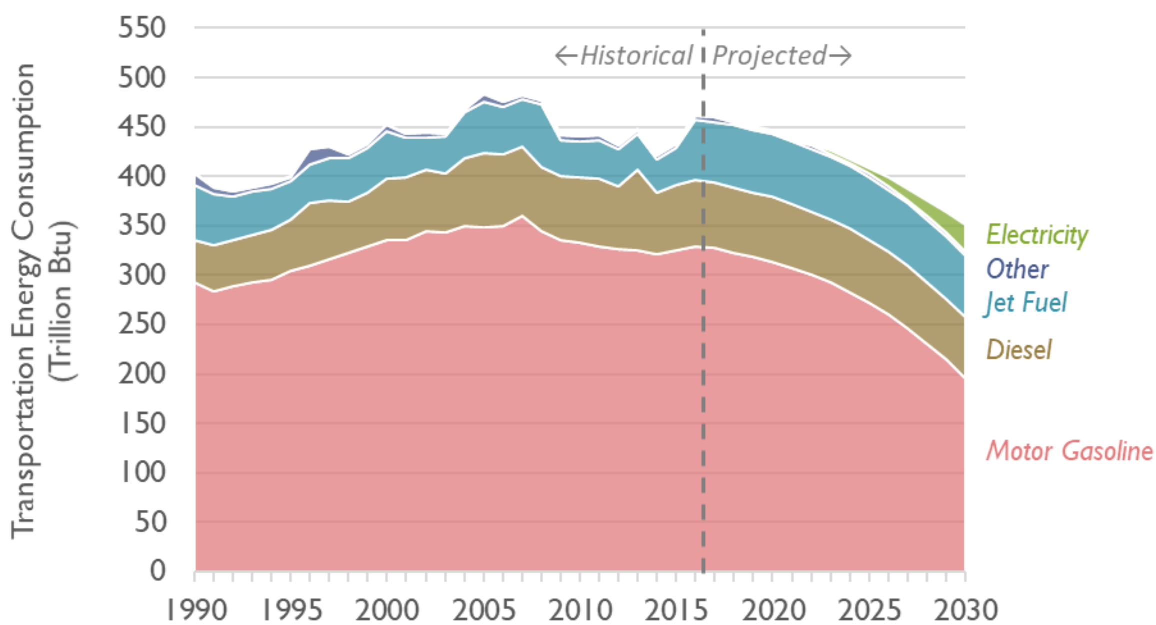


Figure 64. Transportation energy consumption

6.2.3.3 Power

By 2030, New England's fuel mix is 30 percent fossil fuel, a 10 percentage point reduction relative to 2018. By 2030, the fuel mix of wind, solar, hydro, and other renewables is 34 percent, an 18 percentage point increase relative to 2018.

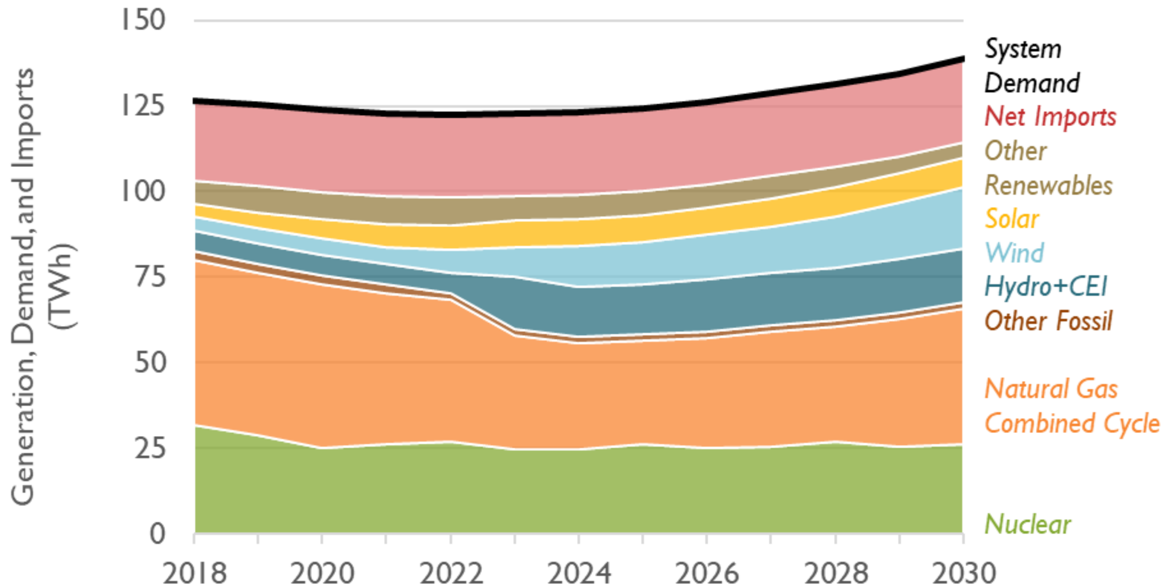


Figure 65. System demand and electricity generation, New England

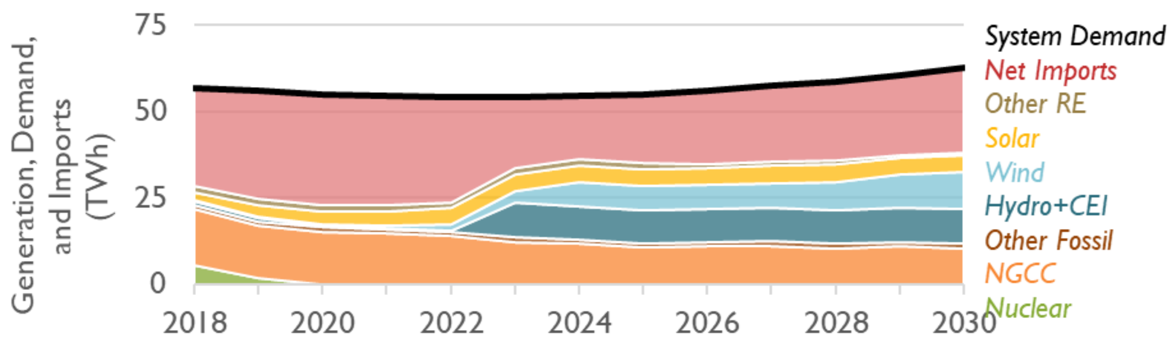


Figure 66. System demand and electricity generation, Massachusetts

6.2.4 Winter Reliability

Winter reliability was not analyzed for this scenario, but was instead analyzed for the combined "High Electrification and High Renewables" scenario.

6.2.5 Costs

In real-dollar terms, residential electricity rates are expected to remain relatively flat through 2030. However, the rate components making up the typical residential electricity rate do change over time as prices for renewable energy credits change and as costs to purchase from the wholesale energy market are replaced with renewable energy procurements.

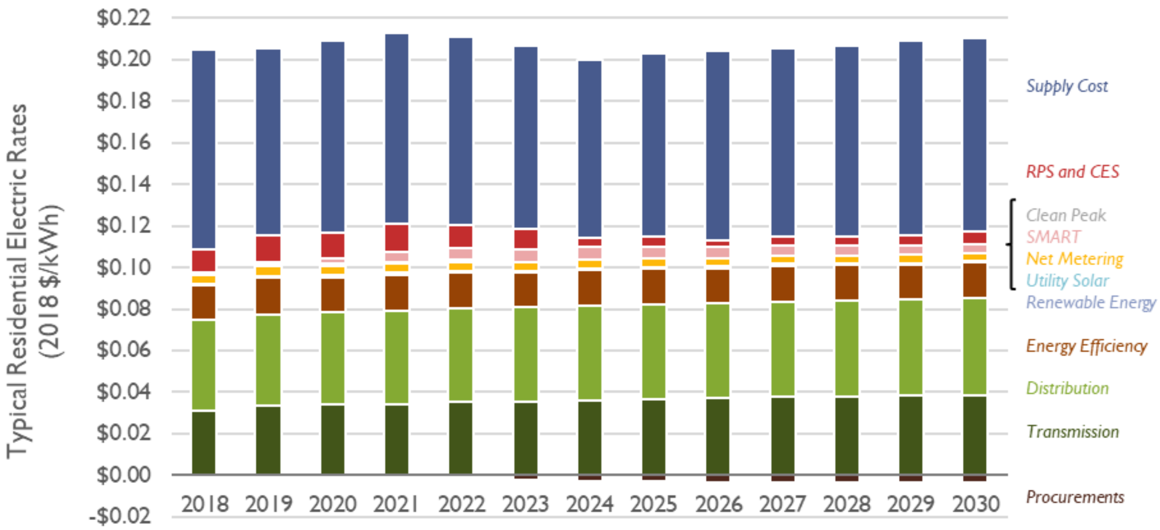


Figure 67. Typical residential electricity rate

By 2030, over half of all residential customers are expected to use natural gas as the primary fuel for thermal demand. These customers are expected to pay the least in their total energy burden at $296 per month. The state as a whole is expected to spend $1.07 billion to meet residential energy demand, with a plurality of spending on gasoline, at $0.30 billion alone.

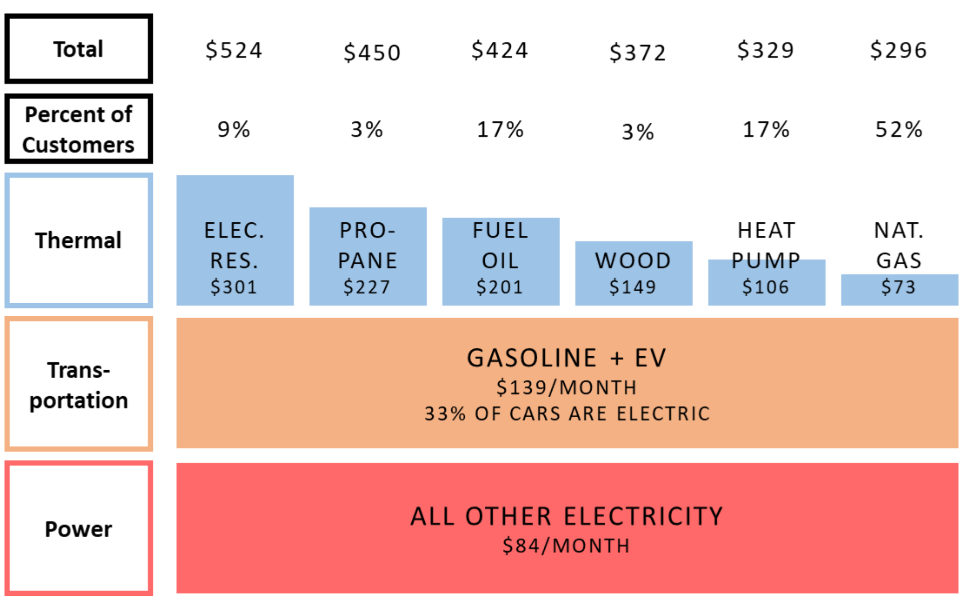


Figure 68. Average monthly energy burden for Massachusetts residents in 2030

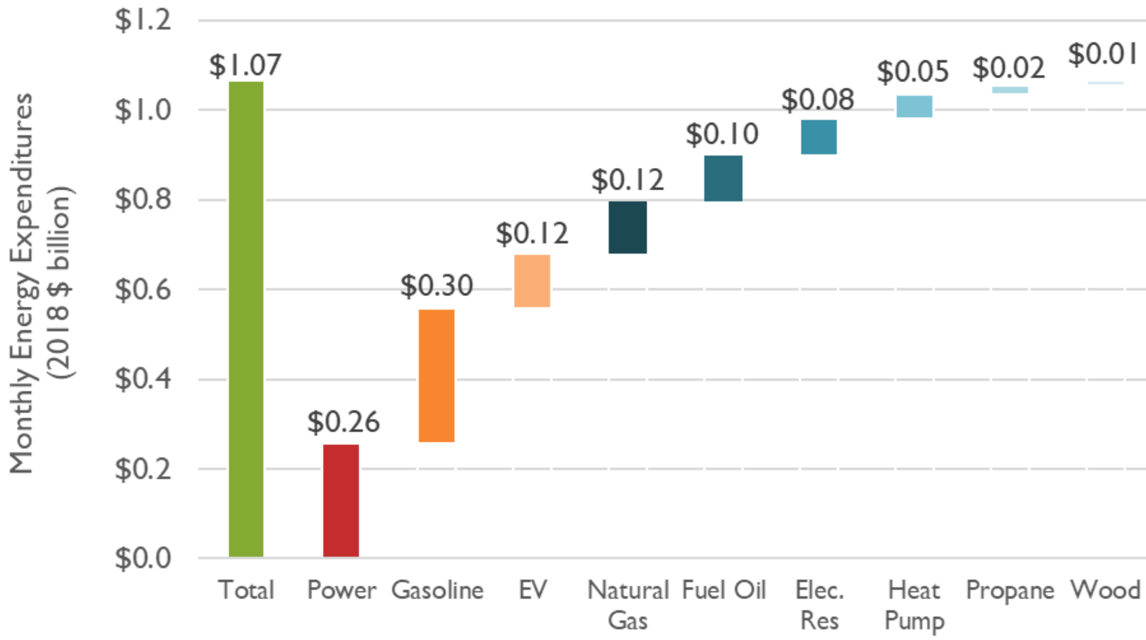


Figure 69. Total state expenditures on energy, 2030

Winter electricity rates were not analyzed for this scenario, but were instead analyzed for the combined "High Electrification and High Renewables" scenario.

6.2.6 Emissions

In 2030, this scenario achieves a reduction in all-sector GHG emissions of 38 percent relative to 1990 emissions. This represents a reduction in GHG emissions of 23 percent relative to today, and a reduction of 3 percentage points relative to 2030 in the Sustained Polices scenario.

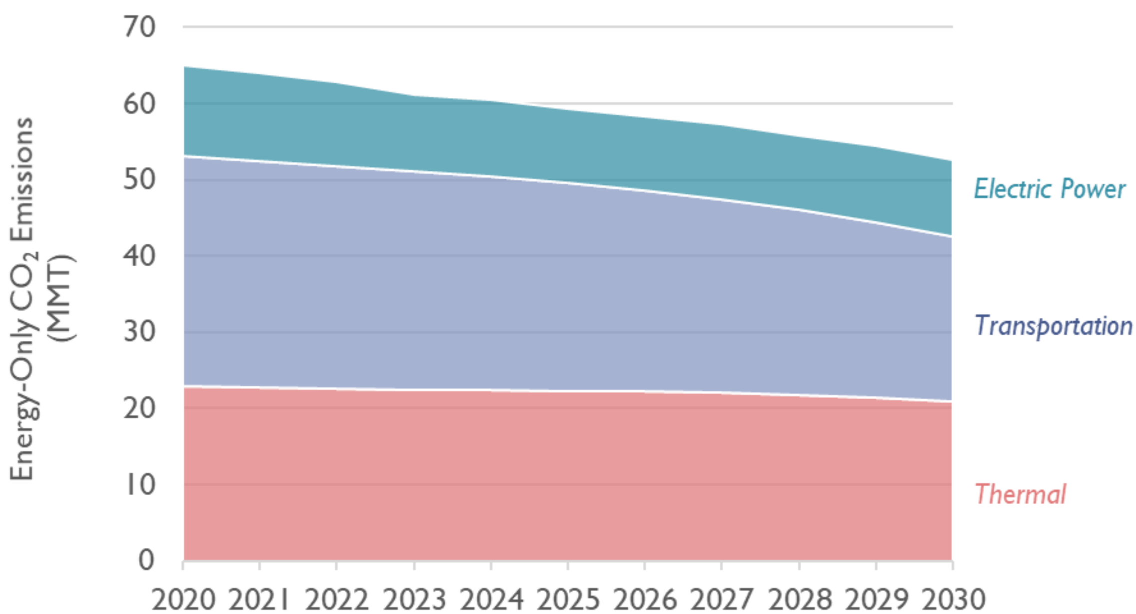


Figure 70. CO_2 emissions from energy

Winter emissions were not analyzed for this scenario, but were instead analyzed for the combined "High Electrification and High Renewables" scenario.

6.3 High Renewables

6.3.1 Scenario Description

This scenario is the same as the Sustained Policies scenario, but features several key changes to power sector energy supply. These include:

- Increasing the Commonwealth's **Clean Energy Supply** by increasing the pace of the renewable portfolio standard to 3 percent per year.

SECTOR	POLICIES	***Continuation of existing policies with expanded renewables in the power sector***
Power	SMART	1600 MW (AC) of distributed solar by December 31, 2022
	Storage	All ACES Grants and current EDC approved storage projects move forward SMART: 80 MW/200 daily MWh when solar hits 1,600 MW (2020) Total by 2030: 164 MW/496 daily MWh
	RPS and CES	3 percent annual increase for RPS (21,300 GWh of Class I RECs in 2030) Current 2 percent annual increase for CES
	Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Procurements	83D: 9.45 TWh of Clean Energy Imports online by 2023 83C: 400 MW offshore wind online in 2022; 400 MW by 2023; 2,200 MW by 2030 Other: 600 MW offshore wind online by 2024 (RI and CT)
Thermal	Heating System Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Building Shell Efficiency	Continue utility EE programs with levels of performance similar to today New buildings (building codes) progress in line with AEO projections
	Electrification (Heat Pumps)	Current programs continue; continue to achieve a few thousand heat pumps per year
	Industrial Efficiency	Continue utility EE programs with levels of performance similar to today Energy use rises 15 percent by 2030
	Gas switching from oil/propane	Continue at AEO 2018 levels (160,000 by 2030)
	Biofuels and the APS	APS remains at current levels, biofuel target reached
Transportation	Electric Vehicles	160,000 light-duty EVs by 2025 Growth until 1.2 million in fleet by 2030 No heavy-duty electrification
	Biofuels	Continue at AEO 2018 levels
	VMT	68 billion miles driven in 2030, up from 63 billion in 2017

6.3.2 Scenario Takeaways

Increasing the amount of energy efficiency, clean energy supply, and electrified end uses produces a future in which 2030 GHG emissions from all sectors are reduced by 36 percent relative to 1990. Meanwhile, 2030 energy expenditures in Massachusetts from all sectors are reduced by 20 percent relative to 2018. In this scenario, Massachusetts and the rest of New England will continue to rely on higher cost stored fuels (such as LNG and fuel oil). As a result, the region will continue to be at risk for price spikes and emission increases during a severe winter with extended cold events. By 2030, state policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, may reduce but will not eliminate risks to reliability.

6.3.3 Supply Mix

6.3.3.1 Thermal

Improved efficiency reduces residential energy demand by 15 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year. Multifamily buildings are projected to be about 6 percent more efficient than they are today. No changes are made to this sector, relative to the Sustained Policies scenario.

Despite improved energy efficiency, continued new construction is expected to increase total commercial thermal demand by 6 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year. No changes are made to this sector, relative to the Sustained Policies scenario.

Industrial energy demand is projected to continue to gradually increase. Increased manufacturing is expected to more-than-offset improved energy efficiency, increasing energy demand by 14 percent by 2030. No changes are made to this sector, relative to the Sustained Policies scenario.

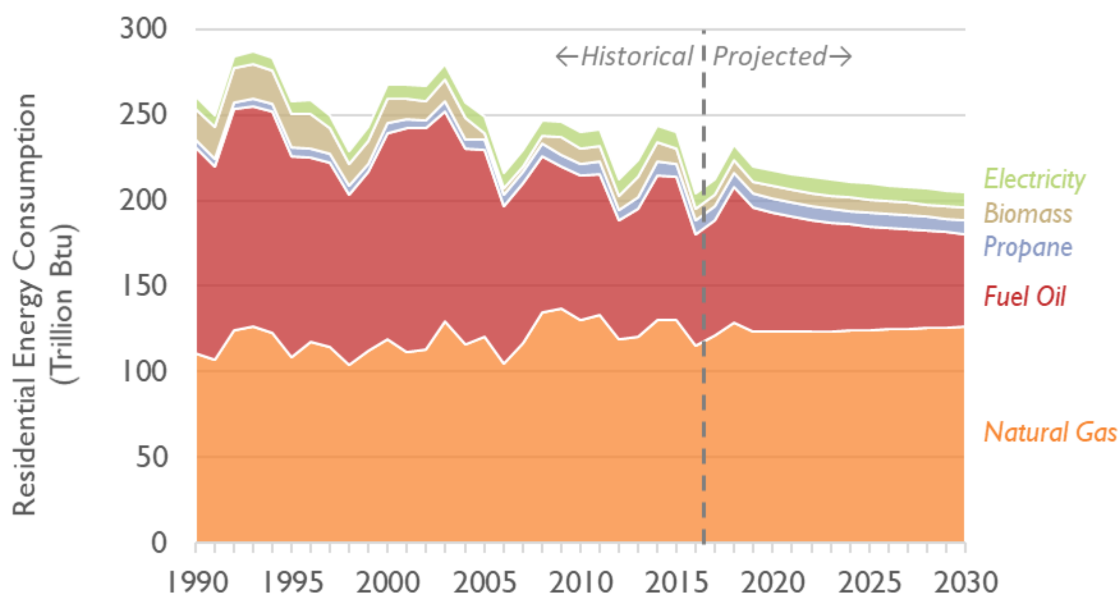


Figure 71. Thermal energy consumption, residential sector

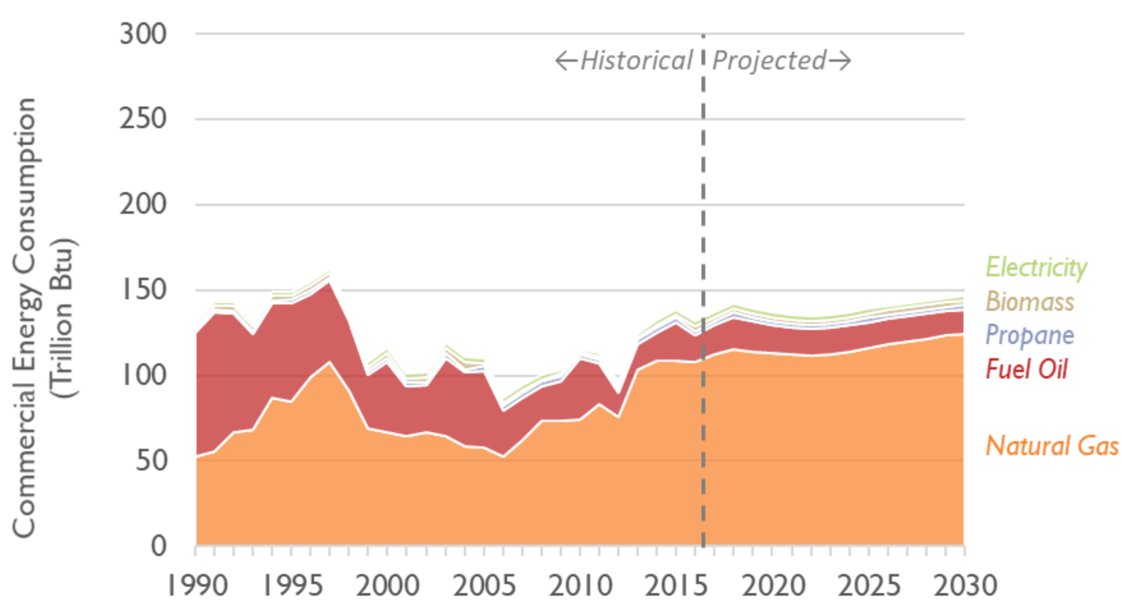


Figure 72. Thermal energy consumption, commercial sector

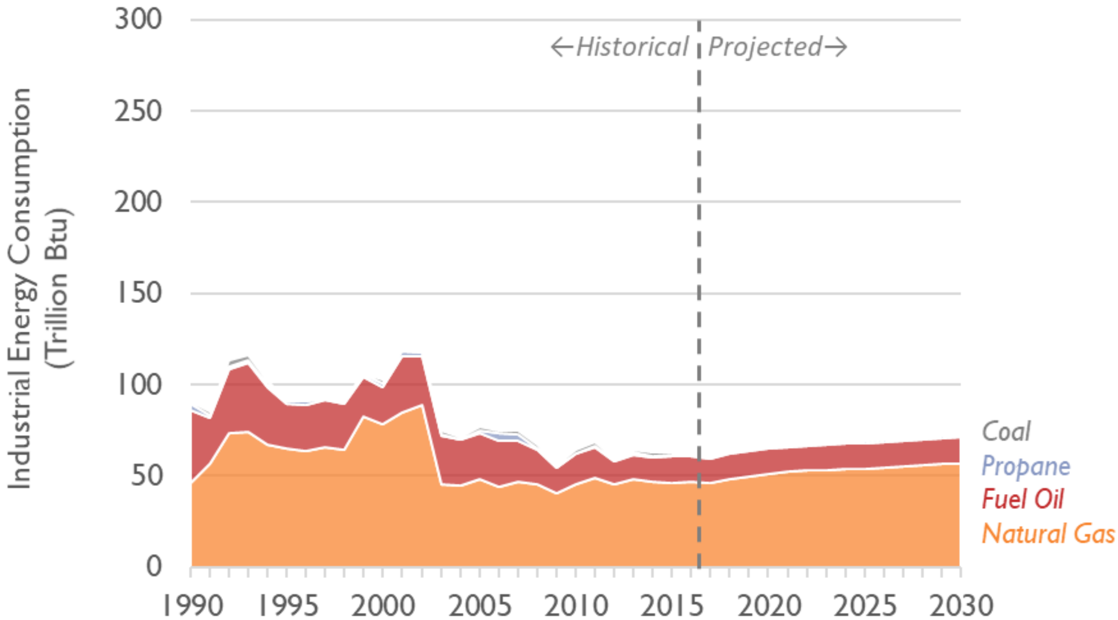


Figure 73. Thermal energy consumption, industrial sector

6.3.3.2 Transportation

While VMT is projected to continue to rise, improved efficiency is expected to reduce fuel consumption. By 2030, CAFE standards are projected to reduce gasoline consumption by 20 percent. Under this scenario, 1.2 million EVs on the road in 2030 reduces gasoline consumption by another 13 percent, meaning that 2 out of 3 vehicles purchased in 2030 are EVs. No changes are made to this sector, relative to the Sustained Policies scenario.

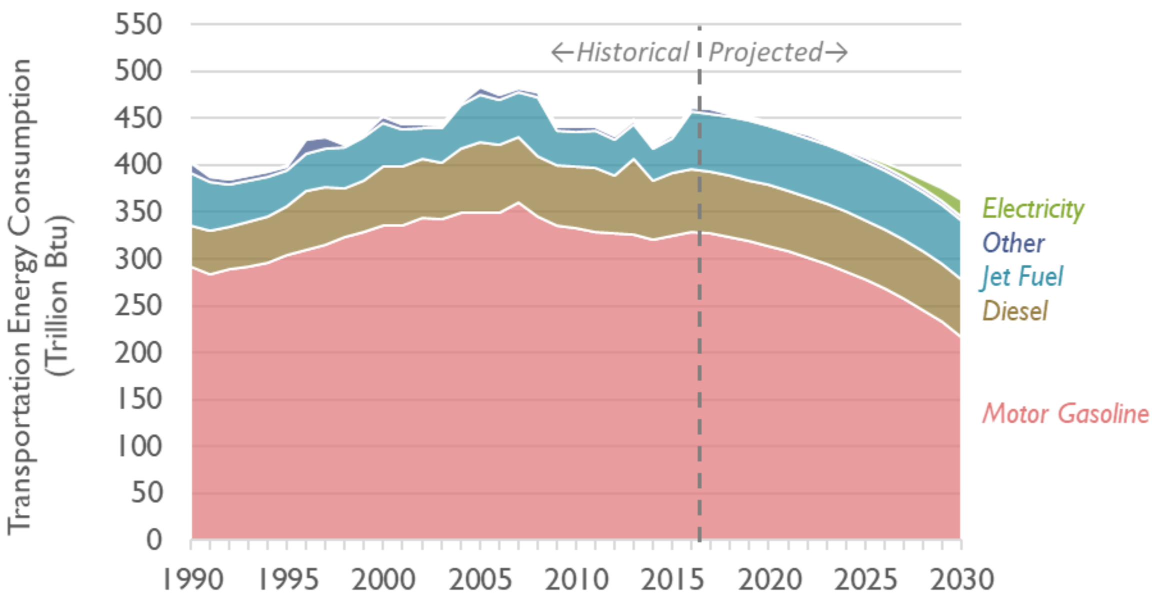


Figure 74. Transportation energy consumption

6.3.3.3 Power

By 2030, New England's fuel mix is 25 percent fossil fuel, a 16 percentage point reduction relative to 2018. By 2030, the fuel mix of wind, solar, hydro, and other renewables is 38 percent, a 22 percentage point increase relative to 2018.

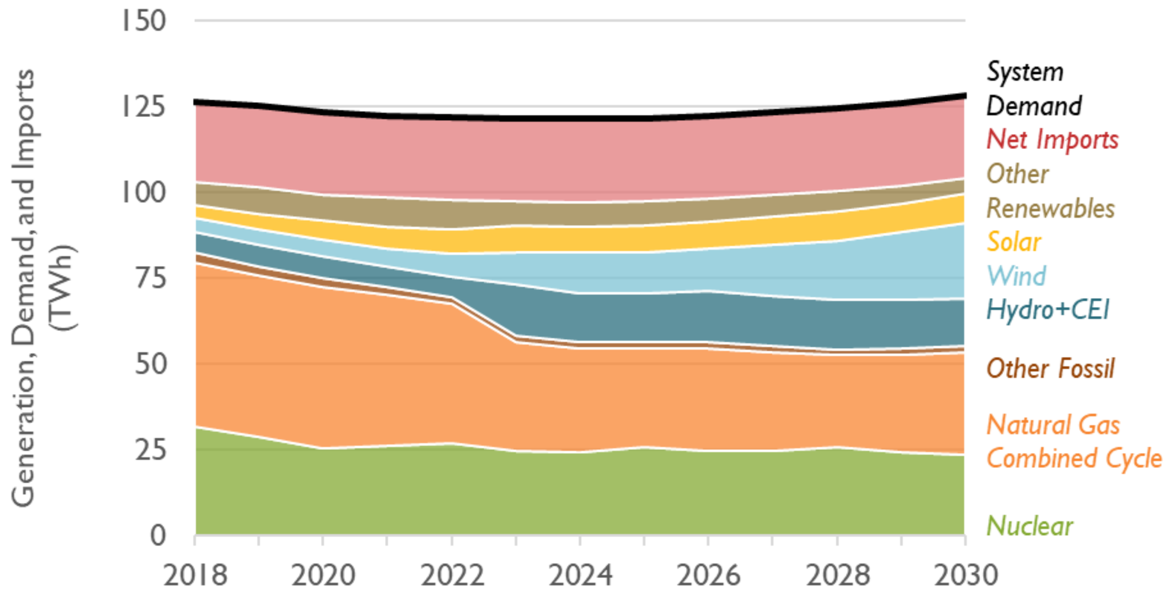


Figure 75. System demand and electricity generation, New England

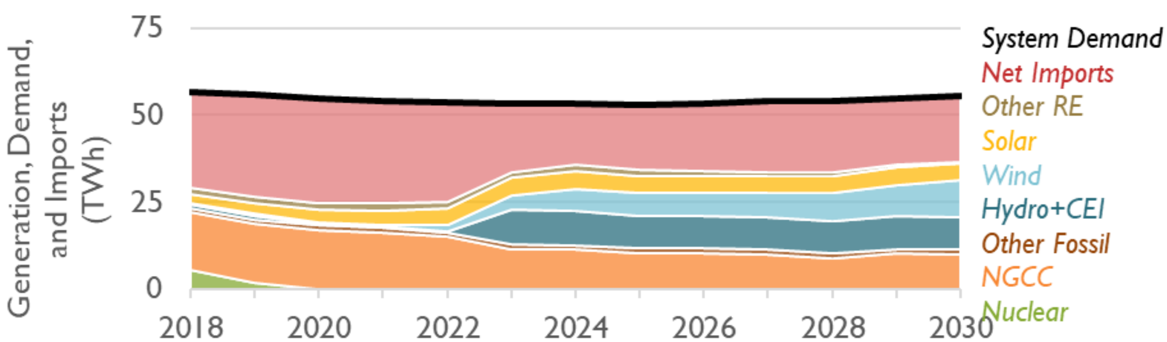


Figure 76. System demand and electricity generation, Massachusetts

6.3.4 Winter Reliability

Winter reliability was not analyzed for this scenario, but was instead analyzed for the combined "High Electrification and High Renewables" scenario.

6.3.5 Costs

In real-dollar terms, residential electricity rates are expected to remain relatively flat through 2030. However, the rate components making up the typical residential electricity rate do change over time as prices for renewable energy credits change and as costs to purchase from the wholesale energy market are replaced with renewable energy procurements.

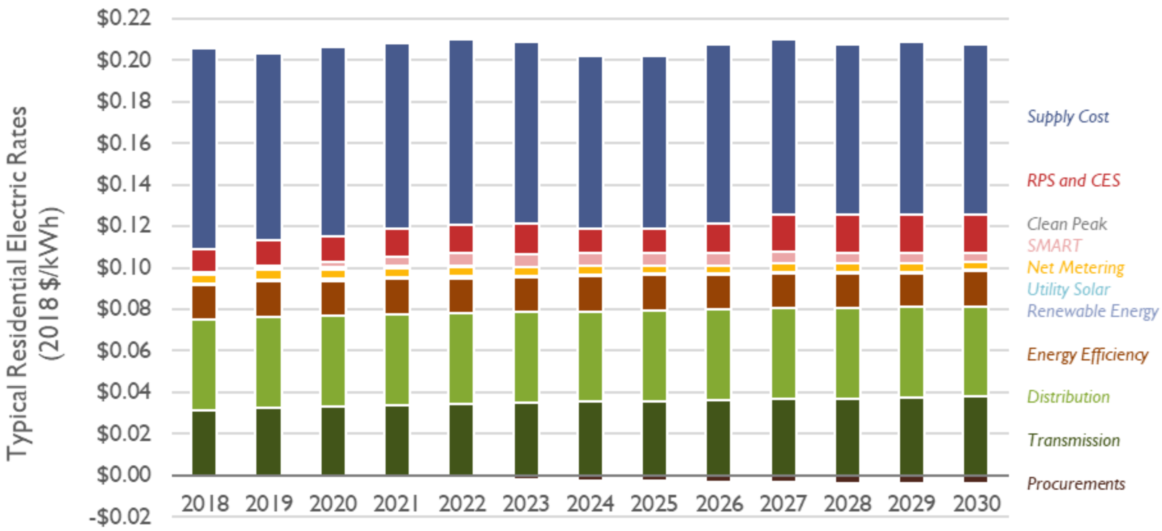


Figure 77. Typical residential electricity rate

By 2030, nearly 60 percent of residential customers are expected to use natural gas as the primary fuel for thermal demand. These customers are expected to pay the least in their total energy burden at $297 per month. The state as a whole is expected to spend $1.09 billion to meet residential energy demand, with a plurality of spending on gasoline, at $0.35 billion alone.

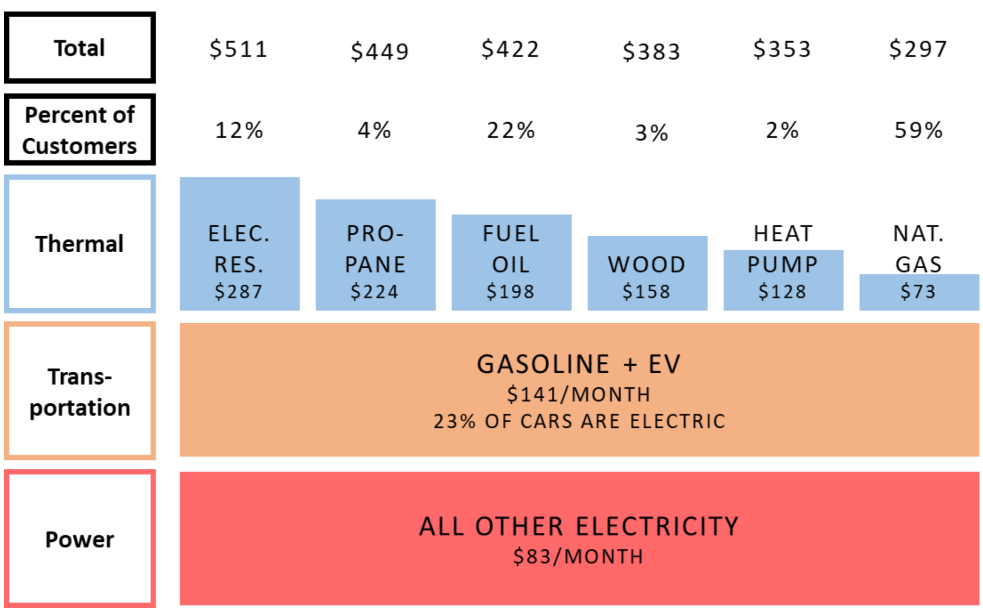


Figure 78. Average monthly energy burden for Massachusetts residents

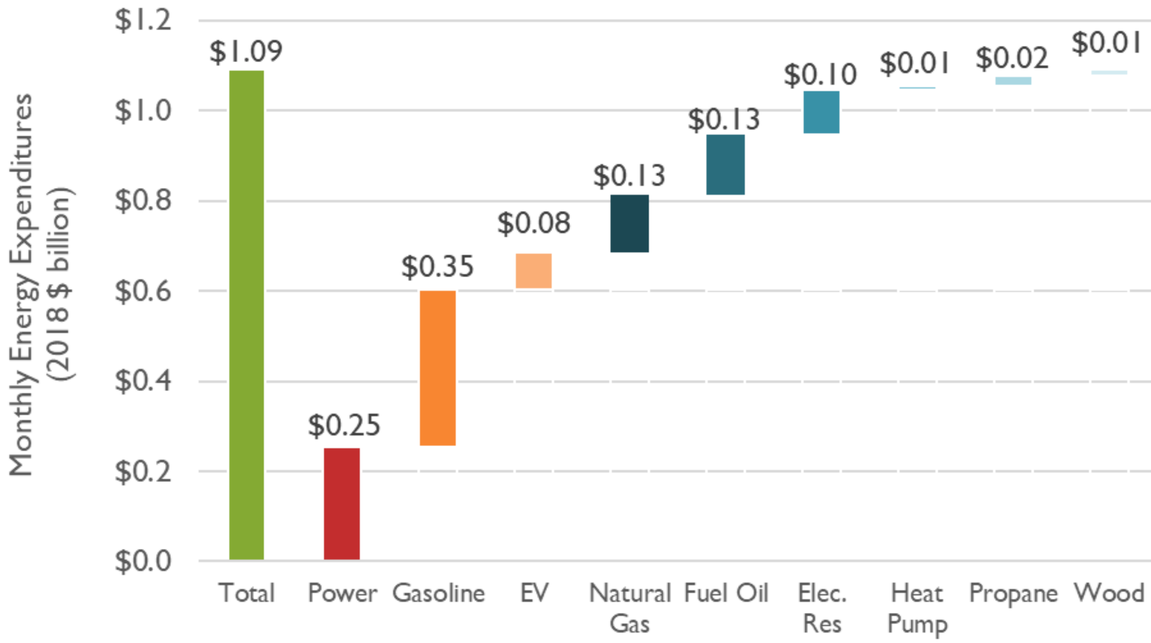


Figure 79. Total state expenditures on energy, 2030

Winter electricity rates were not analyzed for this scenario, but were instead analyzed for the combined "High Electrification and High Renewables" scenario.

6.3.6 Emissions

In 2030, this scenario achieves a reduction in all-sector GHG emissions of 36 percent relative to 1990 emissions. This represents a reduction in GHG emissions of 21 percent relative to today, and a reduction of 1 percentage point relative to 2030 in the Sustained Polices scenario.

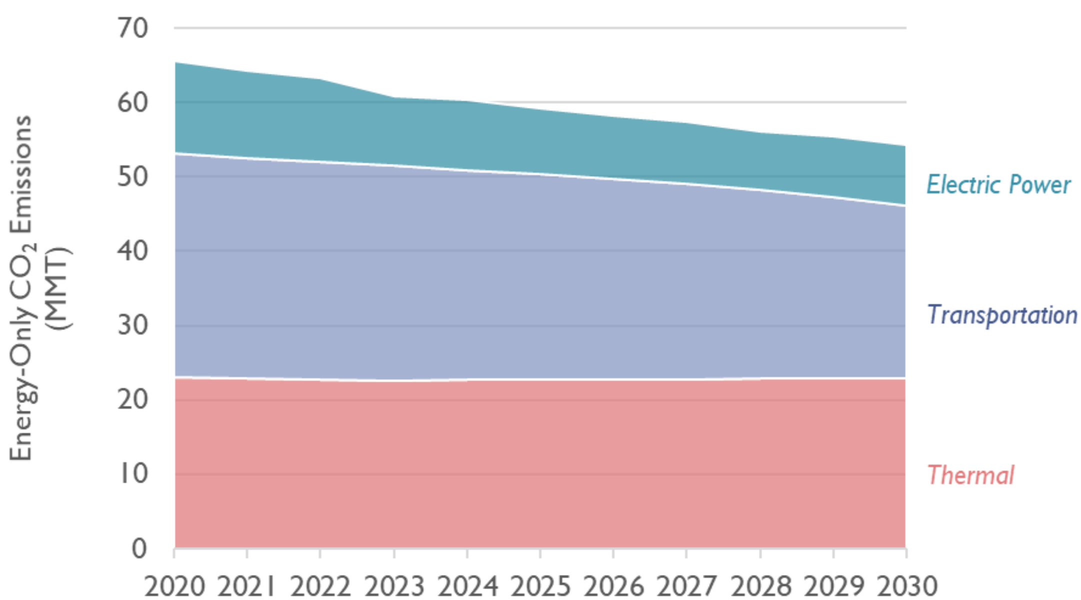


Figure 80. CO_2 emissions from energy

Winter emissions were not analyzed for this scenario, but were instead analyzed for the combined "High Electrification and High Renewables" scenario.

6.4 High Renewables and High Electrification

6.4.1 Scenario Description

This scenario combines the assumptions of the High Electrification and High Renewables scenario. In addition to the assumptions outlined in the Sustained Policies case, it includes:

- Increasing the pace of **heat pump** adoption. By 2030, 533,000 residences and 13 percent of commercial square footage are heated with heat pumps
- Increasing the level of **vehicle electrification** by achieving 300,000 EVs in 2025 and 1.7 million by 2030.
- Increasing the pace of the **renewable portfolio standard** to 3 percent per year.

SECTOR	POLICIES	***Continuation of existing policies with accelerated electrification of the thermal and transportations sectors, and expanded renewables in the power sector***
Power	SMART	1600 MW (AC) of distributed solar by December 31, 2022
	Storage	All ACES Grants and current EDC approved storage projects move forward SMART: 80 MW/200 daily MWh when solar hits 1,600 MW (2020) Total by 2030: 164 MW/496 daily MWh
	RPS and CES	3 percent annual increase for RPS (23,900 GWh of Class I RECs in 2030) Current 2 percent annual increase for CES
	Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Procurements	83D: 9.45 TWh of Clean Energy Imports online by 2023 83C: 400 MW offshore wind online in 2022; 400 MW by 2023; 2,200 MW by 2030 Other: 600 MW offshore wind online by 2024 (RI and CT)
Thermal	Heating System Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Building Shell Efficiency	Continue utility EE programs with levels of performance similar to today New buildings (building codes) progress in line with AEO projections
	Electrification (Heat Pumps)	533,000 residences and 13 percent of commercial square footage are heated with heat pumps by 2030
	Industrial Efficiency	Continue utility EE programs with levels of performance similar to today Energy use rises 15 percent by 2030
	Gas switching from oil/propane	Continue at AEO 2018 levels (160,000 by 2030)
	Biofuels and the APS	APS remains at current levels, biofuel target reached
Transportation	Electric Vehicles	300,000 light-duty EVs by 2025 Growth until 1.7 million in fleet by 2030 No heavy-duty electrification
	Biofuels	Continue at AEO 2018 levels
	VMT	68 billion miles driven in 2030, up from 63 billion in 2017

6.4.2 Scenario Takeaways

Increasing the amount of energy efficiency, clean energy supply, and electrified end uses produces a future in which 2030 GHG emissions from all sectors are reduced by 39 relative to 1990. Meanwhile, 2030 energy expenditures in Massachusetts from all sectors are reduced by 23 percent relative to 2018. In this scenario, Massachusetts and the rest of New England will continue to rely on higher cost stored fuels (such as LNG and fuel oil). As a result, the region will continue to be at risk for price spikes and emission increases during a severe winter with extended cold events. By 2030, state policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, may reduce but will not eliminate risks to reliability.

6.4.3 Supply Mix

6.4.3.1 Thermal

Improved efficiency reduces residential energy demand by 15 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year. Multifamily buildings are projected to be about 6 percent more efficient than they are today.

Despite improved energy efficiency, continued new construction is expected to increase total commercial thermal demand by 6 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year.

By 2030, 25 percent of residential and commercial buildings that currently heat with oil are instead heated by heat pumps; 10 percent of gas-heated buildings use heat pumps. Between half and two-thirds of homes getting a heating system in 2030 choose a heat pump.

Industrial energy demand is projected to continue to gradually increase. Increased manufacturing is expected to more-than-offset improved energy efficiency, increasing energy demand by 14 percent by 2030. This sector is not modified in this scenario, relative to the Sustained Policies scenario.

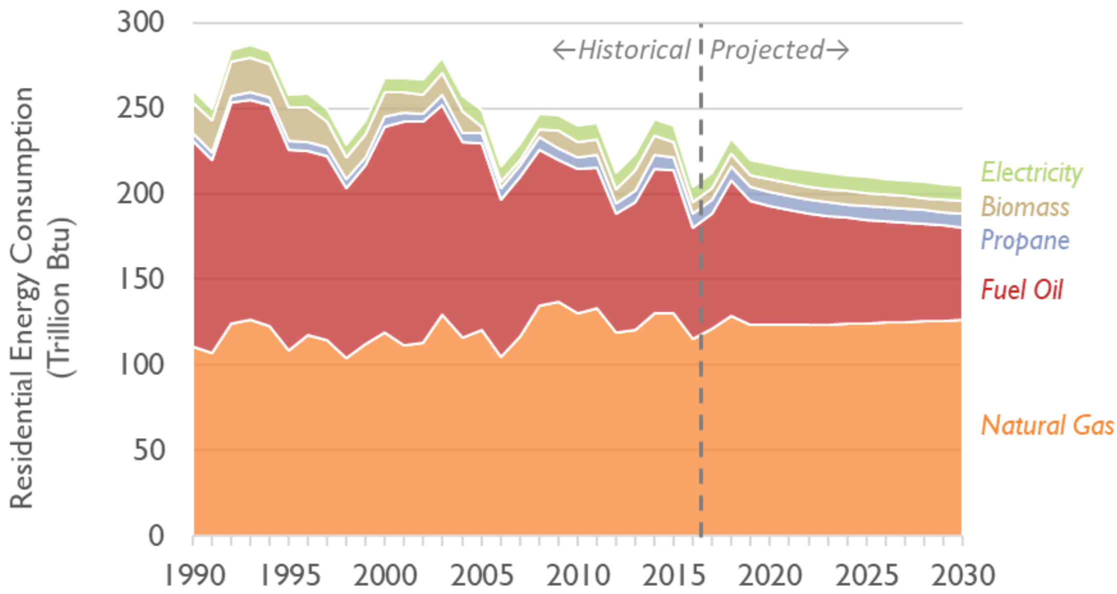


Figure 81. Thermal energy consumption, residential sector

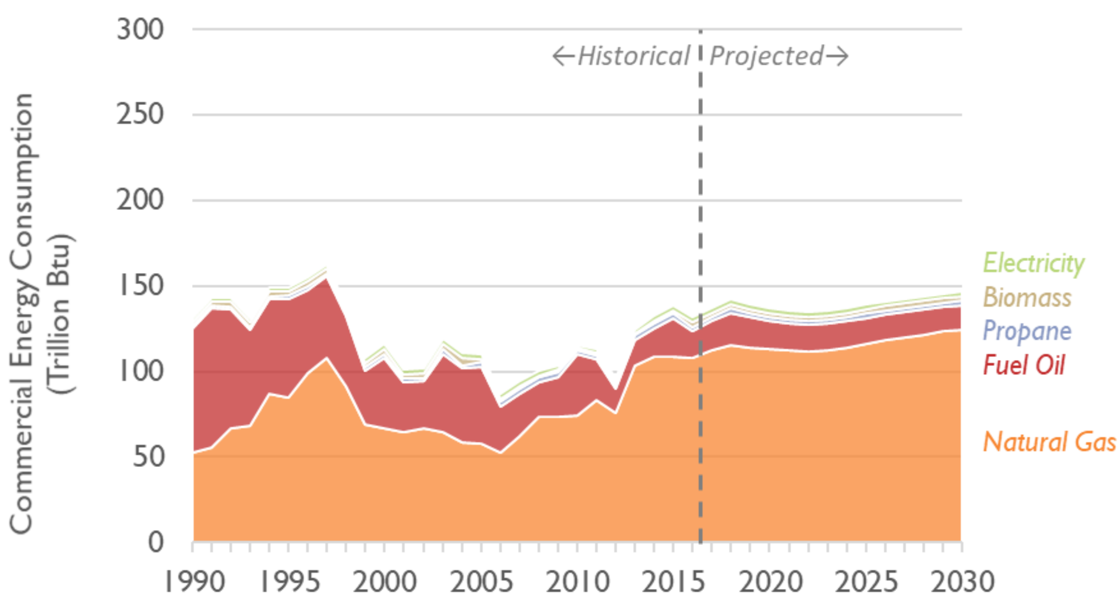


Figure 82. Thermal energy consumption, commercial sector

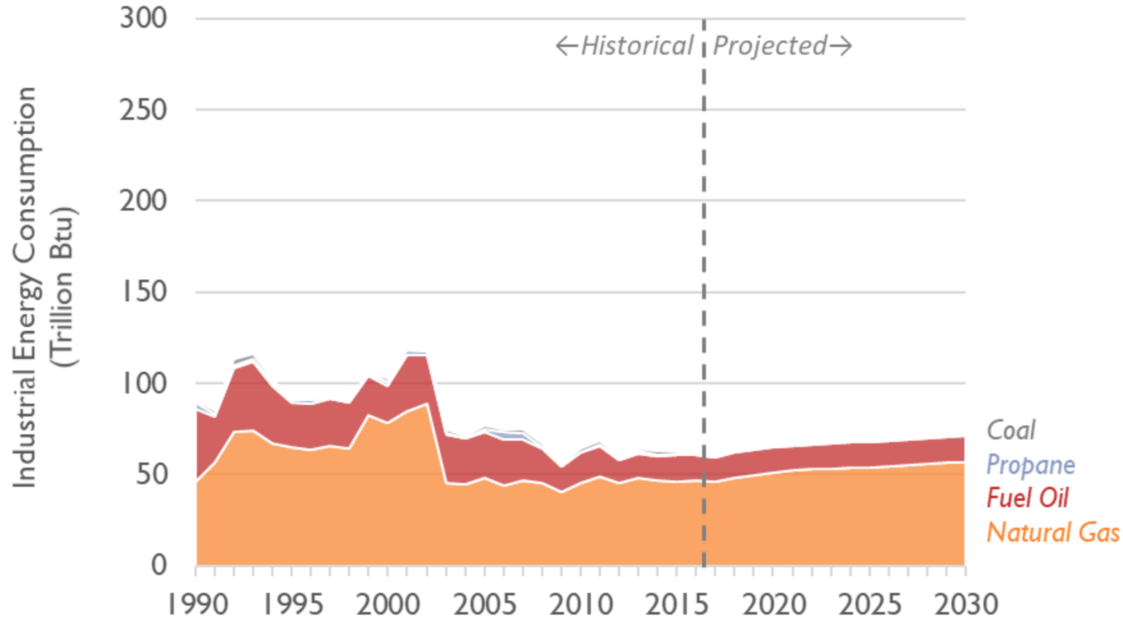


Figure 83. Thermal energy consumption, industrial sector

6.4.3.2 Transportation

While VMT is projected to continue to rise, improved efficiency is expected to reduce fuel consumption. By 2030, CAFE standards are projected to reduce gasoline consumption by 20 percent. Under this scenario, 1.7 million EVs on the road in 2030 reduces gasoline consumption by another 20 percent. By 2030, 6 out of 7 vehicles purchased are EVs.

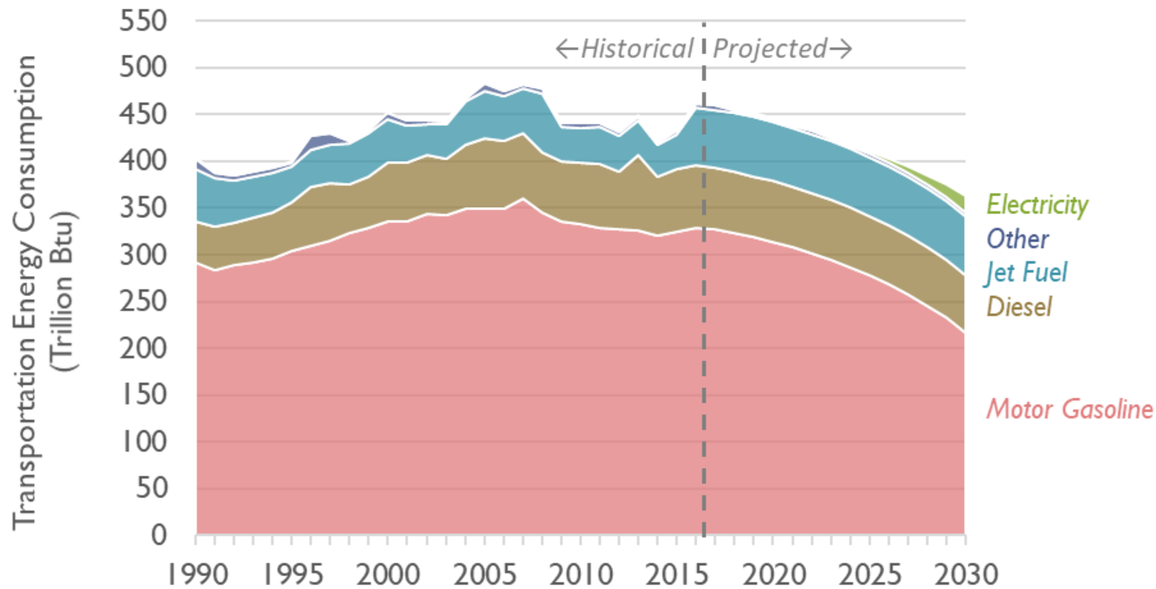


Figure 84. Transportation energy consumption

6.4.4 Power

By 2030, New England's fuel mix is 26 percent fossil fuel, a 14 percentage point reduction relative to 2018. By 2030, the fuel mix of wind, solar, hydro, and other renewables is 38 percent, a 22 percentage point increase relative to 2018.

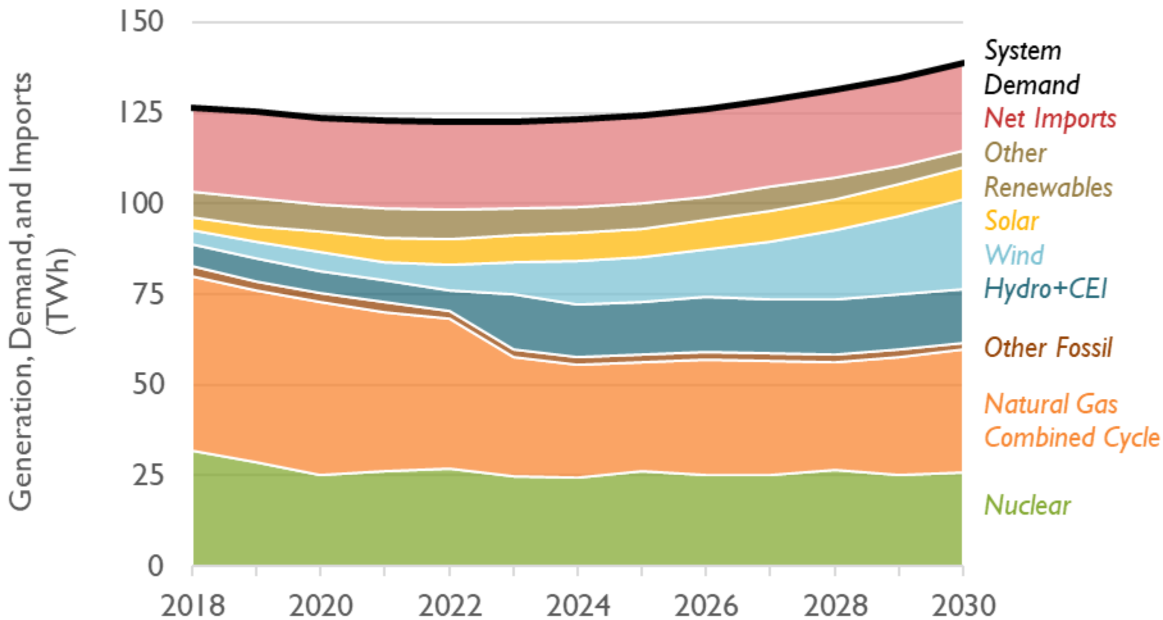


Figure 85. System demand and electricity generation, New England

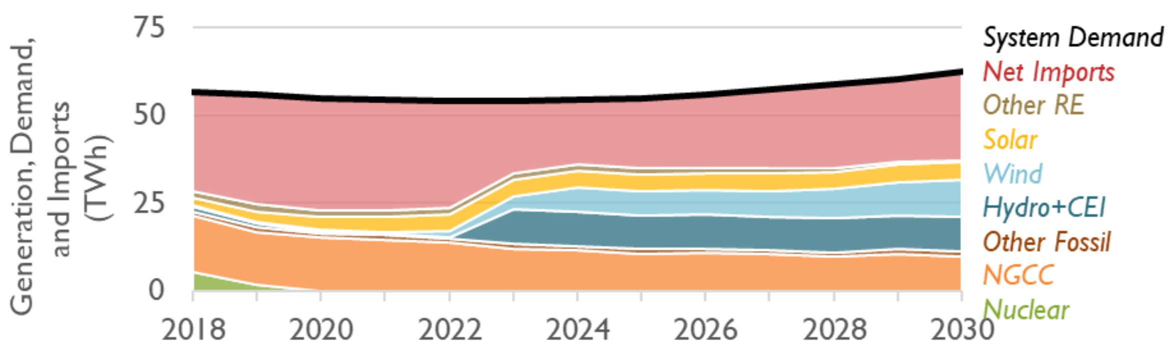


Figure 86. System demand and electricity generation, Massachusetts

6.4.5 Winter Reliability

Under a peak winter day in 2022, New England's power sector is still reliant on a substantial amount of fuel oil in order to reliably supply electricity. By 2025, as the quantity of renewables increases (largely driven by polices incentivizing Clean Energy Imports and offshore wind, as well as an increased requirement for all renewables), the quantity of fuel oil required to supply electricity decreases. On a peak day in 2015, the Commonwealth's natural gas use was 44 percent above the available natural gas delivery capacity, making the region dependent on stored fuels such as LNG and fuel oil. In 2022 on a peak day, this percentage is projected to be reduced, with a peak daily natural gas demand being 8 percent available natural gas delivery capacity. In 2025, this percentage slightly increases to 9 percent.

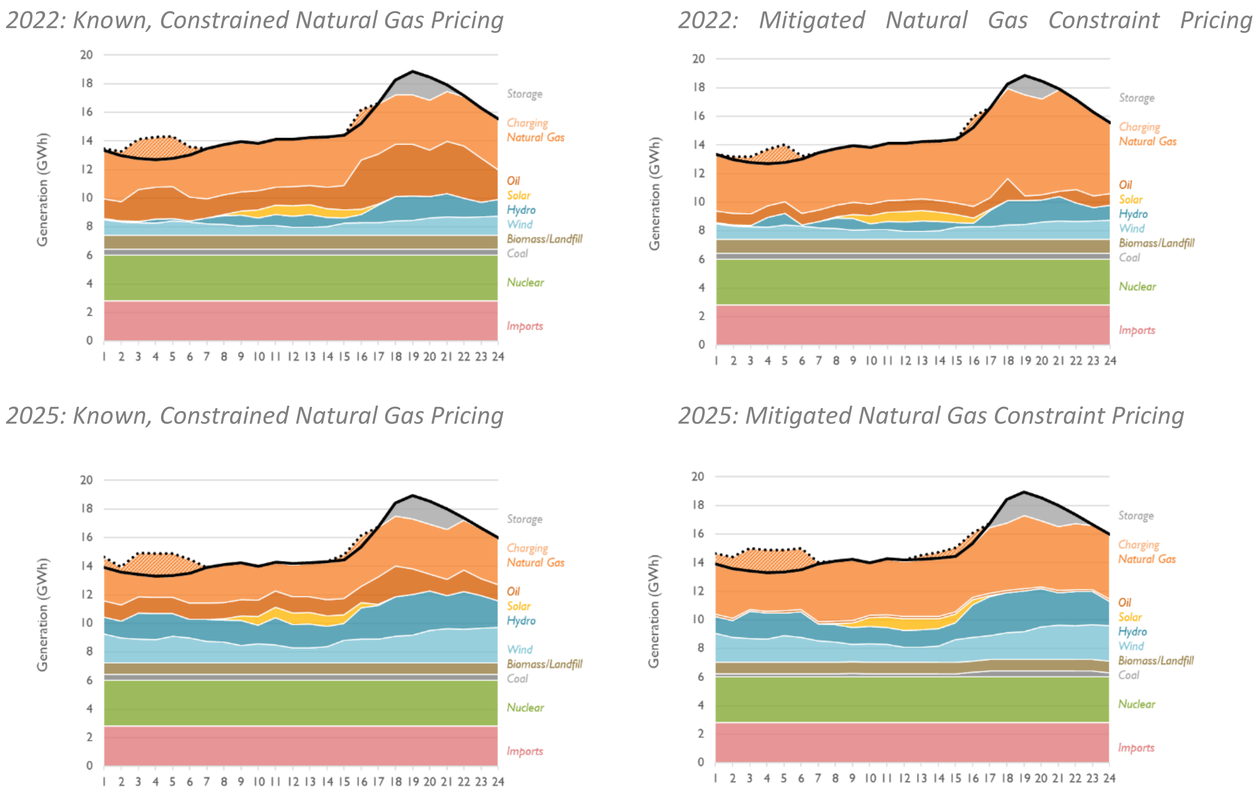


Figure 87. Peak winter day electricity demand and generation, New England

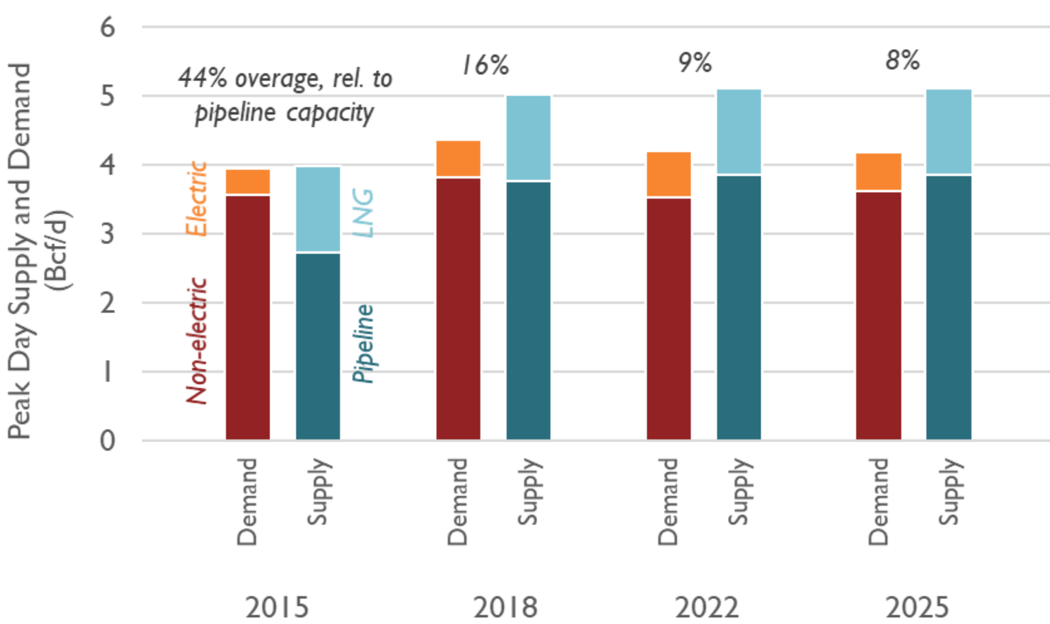


Figure 88. Peak winter day natural gas demand and supply, New England

6.4.6 Costs

In real-dollar terms, residential electricity rates are expected to remain relatively flat through 2030. However, the rate components making up the typical residential electricity rate do change over time as prices for renewable energy credits change and as costs to purchase from the wholesale energy market are replaced with renewable energy procurements.

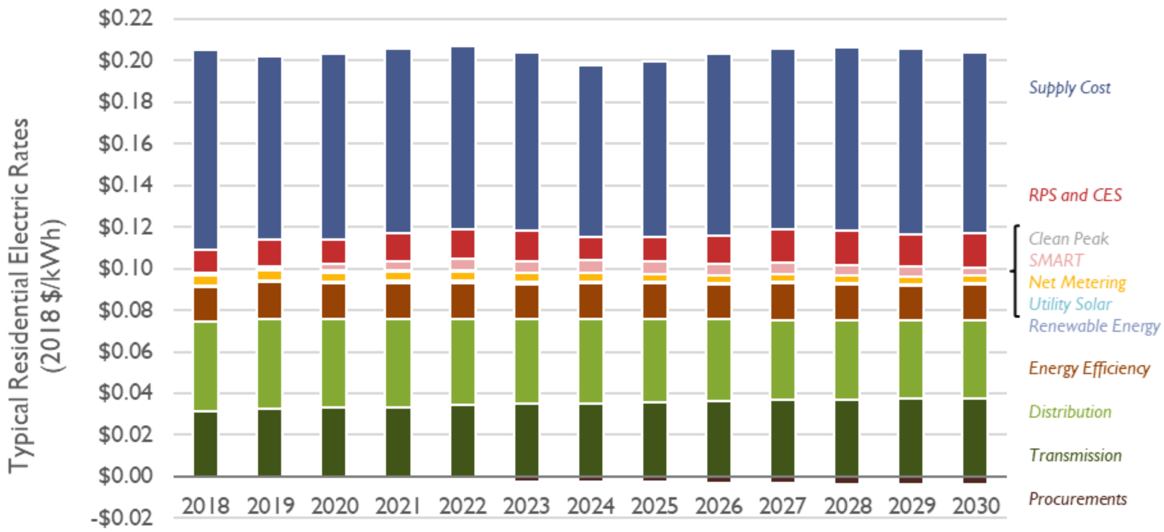


Figure 89. Typical residential electricity rate

By 2030, over half of all residential customers are expected to use natural gas as the primary fuel for thermal demand. These customers are expected to pay the least in their total energy burden at $293 per month. The state as a whole is expected to spend $1.05 billion to meet residential energy demand, with a plurality of spending on gasoline, at $0.30 billion alone.

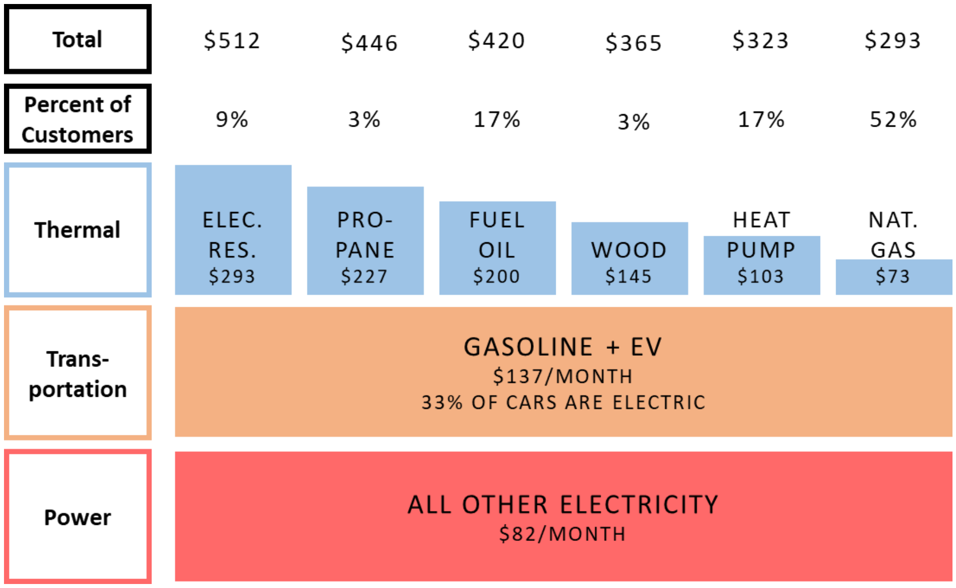


Figure 90. Average monthly energy burden for Massachusetts residents in 2030

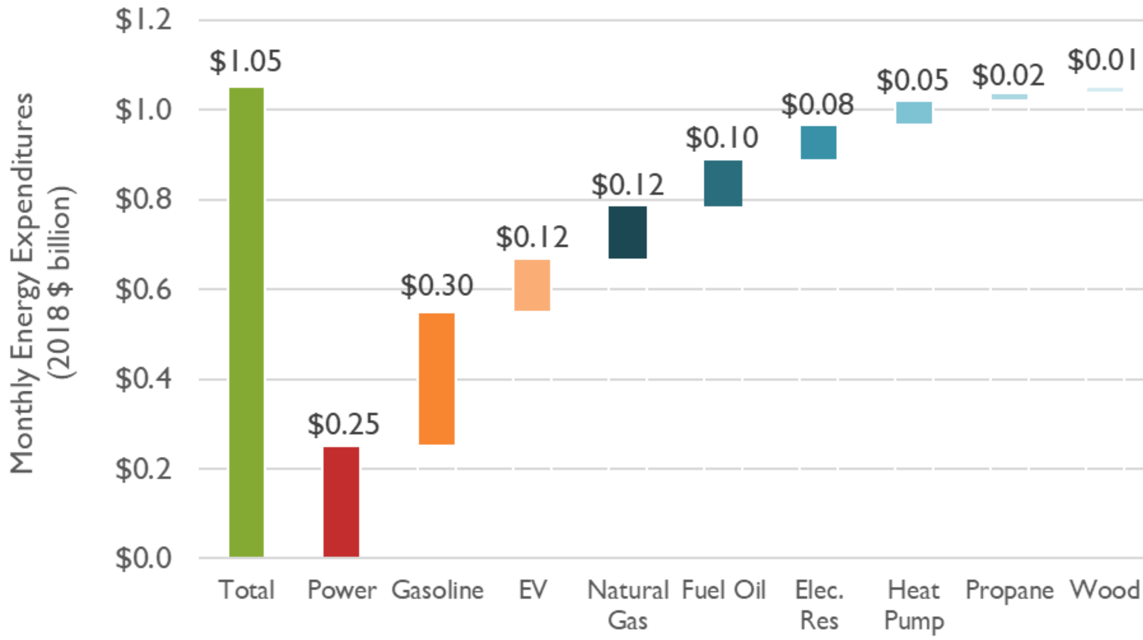


Figure 91. Total state expenditures on energy, 2030

Winter electricity rates are expected to remain relatively constant between 2022 and 2025. In futures in which a severe winter with an extended cold event occurs in either 2022 or 2025, winter electricity rates are likely to be higher.

	Average Winter	Severe Winter with Extended Cold: Constrained Natural Gas Pricing	Severe Winter with Extended Cold: Mitigated Natural Gas Constraint Pricing
2022	$0.215	$0.236	$0.232
2025	$0.215	$0.236	$0.218

Table 13. Annual residential electricity rates in Massachusetts (2018 $/kWh)

6.4.7 Emissions

In 2030, this scenario achieves a reduction in all-sector GHG emissions of 39 percent relative to 1990 emissions. This represents a reduction in GHG emissions of 25 percent relative to today, and a reduction of 4 percentage points relative to 2030 in the Sustained Polices scenario.

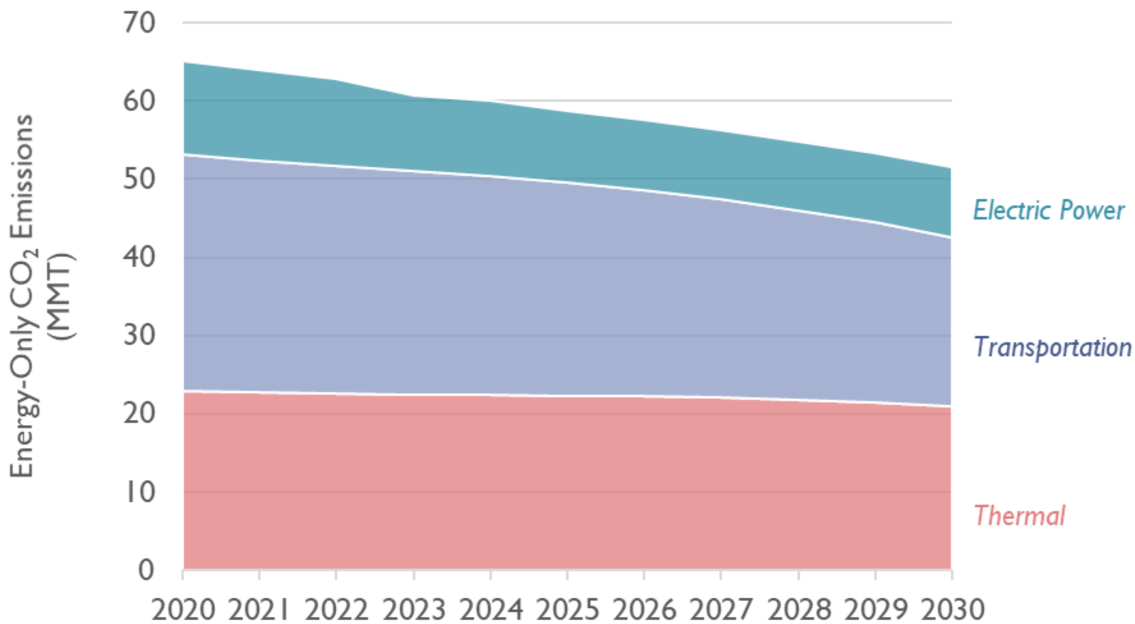


Figure 92. CO_2 emissions from energy

Winter CO_2 emissions from the thermal and power sector are expected to decrease between 2022 and 2025. In futures in which a severe winter with extended cold occurs in either 2022 or 2025, winter electricity rates are likely to be higher.

	Average 20-Day Winter Period	Severe Winter with Extended Cold: Constrained Natural Gas Pricing	Severe Winter with Extended Cold: Mitigated Natural Gas Constraint Pricing
2022	3.9	4.5	4.4
2025	3.5	4.0	3.9

Table 14. Thermal and power sector CO_2 emissions under a 20-day extended cold event (million metric tons CO_2)

6.5 Aggressive Conservation and Fuel Switching

6.5.1 Scenario Description

This scenario projects a future in which numerous policies are accelerated. These include:

- Increasing the Commonwealth's **Clean Energy Supply** by increasing the pace of the renewable portfolio standard to 3 percent per year.
- Increasing efficiency
- Increasing the pace of **heat pump** adoption. By 2030, 766,000 residences and 20 percent of commercial square footage are heated with heat pumps
- Increasing the level of **vehicle electrification** by achieving 370,000 EVs in 2025 and 1.9 million by 2030.
- Reducing energy use and emissions from **heavy-duty vehicles** by switching 10 percent of freight-ton miles to electricity and biofuels by 2030.

SECTOR	POLICIES	***Efficiency, electrification, and clean energy supply policies accelerated in the thermal, transportation, and power sectors***
Power	SMART	1600 MW (AC) of distributed solar by December 31, 2022
	Storage	All ACES Grants and current EDC approved storage projects move forward SMART: 80 MW/200 daily MWh when solar hits 1,600 MW (2020) Total by 2030: 164 MW/496 daily MWh
	RPS and CES	3 percent annual increase for RPS (24,900 GWh of Class I RECs in 2030) Current 2 percent annual increase for CES
	Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Procurements	83D: 9.45 TWh of Clean Energy Imports online by 2023 83C: 400 MW offshore wind online in 2022; 400 MW by 2023; 2,200 MW by 2030 Other: 600 MW offshore wind online by 2024 (RI and CT)
Thermal	Heating System Energy Efficiency	Continue utility EE programs with levels of performance similar to today
	Building Shell Efficiency	Pace of building shell improvements increases to 2 to 2.5 times the current pace, for both existing buildings and new construction
	Electrification (Heat Pumps)	766,000 residences and 20 percent of commercial square footage are heated with heat pumps by 2030
	Industrial Efficiency	Increased EE results in energy use falling 5 percent by 2030 Reduction primarily in use of fuel oil
	Gas switching from oil/propane	Continue at AEO 2018 levels (160,000 by 2030)
	Biofuels and the APS	APS remains at current levels, biofuel target reached
Transportation	Electric Vehicles	370,000 light-duty EVs by 2025 Growth until 1.9 million in fleet by 2030 5 percent of heavy-duty vehicle freight-ton miles switched to electricity by 2030
	Biofuels	5 percent of heavy-duty vehicle freight-ton miles switched to biofuels by 2030
	VMT	68 billion miles driven in 2030, up from 63 billion in 2017

6.5.2 Scenario Takeaways

Increasing the amount of energy efficiency, clean energy supply, and electrified end uses produces a future in which 2030 GHG emissions from all sectors are reduced by 44 relative to 1990. Meanwhile, 2030 energy expenditures in Massachusetts from all sectors are reduced by 27 percent relative to 2018. In this scenario, Massachusetts and the rest of New England will continue to rely on higher cost stored fuels (such as LNG and fuel oil). As a result, the region will continue to be at risk for price spikes and emission increases during severe winter with extended cold events. By 2030, state policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, may reduce but will not eliminate risks to reliability.

6.5.3 Supply Mix

6.5.3.1 Thermal

Improved efficiency reduces residential energy demand by 15 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year. Multifamily buildings are projected to be about 6 percent more efficient than they are today.

Despite improved energy efficiency, continued new construction is expected to increase total commercial thermal demand by 6 percent by 2030. New build and retrofit shells are projected to continue to improve at 0.5 percent per year.

By 2030, 25 percent of residential and commercial buildings that currently heat with oil are instead heated by heat pumps; 10 percent of gas-heated buildings use heat pumps. Between half and two-thirds of homes getting a heating system in 2030 choose a heat pump.

Industrial energy demand is projected to continue to gradually increase. Increased manufacturing is expected to more-than-offset improved energy efficiency, increasing energy demand by 14 percent by 2030. This sector is not modified in this scenario, relative to the Sustained Policies scenario.

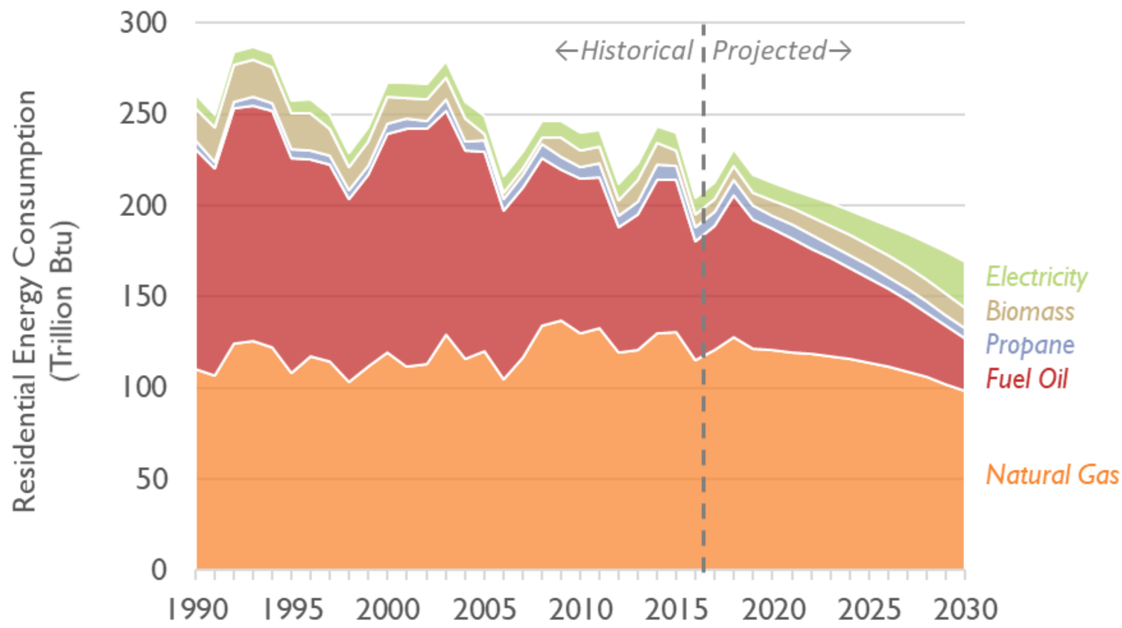


Figure 93. Thermal energy consumption, residential sector

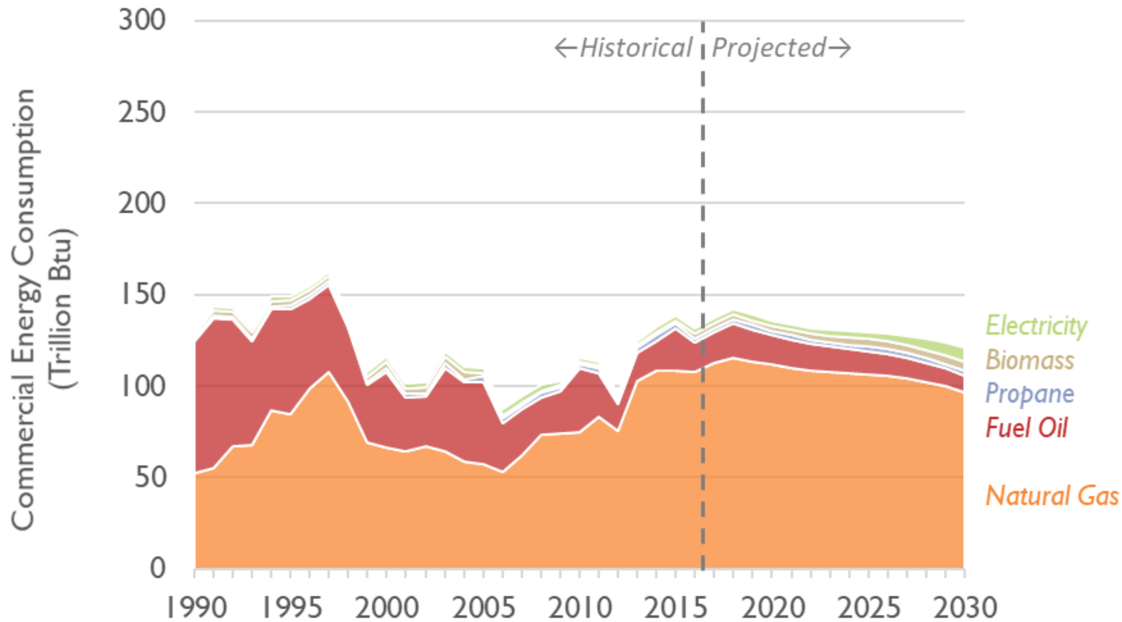


Figure 94. Thermal energy consumption, commercial sector

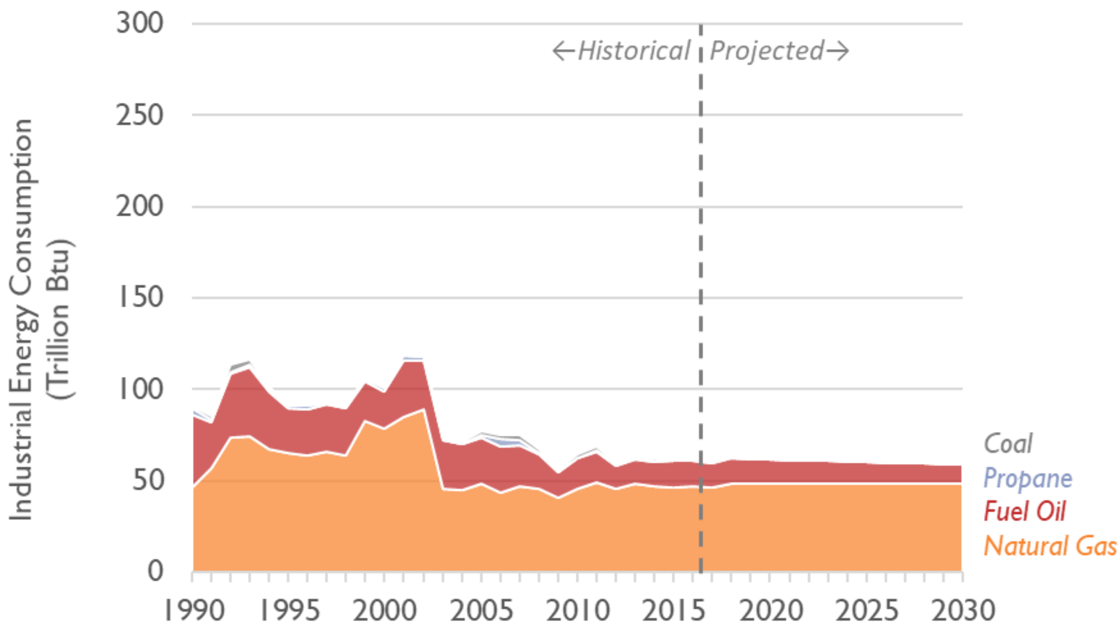


Figure 95. Thermal energy consumption, industrial sector

6.5.3.2 Transportation

While VMT is projected to continue to rise, improved efficiency is expected to reduce fuel consumption. By 2030, CAFE standards are projected to reduce gasoline consumption by 20 percent. Under this scenario, 1.7 million EVs on the road in 2030 reduces gasoline consumption by another 20 percent. By 2030, 6 out of 7 vehicles purchased are EVs.

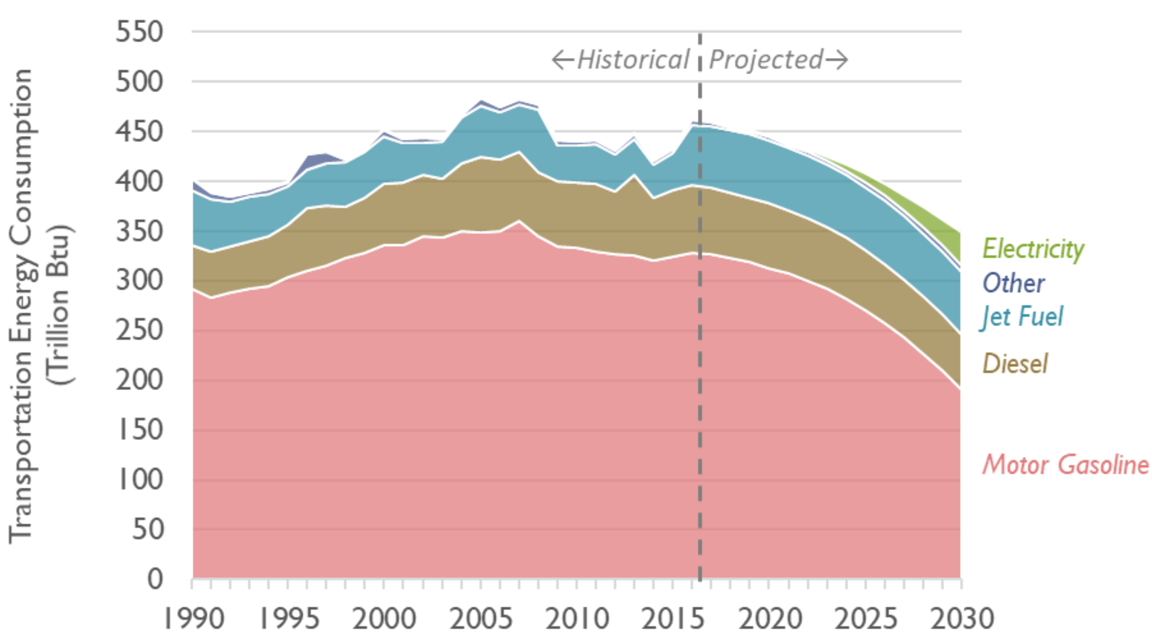


Figure 96. Transportation energy consumption

6.5.3.3 *Power*

By 2030, New England's fuel mix is 27 percent fossil fuel, a 13 percentage point reduction relative to 2018. By 2030, the fuel mix of wind, solar, hydro, and other renewables is 38 percent, a 22 percentage point increase relative to 2018.

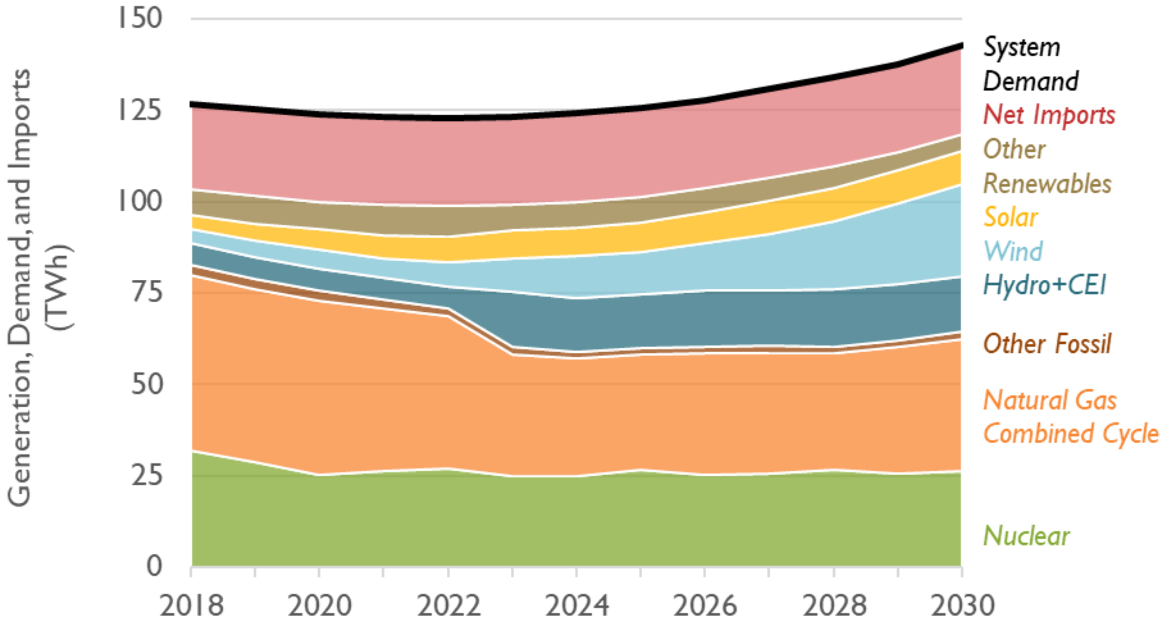


Figure 97. System demand and electricity generation, New England

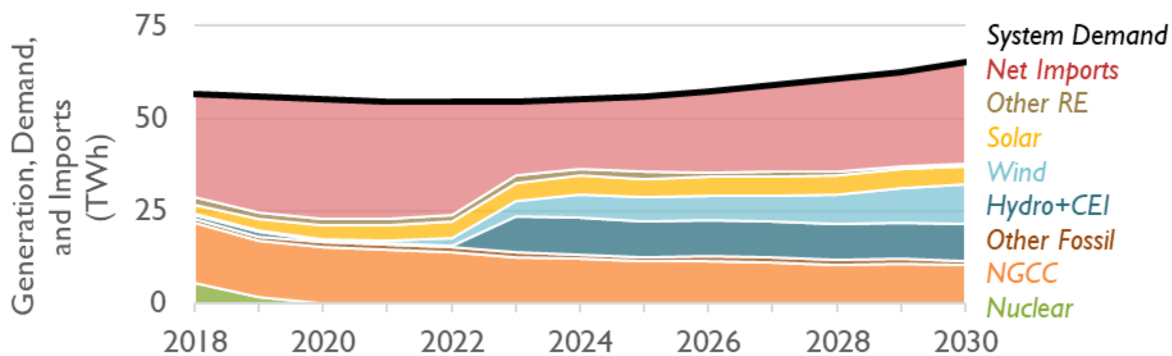


Figure 98. System demand and electricity generation, Massachusetts

6.5.4 Winter Reliability

Under a peak winter day in 2022, New England's power sector is still reliant on a substantial amount of fuel oil in order to reliably supply electricity. By 2025, as the quantity of renewables increases (largely driven by polices incentivizing Clean Energy Imports and offshore wind, as well as an increased requirement for all renewables), the quantity of fuel oil required to supply electricity decreases. On a peak day in 2015, the Commonwealth's natural gas use was 44 percent above the available natural gas delivery capacity, making the region dependent on stored fuels such as LNG and fuel oil. In 2022 on a peak day, this percentage is projected to be reduced, with a peak daily natural gas demand being 5 percent available natural gas delivery capacity. In 2025, this percentage slightly increases to 7 percent.

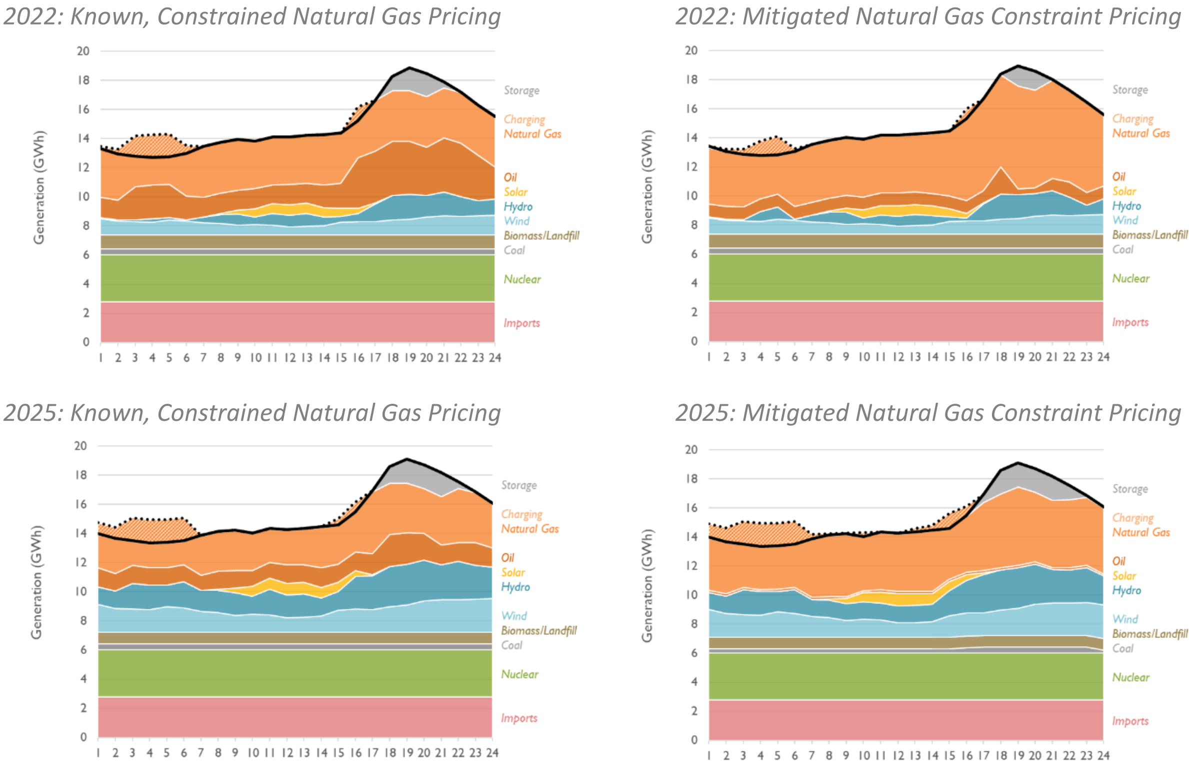


Figure 99. Peak winter day electricity demand and generation, New England

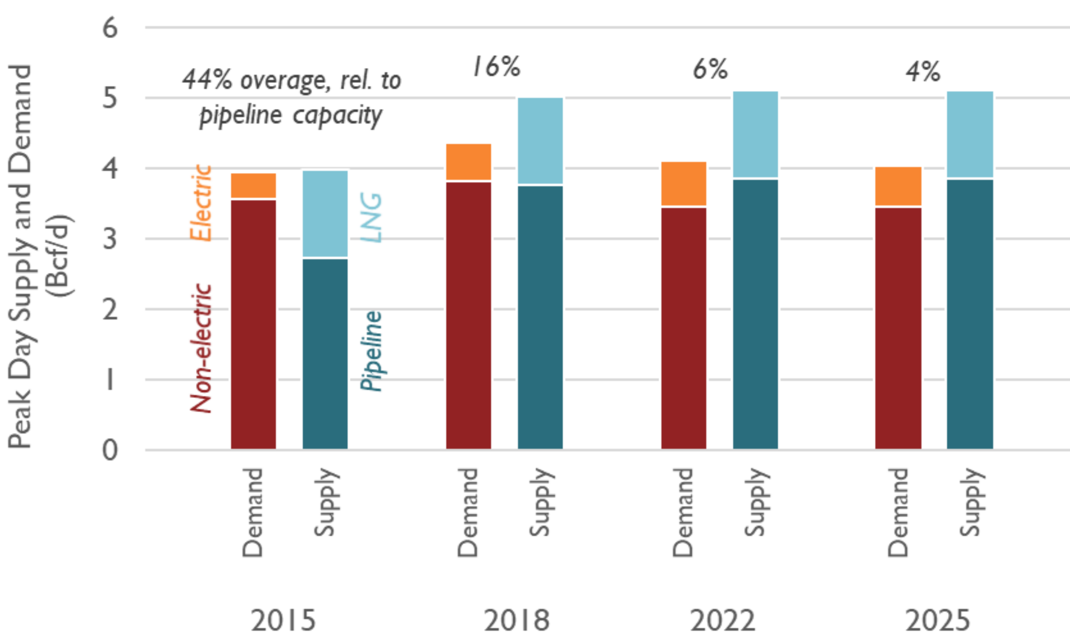


Figure 100. Peak winter day natural gas demand and supply, New England

6.5.5 Costs

In real-dollar terms, residential electricity rates are expected to remain relatively flat through 2030. However, the rate components making up the typical residential electricity rates do change over time as prices for renewable energy credits change and as costs to purchase from the wholesale energy market are replaced with renewable energy procurements.

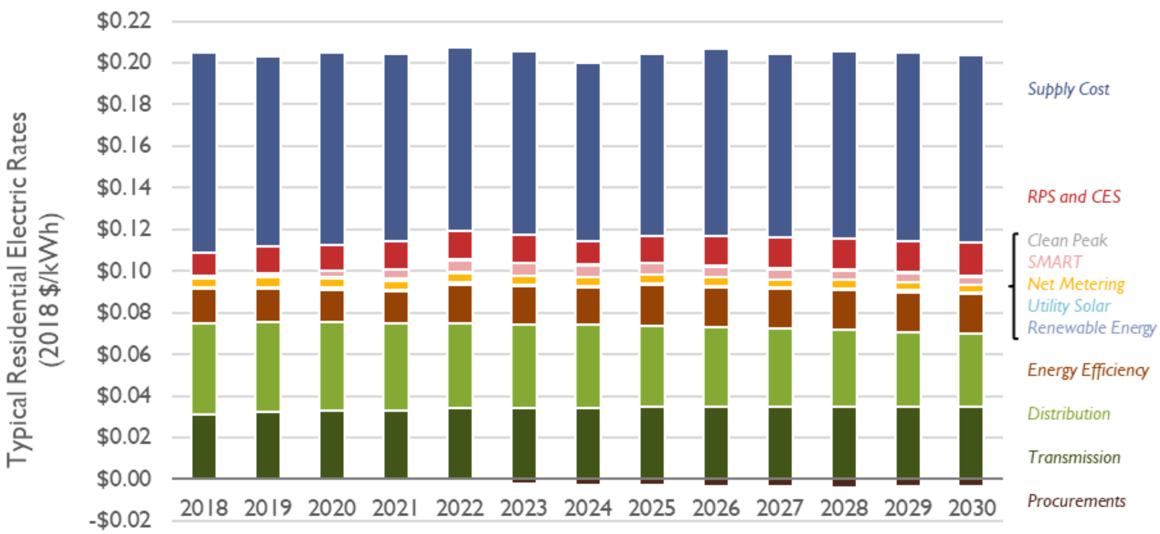


Figure 101. Typical residential electricity rate

By 2030, less than half of all residential customers are expected to use natural gas as the primary fuel for thermal demand, while almost one-quarter of residential customers are expected to rely on heat pumps. Customers relying on natural gas are expected to pay the least in their total energy burden at $283 per month. The state as a whole is expected to spend $0.99 billion to meet residential energy demand, with a plurality of spending on gasoline, at $0.29 billion alone.

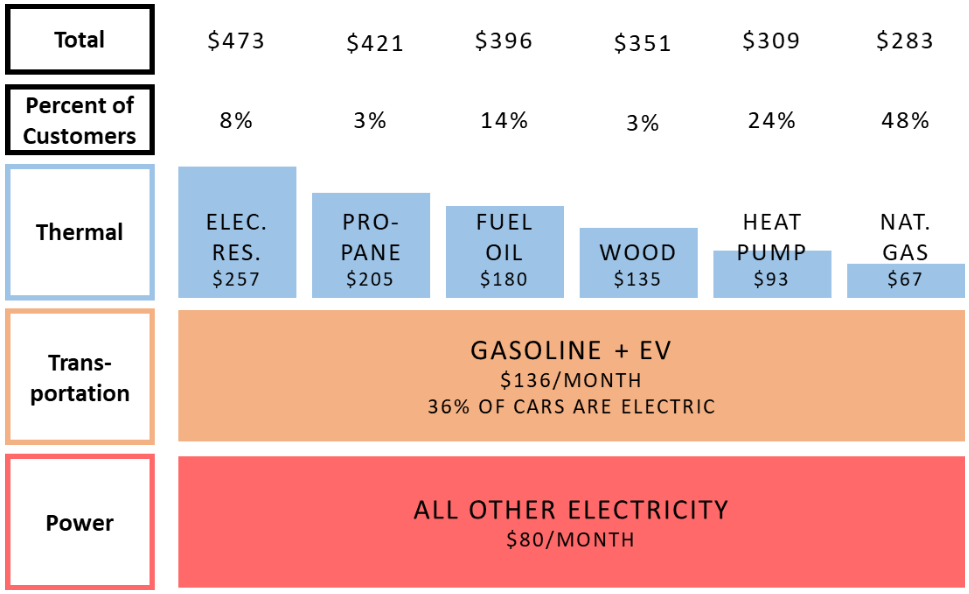


Figure 102. Average monthly energy burden for Massachusetts residents in 2030

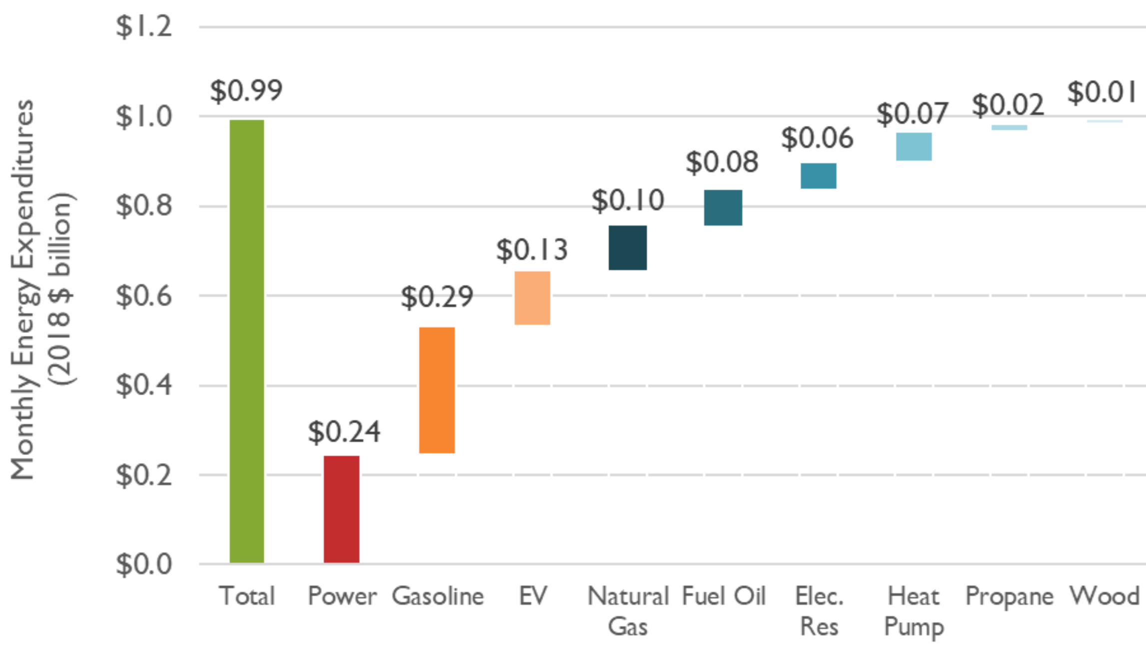


Figure 103. Total state expenditures on energy, 2030

Winter electricity rates are expected to increase slightly between 2022 and 2025, although total expenditures are expected to decrease as a result of increased efficiency, as shown above. In futures in which a severe winter with extended cold events occurs in either 2022 or 2025, winter electricity rates are likely to be higher.

	Average Winter	Severe Winter with Extended Cold: Constrained Natural Gas Pricing	Severe Winter with Extended Cold: Mitigated Natural Gas Constraint Pricing
2022	$0.211	$0.233	$0.228
2025	$0.239	$0.259	$0.241

Table 15. Annual residential electricity rates in Massachusetts (2018 $/kWh)

6.5.6 Emissions

In 2030, this scenario achieves a reduction in all-sector GHG emissions of 44 percent relative to 1990 emissions. This represents a reduction in GHG emissions of 31 percent relative to today, and a reduction of 9 percentage points relative to 2030 in the Sustained Polices scenario.

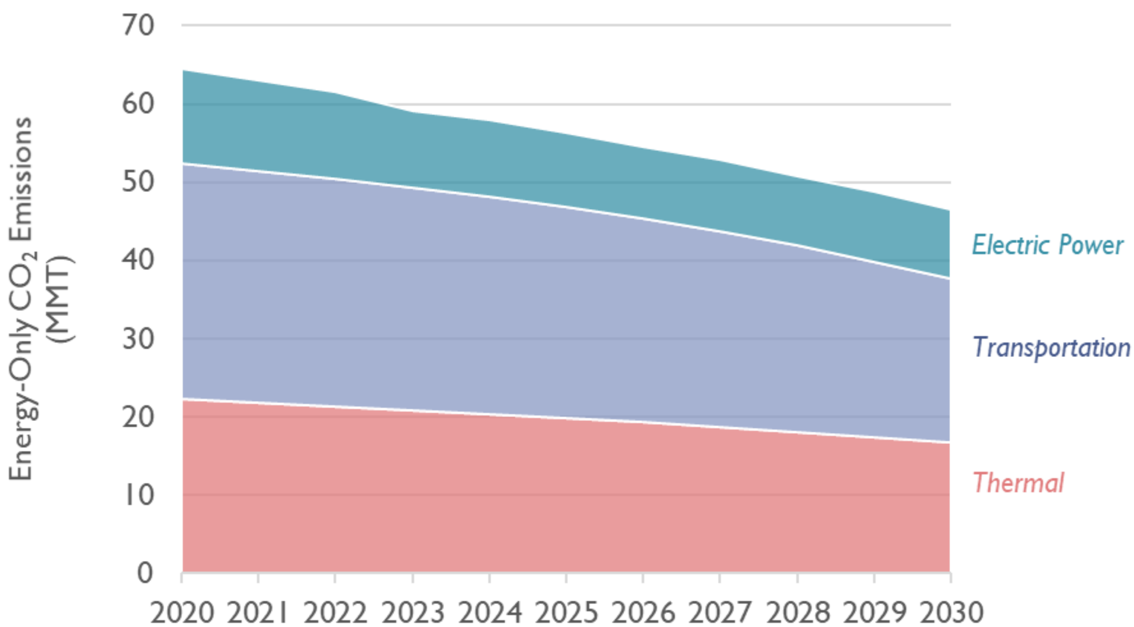


Figure 104. CO_2 emissions from energy

Winter CO_2 emissions from the thermal and power sector are expected to decrease between 2022 and 2025. In futures in which a severe winter with extended cold occurs in either 2022 or 2025, winter electricity rates are likely to be higher.

	Average 20-Day Winter Period	Severe Winter with Extended Cold: Constrained Natural Gas Pricing	Severe Winter with Extended Cold: Mitigated Natural Gas Constraint Pricing
2022	3.8	4.3	3.7
2025	3.4	3.8	3.8

Table 16. Thermal and power sector CO_2 emissions under a 20-day winter event (million metric tons CO_2

7 Comparing the Scenarios

				Sustained Policies	High Electrification[181]	High Renewables	High Electrification + High Renewables	Aggressive Policies
Costs	2030 Electricity	Average Residential Retail Rate	*2018 $/kWh*	$0.20	$0.21	$0.22	$0.21	$0.20
		Total Residential non-Thermal, non-Transportation Electricity Spending	*2018 $/month*	$79	$84	$83	$82	$80
		Total Residential non-Thermal, non-Transportation Electricity Spending	*2018 $ Billion*	$2.9	$3.1	$3.0	$3.0	$2.9
	2022	Average Residential Retail Rate, Average winter	*2018 $/kWh*	$0.22			$0.22	$0.21
		Average Annual Residential Retail Rate With Extended Cold - Constrained Natural Gas Pricing	*2018 $/kWh*	$0.24			$0.24	$0.23
		Average Annual Residential Retail Rate With Extended Cold - - Mitigated Natural Gas Constraint Pricing	*2018 $/kWh*	$0.23			$0.23	$0.23
	2025	Average Annual Residential Retail Rate, Average winter	*2018 $/kWh*	$0.21			$0.22	$0.24
		Average Annual Residential Retail Rate With Extended Cold - Constrained Natural Gas Pricing	*2018 $/kWh*	$0.23			$0.24	$0.26
		Average Annual Residential Retail Rate With Extended Cold – Mitigated Natural Gas Constraint Pricing	*2018 $/kWh*	$0.22			$0.22	$0.24
	2030 Thermal Costs	Average Residential with Natural Gas Heat Spending	*2018 $/month*	$73	$73	$73	$73	$67
		Average Residential with Fuel Oil Heat Spending	*2018 $/month*	$197	$201	$198	$200	$180
		Average Residential with Electric Resistance Heat Spending	*2018 $/month*	$273	$301	$287	$293	$257
		Average Residential with Air Source Heat Pump Spending	*2018 $/month*	$123	$106	$128	$103	$93
		Average Residential with Propane Heat Spending	*2018 $/month*	$224	$227	$224	$227	$205
		Average Residential with Wood Heat Spending	*2018 $/month*	$152	$149	$158	$145	$135

[181] For the individual High Renewables and the High Electrification scenarios, no Winter Peak analysis was completed. It was only completed for the combined High Electrification and Renewables Scenario.

		Total Residential Thermal Spending	*2018 $ Billion*	$4.8	$4.6	$4.9	$4.6	$4.0
	2030 Light Duty Transportation	Total State LDV EV Electricity Cost	*2018 $/month*	$113	$120	$119	$117	$114
		Total State LDV Gasoline Cost	*2018 $/month*	$148	$148	$148	$148	$148
		Total Light Duty Vehicle Fuel Costs (EV and Gasoline)	*2018 $ Billion*	$7.1	$6.7	$7.2	$6.6	$6.4
Emissions	2030	Electric Sector Emissions	*$MMTCO_2$*	9.2	10.0	8.2	8.9	8.9
		Thermal Sector Emissions	*$MMTCO_2$*	23.2	21.6	23.2	21.6	20.9
		Transportation Sector Emissions	*$MMTCO_2$*	22.9	21.0	22.9	21.0	16.8
		Total Emissions (Inventory)	*$MMTCO_2$*	61.3	58.7	60.3	57.5	52.6
		Percent Reduction Below 1990	*%*	-35%	-38%	-36%	-39%	-44%
	2022	Total Emissions (Inventory)	*$MMTCO_2$*	69.1	69.2	68.9	68.9	67.6
		Incremental Emissions from an Extended Cold Event - Constrained Natural Gas Pricing	*$MMTCO_2$*	0.5			0.5	0.5
		Total Emissions from an Extended Cold - Constrained Natural Gas Pricing	*$MMTCO_2$*	69.7			69.4	68.1
		Incremental Emissions from an Extended Cold – Mitigated Natural Gas Constraint Pricing	*$MMTCO_2$*	0.5			0.4	-0.1
		Total Emissions from a an Extended Cold - Mitigated Natural Gas Constraint Pricing	*$MMTCO_2$*	69.6			69.3	67.4
	2025	Total Emissions (Inventory)	*$MMTCO_2$*	65.9	65.3	65.3	64.7	62.3
		Incremental Emissions from an Extended Cold - Constrained Natural Gas Pricing	*$MMTCO_2$*	0.5			0.5	0.4
		Total Emissions from an Extended Cold - Constrained Natural Gas Pricing	*$MMTCO_2$*	66.4			65.2	62.7
		Incremental Emissions from an Extended Cold - Mitigated Natural Gas Constraint Pricing	*$MMTCO_2$*	0.4			0.5	0.4
		Total Emissions from an Extended Cold - Mitigated Natural Gas Constraint Pricing	*$MMTCO_2$*	66.4			65.2	62.7
Reliability	2022	Winter Peak: Power Sector Gas Use	*Bcf/day*	0.65			0.65	0.65
		Winter Peak: Non-Power Sector Gas Use	*Bcf/day*	3.54			3.54	3.46
		Winter Peak: Total Gas Use	*Bcf/day*	4.19			4.19	4.11
		Pipeline Capacity	*Bcf/day*	3.86	3.86	3.86	3.86	3.86
		LNG Capacity	*Bcf/day*	1.25	1.25	1.25	1.25	1.25
	2025	Winter Peak: Power Sector Gas Use	*Bcf/day*	0.45			0.54	0.57
		Winter Peak: Non-Power Sector Gas Use	*Bcf/day*	3.64			3.62	3.46
		Winter Peak: Total Gas Use	*Bcf/day*	4.09			4.16	4.03
		Pipeline Capacity – New England	*Bcf/day*	3.86	3.86	3.86	3.86	3.86
		LNG Capacity	*Bcf/day*	1.25	1.25	1.25	1.25	1.25

8 Key Findings & Take-Aways

8.1 Reducing Emissions

- **The greatest amount of emissions reductions by 2030 are achieved by combining increased use of clean energy in all sectors while simultaneously decreasing overall energy consumption.**

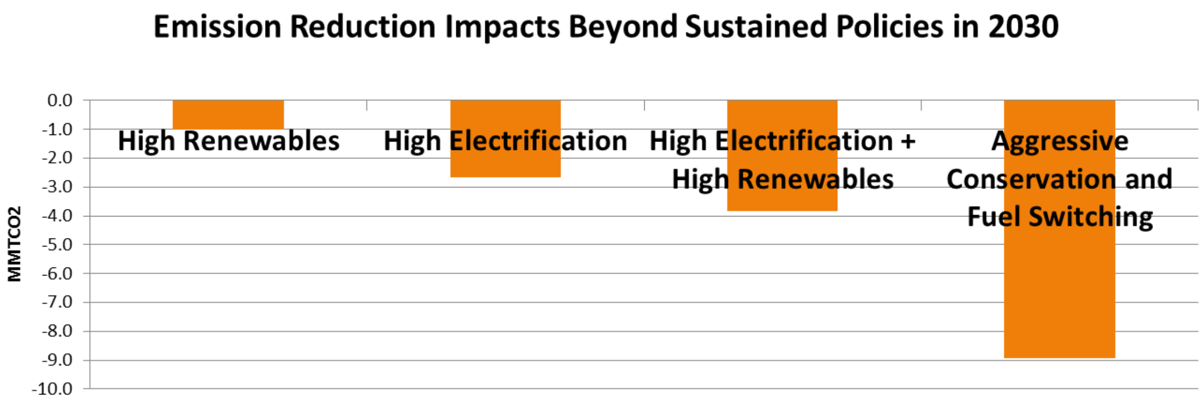


Figure 105: Model Run Emission Results

Figure 105 shows the relative emission reductions associated with each scenario from the Sustained Policies model results.[182] The results are emission reduction numbers assuming average weather. Emission reductions can vary plus or minus 1 $MMTCO_2$ from an average due to many variables including mild or severe weather. Additionally, these results do not correspond to any specific policy pathway to a GWSA emissions limit. Instead, they represent emission reductions associated with policy outcomes or energy futures. The combined Aggressive Conservation and Fuel Switching scenario has the greatest emission reductions, reflecting a reduction in 2030 emissions by 9 $MMTCO_2$ relative to the Sustained Policies case and a 44 percent reduction below 1990 levels, whereas the High Electrification and Renewables Scenario reduces 2030 emissions by less than 4 $MMTCO_2$ relative to the Sustained Policies case and a 39 percent reduction below 1990 levels. The High Renewables and High Electrification scenario reflects aggressive assumptions for fuel switching and renewable electricity, but even with increased levels of adoption rates of electric vehicles, heat pumps, and renewable electric generation deployment, progress is limited by the customer choice and technology turnover. Therefore, to achieve emissions reductions near or at the higher end of the range, i.e. 45 percent below 1990 levels it is necessary to not only increase supply of clean energy but also use less energy in each sector, particularly in the thermal and transportation sectors. Building efficiency, increasing the percentage of vehicle miles

[182] Emission results from modeling analysis provide only energy associated emissions. To approximate the inventory results, an additional 6$MMTCO_2$ were added to reflect average non-energy sector annual emissions

traveled (VMT) by electric vehicles, and peak demand reduction, could reduce the reliance on fossil fuels while we transition to cleaner sources of energy.

- **Focusing clean energy policies primarily on the electric sector has diminishing returns going forward, increases rates with only modest decreases in GHG emissions**

Emission reductions since 1990 have been achieved primarily in the electric sector, and policies in place will accelerate that progress. In the Sustained Policies scenario, Massachusetts significantly increases clean energy through the implementation of new contracts for hydroelectric and offshore wind power, as well as expected increases in solar generation from the SMART program. In the High Renewables Scenario, even with an additional increase of 50 percent more clean electricity in 2030 over the Sustained Policy Scenario, the economy wide reduction in emissions reaches just an additional 1 $MMTCO_2$ reduction by 2030 or only 36 percent below 1990 levels. To achieve additional reductions in emissions, changes must be made in the way energy is used in the thermal and transportation sectors which both dominate the state's fossil fuel use and are where demand is currently met overwhelmingly by fossil fuels.

- **Electrifying the thermal and transportation sector will leverage investments made in a clean electric grid, both reducing emissions and lowering cost**

However, cleaning electric supply provides benefits when that supply is used to meet a greater portion of the Commonwealth's transportation and thermal sector demand. Increasing electrification in the thermal and transportation sectors achieves greater emission reductions than increasing renewable supply alone, as highlighted in Table 17. This is because switching customers from the fossil fuel-dominated thermal and transportation sectors to electric power for space conditioning and travel allows for more customers to take advantage of current —and increasing supplies— of clean electricity. Electrification of the thermal and transportation sectors will allow the Commonwealth to offset high-emitting and costly fuels such as fuel oil and gasoline with efficient heat pumps and EVs. As these customers are added to the electric sector, incremental electric demand is small due to the efficiency of the new technologies and is projected to be met by lower-emitting natural gas. Emission reductions are expanded when increased clean energy in the electric sector is combined with increased electric use by the thermal and transportation sectors. With the addition of clean electricity, incremental new demand is met by clean sources and there is limited growth of fossil fuel generation.

Scenario	Emission Reduction $MMTCO_2$ Below Sustained Policies
High Renewables	-1.0
High Electrification	-2.7
High Electrification + High Renewables	-3.8

Table 17: Emission Reduction Comparison

- **Improving building envelope efficiency decreases emissions and costs in the thermal sector, since a majority of thermal conditioning uses emit fossil fuels.**

Even with aggressive electrification, 93 percent of the thermal sector consumption is met through fossil fuels in 2030 in the High Electrification scenario. Electrification of the thermal sector is limited by the rate of turnover in customers' heating systems. Building shell improvements increase the emission reductions in the thermal sector beyond what is feasible from equipment turnover alone. The value of improvements to building shell efficiency is best seen in the commercial sector thermal load: in the Sustained Policies scenario, thermal sector consumption increases over time due to significant commercial sector growth. However, in the Aggressive Conservation and Fuel Switching scenario, overall thermal consumption in the commercial sector decreases due to improved building shell efficiencies, especially in new commercial buildings (Figure 106). There are potentially more opportunities in commercial building shell improvement (versus residential building shell improvements) as new construction plays a larger role in the commercial sector and it is easier to build a new building with an efficient building shell than it is to retrofit an existing building.

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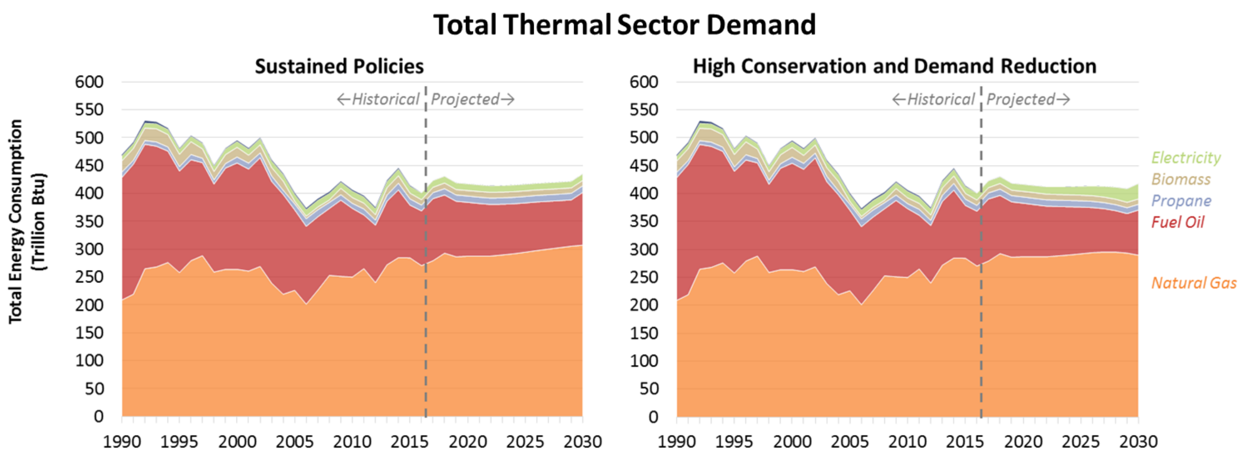

Figure 106: Thermal Sector Demand Comparison

- **Alternative fuels, such as biofuels, assist in the transition to cleaner heating and transportation.**

Biomass is utilized in the Sustained Polices scenario as part of the Alternative Portfolio Standard, which incentivizes the use of renewable heating fuels. This allows for the reduction of cost and emissions for those customers that do not have access to lower emission fuels such as natural gas for heating. One of the challenges of reducing emissions in the thermal sector is that heating technologies have long useful lives, and are typically not replaced until the end of their useful lives. Frequently, consumers do not replace heating technologies until the equipment fails, limiting the consumer's choices for replacement. Increasing the amount of biofuel used in place of oil in existing equipment will reduce emissions and cost for consumers without necessitating equipment replacement. The Aggressive Conservation and Fuel Switching scenario assumes an increase in the amount of biofuel in the heating oil mix and the use of biofuels for freight vehicles that might not be suited for electrification. This allows for additional emission reductions over electrification alone, which is limited by technology turnover.

Additionally, the use of clean or "green" gas would allow the use of existing natural gas distribution systems and would increase the rate at which customers could switch to cleaner thermal fuels. This would reduce the challenge of customer choice and heating system turnover as a limit to switching from fossil fuels. The Aggressive Conservation and Fuel Switching scenario assumes there is available biofuel supply to allow for 5 percent of heavy-duty vehicle freight-ton miles switching to biofuels by 2030 but there are still challenges to implement a green gas program.

8.2 Electric Rates

- **All scenarios modeled show lower retail electric rates in 2030 than the U.S. Energy Information Agency (EIA) projections for 2030, primarily due to the cost-effective large-scale procurements coming on-line in the mid-2020s**

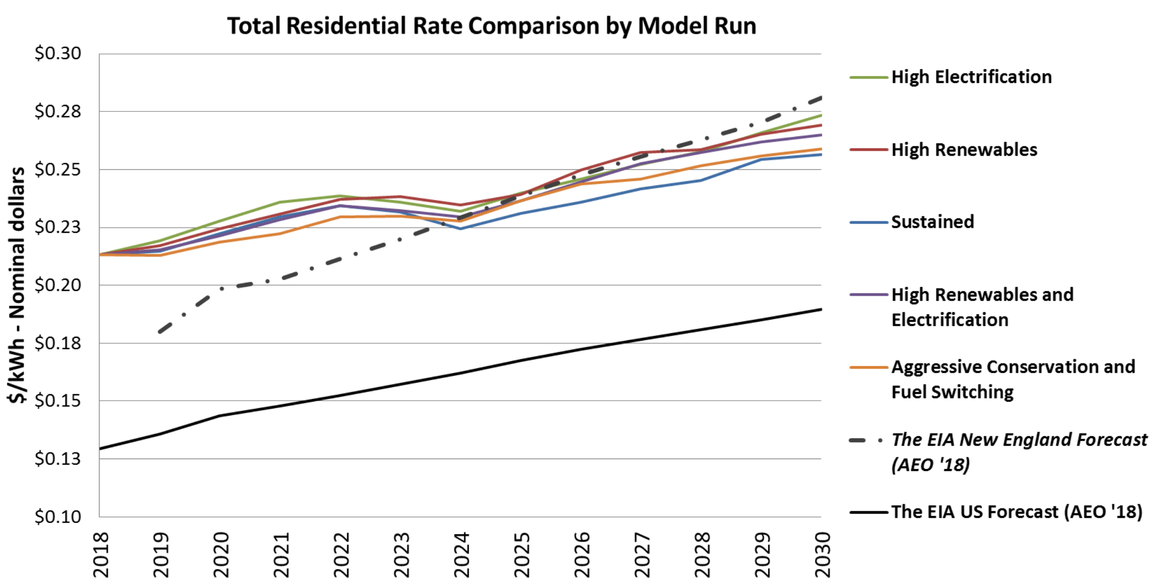

Figure 107: Residential Retail Rate Comparison

The residential retail rate forecasted for each scenario was lower than the projected rate for New England from the Energy Information Agency's 2018 Annual Energy Outlook starting in 2023 (Figure 107) (note that all projections feature rate increases associated with inflation). Currently, Massachusetts has a higher rate than the New England average. All scenarios show a significant dip in the residential retail rate that correlates to the commercial operation of the hydroelectric and offshore wind procurements in 2023. These cost-effective procurements help Massachusetts comply with the RPS and CES at lower cost than projected. In addition, the 83D and 83C procurements will increase regional energy supply and thereby reduce energy costs for the entire region.

- **However, all scenarios show higher electric rates for 2030 than the EIA US Forecast, and all show higher electric rates as compared to the Sustained Policies scenario.**

Each modeled scenario shows additional costs in the supply and/or delivery portions of the retail electric rate. This is caused by an increase in both policy costs, such as the RPS or CES with high renewables assumptions and in wholesale energy costs when electric demand increases. The lowest rates for the Aggressive Conservation and Fuel Switching are due to a reduction in demand for electricity, particularly during peak periods. This lower rate lowers the energy burden on commercial and industrial customers in Massachusetts.

- **Fuel switching from expensive fuels for heating such as electric resistance heat, propane and fuel oil to lower cost fuels, electric air source heat pumps and biofuels can lower an average consumer's monthly energy bills**

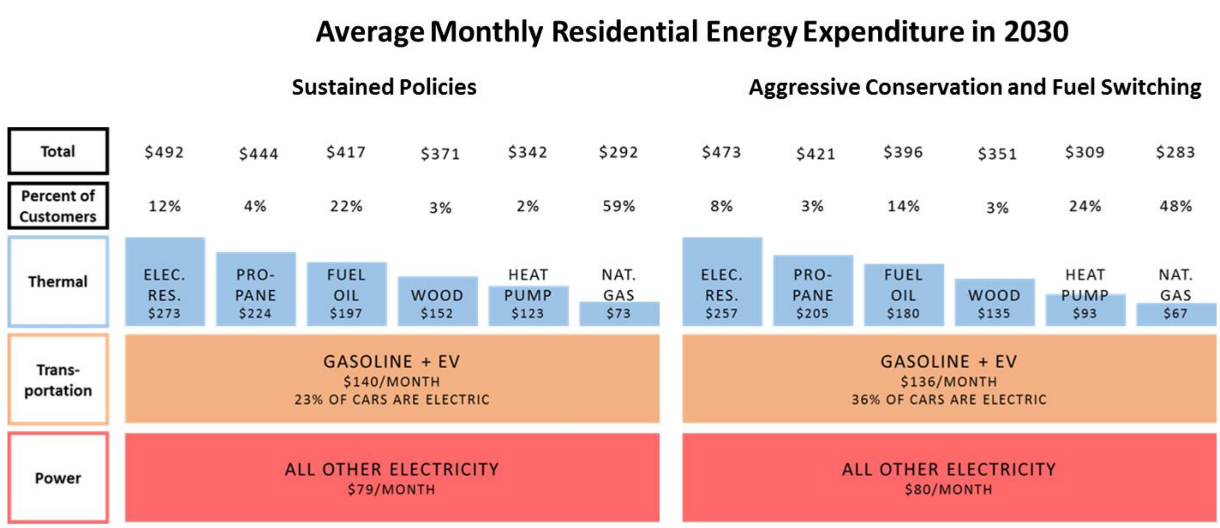

Figure 108: Average Monthly Residential Energy Expenditure (2018$) in 2030 - By Heating Class

Customers that switch from expensive thermal systems see savings in all scenarios. For example, a fuel oil customer switching to an air source heat pump could save almost $900 annually in 2030 in the Sustained Policy scenario. In addition, combining High Renewables with High Electrification reduces overall energy expenditures as more consumers switch from more expensive fuels such as fuel oil and gasoline. In the High Renewables with High Electrification scenario, monthly thermal expenditures for the state as a whole are 5 percent less and transportation sector expenditures are 2 percent less than in the Sustained Policies scenarios (Figure 108).

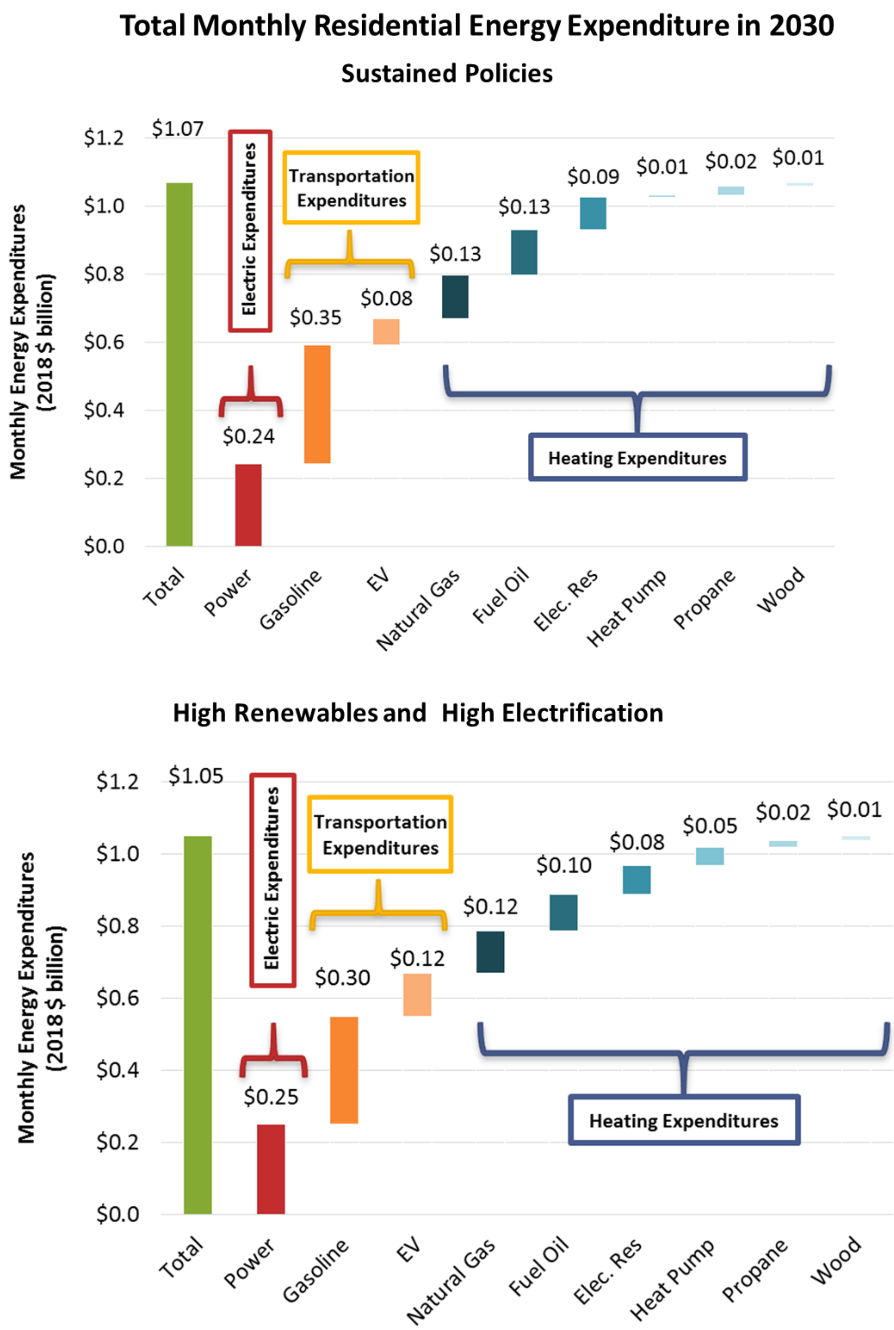

Figure 109: Total Monthly Residential Energy Expenditure in 2030 Comparison

- **Even in scenarios with higher electric rates than the Sustained Policies scenario, total monthly expenditures for energy are decreased.**

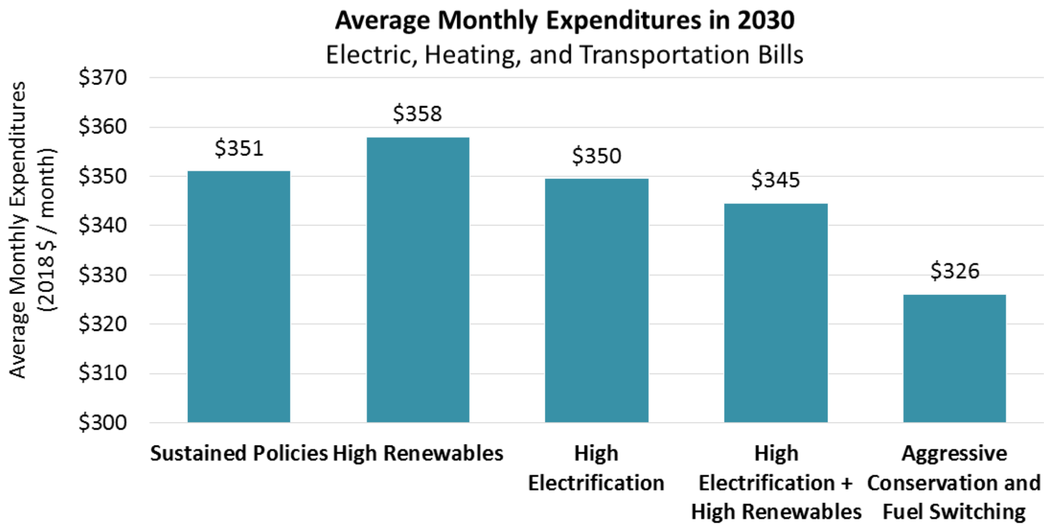

Figure 110: Average Monthly Expenditures

Figure 110 shows the average monthly expenditure for residential ratepayers in Massachusetts for each scenario. All of the policy scenarios reduce winter energy costs from various combinations of reducing demand and/or reduced electric rates. Again, the combined scenario of Aggressive Conservation and Fuel Switching is found to provide the most reduction in costs of any scenario due to (a) reduced consumption in the thermal sector and (b) reduced electric rates associated with peak demand reduction. The reduction of thermal demand not only reduces winter heating expenditures but also improves winter reliability, allowing the electric sector to mitigate its reliance on existing natural gas supply infrastructure. The Aggressive Conservation and Fuel Switching scenario also includes the largest switch to more efficient EVs, lowering the overall transportation costs for the state.

- **The lowest residential retail costs can be achieved by reducing peak demand coupled with significant efficiency and conservation in the thermal sector. Increased policy charges within the retail electric rates associated with expanded policies can be offset in part by bill reductions due to decreased distribution and transmission costs.**

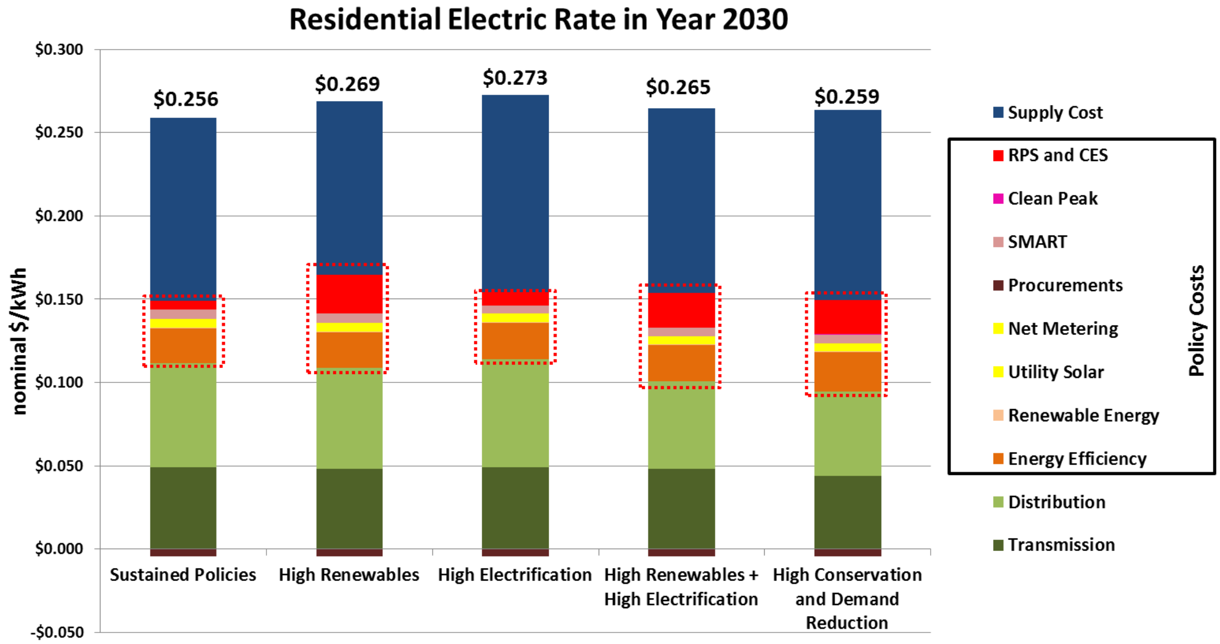

Figure 111: Residential Retail Rate Breakdown in 2030 Comparison

(Nominal $)	Sustained Policies	High Renewables	High Electrification	High Renewables + High Electrification	Aggressive Conservation and Fuel Switching
Supply Cost	$0.110	$0.104	$0.118	$0.111	$0.112
Distribution and Transmission Cost	$0.111	$0.109	$0.114	$0.100	$0.094
Policy Costs	$0.033	$0.051	$0.036	$0.049	$0.050
Residential Retail Rate	**$0.256**	**$0.269**	**$0.273**	**$0.265**	**$0.259**
Percent Policy Costs	12.8%	19.0%	13.1%	18.4%	19.5%

Table 18: Residential Retail Rate Breakdown in 2030 Comparison

Achieving higher levels of clean and efficient energy will likely require additional programs and incentives that will add to the charges on customer bills. However, as seen in Figure 111, even though these policy costs increase as a percentage of the total residential rate, rate reductions caused by policy implementation can offset the increase in part. Of the increased policies scenarios, the Aggressive Conservation and Fuel Switching rate is the lowest despite having the largest percent policy costs (19.5 percent) (Table 18). In the Sustained Policies scenario, policy costs are 3.3 cents/kwh while the Aggressive Conservation and Fuel Switching scenario policy costs are 5 cents/kWh. If future transmission and distribution costs are managed, as described below, additional savings could mitigate the policy cost increases.

- **Reducing peak electric demand lowers both supply costs and the distribution and transmission charges on the electric bill.**

Increased electrification in the transportation and thermal sectors may increase electric load and may increase peak load depending on the timing of energy use, especially the charging of energy storage and EVs. Satisfying demand during peak load times can be one of the most expensive parts of energy cost for both supply and delivery. For energy only, from 2013-2015, the top 10 percent of peak hours accounted for 40 percent ($3 billion) of the Commonwealth's spend on electricity.[183] As for delivery, transmission and distribution infrastructure must be sized to meet the absolute system peak and must be operated to maintain reliability as demand fluctuates throughout the day. The addition of the Clean Peak Standard and technologies, such as storage, that shift peaks and flattens load. Flattened load enables generators to run more efficiently, which reduces costs and emissions. Further, it reduces the need for future investments in transmission and distribution infrastructure, which help to balance any costs from implementing future policies. This reduced cost is approximated in the Aggressive Conservation and Fuel Switching scenario as a reduction in the delivery charges, although the full impact of increasing system efficiency is difficult to calculate. As the impacts of EVs, heat pumps, and behind-the-meter solar increase, the benefits of flattening load become increasingly important.

- **A Clean Peak Standard would provide benefits in all scenarios but the design of the Clean Peak Standard policy will require consideration of wholesale energy pricing and the changing nature of peak demand.**

A significant amount of energy storage was considered as part of the Aggressive Conservation and Fuel Switching scenario. Modeling significant amounts of energy storage is challenging as the model dispatches assets according to standard market structure and the growth of energy storage will likely be supported by policy-driven pricing signals such as a Clean Peak Standard incentive. These complexities demonstrate the need for considering the variability of peaks as a clean peak standard is established. All scenarios demonstrated the correlations between peak electric demands and higher than average prices and emissions, which an effective and flexible clean peak standard would help alleviate.

- **As levels of electrification increase, there is greater importance in managing and incenting the best times for charging of electric vehicles and energy storage while considering the demand associated with electric thermal load and the supply of clean energy.**

When modeling high penetrations of electric vehicles, this study initially assumed that all EVs would charge overnight. This assumption resulted in a new overnight peak. Most EVs only require 2 hours of charging to meet their daily commutes, so all EVs charging simultaneously and at full power is unlikely. As a result, the model assumptions were modified to examine a smoother charging profile across EVs

[183] Mass DOER, *State of Charge*, 2016; page ii.

with most charging occurring overnight and moderate charging occurring mid-day, when Massachusetts residents are at work or school. The smoothed EV charging profile mitigated the artificial overnight peak and enabled the addition of the EVs without substantially impacting peak demands and system ramp rates.

These model results demonstrate that policies to monitor and incentivize EV charging need to consider the impact of establishing discrete times to charge, and need to avoid the inadvertent creation of new system peaks. EVs should not all be incentivized to begin charging at the same time, nor should they be incentivized to all charge at full power if unnecessary. EV charging should be coordinated with electric system demand. Policies should be flexible to shift as demand profiles shift, such as from increased electric thermal load.

8.3 Winter Reliability and Costs

- **In all scenarios, the demand for natural gas on a peak winter day forces the electric sector to rely on liquefied natural gas (LNG) or other stored fuels such as oil for generation, which puts the region at risk for price spikes and emission increases during extended cold weather events.**

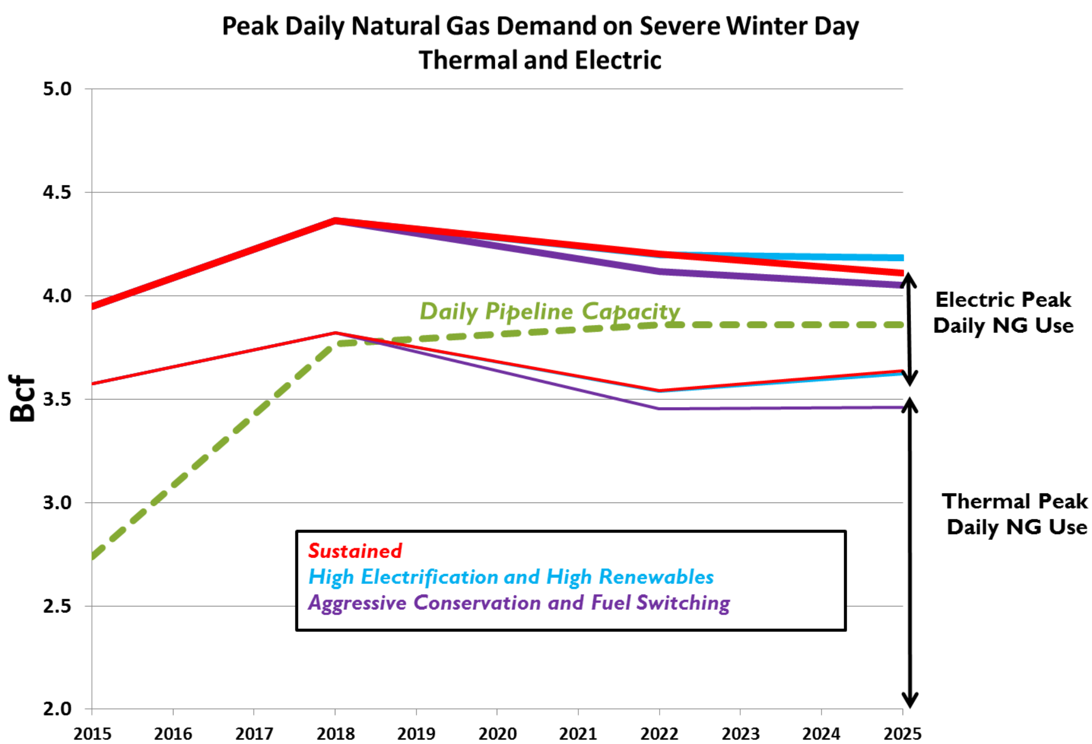

Figure 112: Peak Daily Natural Gas Demand on an Extremely Cold Day - Thermal and Electric

Figure 112 shows the total natural gas demand from both the thermal and electric sectors on a peak winter day currently and in 2022 and 2025. As is the case today, in all scenarios, the total demand exceeds the pipeline capacity, meaning the region will continue to rely on stored fuels during extreme winter conditions. Additional LNG storage and supplies could alleviate these constraints, particularly in the short term, but are not always available due to the more favorable economics associated with exporting domestic supplies rather than consuming them in the United States and delivery restrictions associated with the Jones Act.

While New England's LNG infrastructure is sufficient to meet peak winter day consumption requirements, the refueling of the LNG storage tanks requires substantial logistics and forward planning such as long-term contracts entered into before winter starts. As such, there is a potential reliability concern if the LNG infrastructure is not sufficiently filled and scheduled for refilling during an extended cold weather event. Due to LNG market and logistics structures, there are risks associated with the reliance on timely LNG delivery outside of prearranged contracts.

- **In all scenarios, there is sufficient electric generation capacity to meet the needs of any increased electrification**.

While the model is constrained to not endogenously retire power plants, the model is free to build additional conventional capacity as needed for reliability and as is cost-effective. However, in all scenarios, the model does not construct additional conventional capacity.

- **State policies that reduce natural gas demand, such as increasing clean energy supply and reducing thermal sector demand, reduce but do not eliminate reliance on oil and LNG for electric generation.**

In all policy scenarios, natural gas demand decreases by 2022 due to the increased renewable generation from recent procurements and from additional efficiency gains. The Aggressive Conservation and Fuel Switching scenario shows the greatest reduction in total natural gas demand supported by a significant decrease in the thermal demand on a winter day due to increased electrification and building shell efficiency. However, even significant increases in all mechanisms to reduce natural gas demand; conservation, fuel switching, and additional clean electricity generation; are not enough to eliminate the risk of constrained and expensive natural gas supplies for electricity.

- **Even in cases with aggressive clean and efficient energy policies, reducing the cost of natural gas through mitigating natural gas constraints reduces the reliance on stored fuel oil, reducing emissions during winter events and keeps residential rate increases lower in subsequent years.**

An additional peak winter day analysis was completed where the price of natural gas was reduced from a constrained price ($27/Mcf) to a price closer to regional average natural gas price ($12/Mcf). This reflects mitigation but not complete elimination of a natural gas constraint on a winter peak day. Because the mitigated natural gas constraint price is higher than the natural gas used in the model for average winter weather, this mitigation pricing impacts only the winter peak day results. This price reduction could be achieved through a portfolio of actions including increasing the amount of stored LNG or reducing New England natural gas demand. This lower price for natural gas in the electric sector reduces the amount of oil utilized on a peak day which causes a reduction in cost[184] and emissions. Note that this analysis did not quantify the cost impacts of securing contracts for LNG—proposals would need to undergo rigorous cost-effectiveness modeling to ensure that these projects result in net benefits to ratepayers and do not interfere with the Commonwealth's long-term obligation to reduce GHG emissions under the GWSA. Figure 113 shows that additional supply in all scenarios decreases the amount of oil burned on a peak winter day over scenarios with existing gas infrastructure. This reduction of oil use resulting from additional natural gas supply is seen in both 2022 and 2025.

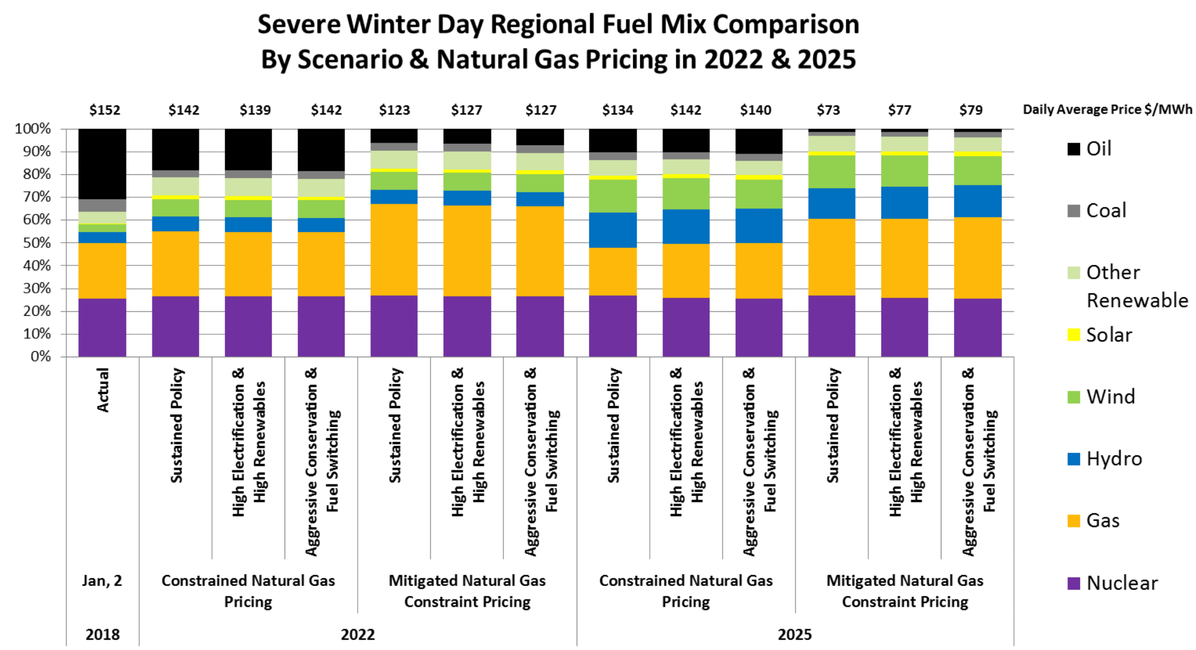

Figure 113: Extremely Cold Day Fuel Mix Comparison

- **The addition of large amounts of hydroelectricity and offshore wind generation that are available in the winter from the procurements will lower costs and emissions, as well as improve winter reliability when they come on-line in 2023.**

New clean electricity, especially from those resources that provide energy during the winter, benefits consumers by lowering the use of expensive, carbon-intensive fuels such as oil and reducing our overall reliance on natural gas for electric generation. The procurements of 9.45 TWh of hydroelectricity and 1600 MW of offshore wind generation, authorized in the 2016 Energy Diversity Act, come online between 2023 and 2024. This energy, especially clean energy that is available in the winter, helps contribute to significantly reduced prices during a winter event when paired with additional natural gas supply to the electric sector. As shown in Figure 113, in 2022, the addition of natural gas supply to the fuel mix decreases average energy costs on a winter day only 11-13 percent. In 2025, after the increase

[184] As the method of mitigating the natural gas constraint to the region is not pre-determined as part of this analysis and may be a combination of multiple policies, the cost of mitigating the constraint is not included in the rate analysis

in wind and hydroelectric energy, the addition of natural gas supply to the fuel mix decreases average energy costs 45 percent. This is caused by the almost complete reduction of expensive oil on a winter day.

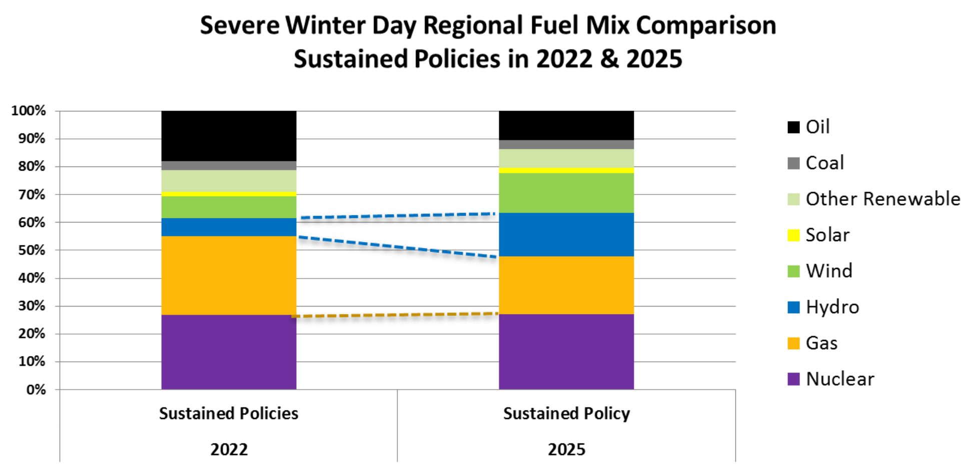

Figure 114: Extremely Cold Day Fuel Mix Comparison - Sustained Policies

In addition, as seen in Figure 114, in 2025, the increase in clean energy from the procurements reduces the use of gas on an extremely cold day by 27 percent when compared to an extremely cold day in 2022. The additional clean energy increases reliability by increasing natural gas availability to the remaining natural gas generators in the electric sector.

- **Mitigating natural gas constraints lowers the impact of extended cold weather on subsequent residential retail rates in all scenarios.**

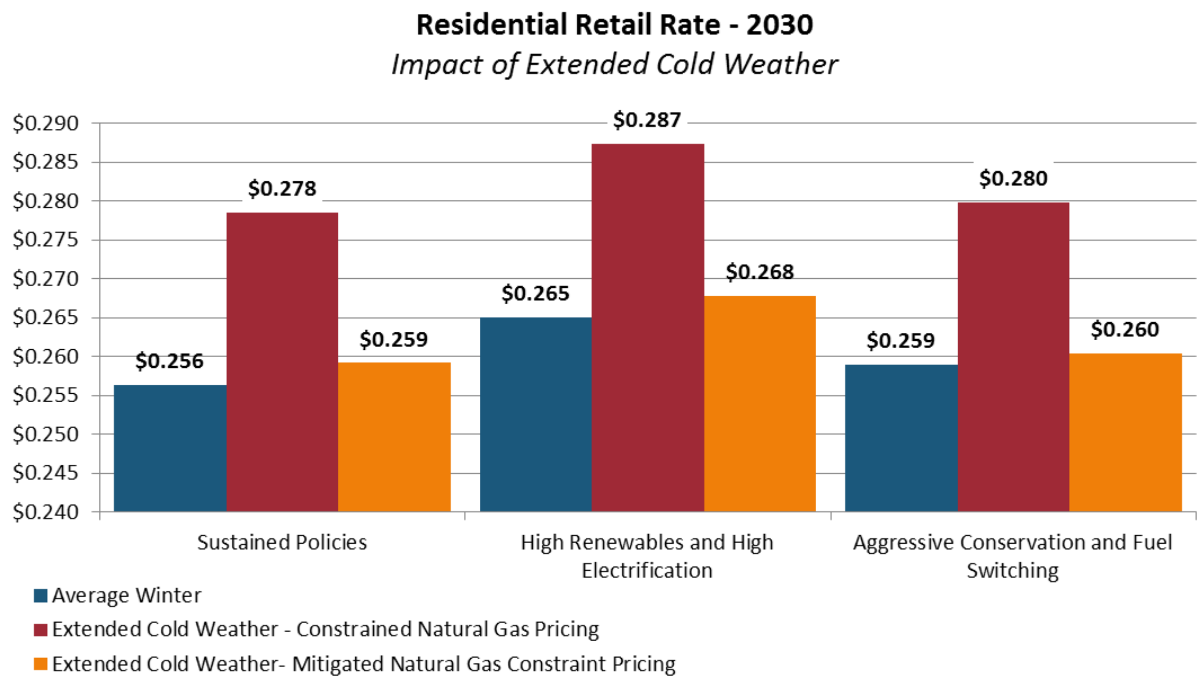

Figure 115: Impact of Extended Cold Weather Events on Residential Retail Rate

In all scenarios, an extended cold weather event increases the annual average residential rate (Figure 115). This is due to the increased demand for electricity as a result of the cold and the use of more expensive fuels to meet the increased demand. Those winter scenarios with mitigated natural gas constraint pricing show increased residential rate, although significantly less than those scenarios with constrained natural gas pricing, resulting in a rate close to the rate without a winter event.

- **Reducing demand in the thermal sector (heating and cooling) reduces cost and emissions for consumers.**

		2022			
Scenario		Residential Retail Rate (nominal $/kWh)	Emissions From Winter Event		
			Thermal Sector	Electric Sector	Total
High Electrification and High Renewables	*Average Winter*	*$0.233*	*2.24*	*1.68*	***3.93***
	Extended Cold – **Constrained Natural Gas Pricing**	$0.256	2.56	1.90	**4.46**
	Extended Cold – **Mitigated Natural Gas Constraint Pricing**	$0.251		1.82	**4.37**
Aggressive Conservation and Fuel Switching	*Average Winter*	*$0.228*	*2.12*	*1.72*	***3.84***
	Extended Cold – **Constrained Natural Gas Pricing**	$0.252	2.42	1.92	**4.35**
	Extended Cold – **Mitigated Natural Gas Constraint Pricing**	$0.247		1.86	**3.72**

Table 19: Cost and Emissions in Extended Cold Weather Comparison

Table 19 shows the impacts of a severe weather event in 2022 for both the High Electrification and High Renewables scenario and the Aggressive Conservation and Fuel Switching scenario. In an extended cold weather event, the electric sector has increased emissions due to the use of oil and increased demand. Because the Aggressive Conservation and Fuel Switching scenario has a greater amount of electrification than the High Electrification and High Renewables scenario, during an extended cold weather event the electric demand is higher, causing a greater increase in emissions, 1.92 vs. 1.90 $MMTCO_2$. But the High Conservation and High Demand Reduction scenario has a greater increase in building shell efficiency, significantly reducing the thermal demand and lowering the emissions, 2.42 vs. 2.56 $MMTCO_2$. This reduction in thermal demand offsets the increased emissions in the electric sector and results in the lowest extended cold weather emissions, 4.35 vs. 4.46 $MMTCO_2$. Reducing the amount of natural gas consumption in the thermal sector during these winter events therefore also increases the availability of natural gas to the electric sector.

9 Policy Priorities and Strategies

Based on the results and findings from the analysis of these four scenarios, under both average and extended cold weather conditions, the following strategies are recommended to achieve a clean, affordable, and resilient energy future for the Commonwealth.

9.1 Electric Sector

Pursue additional cost-effective sources of clean electricity beyond current policies and implement strategies to lower electric use at peak periods, in order to reduce emissions from the electric sector and accommodate growth in electric demand from the transportation and thermal sectors. Explore options for ensuring reliability and mitigating price volatility in the winter months, issues that continue to be a challenge for New England.

9.1.1 Continue to increase cost-effective renewable energy supply.

One of the key findings of this study is that the greatest amount of emissions reductions are achieved by a diverse portfolio that combines increasing supply of clean energy in all sectors while simultaneously decreasing overall energy consumption. A key component of this strategy is to increase clean energy supply as electrification of thermal load and transportation increases. Further, the recent clean energy procurements show an impact on residential electric rates when they come on-line in the mid 2020's. Low cost sources of clean electricity, particularly those that can deliver during peak hours and during winter cold periods, improve costs for customers.

- **Investigate policies and programs that support cost-effective clean resources that are available in winter to provide both cost and emission benefits to customers.** These additional policies may include continued clean energy procurements, especially if strategic electrification policies are successful and total demand for electricity increases. Modeling aggressive renewable energy in the High Renewables and Aggressive Conservation and Fuel Switching scenarios included approximately 8,000,000 MWh of additional clean energy beyond current policies[185] to approximate an outcome with significant emissions reductions by 2030. The exact amount of additional clean resources needed will depend on the 2030 GHG mission reduction goal selected and the extent of other complimentary policies.

- **Consider policies to support distributed resources, including distributed solar development in the Commonwealth after the SMART program concludes, to continue lowering costs while providing benefits to ratepayers.** As DOER continues to implement the SMART program, it will

[185] This amount accounts for the recent increase by the Legislature in the RPS to 2 percent per year between 2020 and 2030 and may vary depending on electric load.

periodically evaluate the impact of the program on development of solar generation and ratepayer costs. Potential policies could include extending the SMART program beyond 1600 MW by adding additional declining incentive blocks to the program.

9.1.2 Prioritize electric energy efficiency and peak demand reductions

Continued improvements in energy efficiency and other efforts to reduce demand are crucial to reduce the energy burden for consumers and help offset increases in electricity demand from electrification. Massachusetts is a leader in energy efficiency, ranked the number one state in energy efficiency nationwide for eight consecutive years by the American Council for an Energy-Efficient Economy. However, to continue to aggressively lower GHG emissions, energy efficiency and conservation is an even more critical component of an overall strategy. Targeting peak demand avoids infrastructure investment and relieves constraints during extended cold weather reducing emissions from oil and LNG electric generation. Energy efficiency and peak demand reduction are important for keeping electricity rates affordable when demand increases from electrifying the thermal and transportation sectors.

- **Implement policies and programs, including the Clean Peak Standard**, **that incentivize energy conservation during peak periods.** Reducing energy demand at times of peak use creates the most value for consumers because it reduces reliance on the highest cost, less efficient generating resources. Also, by levelizing demand on the electric grid across all hours, transmission and distribution infrastructure can be utilized more efficiently mitigating the need for additional new investment.

- **Develop policies to align new demand from the charging of EVs and heating/cooling with the production of clean, low-cost energy**. Review options, including a time-of-use (TOU) rate for EV charging so charging aligns with periods when electricity prices are lowest and mitigates any added strain on the system from additional electric demand. Investigate incentives for the pairing of air source heat pumps with distributed solar.

- **Include cost-effective demand reduction and additional energy efficiency initiatives in our nation-leading energy efficiency programs and plans**. As demand for electricity grows, programs to mitigate this demand provide large savings to consumers. Expanding Massachusetts' nation-leading energy efficiency programs to encourage efficiency and demand reduction initiatives at customers' homes and businesses in a cost-effective manner will deliver significant benefits to consumers.

- **Utilize our successful Green Communities and Leading By Example programs to continue to make state and municipal infrastructure clean and efficient.** These programs lower the operating costs of government, reduce emissions, and promote consumer awareness about the benefits of efficiency.

9.1.3 Support grid modernization and advanced technologies

New technologies, such as storage, and modernization of the grid, for greater resiliency and integration of renewables, will help enable greater efficiency and provide new opportunities for demand reduction. Technologies that provide greater grid transparency to electric utilities can help facilitate advantageous location of distributed generation as well as help target demand reduction programs. The importance of these new technologies was reinforced by the Massachusetts' Department of Public Utilities recent approval of utility grid modernization investments that reduce effects of outages, optimize demand, integrate distributed energy resources, and improves workforce and asset management. Continued development and deployment of new and advanced technologies will complement and augment traditional programs.

- **Promote microgrids to provide greater overall grid resiliency and reduce transmission and distribution costs from building out the grid to meet new demand.** Enabling local generation to serve critical loads through an outage is an effective way to improve customer energy resilience to external disruptions. Offsetting energy and demand charges with the microgrid technologies are key to providing a cost effective return on investment for customers, driving them to select resilient energy technologies when they move forward with capital projects.

- **Review existing and possible new policies to support new technologies, including energy storage, that can align supply and demand and provide grid flexibility.** The electric sector is a just-in-time supply chain, where supply and demand must always be balanced. Historically, in order to assure the ability to meet that balance, we have built infrastructure to meet peak demand. Policies which align supply and demand enable the shift away from substantial overbuild of infrastructure while enabling flexibility to continue to adopt intermittent resources.

9.1.4 Examine potential strategies to lower the price of natural gas and mitigate natural gas constraints

Reliability and affordability in the winter continues to challenge the region due to a high reliance on natural gas for both electric generation and heating. In the winter, demand for natural gas to both heat the Commonwealth's buildings and generate electricity relies on stored fuels such as LNG and oil to meet demand needs. Even with aggressive investment in new clean electricity sources, demand reduction and energy efficiency measures, reliability and price volatility risks in the winter remain for the electric sector. Mitigating natural gas constraints would eliminate the need to turn to high cost, carbon-intensive oil to satisfy demand during an extended cold weather event. Strategies could include:

- **Encourage contracting with LNG supply ahead of the winter to ensure LNG supplies are available to be used by gas-fired generators.** LNG requires substantial logistical planning ahead of winter deliveries. While firm long-term LNG contracts may increase costs in mild winters, the combination of cost savings and fuel security may offset those costs in an extreme cold event winter. The terms of the contract would determine the magnitude and the impact of the associated cost allocation

- **Work with federal officials to explore modifying the Jones Act to facilitate shipping of LNG from domestic sources.** Enabling delivery of domestic LNG shipments into New England may reduce costs and improve our fuel security while reducing our energy reliance on foreign nations.

- **Examine encouraging improved heat rates for all new natural gas plants.** The heat rate of a power plant is an efficiency metric of the plant's ability to convert fuel into electricity. More efficient plants can provide the same electricity with less gas and less emissions.

- **Continue to reduce thermal sector demand.** Efforts as described below in energy efficiency for thermal sector demand will reduce demand for natural gas in the thermal and electric sectors during winter weather events, increasing the availability of pipeline natural gas to electric generators.

9.2 Thermal Sector

Encourage beneficial fuel switching from higher cost, higher emission fuel sources for heating to lower cost, lower emitting fuel sources for heating. Motivate consumers to make choices that improve the efficiency of their homes and businesses. Utilize cost-effective means to transform building envelopes in both new construction and building retrofits.

9.2.1 Leverage investments made in the clean energy sector through electrification

Focusing clean energy policies primarily on the electric sector has diminishing returns going forward, increases rates with only modest decreases in GHG emissions. Electrifying the thermal and transportation sector will leverage investments made in a clean electric grid, both reducing emissions and lowering cost. Reducing heating demand in winter will help alleviate competing demands for natural gas during severe weather and helping to mitigate constraints and resulting price spikes.

- Increase electrification of the thermal sector by providing program incentives for air source heat pumps for heating though MassSave.

9.2.2 Promote fuel switching in the thermal sector from more expensive, higher carbon intensive fuels to lower cost, lower carbon fuels such as electric air source heat pumps and biofuels.

Fuel switching in the thermal sector is challenging but necessary to achieve increased emissions reductions from the thermal sector. Penetration of electric air source heat pumps may be difficult due to the investment necessary to change-out existing equipment and its associated distribution system. Biofuels can play an important role in providing a transition for oil-heating equipment.

- **Promote, though the Alternative Portfolio Standard, conversion of oil to biofuels** as a measure to reduce emissions until equipment replacement is cost-effective. Encourage biomass for renewable heating, particularly as a replacement for oil and propane.

- **Encourage MassSave Program Administrators to implement a residential program redesign** that ensures all contractors that are making improvements to a home have access to energy efficiency incentives, and improves customer engagement by providing the homeowner access to their energy usage data.

9.2.3 Reduce thermal sector consumption.

Reduction in thermal demand is necessary to achieve significantly more GHG emission reductions to meet future goals. Addressing existing building stock in a comprehensive manner beyond more limited equipment choices are challenging investments for home and business owners to identify and implement. Further improvements in new building stock needs to provide reductions in overall energy costs to address concerns of low-income and moderate-income housing needs.

- **Explore possible ways to strengthen building codes to drive additional efficiency in new buildings**. As commercial square footage expands and the population grows, mitigating energy demand from the building sector will be necessary to meet our cost and emissions goals. Building codes can be a cost-effective way to make lasting and long-term change in building infrastructure. Code provisions to consider include maintaining the stretch code and creating an "envelope backstop" to preserve envelope performance in commercial buildings so that envelope improvements cannot be traded away for other measures.

- **Increase weatherization measures to improve building shell efficiencies and promote technologies targeted at winter gas savings through the MassSave gas efficiency programs**. Add a new performance metric to the MassSave Program Administrators (PAs) tied to reducing winter gas demand, both active and passive. A performance metric could be used to encourage PAs to increase the amount of homes and businesses weatherized each year, utilize new technologies, such as Wi-Fi thermostats, to enable greater reductions of energy use in cold weather without disrupting comfort, and adopt programs for Commercial and Industrial customers who can reduce gas consumption for industrial processes during severe cold weather.

- **Promote high efficiency building construction, such as Passive House standards, to further reduce energy demand from the thermal sector**. Utilize our energy efficiency programs to provide incentives to developers to develop to Passive House standards.

9.2.4 Drive market/consumer demand for energy efficiency measures and fuel switching

Reducing emissions in the thermal sector is limited by the lifetime use of equipment and consumer choices and information available at the time of asset replacement. Heating equipment has a long useful life, and frequently equipment is not replaced until the point of failure during times of emergency or need, limiting the consumer's ability to consider alternatives for replacement. Consumer education on the value of heating choices and efficiency improvements is essential. Similarly, buildings are long-term assets and choices made in building construction today, have impacts that easily last 20-, 30- or 50-years.

- **Educate consumers about the benefits of energy efficiency and create a market incentive for consumers to invest in energy efficiency improvements through a "Home Energy Score Card" program**. Enabling homeowners and prospective homebuyers to have access to information about the anticipated energy efficiency characteristics of residences and recommended cost-effective energy efficiency improvements will help families be better informed about their homes' energy performance and how they can reduce those costs through incentivized energy efficiency upgrades. Provide scorecards as part of Massachusetts energy efficiency providers no cost home energy audit.

- **Address the split incentive between landlords and renters for investments in energy efficiency.** In many instances if a landlord invests in energy efficiency the benefits go to the renter in terms of lower utility bills or, even if the landlord is paying the utility bills, it is a "pass through" cost so there is little incentive for landlords to invest in efficiency improvements to their buildings. This is particularly problematic for Massachusetts residents because low and moderate-income residents make up a higher proportion of renters. Strategies could include:

    - Encourage a "Renter Energy Score Card" so renters can make informed choices about the total cost of where they live and to encourage landlords to invest in energy efficiency.

    - Create targeted programs for renters and landlords through our energy efficiency programs.

    - Support programs that test the impact of whole building energy efficiency measures in affordable housing to maximize energy savings during times of refinance or capitalization.

9.2.5 Invest in R&D for clean heating fuels, such as renewable gas, that can utilize investments already made in heating infrastructure.

As already noted, heating technologies have long useful lives. If renewable gas sources and expansion of renewable heating fuels could be developed and utilized in existing equipment and infrastructure, reduction in thermal emissions could be greatly accelerated. Development of new technologies has been an important economic driver in Massachusetts, and this may be a potentially new area of focus for our entrepreneurial community.

9.3 Transportation Sector

Significant reductions of emissions from the use of gasoline and diesel in the transportation sector are needed to meet GWSA goals. Development of high-level recommended actions to reduce VMTs and enable electrification is underway through Governor Baker's Commission on the Future of Transportation established by Executive Orders No. 579 and 580The Commission is tasked to examine at least five key areas: climate and resiliency; transportation electrification; autonomous and connected vehicles; transit and mobility services; and land use and demographic trends. The Commission will provide a report on their findings and recommendations in December 2018.

While the electric sector is highly regulated, making it easier for policymakers to implement changes in this sector, the transportation sector is primarily dependent on consumer choices. The transportation sector remains highly dependent on fossil fuel to power vehicles and emissions from this sector have remained relatively similar to 1990 levels. The following are some of the broad strategies recommended by the CEP for transportation electrification to be considered by the Commission.

- **Increase in deployment of EVs and charging infrastructure.** Demonstrate cost-effectiveness of EVs to encourage adoption by consumers. Develop an adequate charging infrastructure to be complementary with available ranges of commercially available vehicles.

- **Support development of a biofuels industry to provide alternative transportation fuels.** Support R&D and commercialization of bio fuels especially for vehicles that may be more difficult to convert to an electric power source such as freight.

Appendix A: Modeling Methodology

Under the current project framework, we model the years 2018 through 2030 on an in-depth basis.[186] This modeling process applies three models to concurrently project Massachusetts's (and New England's) energy demand and supply. These models include:

9.4 The EnCompass model

Developed by Anchor Power Solutions, EnCompass is a single, fully integrated power system platform that allows for utility-scale electric power generation planning and operations analysis. EnCompass is an optimization model that covers all facets of power system planning, including the following:

- Short-term scheduling, including detailed unit commitment and economic dispatch
- Mid-term energy budgeting analysis, including maintenance scheduling and risk analysis
- Long-term integrated resource planning, including capital project optimization and environmental compliance
- Market price forecasting for energy, ancillary services, capacity, and environmental programs

EnCompass provides unit-specific, detailed forecasts of the composition, operations, and costs of the regional generation fleet given the assumptions described in this document. Synapse has populated the model with a custom New England dataset developed by Anchor Power Solutions and based on the 2015 Regional System Plan, which has been validated against actual unit-specific 2015 dispatch data.[187] Synapse integrated the New England dataset with the EnCompass National Database, created by Horizons Energy. Horizons Energy benchmarked their comprehensive dataset across the 21 NERC Assessment Areas and it incorporates market rules and transmission constructs across 76 distinct zonal pricing points. Synapse uses EnCompass to optimize the generation mix in New England and to estimate the costs of a changing energy system over time, absent any incremental energy efficiency or DSM measures.

More information on EnCompass and the Horizons dataset is available at www.anchor-power.com.

EnCompass, like other production-cost and capacity-expansion models, represents load and generation by mapping regional projections for system demand and specific generating units to aggregated

[186] While they are not explicitly modeled, we also take into account potential versions of futures from 2031 through 2050.

[187] ISO New England. "2015 Regional System Plan." Available at: https://www.iso-ne.com/system-planning/system-plans-studies/rsp.

geographical regions. These load and generation areas are then linked by transmission areas to create an aggregated balancing area. Neighboring regions that are modeled in this study are New York, Quebec, and the Maritime Provinces. These regions are not represented with unit-specific resolution. Instead, they are represented as a source or sink of import-export flows across existing interfaces in order to reduce modeling run time.[188]

9.5 The Renewable Energy Market Outlook model

In addition to EnCompass, this analysis uses Sustainable Energy Advantage's New England Renewable Energy Market Outlook (REMO), a set of models developed by Sustainable Energy Advantage that estimate forecasts of scenario-specific renewable energy build-outs, as well as renewable energy certificate (REC) and clean energy certificate (CEC) price forecasts. Within REMO, Sustainable Energy Advantage can define forecasts for both near-term and long-term project build out and REC pricing.

Near-term renewable builds are defined as projects under development that are in the advanced stages of permitting and have either identified long-term power purchasers or an alternative path to securing financing. These projects are subject to customized, probabilistic adjustments to account for deployment timing and likelihood of achieving commercial operation. The near-term REC price forecasts are a function of existing, RPS-certified renewable energy supplies, near-term renewable builds, regional RPS demand, alternative compliance payment (ACP) levels in each market, and other dynamic factors. Such factors include banking, borrowing, imports, and discretional curtailment of renewable energy.

The long-term REC price forecasts are based on a supply curve analysis taking into account technical potential, resource cost, and market value of production over the study period. These factors are used to identify the marginal, REC price-setting, resource for each year in which new renewable energy builds are called upon. The long-term REC price forecast is estimated to be the marginal cost of entry for each year, meaning the premium requirement for the most expensive renewable generation unit deployed for a given year.

9.6 M-SEM

Synapse has developed the Multi-Sector Emissions Model (M-SEM), a state-specific model used for tracking historical energy use and emissions and for projecting future energy use and emissions based on a set of policy changes. This dynamic spreadsheet model includes state-specific information on energy use and emissions in the electric, residential, commercial, industrial, and transportation sectors. It employs historical data from the Energy Information Administration's (EIA) State Energy Data System

[188] In this analysis, the Maritimes zone includes Emera Maine and Eastern Maine Electric Cooperative (EMEC) which are not part of ISO New England and, therefore, are not included in any of the New England pricing zones used in this study. These regions are not modeled as part of the Maine pricing zone and were modeled as part of the New Brunswick transmission area.

(AEO) and Annual Energy Outlook 2018, the most recent release of the EIA's annual AEO report.[189] More information on M-SEM is available at http://www.synapse-energy.com/MSEM

[189] Energy Information Administration. 2018. Annual Energy Outlook 2018, released February 6, 2018.

Appendix B: Stakeholder Process and Feedback

9.7 Stakeholder Process

In July 2018, the Department of Energy Resources (DOER) hosted a series of stakeholder sessions across the Commonwealth to solicit feedback on initial data and analysis for the development of the Comprehensive Energy Plan. DOER hosted three stakeholder sessions: in Boston on July 17, Westborough on July 18, and Westfield on July 19. The sessions included introduction to the goals and process of the CEP by DOER leadership as well as presentation by the CEP consultant, Synapse Energy Economics, on the initial analysis of drivers for energy supply and demand across the transportation, thermal conditioning, and power sectors.

The goal of these sessions was to invite feedback from key stakeholders and members of the public on the assumptions about supply and demand drivers included in the CEP modeling. DOER published materials from the meetings online following the sessions. All stakeholders, including those who could not attend the in-person sessions, were invited to provide written comments to DOER on the CEP. Feedback from the meetings and written comments informed subsequent modeling, analysis, and report writing as DOER and the consultant finalized the CEP.

DOER also recognizes that many stakeholders expressed frustration with the short turnaround time for comments and with technical difficulties in the online feedback survey. DOER thanks stakeholders for cooperating through this process. It was important to DOER to get initial input from stakeholders before results were finalized and these interim comments helped guide the report through publication. Although not all comments could be addressed in the scope of this Comprehensive Energy Plan, the CEP is meant as the beginning of an ongoing conversation with stakeholders about the Commonwealth's energy future. Future planning processes through the 80 by 50 Study, 2030 CECP, and the Future of Transportation Commission will provide further opportunities for stakeholders to engage on specific policies and strategies to guide long-term energy and climate policy.

9.8 Overview of Stakeholder Feedback

Stakeholders provided helpful feedback to DOER on the modeling assumptions in the CEP as well as possible policy pathways to achieve a clean, affordable, and reliable energy supply. Regarding modeling assumptions, stakeholders provided input on the pace of changes assumed in the Sustained Policies (baseline) case, drivers of energy demand in the three sectors, and overall model design. These comments are described and summarized in section 9.10. Regarding possible pathways, stakeholders provided a variety of useful comments on topics including electrification, building codes, and demand management. These comments are described and summarized in section 9.11. DOER also received stakeholder comments relevant to the Commonwealth's energy future, but these comments are ultimately beyond the scope of this Comprehensive Energy Plan: for example, suggestions regarding the design of specific programs, legislative actions, or siting of energy facilities.

DOER is grateful to all the stakeholders who participated for the thoughtful feedback and detailed recommendations that helped guide the development of this Comprehensive Energy Plan. The CEP is one of many policy and planning documents that the Commonwealth prepares regarding the energy system. DOER welcomes further comments on this finalized report and encourages continued stakeholder engagement in future policy and planning processes that will build on the findings of the CEP.

9.9 Response Metrics

162 people registered for or attended the in-person stakeholder sessions held in Boston, Westborough and Westfield. Following the sessions, and publication of stakeholder materials online, DOER received 76 written comments on the CEP from a diverse set of stakeholders including 36 comments from representatives of non-profit organizations, 13 from industry groups, 6 from municipal governments, and 21 from individual Massachusetts residents.

9.10 Comments on Modeling Assumptions

Stakeholders provided useful feedback on the assumptions underlying the supply and demand modeling in the CEP.

Regarding the power sector, several stakeholders pointed out that the Sustained Policies scenario does not reflect the most recent energy policies in *An Act to Advance Clean Energy*, a new law signed by Governor Baker on August 9, 2018 that includes changes to the Renewable Portfolio Standard and other new energy policies. As discussed in Chapter 5 of this report, the timing of this report's preparation and publication did not allow for the inclusion of these most recent policy changes in the Sustained Policies scenario. Additionally, some stakeholders pointed out possible future sources of electricity demand growth that are difficult to forecast, for example energy demand from indoor cannabis cultivation.

For the thermal sector, some stakeholders suggested that the assumed pace of building shell efficiency improvements and heat pump adoption in the Sustained Policies scenario are too conservative and that higher rates are likely.

Regarding the transportation sector, many stakeholders commented that the CEP should consider how a reduction of vehicle miles traveled (VMT) in the Commonwealth would change energy consumption. Decreasing VMT could substantially reduce energy consumption and fuel demand in the transport sector. Some stakeholders also expressed skepticism about the assumed high growth rate in electric vehicle (EV) sales in the CEP scenarios, highlighting the currently low penetrations of EVs in the Commonwealth and barriers to adoption like availability of charging infrastructure and consumer acceptance. Finally, stakeholders pointed out the current political uncertainty regarding federal fuel economy standards, highlighting that changes to these standards would affect the assumptions in the Sustained Policies scenario.

Regarding the overall design of the scenarios, several stakeholders suggested that the emissions reductions mandated by the Global Warming Solutions Act (GWSA) should have been built into the model as a constraint, since they are legally binding. Similarly, many stakeholders highlighted the need for long-term planning around the 2050 GWSA emission targets, rather than using an interim 2030 time horizon. Stakeholders highlighted the importance of this type of long-term planning to avoid lock-in and inefficient investments in the short- and medium-term.

Finally, stakeholders suggested incorporating climate change variability in the modeling, for example the impact of more frequent extreme weather on energy reliability and changes to overall heating and cooling demand in a warming climate.

9.11 Comments on Possible Pathways

Stakeholders also provided a variety of useful comments regarding the possible pathways and policies presented in the CEP.

In the power sector, stakeholders highlighted the importance of policies to help manage electricity demand during peak periods, especially with increased load from electrification. Some stakeholders expressed support for energy storage to help manage demand, while others expressed skepticism about the cost and maturity of large-scale battery storage technology. Many stakeholders expressed support for policies to promote the use of distributed energy resources like rooftop solar. Many stakeholders also expressed concerns regarding the technical potential or local environmental impacts of specific energy generation technologies like onshore wind, biomass, and large hydropower.

In the thermal sector, stakeholders presented feedback regarding electrification and energy efficiency pathways. Many stakeholders expressed support for electrification to reduce fuel use and emissions in the heating sector, but industry stakeholders expressed concerns about policies favoring certain technologies in the heating market and raised concerns about the performance of heat pumps in extreme cold weather. Stakeholders also highlighted the challenge that system turnover presents given that most heating system change-outs only occur in an emergency when the existing system has failed.

Regarding thermal sector efficiency, many stakeholders advocated for policies to increase building energy efficiency, including updating the stretch code to meet net zero energy or passive house standards, introducing standardized energy efficiency ratings and labels for buildings, and expanding energy efficiency programs for multifamily, low-income, and rural residents. Stakeholders also suggested streamlining rebates and incentives for thermal energy across different agencies like MassCEC, Mass Save, and DOER.

In the transportation sector, many stakeholders highlighted the importance of policies to support public transit and smart growth in order to reduce VMT and transportation energy use. Many stakeholders also highlighted challenges for electric vehicle (EV) adoption including the availability of charging infrastructure, consumer acceptance of existing EV models, cost of the technology, and equity of EV subsidies. Stakeholders also urged the consideration of other alternative vehicle technologies like hydrogen fuel cells, compressed natural gas (CNG), and propane autogas that could provide benefits in the transportation sector, especially for medium and heavy-duty vehicles. Finally, stakeholders advised that emerging trends in the transportation sector like ridesharing and autonomous vehicles could also have significant, although as yet uncertain, effect on future energy use.